Science Fiction Roleplaying Game

TRAVELLER®
The New Era

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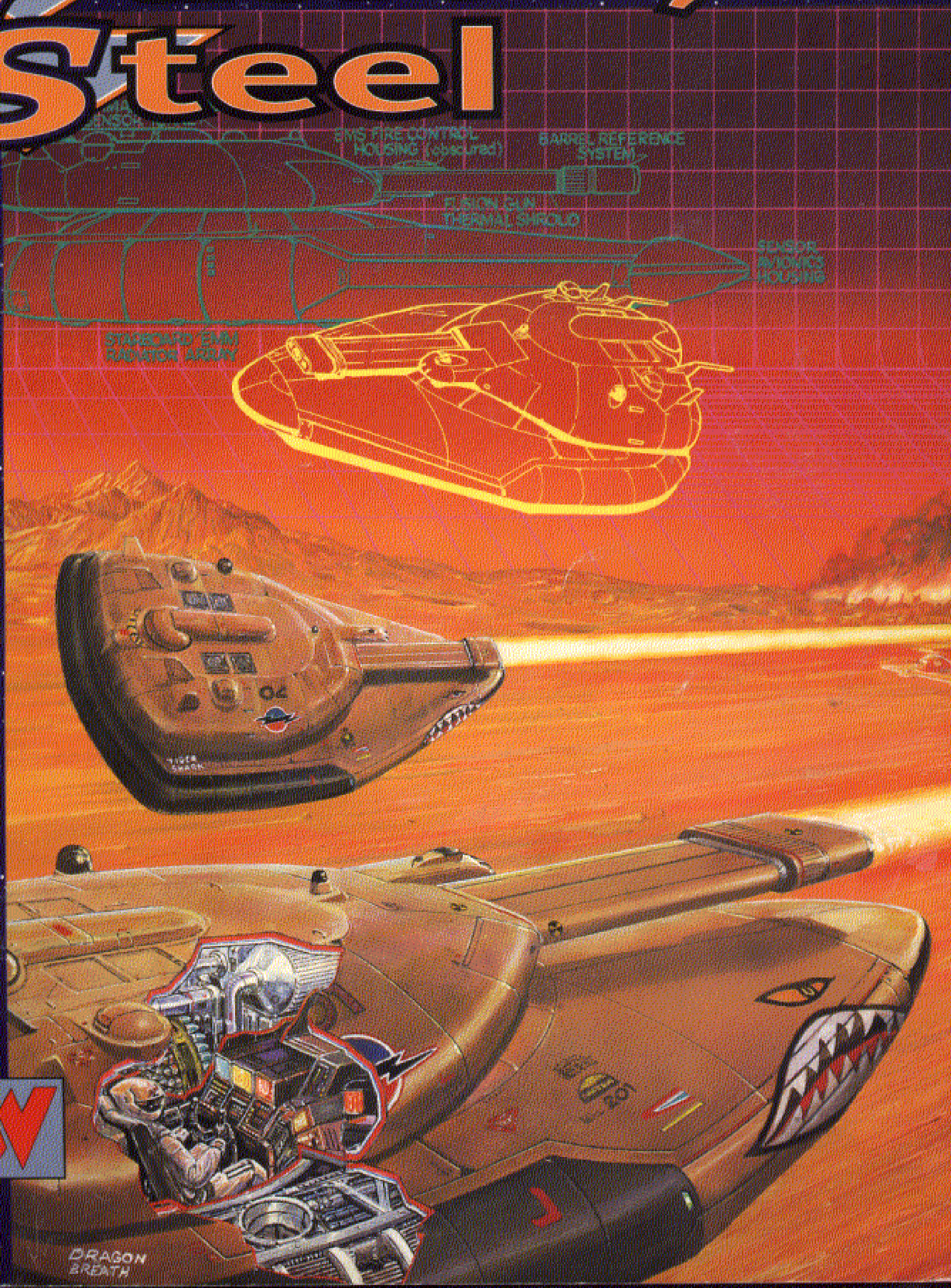
Fire, Fusion, & Steel™

Technical Architecture



GDW

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Technical Architecture

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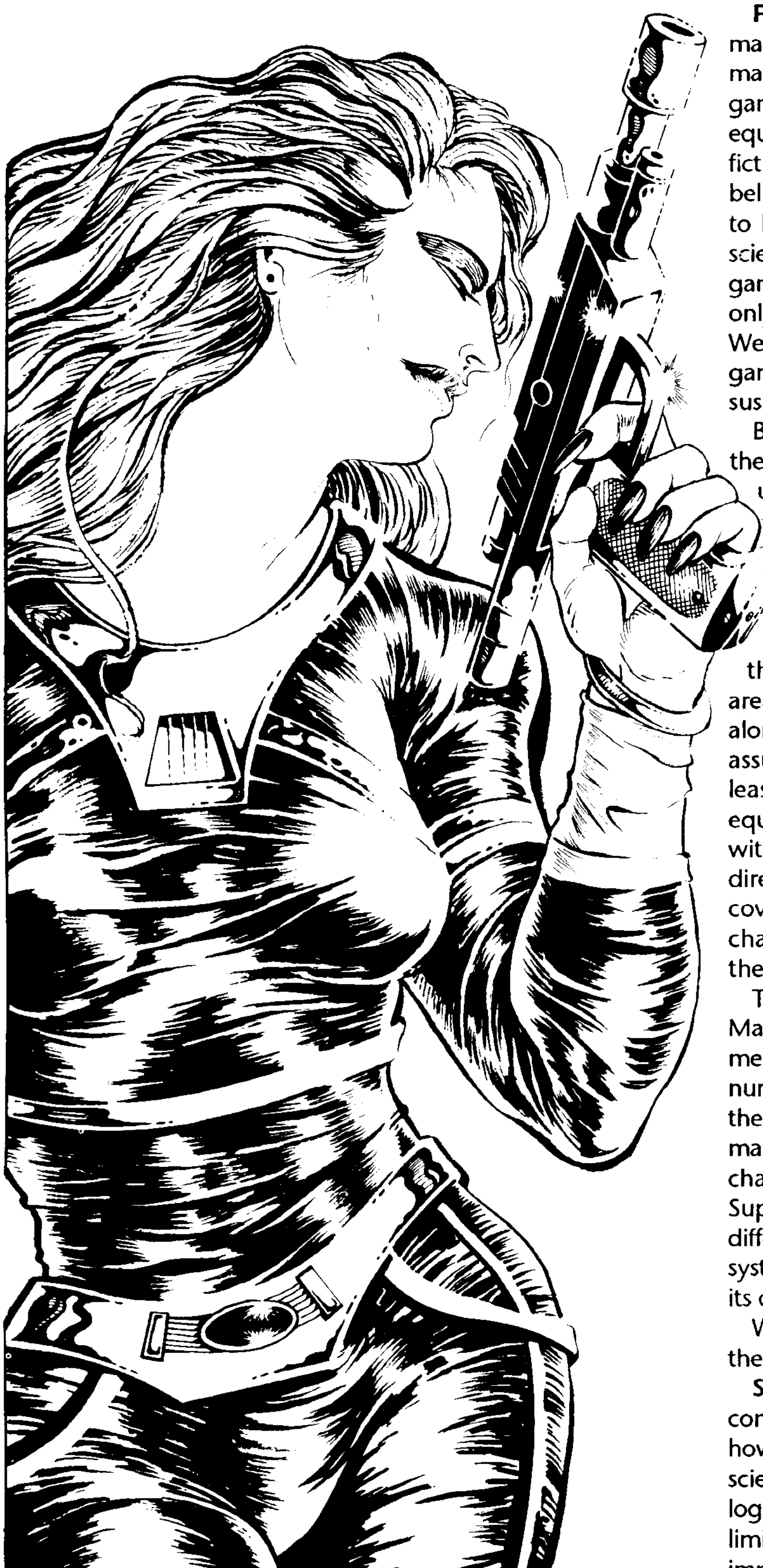
FIRE, FUSION, & STEEL



Fire, Fusion, & Steel (**FF&S**) is the technical architecture manual for **Traveller.** It enables referees and players to design major items of equipment to meet the specific needs of their games. It is also meant to explain the genuine scientific basis of the equipment in the game, where such basis exists, and provide the fictional rationale for other technical items. We do this because we believe that, to the extent possible, a science fiction game ought to be grounded in real science. Of course, the game isn't just science, it is science *fiction*, and so the technology used in the game departs from reality in a number of significant areas. But it only does so where required by the necessities of high adventure. We believe firmly that a grounding in solid science for much of the game's technology adds to the sense of realism, the "willing suspension of disbelief," so important to enjoyable roleplaying.

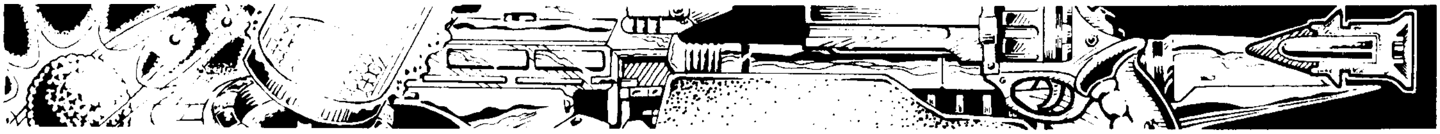
Beyond those goals, this manual also enables referees to tailor the **Traveller** rules to fit a variety of other possible science fiction universes with different departures from scientific reality. While this gives unprecedented control of the game environment to the referee and players, it poses some problems for the organization of this book.

For purposes of clarity, the environment in which **Traveller: The New Era** is played is called *Imperial Space* throughout this book. It represents not a specific astrographic area, but rather the specific future history detailed in the game, along with the technological reality of that future history. The assumption of this book is that the vast majority of users will, at least initially, be using it to design Imperial Space technical equipment. As a result, each chapter of the manual is organized with all Imperial Space technologies first, and incorporated directly into the various design sequences. Then a section covering alternate technologies is provided at the end of most chapters which details alternative technological approaches to the issue addressed by the chapter.

The manual itself is divided into three broad areas, or "books": Major Systems, Subsystems, and Weaponry. By major systems we mean vehicles and craft of various sorts which incorporate a large number of subsystems in their design. The design sequences for these major systems include tables and subsystems unique to the major system (such as tracked suspensions in the Ground Vehicle chapter), but will refer you to subsystem chapters (such as Life Support or Electronics) for material common to a number of different major systems. Weaponry could be included in subsystems but constitutes such a large body of material as to justify its own section of the book.

We hope that this organization proves to be the most useful in the long run.

Special Note: It was our original aim to make this manual complete under one cover. In the course of preparing the book, however, it became clear that that simply was not possible. A science-fiction game should always be open to additional technological treatments, and no one book should ever impose absolute limits on what the game can cover. We've covered the most important subjects in this manual, but look for treatments of additional subjects ("wet" ships, robots, disintegrators, neural weapons, primitive transport, genetic engineering, jump projectors, etc.) in future products. When a sufficient number of these have been published, they will be gathered into a single follow-on volume.



The Metric System of Measure

The **Traveller** game exclusively uses the metric system of measure. Those players from countries (such as our own) which still cling to the archaic English system of measure have our sympathy. For you we present the following summary of the major metric units commonly used in the game, an explanation of what they mean, and an approximate conversion system.

The conversion system is by no means precise, but is instead intended to provide a rough feel for equivalencies.

The metric system is a decimal system. Each area of measurement (distance, volume, power, energy, etc.) has a base unit of measure (meter, liter, watt, joule) and all other units are either decimal multiples or fractions of that base measurement. Whether it is a fraction or multiple, and by how much, is indicated by a prefix attached to the base unit of measure. These prefixes are:

micro-	1/1,000,000
milli-	1/1000
centi-	1/100
deci-	1/10
deka-	×10
kilo-	×1000
mega-	×1,000,000

Distance

millimeter	about 1/25 of an inch
centimeter	about 2/5 of an inch
meter	about 1 yard (and 3 inches)
kilometer	about 3/5 of a statute mile, 5/9 of a nautical mile

Volume

liter	(1000 cubic centimeters) about 1 quart
kiloliter	(1 cubic meter) about 1 ton of water

Weight

gram	(weight of 1 cubic centimeter of water) about 1/30 of an ounce.
kilogram	2.2 pounds
tonne	(1000 kilograms, also called a metric ton) about 2200 pounds

Energy

joule	work done by a current of 1 amp flowing at a potential of 1 volt
megajoule	power produced by the explosion of between 6 and 7 ounces of TNT

Power

watt	1 joule per second
kilowatt	about 1 1/3 horsepower

***Important Note:** Throughout this book, the word "tonne" always means a metric ton. A "ton" in its meaning of 14 cubic meters of volume will always be specified in the text as "displacement ton."*

Interpolation

The design rules will often allow you to design a component which falls somewhere between two entries on a table and direct you to interpolate the correct value. Interpolation is a method of determining a value which falls between two known values. As an example, look at the CPR Gun table on page 109, and assume we want to know the weight of a 7.62 cm gun. We know the weights for a 7cm gun (.54 tonnes) and for an 8cm gun (.66 tonnes).

To interpolate, first find out how far between the the two reference points your intermediate data point falls. This is done in three steps.

Step 1: Subtract the lower reference point from the higher reference point. 8cm–7cm=1cm.

Step 2: Subtract the lower reference point from the intermediate reference point. 7.62cm–7cm=0.62cm.

Step 3: Divide the result of step 2 by the result of step 1. The result will be a decimal value. 0.62÷1=0.62.

In the case of our example, the result will be 0.62.

Second, find out the the differences in values between the two reference points, by subtracting the lower value from the higher. In our example, the difference in weight is 0.12 tonnes.

Third, multiply the decimal value of the difference in data points times the difference in values and add the result to the lower of the two reference point values. In our example, we multiply 0.62 times 0.12 (product of .0744) and add it to the lowest data point value (.54) for a result of 0.6144. The 7.62cm gun weighs 0.6144 tonnes (614.4 kilograms).

TECHNOLOGY ASSUMPTIONS

Traveller: The New Era is intended to not be limited to a single campaign background or to a single set of future science assumptions. Its rules are intended as a framework that will allow the play of a wide variety of science-fiction visions. Such different visions have distinctive technologies that separate them from speculative universes without such technologies. Matter teleportation, stardrives, and antigravity are all forms of technology whose presence in or absence from a setting have a major influence on the overall feel of that science fiction setting, and are all directions that can be explored in **Fire, Fusion & Steel: Traveller Technical Architecture.**

However, like any roleplaying game, **Traveller** must have a basic set of assumptions which drive a basic campaign setting. Not all referees wish to design their own unique universes. Many would rather start playing in a standard campaign setting that they know will be supported by future products and source material. For **Traveller**, this standard campaign is the Imperial campaign that was started with the first **Traveller** edition. This campaign will continue to be supported as the standard default campaign of **Traveller: The New Era.**

The purpose of this chapter is to explain to referees and players how the technological assumptions of this standard Imperial campaign fit into the variable technology schemes presented in **Technical Architecture.** Players and referees who have no desire to use a campaign other than the Imperial campaign may still find this information interesting.

Different Universes

The approach taken by **Traveller: The New Era** is that each of these different technological visions are actually different universes. The different technologies seen in these universes are the result of differing physical laws. These physical laws will make certain technological breakthroughs more or less difficult, perhaps even impossible. The more a universe's physics resist a certain development, the longer it will take to make the initial breakthrough, and the more time will pass between successive improvements. Likewise, the physics of a universe will allow one form of stardrive to be developed, but not another—say the use of naturally occurring warp points instead of **Traveller**'s standard jump drive.

Traveller divides the technology of the future into two types: baseline technology and projected technology.

Baseline Technology: Baseline technology is technology based on physical laws that we understand and can effectively manipulate in the 20th century. This includes such things as firearms, internal combustion engines, nuclear fission, ballistic computers, etc. Baseline technology also includes one important set of extrapolated technologies: advanced power generation. The ability to create power of a certain quantity using a certain amount of fuel is the most important consideration for the use of any other technology, and hence is included in **Traveller**'s baseline technology. This particularly refers to the harnessing of fusion technology at ever increasing levels of efficiency. It is this baseline technology that defines the **Traveller** technology, or tech, level.

Tech Level: Tech level is a shorthand scale to show the level of baseline technology available. See the table for examples.

In different universes, different projected technologies may be added at different tech levels, indicating the point on the baseline scale at which they initially become possible. But not all projected technologies will be possible in a given universe, nor will they become possible at the same time as in other universes.

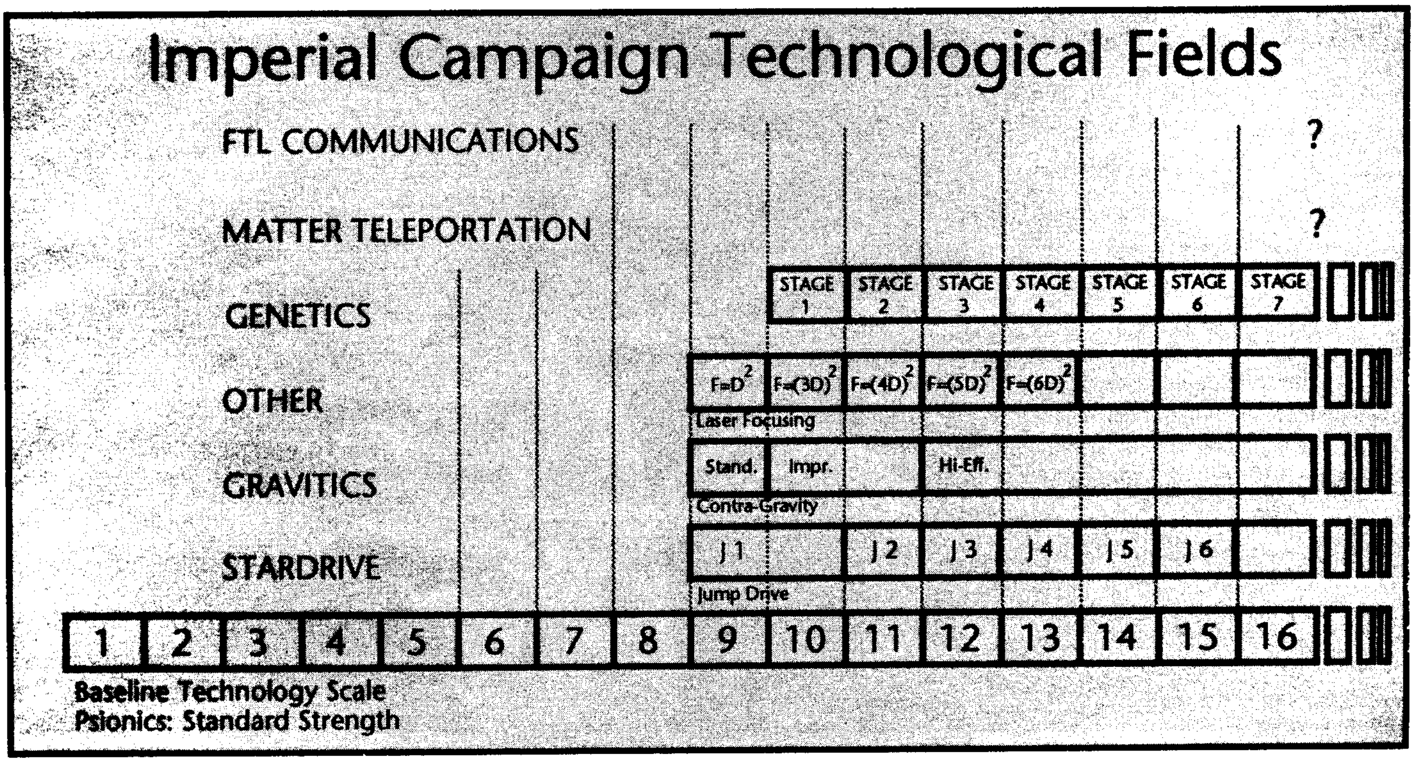
Note that baseline technology levels have fuzzy borders. Certain technologies become available as experimental systems before they are routinely useful and economically practical. Furthermore, the model of Earth history can be misleading when applied to an interstellar community, because worlds do not need to individually discover basic scientific principles. The best example is the discovery in Earth's history of microbes and the medical revolution that this brought about. A low-tech world would not have to develop its own microscopes to learn about these facts. Such a world would only have to be told about certain principles of infection and sanitation in order to realize the great health benefits that come from boiling water, maintaining standards of cleanliness, etc.

Also note that baseline technology allows unusual technical breakthroughs under specific local conditions. For example, on a world with a dense atmosphere and low gravity (an unlikely combination to be sure), practical aircraft will become available before they were on Earth, as it would be easier to generate sufficient power to keep an aircraft in the air.

Projected Technology: Projected technology refers to breakthroughs using physical laws not currently known (for example, stardrives and antigravity), or physical laws that we do know and understand to some extent, but which we do not yet understand how to completely manipulate (the cloning of higher animals is an example of this). Because projected technology deals with the ability to do certain things in a universe because the physical laws there allow it, projected technology also refers to things not normally thought of as technology, like psionics. Psionics is not a technology *per se*, but rather a natural phenomenon which can be exploited.

Available Baseline Technology

Baseline Tech Level	*Period in Earth's History*	*Available Technology*
0	Stone Age	Fire, stone tools
1	Middle Ages	Wind power
2	c. 1600	Early firearms
3	c. 1800	Steam power
4	c. 1900	Internal combustion engines, electricity
5	c. 1930	Radio, radar, rocketry
6	c. 1950	Jet engines, nuclear fission
7	c. 1970	Low-power lasers, printed circuits
8	c. 1990	Fiber-optics, microchips
9	Beyond 2000	Fusion power
10+	Farther beyond	Increasingly efficient fusion power



The Imperial Campaign as Example

In order to clearly explain these concepts, we will examine the technological underpinnings of the standard Imperial campaign. This campaign is a variant universe like any other described above. It has its own set of technological assumptions which reveal the background physics of the universe.

A universe can be thought of as having "settings" which dictate the sort of things that can and cannot be done in that universe, and how difficult these things are. The harder a certain technology is to perfect, the later it will be introduced on the baseline technology scale.

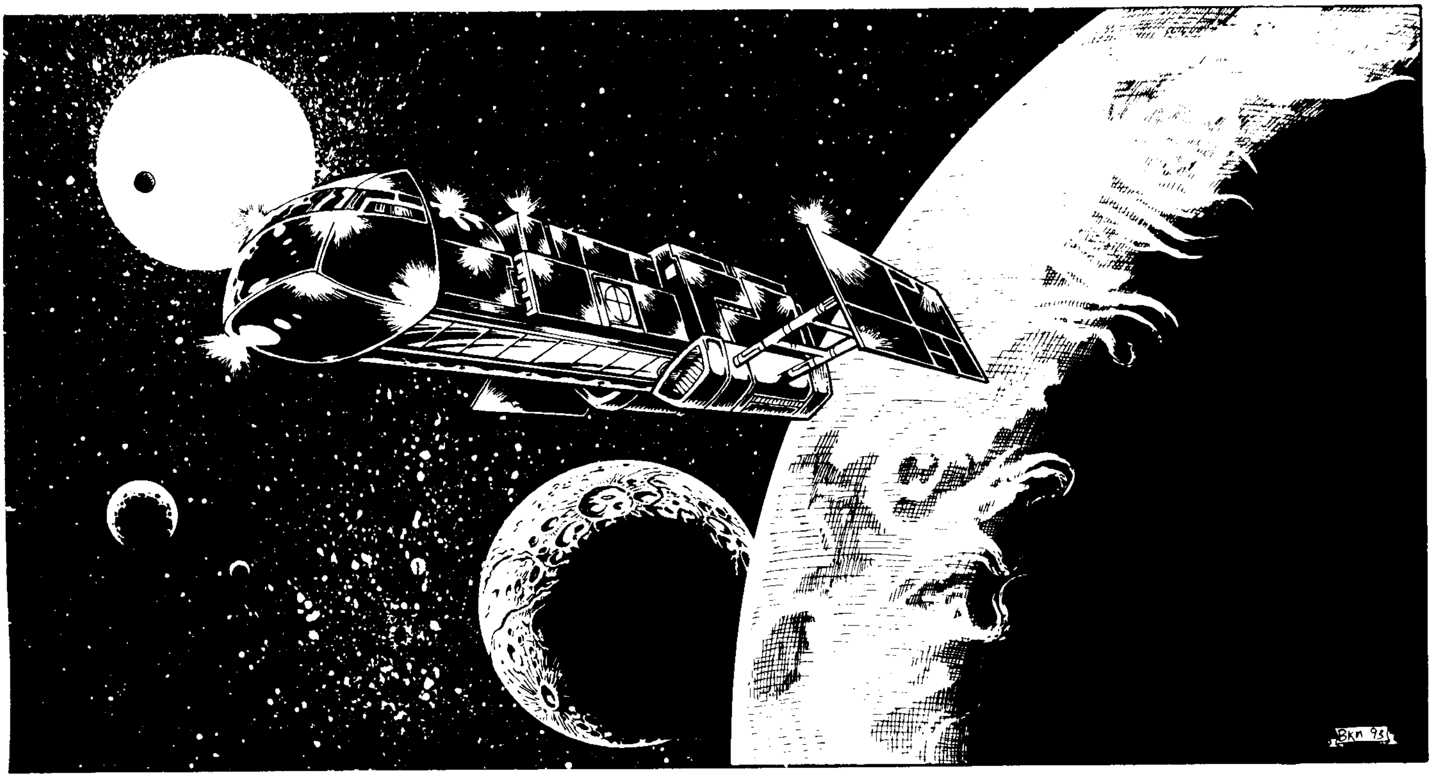
Looking at the technology chart above for the Imperial campaign, we see that, like any **Traveller** universe, it begins with the baseline tech level scale. To this baseline are added the projected technology fields.

Projected technology is divided into several different fields. Each field represents a solution to a problem or goal. For example, the stardrive field answers the problem of how people get from star to star. Some of these fields present alternative approaches to those goals. In the case of the stardrive field, a universe's projected technology can be jump drive, stutterwarp, natural warp points, star gates, hyperspace, or psionic shifting (as a rule of thumb, only one type of stardrive should be included in a universe). Other fields have just one approach and effect (matter teleportation, for example).

When a field is selected to use in a universe, it must be given an initial availability point in relation to the baseline tech level scale. For example, in the Imperial campaign, the stardrive type chosen, jump drive, becomes available at tech level 9.

After setting the tech level of initial availability, the field's "slope" must be set. Most fields will have scales of improvement within them (for example, jump drive availability starts out with jump 1, then advances to jump 2, jump 3, and so on). The slope determines how rapidly these improvements are made with respect to the baseline tech level. The standard 1:1 slope allows one of these improvements per baseline tech level. A shallow slope reflects the fact that each incremental improvement takes longer. A shallow slope could be designated by the referee as requiring two (a 1:2 slope) or even three (a 1:3 slope) tech levels per improvement. For example, if jump drive technology were placed on a 1:2 slope, jump 1 would become available at tech level (TL) 9, jump 2 at TL 11, jump 3 at TL 13, and so on. A universe might also have a steep slope, showing that once a certain breakthrough was made, further development proceeded rapidly. At a 2:1 slope, jump 1 and 2 would appear at TL 9, jump 3 and 4 at TL 10, and so on. In the Imperial campaign, there is an initial flat spot immediately following introduction at TL 9 and 10, but once TL 11 is reached, jump performance increases at the 1:1 rate.

Note the other fields used in the Imperial campaign. There is contra-gravity technology appearing at TL 9. This is one of the subset approaches to the gravitics field. Contra-gravity means the negation of gravitational attraction. Another gravitic approach is thruster plate technology, in which gravitic force is transformed into directional thrust. Both these also allow the generation of artificial gravity fields aboard spaceships.



Laser focusing technology is another field included in the Imperial campaign, also appearing at TL 9. This allows laser beams to hit targets beyond a mere few thousand kilometers.

Psionics is given at the standard strength level. Some universes may not allow psionics at all, while some might use weaker or stronger variations. Note that psionics has no introduction TL, as it is not limited by technology, but only by human awareness of its existence. Because psionics is not a technology as such, and this book is specifically about technical issues, **FF&S** does not include alternative psionics rules.

Some fields are not included here, as they do not appear by TL 16, which is the current limit of the **Traveller: The New Era** Imperial campaign. Whether such fields as FTL (faster-than-light) communications or matter teleportation become available after TL 16 or are altogether impossible in this universe cannot be known to characters in the universe, as everything is impossible until the first time it is done.

The Representative Fields and Effects table shows certain representative fields and their general effects. All universes should have at least a stardrive and a defined TL for the beginning of genetic manipulation techniques. All of the other fields are optional, although most campaigns will have a gravitics approach and some form of psionics.

Some of these fields are linked to each other. For example, if using the psionic shifting approach to stardrive technology, not only would the psionic shifting capability have to be assigned to the tech level at which it becomes available, the universe would also require psionic abilities to use with the drives.

Referees who plan to create their own technological backgrounds should see Appendix II for more details.

Note on Use

The following sections are organized into three books: Major Systems, Subsystems, and Weaponry. Each of these books is further subdivided into specific chapters.

Major systems include spacecraft and vehicles, and subsystems are things like power plants, electronics, controls, etc., that are installed in the major systems. Weaponry includes those weapons installed aboard major subsystems, as well as those used on their own.

Both Book 1 and Book 3 will require the use of the subsystems book to complete their design. For this reason, **FF&S** is thumb-indexed to allow easy access to the chapters of Book 2. When a reference to a "section" of Book 2 appears in Books 1 and 3, place your thumb on the corresponding number in the column on the page's outer margin. By flipping through the book until the number appears reversed white out of a black band, you can move directly to the required section.

Representative Fields and Effects

Representative Fields	*Effects*
Stardrive	Several styles of approach (jump drive, star gates, etc.)
Gravitics	Several styles of approach (antigrav, thruster plates, etc.)
Psionics	Levels of approach (weak, standard, powerful, etc.)
Laser focusing	Yes or no, plus initial TL and slope
Matter teleportation	Yes or no, plus initial TL and slope
FTL communications	Yes or no, with styles of approach, TL, and slope

Book 1: Major Systems

CHAPTER 1
1
Designing Spacecraft

Traveller, as the name indicates, is a game about travel
between the stars. This focus makes starships central to the
game, and so players and referees will want to take a hand at
2 designing ships of their own. It is natural, then, to begin this
book with the spacecraft design sequence.

Designing ships serves two functions. First, even if the
players never own or use any of the ships designed, the designs
3 can add diversity to the sorts of ships they will encounter.
Second, working a design through from hull structure to final
additions to the command bridge will give players a much
4 deeper understanding of what starships are like and how they
work in the **Traveller** universe.

Before starting the design, there are several items which
need to be determined. What is the tech level of the ship? What
5 is its mission? Are there any limits on its price?

Once these decisions are made, take a sheet of paper and
divide the right two-thirds of it into five columns, and label
them Volume, Mass, Power, Surface Area, and Price. This will
6 be your worksheet as you do your design (pre-made worksheets
of this type are available in **Traveller Players' Forms**). When-
ever a component uses volume, mass, power, or hull surface
area, write the amount in the correct column. Whenever a
7 component contributes volume, surface area, or power (hulls
contribute volume and surface area, power plants contribute
power) write the amount in the correct column but indicate it
8 with a plus sign or by enclosing it in brackets. This worksheet
will make designing your vessel much easier.

STEP 1. HULLS

9 The first step in designing a space craft is to determine the
size, shape, and special configuration of the hull. All other
components will then be placed inside the hull or on its
surface.

10 First select a basic hull size from the Hull Size table (page 11).
All hulls have a rate (or "tonnage") which is the displacement
of the hull in tonnes of liquid hydrogen (the most common
starship fuel). Therefore, a ship with a rate of 7 could hold 7
11 tonnes of liquid hydrogen (provided nothing else was put in
the hull). Thus, **Traveller** uses the term "ton" as a unit of
volume where 1 ton equals 14 cubic meters (m^3) of internal
12 volume (also measured as 14 kiloliters). The Hull Size table
indicates the volume (in cubic meters), the material volume of
the shell (assuming a uniform thickness of 1 centimeter) in
cubic meters of hull material, and the length of the hull
13 (actually its diameter, as all hull ratings are based on the
characteristics of a sphere) in meters.

Next, decide on the hull's form and configuration. Hull
form is the basic geometric shape of the hull. As indicated
14 above, the base values for hulls assume a spherical shape. As
all hulls of the same rate have the same interior volume, hulls
in less space-efficient shapes than spheres will have more
surface area, greater length, and require more hull material
to achieve an equivalent volume. The Hull Form and Configuration table (page 12) indicates the various hull forms available and the effects on length and material volume.

Once the basic shape is determined, the designer specifies whether the hull has an unstreamlined, streamlined, or an airframe configuration. This decision will affect the cost of the hull (streamlined and airframe configurations are more expensive). In general, airframe hulls may enter any planetary atmosphere to land on the surface or skim fuel; streamlined hulls may skim gas giants but may not land on planetary surfaces with atmospheres of greater than Thin; and unstreamlined hulls may do neither. These capabilities may be modified if the vessel is equipped with some form of weight compensating drive, such as contra-grav—see the Sublight (Maneuver) Drives chapter (Section 9).

Once the basic size and shape is determined, the hull itself is constructed. Hulls consist of hull plating and internal structure.

Hull plating may be thinner or thicker than 1 cm, but all hulls must have an armor value of at least 1. Interplanetary and interstellar vessels must have a minimum hull armor value of 10 per G rating of the maneuver drive (to protect against micro-meteors). To determine the armor value of the hull plating, decide on a thickness (in centimeters) and multiply the thickness by the toughness of the material used to construct the hull (round to the nearest whole number).

The Vehicle and Craft Construction Materials table (page 38) lists a variety of materials available at different tech levels, along with their toughness, mass per cubic meter, and their price per cubic meter. Once the designer has decided on a thickness, multiply the hull's material volume value by the hull thickness (in centimeters) to determine how many cubic meters of material is used for hull plating. Multiply this by the correct values on the Vehicle and Craft Construction Materials table (as modified by hull form and configuration) to determine mass and price.

Internal structure is also a function of the craft's acceleration and its hull material value. Multiply the hull material value from the Hull Size table (as modified by hull form, but not by configuration) by the craft's maximum acceleration in Gs, and divide the result by the hull material toughness value. The result is the volume of internal structure material used; use the Vehicle and Craft Construction Materials table to determine price and mass. The following equations recapitulate these procedures:

Hull Plating

Minimum Hull Thickness = (Gmax×10) + Toughness of hull material from Vehicle and Craft Construction Materials table

Hull Plating Volume (Unstreamlined or Streamlined configuration): HPV = MV×MVM×Ht

Hull Plating Volume (Airframe configuration): HPV= MV×MVM×1.3×Ht

Hull Plating Mass (in tonnes) = HPV×Mass value of hull material from Vehicle and Craft Construction Materials table

Hull Plating Cost (in MCr) = HPV×Sm×Price of hull material from Vehicle and Craft Construction Materials table

Internal Structure

Internal Structure Volume: ISV = (MV×MVM×Gmax) + Toughness from Vehicle and Craft Construction Materials table

Internal Structure Mass: ISV×Mass value of hull material from Vehicle and Craft Construction Materials table

Internal Structure Price: ISV×Price of hull material from Vehicle and Craft Construction Materials table

Gmax: Maximum rated performance in Gs

HPV: Hull plating volume, in cubic meters

Ht: Hull thickness in centimeters, chosen by designer, but at least equal to minimum hull thickness

ISV: Internal structure volume, in cubic meters

MV: Material volume from Hull Size table, in cubic meters

MVM: Material volume multiplier from Hull Form and Configuration table

Sm: Streamlining price modifier according to selected streamlining configuration

Note also that the hull form will affect the surface area of the hull. Note at this time how much surface area is available. Surface area is used for the attachment of weapons, sensors, communicators, launch ports, etc. Keep a running record of how much surface area is used as the ship is designed.

Hull Size

Rate	*Vol*	*MV*	*L*
1	14	0.4	3.2
2	28	0.5	4
3	42	0.7	4.6
4	56	0.9	5.2
5	70	1.1	5.6
6	84	1.3	5.8
7	98	1.4	6.2
8	112	1.6	6.6
9	126	1.8	6.8
10	140	1.9	7
15	210	2.1	7.5
20	280	2.3	8.0
25	350	2.5	8.6
30	420	2.7	9.2
35	490	2.9	9.8
40	560	3.1	10.4
45	630	3.4	10.8
50	700	3.8	11.2
55	770	4	11.4
60	840	4.2	11.6
65	910	4.4	12.1
70	980	4.6	12.5
75	1050	4.8	12.9
80	1120	5.1	13.2
85	1190	5.3	13.4
90	1260	5.5	13.6
95	1330	5.8	13.8
100	1400	6	14
200	2800	9	17
300	4200	12	20
400	5600	15	22
500	7000	17	24
600	8400	20	25
700	9800	22	27
800	11,200	24	28
900	12,600	26	29
1000	14,000	28	30
2000	28,000	43	36
3000	42,000	57	42
4000	56,000	70	47
5000	70,000	80	51
6000	84,000	90	53
7000	98,000	100	57
8000	112,000	110	60
9000	126,000	120	62
10,000	140,000	130	64
20,000	280,000	200	80
30,000	420,000	260	92
40,000	560,000	320	104
50,000	700,000	370	112
60,000	840,000	420	116
70,000	980,000	470	125
80,000	1,120,000	510	132
90,000	1,260,000	550	136
100,000	1,400,000	590	140
200,000	2,800,000	940	170
300,000	4,200,000	1220	200
400,000	5,600,000	1485	220
500,000	7,000,000	1730	240
600,000	8,400,000	1950	250
700,000	9,800,000	2160	270
800,000	11,200,000	2360	280
900,000	12,600,000	2550	290
1,000,000	14,000,000	2740	300

Rate: The hull rating is a standard measure of the volume of the hull expressed in tonnes of liquid hydrogen. Each tonne of liquid hydrogen displaces 14 cubic meters of volume (and is referred to as a "displacement ton").

Vol: The enclosed volume of the hull in cubic meters (m³). Each cubic meter contains 1000 liters of volume, and so the term kiloliter is sometimes used interchangeably with cubic meter.

MV: Material volume, the volume (in cubic meters) of material required to enclose the hull in a shell 1 centimeter thick.

L: The length of the hull in meters. For spherical hulls, this is also the diameter.

Surface Area: Surface area in square meters is the hull material volume (after hull form and airframe modifications, but without adjustment for hull thickness) multiplied by 100.

Price: The price of a hull in credits is its material volume multiplied by the price shown on the Vehicle and Craft Construction Materials table.

Configuration: Hulls may be in any of several configurations. The values on the Hull Size table are for a spherical hull. With a different configuration, modify the hull material and price as shown on the Hull Form and Configuration table.

Hull Form and Configuration

Hull Form	MVM	Unstrm	Stream	Airframe	LM
		Streamlining Price Modifier			
Open Frame	**2***	**0.3**	**N/A**	**N/A**	**[illegible].5**
Needle	1.3	0.7	0.8	1.2**	3
Wedge	**1.5**	**0.5**	**0.7**	**1.5****	**2.5**
Cylinder	1.1	0.6	0.8	2**	2
Box	**1.2**	**0.4**	**0.6**	**N/A**	**1.25**
Sphere	1	0.8	1	N/A	1
Dome/Disc	**1.2**	**1.4**	**1.6**	**1.2****	**1.5**
Close Structure	1.4	0.3	N/A	N/A	1.75
Slab	**1.5**	**0.5**	**0.7**	**1.5****	**2.75**

* Modifies hull material volume only. Surface area remains unchanged.

** Airframe configuration increases hull shell material volume (and surface area), but not internal structure. Modify hull shell material volume ×1.3 for airframe configuration hulls.

MVM: Material volume multiplier. Multiply the material volume (MV) from the Hull Size table to get the volume of 1cm-thick hull plating for a hull of the corresponding mass and configuration.

Perform the same calculation to get the volume of that hull's internal structure stressed to 1G.

LM: Length Multiplier. Multiply the length L obtained from the Hull Size table by LM to get the length of the hull for a particular hull form.

N/A: Not available; that configuration of hull may not be built with that streamlining option.

Target Size

Once the hull size has been selected, determine its target size based on the following table.

Tons	*Size*
less than 1	**Sub-Micro (SM)**
1+	Micro (Mc)
10+	**Very Small (VS)**
100+	Small (S)
1000+	**Medium (M)**
10,000+	Large (L)
100,000+	**Very Large (VL)**
1,000,000+	Gigantic (G)

STEP 2. FASTER-THAN-LIGHT DRIVE

If a vessel is intended to serve as a starship (i.e., travel between stars), it will need an FTL drive. In the Imperial Space setting of **Traveller**, this will be a jump drive, but other types of drives are available in different science-fiction settings. Faster-than-light drives are covered in detail in the chapter of that name (Section 3).

STEP 3. CONTROL SYSTEMS

Control systems fall into three categories: the actual spacecraft controls, computers, and navigational aids. These are covered in detail in the Control Systems chapter (Section 4).

STEP 4. ELECTRONICS

Electronics fall into four categories: communicators, sensors, electronic countermeasures (ECM), and electronic counter-countermeasures (ECCM).

Players should be familiar with the **Traveller** space combat rules for how communicators, sensors, ECM, and ECCM systems work in order to decide which of these systems to install. All of these systems are covered in the Electronics chapter (Section 5).

STEP 5. WEAPONRY

Ships may be equipped with beam weapons, missiles, defensive screens, and the fire control systems that enable them to function effectively. All of these are covered in the Weaponry book (page 91) except for defensive screens, which are covered in the Defenses chapter (Section 6).

Sockets

If desired, a designer may install turret and/or barbette hardpoint sockets while the ship is being built. This allows easy installation of a standard turret or barbette weapon. Turret hardpoint sockets consume 3 displacement tons (42 cubic meters) while barbette hardpoint sockets consume 6 displacement tons (84 cubic meters). Both cost MCr.005 if installed during construction and, as they are empty, have negligible mass.

See Appendix 1 (page 153) for a selection of standard modular 3-ton (42 kiloliter) turrets, 6-ton (84 kiloliter) barbettes, and larger bays which can be installed on starships. Each turret and barbette is designed to fit into a standard turret hardpoint socket or barbette hardpoint socket. The turret or barbette does not add to the displacement of the ship (as the socket itself takes up the full displacement of the mount), but does add weight as shown on the chart. Sockets may be included in a design even if no weapons are installed until later.

Turret Hardpoint Socket

Displacement: 3 tons
Price: MCr0.005

Barbette Hardpoint Socket

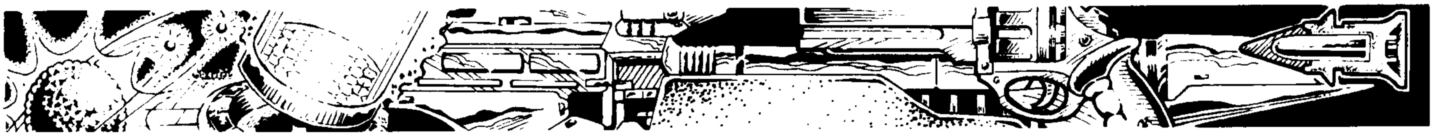
Displacement: 6 tons
Price: MCr0.005

Type	*Displacement*	*Volume*	*Diameter*	*Height*	*Surface Area*
Turret	3 tons	42 m³	3.6 m	4.2 m	10m²
Barbette	6 tons	84 m³	4.5 m	5.25 m	16m²

Bays are built in 50-ton and 100-ton versions. There are no standard sockets for bays, and they are instead custom-installed when the ship is built.

Socket Extenders: Turrets and barbettes may be mounted on extended mounts to achieve better arcs of fire. These are only practical on larger ships. Bays and spinal mounts may not be mounted on extenders.

When mounted on an extender, a turret or barbette has its arc of fire increased by one arc on each side of its normal arc. For example, a turret mounted in hit location 6 of a box hull form would normally have an arc of fire of 2, 3, and 4. If mounted on an extender, it would cover 1-5. Because of location, many arcs of fire will only be increased by one arc.



A turret at hit location 5 on the same box hull, normally arcs 1-3, would only be increase to 1-4.

Each extender is a projection from the hull which requires additional armor and internal structure to support it. Each turret extender requires a basic shell volume of 1.43 cubic meters, which is modified by the hull material and thickness values of the spacecraft's hull as calculated in Step 1. It also requires a basic internal structure volume of 1.43 cubic meters, which is modified by the same maximum G and hull material modifiers as the craft's hull.

Barbette extenders require 2.18 cubic meters of basic shell volume and 2.18 cubic meters of basic internal structure volume, also modified by the same hull thickness, G performance, and hull material values of the craft's hull.

Each such extender has a standard turret or barbette socket on the end of it which can accommodate any standard turret or barbette. The structural requirements of the extender itself are required for the spacecraft; no modifications are required for the weapon fitted in it. A spacecraft may mount no more than two turret extenders or one barbette extender per 500 displacement tons of hull. The minimum hull volume for a single turret extender is 250 tons.

Any spacecraft fitted with a turret or barbette extender becomes unstreamlined, regardless of its original hull configuration. Ships equipped with one or more extender are treated as being one target size larger (i.e., small becomes medium, medium becomes large) when being scanned by active sensors.

OPTIONAL FEATURES

A variety of optional features are possible, such as fuel scoops, laboratories, machine shops, vehicle launch facilities, etc. Consult the Optional Features chapter (Section 7) for a complete discussion.

STEP 7. POWER SUPPLY

The ship needs a power plant to provide electric energy to various subsystems as well as to power the maneuver drive (assuming one is installed). A variety of power plants are available and are detailed in the Power Production chapter (Section 8).

STEP 8. SUBLIGHT DRIVE

The ship's power plant as installed provides electrical power to run the ship's basic systems. The power plant can be (and almost always is) also modified to provide thrust by the addition of a combustion chamber, or to power a more exotic maneuver drive. The variety of maneuver drives available are detailed in the Sublight (Maneuver) Drives chapter (Section 9).

Also included under this heading is the addition of lifter technology as required for movement on or near a planet. This is particularly the case for spacecraft in the Imperial Space campaign, which use contra-grav lifters. See the Lifters chapter (Section 10).

STEP 9. CREW AND LIFE SUPPORT

Determine the crew requirements of the ship and then fit life support to accommodate them. A variety of options for life support are covered in the Life Support chapter (Section 11).

Crew Requirements

Engineering: Ce=(P×Cp)+30
Ce = Engineering crew 1
P = Power plant peak output in megawatts
Cp = Computer control multiplier

Electronics: Cl = (C+S)×Cp
Cl = Electronics crew 2
C = Number of installed communicators
S = Number of installed sensors
Cp = Computer control multiplier

Maneuvering: Cm=D 3
Cm = Maneuvering crew
D = Number of installed drives (maneuver drive = 1, jump drive = 1, maneuver and jump drive = 2) 4

Gunnery: Cg = FD+Wm
Cg = Gunnery crew
FD = Number of master fire directors
Wm = Sum of the installed weapon mounts which are to be manned in action, times the number of crew each 5

Maintenance Crew: Cr = Mp+50
Ct = Maintenance crew
Mp = Maintenance points 6
= (Jm+Em+Wm+Pm+Mm+Sm)×(0.1×Cp)
Jm = Mass of installed jump drive, in tonnes
Em = Mass of all installed electronics, in tonnes
Wm = Mass of all installed weapons systems, in tonnes 7
Pm = Mass of all installed power plants, in tonnes
Mm = Mass of heat exchanger/ignition chamber, in tonnes
Sm = Mass of all carried spacecraft, in tonnes
Cp = Computer control multiplier 8

Ships Troops: Ct as desired.
Ct = Ship's troops

Flight Crew: Cf = Q×R
Cf = Flight crew 9
Q = Total number of carried craft
R = Crew required of each craft

Command: Cc = Z+6
Cc = Command crew 10
Z = Ce+Cl+Cm+Cg+Cr+Ct+Cf

Stewards: Cs = [(Cc+Ph)+8] + {[(Z+Pm)+50]×Cp}
Cs = Stewards 11
Cc = Command crew
Ph = High Passengers
Z = Ce+Cl+Cm+Cg+Cr+Ct+Cf
Pm = Middle Passengers 12
Cp = Computer control multiplier

Medical: Cd = [(Z+Cc+Cs+Ph+Pm)+120] + (Pl+20)
Cd = Medical crew
Z = Ce+Cl+Cm+Cg+Cr+Ct+Cf 13
Cc = Command crew
Ph = High Passengers
Pm = Middle Passengers
Pl = Low Passengers 14

Note: Retain fractions during multiple-step calculations; round all fractions in the final result down.

STEP 10. WORKSTATIONS AND BRIDGE

Workstations

Certain crewmembers require the installation of workstations at which they perform their duties of controlling or monitoring certain equipment. One standard workstation (7 m³, see the Controls chapter, Section 4) must be installed for each engineering, electronics, maneuvering, master fire director, and command crewmember as calculated in the Life Support step above. Workstations for weapons are included in the weapons themselves, and need not be allocated again.

If a ship requires a bridge (see section immediately below), the workstations for the electronics, maneuvering, master fire director, and command crewmembers are installed according to those guidelines, and do not need additional normal workstations. Each engineering crewmember requires one normal workstation, regardless of whether the ship requires a bridge or not.

Even if a ship does not require the specific fitting of bridge workstations as discussed below, the workstations for electronics, maneuvering, master fire director, and command crewmembers are still considered to be grouped together into an area called the "flight deck." This flight deck is treated as a bridge, and its crew as bridge crew for purposes of hits and damage in combat.

Bridge

The ship's bridge is a compartment in the vessel containing crew workstations for command, maneuvering, sensor, communications, and fire direction personnel. It is the ship's nerve center, particularly during combat. The basic parameters of the bridge are laid down at this time, but its dimensions are not finalized until all electronics and fire control equipment is installed.

The bridge consists of a number of 1-dispacement-ton (14 cubic meters) workstations. The larger size of the workstations is to allow room for easy movement and communication by command and replacement personnel as well as to allow inspections and conferences on the bridge itself without interfering with the crew's duties.

One workstation is required per electronics, maneuvering, and command crewmember, as determined in the Life Support step, as well as one workstation per master fire director. Each bridge workstation uses 14 cubic meters of volume, masses 0.2 tonnes total, and costs an amount as shown on the Workstations table found in the Controls chapter (Section 4)

Not all ships are large or complex enough to require a bridge. A ship requires a bridge if, during the Crew Requirements step (page 13), it is discovered that *two or more* command crew are required. If a ship is of sufficient size/complexity to require a bridge and does not have one installed (i.e., has only a flight deck installed instead), the following penalties apply:

- All sensor tasks are one level more difficult
- No sensor hand-offs are allowed
- Jamming tasks are one level more difficult
- Fire tasks for turrets under local control are one level harder
- MFD-directed fire tasks are one level harder on each turn that the battery composition is changed
- Jump tasks are one level more difficult

Auxiliary Bridge: A designer may wish to install one or more auxiliary bridges with as many or fewer bridge workstations as are installed on the operating bridge (auxiliary flight decks may be installed as well, using normal workstations). Fewer workstations will limit the number of fire directors, sensors, or communicators which can be operated from the site, calculated using the normal crew formulae. If an auxiliary bridge is constructed, additional crewmembers must be carried to man it.

Flag Bridge: If the vessel is to serve as the flagship of a group of ships, it should have a flag bridge. The flag bridge is the facility from which the flag officer commanding (admiral) exercises command and control. The bridge should have bridge workstations for the same number of sensor and communication crew as does the ship's command bridge, plus bridge workstations for additional command crew, depending upon the size of the force being commanded (3+0.25×[Number of ships in the fleet]). Ships which carry large numbers of small craft may have a fighter control bridge containing 3+0.06×(Number of fighters carried) bridge workstations. These bridges allow the application of Fleet Tactics skill to multi-vessel operations. Volume, weight, and price are calculated in the same way as for the ship's bridge.

Fire Control Bridge: On particularly large ships, the designer may wish to designate a number of MFDs that are not located on the main bridge, but are grouped together separately as their own bridge. This decreases the chance of fire control capabilities being lost from hits on the operating bridge.

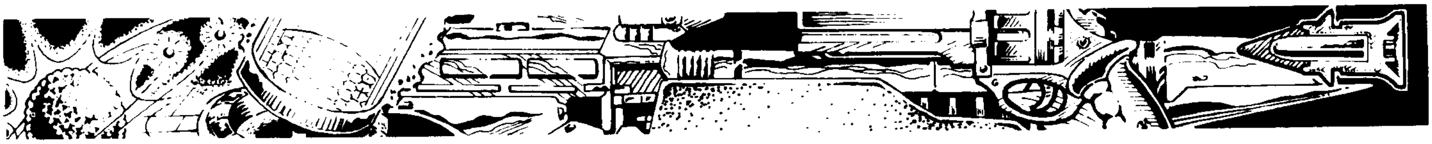
DESIGN EVALUATION

Once the design is complete, you will need to evaluate it to determine its game ratings.

1. Check Step

Go back and add up the volume, price, surface area, and mass of all the components. This is your chance to check to make sure that its internal occupied volume and area of surface fixtures are within what is allowed by the size of its hull. This step also provides you with a total price and mass.

Calculate two masses, loaded and empty. Loaded includes a full load of fuel, full load of cargo (assume 1 tonne per m³), and all carried craft and vehicles on board. Empty is emptied of all jump fuel and reaction mass, all cargo, and all carried craft and vehicles.



2. Record Design Features

Most of the evaluation of your design will consist of recording the features already determined by the design, such as hull form, configuration, armor value, acceleration, jump number, computer type, installed electronics, etc.

If the ship is equipped with drop tanks, it is necessary to record its displacement and determine its G-rating and jump range both with and without the tanks (this can be complicated by the fact that sometimes the higher jump performance possible with the lower displacement cannot be achieved with the fuel remaining). By the same token, a ship which carries other vessels by means of external grapples may need to calculate its jump and maneuver performance separately for when the vehicle(s) are attached and detached. In most cases these figures will be the same, as the vessel is equipped with drives large enough to operate with the small craft attached, and the craft is a small enough percentage of the mother ship that jump and maneuver do not increase appreciably when the craft is detached.

3. Allocate Damage Areas

Divide the volume (cubic meters) of the ship's components into the following categories:

Electronics: All sensors, communicators, ECM, ECCM, control systems, workstations, flight deck/bridge spaces, fire directors, and internal screens (i.e., those not mounted in bays, barbettes, or turrets).

Hold: All fuel, cargo space, hangars, labs, and shops.

Quarters: All life support systems (including the installed artificial gravity/G-compensators), hull material volume, accommodations, sick bays, and low berths.

Engineering: All power plant, FTL drives, sublight (maneuver) drives (including CG lifters), and fuel-processing equipment.

Weapons Mounts: Each individual weapons mount, including bay-, barbette-, or turret-mounted defensive screens.

Now take the total displacement of the ship and divide by 20. The result is the number of cubic meters of volume available in each of the 20 hit location areas. Allocate the above damage areas to distinct hit locations in proportion to how much of the volume of the ship they consume. Use the ships already rated as a guide.

In general, the bridge (i.e., the largest concentration of electronics) should be in the nose of the vessel to minimize the amount of circuitry between the bridge and the sensor arrays, which are usually mounted forward as well. If the ship has a maneuver thruster, the majority of the engineering space should be aft, but any ship with CG lifters can have engineering space forward on its ventral side as well. If you have a visual image of what the ship looks like, try to make the hit locations correspond with that as much as possible. When allocating the volume of a spinal mount to hit locations, divide it evenly among all 20 hit locations.

4. Place Surface Fixtures

Surface fixtures include all antennae, radiators, external
grapples, and hatches. Surface area devoted to slower-than-light 1
maneuver drive (aft), jump drive (aft), and lifters (ventral surfaces)
should also be allocated. These systems do not have surface hit
locations listed on the ship's damage table (these have their
damage handled by internal damage in the same hit locations), but 2
are allocated in this step to ensure that other systems are not
improperly placed where these engineering systems should be.
Divide the total hull surface area by 20 to determine the surface area 3
of each hit location and allocate surface fixtures accordingly.

5. Evaluate System Damage

Record the tonnage of each major system in the vessel (each 4
entry on the Damage Type chart, plus each separate weapons
mount, plus each antenna on the hull surface) and determine
its damage capacity. Systems can take 1 minor hit per 5 metric
tonnes of mass (to a maximum of 4), or 1 major hit per 100 metric 5
tonnes of mass (21 or more metric tonnes rounds up to 1 major hit;
above multiples of 100 tonnes, 20 tonnes or less round down, 21+
round up). Note that small components (such as laser communi-
cators or active EMS antennae) always take 1 minor hit, even if they 6
have no listed mass or a total mass much smaller than 5 tonnes.

The following specific systems should always be evaluated:

Electronics

Each sensor and its antenna, based on mass. 7

Each communicator and its antenna, based on mass.

Each master fire director and its antenna, based on its mass.

Each ECM system and its antenna, based on its mass. EMM 8
is a special case. The EMM controller has its hits based on its
total mass, using normal procedures. For the radiators, allow 1
minor hit for each whole MW of power allocated to the EMM
system (i.e., drop fractional MW). Note that this is an exception to 9
the rule that systems may only have a maximum of 4 minor hits.

Hold

Hangar: The total mass of the hangar spaces divided by 20 equals
the number of major hits (round to the nearest whole number). 10

Labs: Based on the total mass of each lab.

Shops: Based on the total mass of each shop.

Cargo Space (CS): The total mass of the cargo carried is a 11
measure of how much damage is absorbed when the cargo is
hit by a weapon. This varies with cargo type. If cargo space is
empty, cargo space hits are re-rolled as excess damage.

Quarters 12

Stateroom (SR): Each large stateroom takes 1 major hit. Each
small stateroom takes 2 minor hits.

Life Support: This value is based on the mass of all life support
machinery (not including G-compensators) plus the total hull 13
material mass (hull shell and internal structure). Two-thirds of
the total mass is used to determine the damage level of the
main life support system (LS), and the remaining third deter-
mines the damage of the emergency life support (ELS) system. 14

Artificial Gravity (AG): Based on the total volume of the
vessel's G-compensators.

Low Berth (LBth): The low berths take 1 minor hit per low berth.

Engineering

When using alternate technology fields for FTL and/or sublight drives, the names and number of these systems will change. For example, a ship with stutterwarp uses this for FTL and sublight drive, while a ship with thruster plates uses these for sublight drive and lifters. The systems listed below are for the Imperial Space campaign, which uses three systems (JD, MD, CG). Designers using other systems must make adjustments accordingly.

Jump Drive (JD): Based on the mass of the jump drive itself.

Power Plant (PP): Based on the mass of the power plant.

Maneuver Drive (MD): Based on the mass of the heat exchanger/ignition chamber for the maneuver drive.

Contra-Grav Lifters (CG): The mass of the CG lifters.

Fuel-Processing Plant (FPP): Based on the total mass of the plant.

Weapons Mounts

Each individual weapons mount: These may be laser turrets (LT), barbettes (LB), or bays (LBy); missile turrets (MT), barbettes (MB), or bays (MBy); particle accelerators (PA); meson guns (MG); etc. All weapons take hits based on their total mass.

6. Determine Arcs of Fire

The arc of fire of each weapon is determined by the hull location of the weapon and the hull form of the vessel. The following table shows which hull location weapon stations can fire into which arcs on each type of hull form available.

After determining which arcs a weapon can fire into, note the information on the ship's control panel data sheet.

Arcs of Fire by Hull Form

Hull Form	*(1) Bow On*	*(2) Bow Quarter*	*(3) Broadside*	*(4) After Quarter*	*(5) Stern On*
Open Frame	**1-20**	**1-20**	**1-20**	**1-20**	**1-20**
Needle	1-15	1-19	1-20	2-20	6-20
Wedge	**1-19**	**1-19**	**2-19**	**16-20**	**16-20**
Cylinder	1-5	1-15	2-19	6-20	16-20
Box	**1-5**	**1-15**	**2-19**	**6-20**	**16-20**
Sphere	1-11	1-15	2-19	6-20	10-20
Dome/Disc	**1-11**	**1-15**	**2-19**	**6-20**	**10-20**
Close Structure	1-9	1-15	2-19	6-20	12-20
Slab	**1-5, 10-11**	**1-15**	**2-19**	**6-20**	**10-11, 16-20**

7. Determine Maintenance Points

Take the loaded mass of the vessel, but subtract the weight of any carried craft and vehicles (their maintenance points are calculated separately), then subtract the mass of its hull shell. Divide the result by the TL modifiers here.

TL	*Maint Modifier*
4-5	**2**
6-7	3
8-9	**4**
10-12	5
13-15	**6**
16-18	8
19-21	**10**
22+	12

If the craft has two or more computers installed (three or more computers for jump-capable ships, St or Fb only, not flight computers), one of these is considered to be a dedicated maintenance troubleshooting computer, which allows the current figure to be divided by 4. If there is only one computer (or two or less for a starship), the figure remains unreduced. This is the number of maintenance points required by the craft. (The loaded figure is used because items such as cargo and fuel do require regular attention to see that they have not shifted, leaked, etc.)

Note that maintenance points may be temporarily increased by environment (see "Carrier Aircraft," page 30 and **TNE**, page 309). Spacecraft constantly exposed to saltwater use a different multiplier for saltwater corrosion than aircraft do (page 30), a constant value of 1.5, as all spacecraft are sealed. Hybrid spacecraft that use air-breathing engines in atmospheres are also subject to "Atmospheric Performance," page 64.

8. Atmospheric Speed

Any spacecraft which is streamlined can hurtle through the atmosphere at hypersonic speeds (and will have to in order to reach orbit), but it cannot necessarily maneuver at those speeds. The maximum atmospheric maneuver speed of a streamlined spacecraft, regardless of its G rating, is 1100 kph. The maximum atmospheric maneuver speed of an airframe spacecraft is determined by the G rating, as shown below

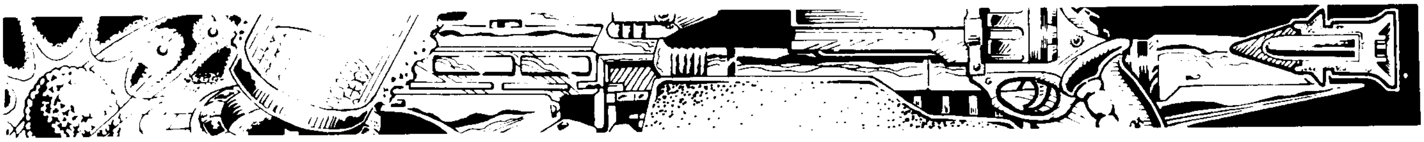
G	*Speed (kph)*
1	**3500**
2	4700
3	**5300**
4	5600
5	**5800**
6	5900

Maximum atmospheric maneuver speed is used to determine the difficulty modifier for hitting a flying spacecraft in an atmosphere (**Traveller**, page 294). The maximum atmospheric maneuver speed multiplied by 0.75 is the spacecraft's atmospheric cruising speed, which is used to determine travel times in the atmosphere when the spacecraft is used as an aircraft.

Spacecraft with lifters (contra-gravity, thruster plates, etc.) may fly NOE (nap-of-the-earth). Spacecraft have a safe NOE speed equal to their maximum atmospheric speed multiplied by 0.25, but never more than allowed by their installed terrain-following avionics (or 40 kph if no avionics are installed).

Combat Move: The high mode combat movement (in 10-meter grid squares per combat turn) is equal to the spacecraft's maximum atmospheric flight speed (in kilometers per hour) multiplied by 0.139. The safe NOE combat movement (in 10-meter grid squares per combat turn) is equal to the spacecraft's maximum NOE speed (in kilometers per hour) multiplied by 0.139, rounded to the nearest whole number.

Travel Move: The high mode travel movement rate (in kilometers per 4-hour period) is equal to the cruising speed (in kilometers per hour) multiplied by 4. The NOE mode travel movement rate (in kilometers per 4-hour period) is equal to the safe NOE speed (in kilometers per hour) multiplied by 6.



CHAPTER 2
Ground Vehicle Design

A ground vehicle, for purposes of these rules, is defined as any conveyance which operates in physical contact with the ground. This includes wheeled vehicles, tracked vehicles, and legged vehicles. Ground vehicles are produced by adding components to a basic structure. The vehicle's volume is determined first and specific components are then added until the volume is filled. Components have a weight and price; the vehicle's weight and price are determined by adding together the weights and prices of its components.

Before starting the design, there are several items which need to be determined. What is the tech level of the vehicle? What is its mission? Are there any limits on its price?

Once these decisions are made, take a sheet of paper and divide the right two-thirds of it into five columns, and label them Volume, Mass, Power, Surface Area, and Price. This will be your worksheet as you do your design. Whenever a component uses volume, mass, power, or chassis surface area, write the amount in the correct column. Whenever a component contributes volume, surface area, or power (hulls contribute volume and surface area, power plants contribute power) write the amount in the correct column but distinguish it with brackets or a "+" sign. This worksheet will make designing your vehicle much easier.

STEP 1. CHASSIS

The first step is to determine the size and general configuration of the chassis. Select a chassis size from the Chassis Size table below. All chassis have a rate which is the displacement of the hull in tonnes of liquid hydrogen (a common measure as it is the most common fuel). Therefore, a vehicle with a rate of 1 could hold 1 tonne of liquid hydrogen (provided nothing else was put in the chassis). Each "ton" of displacement consists of 14 cubic meters (m^3) of internal space (or 14 kl). The Chassis Size table indicates the volume (in m^3), and the material volume of the shell (assuming a uniform thickness of 1 cm) in cubic meters of material.

Note that this table is identical to that found in the starship design section of the rules, with two exceptions. First, the vehicle chassis listed are all assumed to be laid out as elongated six-sided blocks, and so have already had their material volumes modified accordingly. Second, the "hull length" column is omitted as being irrelevant to vehicle design.

Vehicles may be designed using chassis which fall between two listed values on the table by means of interpolation. Larger vehicle chassis may be used by using the spacecraft Hull Size table (page 11). Use 1.4 for the material volume multiplier (MVM) for a vehicle chassis.

CHASSIS SIZE

Rate	*Vol*	*MV*
1	14	0.6
2	28	0.7
3	42	1.0
4	56	1.3
5	70	1.5
6	84	1.8
7	98	2.0
8	112	2.2
9	126	2.5
10	140	2.7

Once the chassis size is determined, determine its configuration. There are three general vehicle configurations: standard, turret, and small turret. Most vehicles, such as cars, trucks, air 1
rafts, etc., are standard configuration. Turret vehicles, like tanks, have a turret which holds a large gun and one or more crewmembers. Small turret vehicles have a single small turret which holds a light weapon and sometimes a gunner (although 2
it is often remotely controlled).

A turret vehicle has considerable waste volume representing the free area around the turret to enable it to traverse and fire in all directions. At higher tech levels, advances in engineering allow 3
larger and larger turrets on chassis of a given size, reducing this inefficiency. To represent this feature in the design, all components mounted in the turret consume more than their *actual* volume. To determine the exact increase in volume, consult the 4
Turret Efficiency table, below.

TURRET EFFICIENCY

TL	*Volume*	
		5
4	×6	
5	×5	
6	×4	
7	×3	6
8+	×2	

The volume of turret components after multiplying them by 7
these turret efficiency values is referred to as their *effective volume.*

All components in a small turret (see below, in Weaponry) have an effective volume equal to 10 times their actual volume.

Next, the chassis itself is constructed by enclosing the chassis 8
space with hull material, called hull plating.

The Vehicle and Craft Construction Materials table (Section 1, page 38) lists a variety of materials available at different tech levels, along with their toughness, mass per cubic meter, and their price per cubic 9
meter. Once the designer has decided on a thickness, multiply the hull's material volume value by the hull thickness (in centimeters) to determine how many cubic meters of material is used for hull plating. Multiply this by the correct values on the Vehicle and Craft Construc- 10
tion Materials table (as modified by hull form and configuration) to determine mass and price.

Hull plating may be thinner or thicker than 1 cm, but all chassis must have an armor value of at least 1. To determine the armor value of the 11
hull plating, decide on a thickness (in centimeters) and multiply the thickness by the toughness of the material used to construct the hull.

Once the base armor value (that enjoyed by all surfaces) is determined, the designer may decide to put additional armor on one 12
or more surfaces of the vehicle. This is done by adding material weight and cost to the vehicle, but it adds additional thickness (and thus protection) to that face. Each additional centimeter of material adds to the material volume as shown on the following table. 13

Face	*Increase per cm*	
Front or rear (each)	10%	
Sides (both)	15%	14
Top or bottom (each)	25%	

For example, a vehicle built around a 3-ton hull (42 kiloliters) has a material volume of 1 (meaning each centimeter of hull thickness all the way around the hull requires 1 cubic meter of actual hull material). The designer decided to increase the thickness of the front armor of the vehicle. For each extra centimeter of front armor, add 0.1 (10% of 1) cubic meters to the total hull material.

Once all armor is installed, the designer may further increase its effectiveness by sloping it. The top and bottom may not be sloped, but the front, rear, and sides may be. Armor may be installed at a moderate slope (about 30°) or a radical slope (about 60°). A moderate slope increases the effective armor value of a face by 50%. A radical slope increases the effective armor value of a face by 100%.

Sloping armor does not add to either the weight or price of the vehicle, but does subtract from its volume. The volume cost of sloping an armored face is expressed as a multiple of the entire enclosed volume of the chassis and is noted on the table below.

Armor Slope

Face	*Moderate*	*Radical*
Front or rear	10%	20%
Sides (both)	20%	40%

For example, a vehicle with a size 6 hull (84 kiloliters) has a radical slope to its frontal armor. This uses up 20% of the original volume, or 16.8 cubic meters.

Vehicles may be designed as *open* vehicles, meaning they are open-topped and partially open-sided. These vehicles sometimes have a glass or plastic transparent windscreen or roof added later. Open vehicles multiply their hull material volume by 0.7. They have no armor against overhead attacks, and attacks from the side and rear are rolled for to determine if they strike armor or glass (using the open vehicle rule).

STEP 2. SUSPENSION

The suspension is the mechanism in contact with the ground. There are five specific suspension types: restricted wheel, wheel, cross-country wheel, track, and walker. Different suspension types are available at different tech levels. Each suspension takes up a fixed percentage of the chassis volume. The Suspension Table lists those values as well as the weight and price per cubic meter of installed suspension.

Suspension

Type	*TL*	*Vol*	*Mass*	*SA*	*Price*
Restricted Wheel	4	2.1	0.42	70	.000525
Restricted Wheel	5	1.4	0.28	70	.00035
Wheel	5	2.1	0.42	70	.000525
Cross Country Wheel	5	2.8	0.56	60	.0007
Track	5	2.8	4.2	50	.0014
Walker	8	2.8	2.8	80	.0028

TL: Tech level available.

Kl: Volume in kiloliters (cubic meters) per displacement ton (14 kl) of hull.

Mass: Mass in tonnes per displacement ton (14 kl) of hull.

SA: Useful surface area in square meters is equal to the chassis material volume (from the Chassis Size table) times this number. This computation shows the surface area left after allowing for the surface area of the suspension itself plus such standard features as hatches, vision devices, etc. Useful surface area is used for the installation of sensor and communications antennae, and other surface area consuming items.

MCr: Price in millions of credits per displacement ton (14 kl) of hull.

STEP 3. CONTROL SYSTEMS

Vehicles require only basic mechanical controls to drive, but may have more sophisticated controls if a computer is installed. These are covered in detail in the Control Systems chapter (Section 4).

STEP 4. LIFE SUPPORT

The type of life support required by a vehicle depends largely on its intended mission. A variety of options for life support are covered in the Life Support chapter (Section 11). If any extended accommodations are to be fitted (such as staterooms or bunks), they are installed at this time. Only vehicles intended for very long trips, days or weeks, are fitted with bunks or staterooms, and even then they are usually intended for use by several crewpersons in rotation.

STEP 5. ELECTRONICS

Electronics fall into four categories: communicators, sensors, electronic countermeasures (ECM), and electronic counter-countermeasures (ECCM).

Players should be familiar with the **Traveller** combat rules for how communicators, sensors, ECM, and ECCM systems work in order to decide which of these systems to install. All of these systems are covered in the Electronics chapter (section 5).

STEP 6. WEAPONRY

Vehicles may be equipped with weapons, missiles, defensive systems, and the fire control systems that enable them to function effectively. All of these are covered in the Weaponry book (beginning on page 91) except for defensive systems, which are covered in the Defenses chapter (Section 6), and fire control, which is in Section 14. A number of special considerations apply to vehicle-mounted weapons, however.

Weapon Mounts: Vehicle-mounted guns do not require carriages, tripods, or other such mounts, as the vehicle itself serves as the mount. However, the type of vehicle mount and its location must be specified. There are five main types of vehicle mounts: chassis, turret, small turret, pintel, and open. As a sixth option, tac missiles may be mounted on the outside of the vehicle on launch rails.

Weapons in chassis mounts emerge from one of the six faces of the chassis. Although fine adjustments to their bearing and elevation is possible, gross weapon pointing is achieved by repositioning the vehicle itself.

A turret is a fully rotating armored compartment set onto the top of the chassis. The advantage of a turret is that it allows fire in any direction without without requiring the vehicle to be pointing or travelling in that direction. A turret (as opposed to a small turret) is one whose effective volume is more than 10% of the total chassis volume. Indirect fire weapons must be in either turrets or open mounts (see below). Although referred to simply as "turrets" in the basic rules, these will sometimes be referred to as "main turrets" in the rules below to distinguish them from small turrets.

A small turret is usually on top of a turret, or in the case of a turretless vehicle, on top of the chassis itself, but it could be mounted on any face of the vehicle. Small turrets may have an effective volume of no more than 10% of the total vehicle volume. If a small turret is to be manned, it must allocate volume for the crewmember equal to one-half the volume of the member's crewstation. Manned small turrets are also called cupolas, unmanned small turrets are referred to as *remote mounts*. Remote mounts are controlled from crewstations within the hull. The equipment necessary to remotely control the mount (periscopes, repeaters, etc.) is subsumed within the mass and price of the remote turret and crewstation (but see Step 8, Crew, below for fire control requirements).

Both types of turret have front, side, top (or in the case of a belly turret, bottom), and rear armor equal to those values calculated for the entire vehicle.

A pintel mount is a simple post or curved rail on which is mounted a light weapon, such as a machinegun or autocannon. It is usually mounted on top of the chassis or turret.

An open weapon is a large weapon mounted in the chassis of an open-topped vehicle. Many early self-propelled artillery pieces were of this configuration. Indirect fire weapons must either be in open mounts or turrets.

Weapon Stabilization: Stabilization gear enables a vehicle to fire its weapons while moving; the Stabilization table (see the Fire Control chapter, Section 14) lists the characteristics of stabilization gear at various tech levels.

Mechanical Loading Assistance: A gun may reduce its requirement for loaders by having mechanical loading assistance for the gun. Mechanical loading assistance is covered in the actual weapon design sequences. Loading assisters have a volume of 1 cubic meter per ton and must be located with the weapons mount and the ammunition. (Note that with mechanical loading assistance, the ammunition must be stored in the same part of the vehicle as the gun mount; i.e., in the turret for a turret-mounted weapon, or in the hull for a chassis or open-mount weapon.)

Autoloader: CPR guns require one or more crew as loaders in addition to the gunner. All of the weapon's loaders may be replaced by an autoloader; weapons in remote mounts *must* have autoloaders. Autoloader characteristics are calculated during the weapon design sequence. Half of the autoloader's volume is in the part of the vehicle with the weapon mount and the rest is in the part of the vehicle where the ammunition is stored.

STEP 7. POWER PLANT

The vehicle needs a power plant to provide electric energy to various subsystems as well as to power the suspension. A variety of power plants are available and are detailed in the Power Production chapter (section 8).

Fuel: Fuel tankage for the power plant is also calculated at this time.

Auxiliary Water Propulsion: Amphibious tracked vehicles do not require auxiliary water propulsion, as their tracks act as paddles and can drive them forward slowly. Wheeled amphibious vehicles (and tracked amphibious vehicles looking for more speed than their tracks will give them) may have auxiliary water propulsion. Auxiliary water propulsion occupies volume equal to 0.05 of the power plant volume. It masses 1 tonne per cubic meter and costs MCr0.001 per cubic meter.

STEP 8. TRANSMISSION

Ground vehicles must have a transmission. The size of the transmission depends on the tech level of the vehicle and the output of the power plant. 1

Wheel and Tracked Transmissions

2

TL	Vol/T	Vol/W	Price
4-5	5	3	1000
6	2	1	1250
7+	.5	.3	1500

3

Walker Transmissions

TL	Vol/L	Price
8	8	10,000
9	2	2500
10	.4	675

4

TL: Tech level of availability

Vol/T: Volume (in cubic meters) of a tracked vehicle suspension per MW of power output. 5

Vol/W: Volume (in cubic meters) of a wheeled vehicle suspension per MW of power output.

Vol/L: Volume (in cubic meters) of a legged (walker) vehicle suspension per MW of power output. 6

Price: Price (in Cr) per cubic meter of installed transmission.

Mass: The mass (in tonnes) of the transmission is equal to its volume (in cubic meters) 7

STEP 9. CREW

Each vehicle crewmember requires a crewstation, and each passenger requires a seat. 8

Crewstations: Two types of crewstations are possible: cramped and open. Open vehicles may have cramped crewstations while enclosed vehicles must have open crewstations. Both types are listed in the Controls chapter (Section 4). The crewstations must be from the same tech level as the controls installed in Step 3. 9

Seats: Passenger seats are found in the Optional Features chapter (Section 7).

Each vehicle requires a driver. A vehicle commander is optional but recommended on enclosed armored fighting vehicles. If the vehicle has a main turret, the commander's station must be in the turret. 10

If one or more weapons are installed, a gunner is required, and a loader may be necessary as well. A gunner may fire more than one weapon, but he may only fire weapons controlled from his station (called a *weapon station*). One station may control all weapons mounted on the same side of the chassis or in any part of a turret. One station is required for each small turret unless it is remotely controlled. One station may control any number of remote turrets, but a gunner may never operate more than one weapon in a single turn. A weapon station must be in the same part of the vehicle as the weapons controlled, except that a turret-mounted weapon may be controlled from the chassis and remote-mounted weapons may be controlled from anywhere. 11 12 13

Fire Control: During the weapon design sequence, fire control systems are specified for various weapons. However, the designer should note that for vehicle-mounted weapons, fire control systems must be provided for each weapon station, not just for 14

each weapon. For a vehicle with only one weapon and only one
gunner, this distinction is immaterial, but if that same vehicle were
1 designed to allow the gun to be fired from two separate weapon
stations, each would require a separate fire control system.
If the weapon station controlling a weapon is in a different part
of the vehicle from the weapon itself, the volume of the fire
2 control equipment is divided evenly between the two locations.
Weapon stations that only control small arms or tac missiles do
not require fire control systems. However, tac missile weapon
stations are equipped with tac missile control units (see page 149).
3

STEP 11. CARGO

All remaining volume may be allocated to ammunition stow-
age, cargo space, or declared waste volume. Waste volume has
4 no effect on the design.
Ammunition stowage has no cost but adds the weight of the
ammunition to the loaded weight of the vehicle.
Cargo volume has no cost but adds to the loaded weight of the
5 vehicle. Multiply the cargo volume, in cubic meters, by 0.25 to
determine the addition, in metric tonnes, to the vehicle's loaded
weight.

6 DESIGN EVALUATION

Once the design is complete, you will need to evaluate it to
determine its game ratings.

7 1. Check Step

Go back and add up the volume, price, surface area, and mass
of all the components. This is your chance to check to make sure
that its internal occupied volume and area of surface fixtures are
8 within what is allowed by the size of its hull. This step also provides
you with a total price and mass.

9 2. Record Design Features

Most of the evaluation of your design will consist of recording
the features already determined by the design, such as armor
values, weapon statistics, installed electronics, crew, passengers,
10 etc. Note the volume of the original chassis as its transport volume
(the space it takes up in the hold of a starship or transport vehicle).
At the same time, total the price of the vehicle and its empty
and loaded weights. Empty weight is the vehicle without any
11 ammunition, fuel, cargo, crew, or passengers. This is essentially the
weight of the vehicle as it comes off the assembly line, and is also what
it weighs when being transported by another vehicle or starship.
Loaded weight includes a full load of ammunition and fuel, full
12 cargo (0.25 tonnes per cubic meter), and a weight allowance of
100 kilograms per passenger and crew. This is its typical weight
when in operation.
Flotation: Determine enclosed volume. To do so, first add up
13 actual turret volume, then add up the effective turret volume.
Subtract the effective turret volume from the vehicle's transport
volume (the volume of its nominal chassis size) and add the actual
turret volume. The result is the vehicle's enclosed volume. Divide
14 the enclosed volume by the vehicle's loaded weight in metric
tonnes. If the result is greater than 1, the vehicle floats; if it is 1 or
less, the vehicle will not float.
Suspension Damage Resistance: Compute suspension damage resistance (SDR): for tracked vehicles, this is the suspension's armor value; for wheeled and walker vehicles, its critical damage level (see **TNE** page 300). These are based on the vehicle's chassis size *in displacement tons* as chosen in Step 1.

Tracked SDR = 2 × chassis size, Wheeled SDR = 1 + chassis size, Walker SDR = chassis size.

3. Determine Movement

Movement of ground vehicles is based on top road speeds and cross-country speeds, both of which are determined by the vehicle's loaded power-to-weight ratio as well as its suspension. For purposes of the power-to-weight calculations, the vehicle's motive power is the total output of its power plant minus energy used to run other systems (such as life support, electronics, weapons, etc.).

Road Speed:

Base road speed in kilometers per hour = 5 + ([MW ÷ LW]×2500)

MW: Vehicle motive power in megawatts

LW: Loaded weight of the vehicle in tonnes

Tracked and wheeled vehicle modifiers

Each tech level above 5	+1 kph
If wheeled	+10 kph
If light wheeled*	+15 kph
If legged	×0.25 kph

*To qualify for the light wheeled bonus, vehicle must be equal to or less than the listed weight (in tonnes) for its tech level on the following table:

Light Wheeled Vehicles

TL	*Weight*
5	5–
6	10–
7	15–
8	20–
9	25–
10	30–
11	35–
12	40–

TL: Tech level at which vehicle appears.
Weight: Maximum weight of a light vehicle at that tech level.

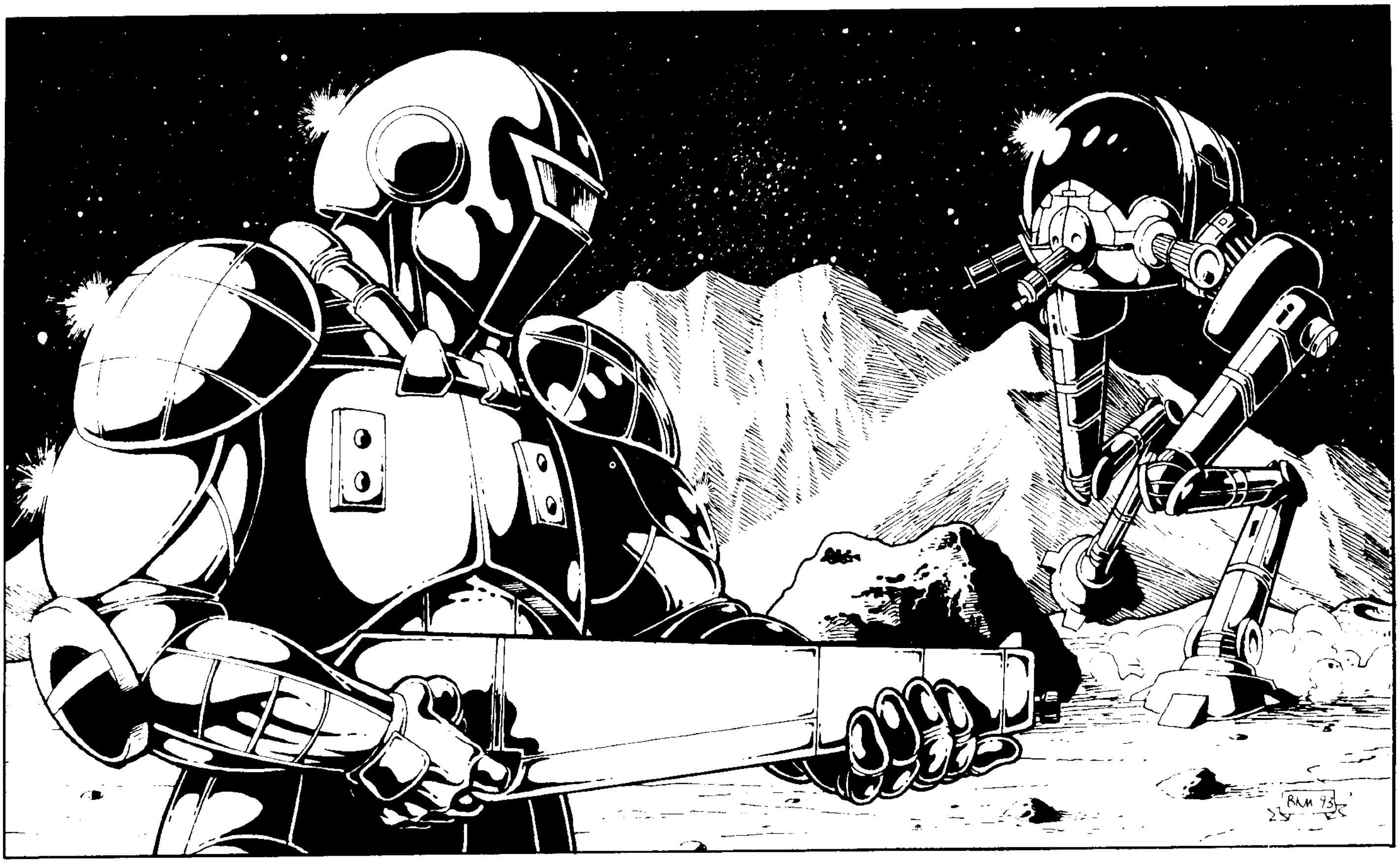
Cross-Country Speed:

Legged vehicles have the same speed cross-country as they have on a road.

Wheeled vehicle cross-country speed depends on the type of suspension used.

Type	*Cross-Country*
Restricted Wheel	0.1
Wheel	0.2
Cross-Country Wheel	0.4

Type: Suspension type installed on vehicle.
Cross-Country: Cross-country speed in kph equals road speed times this multiplier.



Tracked vehicle cross-country mobility depends on the power-to-weight ratio of the vehicle.

P/W	*T*
.001-.0039	**0.4**
.004-.0079	0.5
.008-.0119	**0.6**
.012-.0159	0.7
.016+	**0.8**

P/W: Power-to-weight ratio. Divide vehicle's motive power in megawatts by its loaded weight in tonnes. Use the line that corresponds to the result.

T: Tracked multiplier. Cross-country speed in kph equals road speed times this multiplier.

Water Speed: Tracked vehicles without auxiliary water propulsion and wheeled vehicles with auxiliary water propulsion have a water speed equal to their road speed multiplied by 0.1. Tracked vehicles with auxiliary water propulsion have a water speed equal to their road speed multiplied by 0.2.

Combat Move: The safe combat movement (in meters per turn) is the vehicle's maximum speed, in kilometers per hour, multiplied by 0.463, rounding the result to the nearest increment of 5. This calculation is made separately for road, off-road, and water movement based on the maximum road, off-road, and water speeds.

Travel Move: The vehicle's travel movement rate (in kilometers per 4-hour period) is equal to its safe combat move (in meters per turn) multiplied by 4.32, rounded to the nearest increment of 5.

4. Firing Characteristics

Records the firing characteristics of each mounted weapon as well as the effects of installed stabilization and fire control.

5. Determine Maintenance Points

Divide the loaded mass of the vehicle by the maintenance modifier appropriate to tech level as shown below.

TL	*Maintenance Modifier*
4-5	**2**
6-7	3
8-9	**4**
10-12	5
13-15	**6**
16+	8

Any ground vehicle which has two full-size computers (model St or Fb) installed should divide this result by 4 to get final maintenance points.

Note that maintenance points may be temporarily increased by environment (see "Carrier Aircraft," page 30, "Atmospheric Performance," page 64, and **TNE**, page 309). Ground vehicles constantly exposed to saltwater use different multipliers for saltwater corrosion: 3 and 1.5 rather than 5 and 2 (page 30).

CHAPTER 3

1 Lift Vehicle Design

A lift vehicle is a transition between ground vehicles and aircraft, and has some of the characteristics of each. Lift vehicles are those which are, literally, lifted or levitated off the ground by
2 some means other than wings. In the basic design rules there are two means of lifting a vehicle: contra-gravity and air cushion.

Lift vehicles are produced by adding components to a basic
3 structure. The vehicle's volume is determined first, and specific components are then added until the volume is filled. Components have a mass and price; the vehicle's mass and price are determined by adding together the masses and prices of its
4 components.

Before starting the design, there are several items which need to be determined. What is the tech level of the grav vehicle? What is its mission? Are there any limits on its price?

5 Once these decisions are made, take a sheet of paper and divide the right two-thirds of it into five columns, and label them Volume, Mass, Power, Surface Area, and Price. This will be your worksheet as you do your design. Whenever a component uses
6 volume, mass, power, or chassis surface area, write the amount in the correct column. Whenever a component contributes volume, surface area, or power (chassis contribute volume and
7 surface area, power plants contribute power) write the amount in the correct column, but distinguish it with brackets or a "+" sign. This worksheet will make designing your vehicle much easier.

8 *STEP 1. CHASSIS*

The first step is to determine the size and general configuration of the chassis. Select a chassis size from the Chassis Size table
9 below. All chassis have a rate which is the displacement of the hull in tonnes of liquid hydrogen (a common measure as it is the most common fuel). Therefore, a vehicle with a rate of 1 could hold 1 tonne of liquid hydrogen (provided nothing else was put in the
10 chassis). Each "ton" of displacement consists of 14 cubic meters (m^3) of internal space (or 14 kiloliters). The Chassis Size table indicates the volume (in cubic meters), and the material volume
11 of the shell (assuming a uniform thickness of 1 centimeter) in cubic meters of material.

Note that this table is identical to that found in the starship design section of the rules, with two exceptions. First, the vehicle
12 chassis listed are all assumed to be laid out as elongated six-sided blocks, and so have already had their material volumes modified accordingly. Second, the "hull length" column is omitted as being irrelevant to vehicle design.

13 Lift vehicles may be designed using chassis which fall between two listed values on the table by means of interpolation. Larger vehicle chassis may be used by using the spacecraft Hull Size table on page 11. Use 1.4 for the material volume multiplier (MVM) for
14 a vehicle chassis.

Chassis Size

Rate	*Vol*	*MV*
1	14	0.6
2	28	0.7
3	42	1.0
4	56	1.3
5	70	1.5
6	84	1.8
7	98	2.0
8	112	2.2
9	126	2.5
10	140	2.7

Once the chassis size is determined, determine its configuration. There are five general chassis configurations: Simple, Fast Subsonic, Transonic, Supersonic, and Hypersonic. Each of these represents progressively more streamlined chassis which can reach higher and higher speeds. Air cushion vehicles may only use simple chassis; grav vehicles may use any chassis shown.

Each chassis size has a volume cost, which is the waste volume consumed by streamlining, as well as a variety of other values used in later calculations.

Lift Vehicle Chassis Configurations

Type	*Vol*	*SA*	*Price*	*Max*	*Eff*
Simple	0.00	70	1.00	400	0.85
Fast Subsonic	0.05	70	1.02	800	0.90
Transonic	0.10	65	1.03	1200	0.95
Supersonic	0.20	60	1.04	2800	1.00
Hypersonic	0.30	55	1.1	5000	1.00

Vol: Waste volume consumed by streamlining is equal to the total volume of the chassis multiplied by this value.

SA: Useful surface area in square meters is equal to the chassis material volume (from the Chassis Size table) times this number. This computation shows the surface area left after allowing for standard features such as hatches, vision devices, intakes, exhausts, lifter plates, landing skids, etc. Useful surface is used for the installation of sensor and communications antennae, and other surface area consuming items.

Price: The price of the hull plating is its normal material cost times the value shown on the chart.

Max: The maximum atmospheric speed of the chassis in kilometers per hour.

Eff: The efficiency of the chassis, used to calculate maximum speed.

Once the chassis configuration is chosen, the chassis itself is constructed by enclosing the chassis space with hull material, called hull plating.

The Vehicle and Craft Construction Materials table (Section 1, page 38) lists a variety of materials available at different tech levels, along with their toughness, mass per cubic meter, and their price per cubic meter. Once the designer has decided on a thickness, multiply the hull's material volume value by the hull thickness (in centimeters) to determine how many cubic meters of material is used for hull plating. Multiply this by the correct mass value on the Vehicle and Craft Construction Materials table to determine mass. Price in millions of credits is determined by multiplying material volume by hull thickness in centimeters, the correct price multiplier from the Vehicle and Craft Construction Materials table, and the price modifier from the Lift Vehicle Chassis Configuration table.

Hull plating may be thinner or thicker than 1 centimeter, but all chassis must have an armor value of at least 1. To determine the armor value of the hull plating, decide on a thickness (in centimeters) and multiply the thickness by the toughness of the material used to construct the hull.

Once the base armor value (that enjoyed by all surfaces) is determined, the designer may decide to put additional armor on one or more surfaces of the vehicle. This is done by adding material weight and cost to the vehicle, but it adds additional thickness (and thus protection) to that face. Each additional centimeter of material adds to the material volume as shown on the following table.

Face	Increase per cm
Front or rear (each)	**10%**
Sides (both)	30%
Top or bottom (each)	**25%**

For example, a vehicle built around a 3-ton hull (42 kiloliters) has a material volume of 1 (meaning each centimeter of hull thickness all the way around the hull requires 1 cubic meter of actual hull material). The designer decided to increase the thickness of the front armor of the vehicle. For each extra centimeter of front armor, add 0.1 (10% of 1) cubic meters to the total hull material.

Once all armor is installed, the designer may further increase its effectiveness by sloping it. The top and bottom may not be sloped, but the front, rear, and sides may be. Armor may be installed at a moderate slope (about 30°) or a radical slope (about 60°). A moderate slope multiplies the effective armor value of a face by 1.5. A radical slope multiplies the effective armor value of a face by 2.

Sloping armor does not add to either the weight or price of the vehicle, but does subtract from its volume. The volume cost of sloping an armored face is expressed as a multiple of the entire enclosed volume of the chassis and is noted on the table below:

Armor Slope

Face	Moderate	Radical
Front or Rear	**10%**	**20%**
Sides (both)	20%	40%

For example, a vehicle with a size 6 hull (84 kiloliters) has a radical slope to its frontal armor. This uses up 20% of the original volume, or 16.8 cubic meters.

Simple chassis must have at least a moderate frontal slope. Fast subsonic chassis must have a radical frontal slope.

Vehicles may be designed as *open* vehicles, meaning that they are open-topped and partially open-sided. These vehicles sometimes have a glass or plastic transparent windscreen or roof added 1
later. Open vehicles multiply their hull material volume by 0.7. They have no armor against overhead attacks and attacks from the side and rear are diced for to determine if they strike armor or glass (using the open vehicle rule). 2

Turrets: Any vehicle may be built as a turreted vehicle. A turreted vehicle has a large main turret mounting a powerful weapon. There is considerable waste volume representing the 3
free area around the turret to enable it to traverse and fire in all directions. All components mounted in a large main turret consume more than their *actual* volume. To determine the exact increase in volume, consult the Turret Efficiency table, below. 4

Turret Efficiency

TL	Volume	
6	**×4**	5
7	×3	
8+	**×2**	

The volume of turret components after multiplying them by 6
these turret efficiency values is referred to as their *effective volume*.

All components in a small turret (see below, in Weaponry) have an effective volume equal to 10 times their actual volume. 7

In addition, turreted vehicles are less aerodynamic than non-turreted vehicles. For each 1% of the total chassis volume (after reductions for hull slope) that is devoted to *effective* turret volume, the maximum speed of the chassis will be reduced by 1% (see 8
page 26, "Determine Movement").

Main turrets (see Step 6, Weaponry, below) must be locked in the forward position during high-speed flight or the vehicle will become unstable and risk crashing. The maximum safe speed of 9
any lift vehicle while slewing its turret is 300 kilometers per hour. (Lift vehicles may fly at higher speeds while slewing their turrets, but the drivers must make skill rolls to avoid a mishap according to the normal overdriving rules.) Small and airborne type turrets 10
(see Step 6, Weaponry, below) have no such penalty.

STEP 2. SUSPENSION

The suspension is the mechanism in contact with the ground. 11
There are four specific suspension types: air cushion, standard contra-grav, improved contra-grav, and high-effeciency contra-grav. Different suspension types are available at different tech 12
levels. Each suspension takes up a fixed percentage of the chassis volume. The suspension table lists those values as well as the weight and price per cubic meter of installed suspension.

Contra-grav negates the gravitational force of over 99% of the 13
vehicle's weight. This allows light lift vehicles to actually be buoyant on worlds with sufficiently dense atmospheres. However, all contra-grav vehicles are assumed to have vectored thrust agencies to hold up the remaining fraction of their weight, allowing them to hover. 14

If air cushion suspension is installed, usable surface area must be multiplied by 0.6 to allow for the tremendous space taken up by this suspension type.

Suspension						
Type	*TL*	*Vol*	*Mass*	*Price*	*MW*	*Min Vol*
Air Cushion	**6**	**4.2**	**0.84**	**.0042**	**0.1**	**1**
Standard CG	9	0.5	0.4	.02	0.3	1
Improved CG	**10**	**0.3**	**0.3**	**.025**	**0.2**	**0.3**
High-Efficiency CG	12	0.3	0.2	.03	0.1	0.03

TL: Tech level available.
MW: Power requirement per displacement ton (14 kl) of hull.
Vol: Volume in kiloliters (cubic meters) per displacement ton (14 kl) of hull.
Mass: Mass in tonnes per displacement ton (14 kl) of hull.
Price: Price in megacredits per displacement ton (14 kl) of hull.
Min Vol: Smallest installation volume allowed.

STEP 3. CONTROL SYSTEMS

Control systems fall into three categories: the actual vehicle controls, computers, and navigational aids. These are covered in detail in the Controls chapter (Section 4). Note that some control systems may not be installed on high-speed chassis.

The tech level of the control system must be equal to or greater than the tech level of the installed suspension.

CG-equipped vehicles require flight avionics and flight computers; air cushion vehicles do not.

STEP 4. LIFE SUPPORT

The type of life support required by a vehicle depends largely on its intended mission. A variety of options for life support are covered in the Life Support chapter (Section 11). If any extended accommodations are to be fitted (such as staterooms or bunks) they are installed at this time. Only vehicles intended for very long trips, days or weeks, are fitted with bunks or staterooms, and even then they are usually intended for use by several crewpersons in rotation.

STEP 5. ELECTRONICS

Electronics fall into four categories: communicators, sensors, electronic countermeasures (ECM), and electronic counter-countermeasures (ECCM).

Players should be familiar with the **Traveller** combat rules for how communicators, sensors, ECM, and ECCM systems work in order to decide which of these systems to install. All of these systems are covered in the Electronics chapter (Section 5).

STEP 6. WEAPONRY

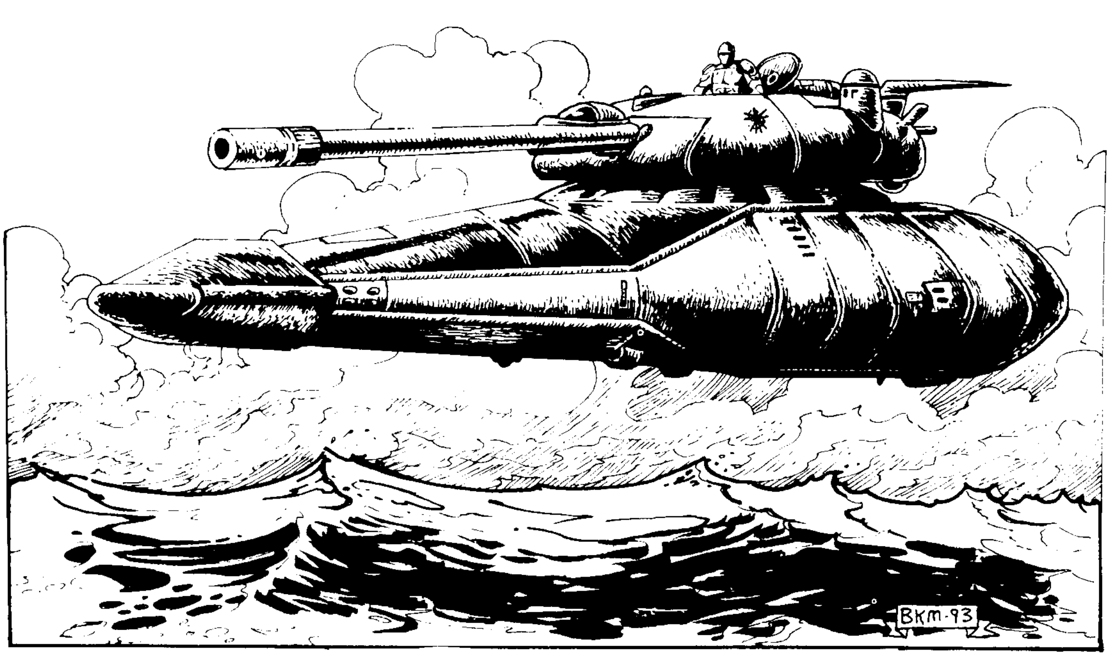
Vehicles may be equipped with a wide variety of weapons. All of these are covered in the Weaponry section, beginning on page 91, except for defensive screens, which are covered in the Defenses chapter (Section 6). A number of special considerations apply to vehicle-mounted weapons, however.

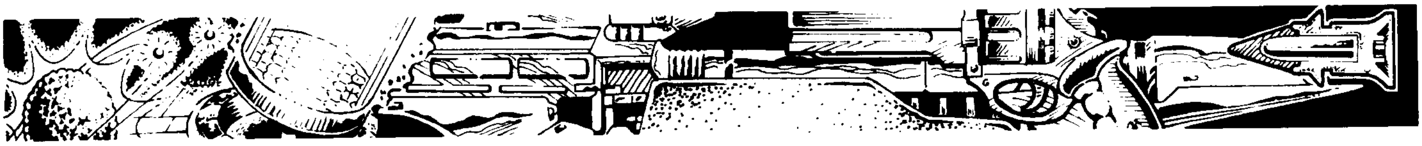
Weapon Mounts: Vehicle-mounted guns do not require carriages, tripods, or other such mounts, as the vehicle itself serves as the mount. However, the type of vehicle mount and its location must be specified. There are five main types of vehicle mounts: chassis, turret, small turret, pintel, and open. As a sixth option, tac missiles may be mounted on the outside of the vehicle on launch rails.

Weapons in chassis mounts emerge from one of the six faces of the chassis. Although fine adjustments to their bearing and elevation is possible, gross weapon pointing is achieved by repositioning the vehicle itself.

A turret is a fully rotating armored compartment set onto the main vehicle chassis (it is usually on top of the chassis, but in the case of contra-grav vehicles, a turret could as easily be on the belly to allow the vehicle to fire at ground targets as it flies over them). The advantage of a turret is that it allows fire in any direction without without requiring the vehicle to be pointing or travelling in that direction. A turret (as opposed to a small turret) is one whose effective volume is more than 10% of the total chassis volume. Indirect fire weapons must be in either turrets or open mounts (see below). Although referred to simply as "turrets" in the basic rules, these will sometimes be referred to as "main turrets" in the rules below to distinguish them from small turrets, and from the aircraft-style turrets discussed below.

A small turret is usually on top of a turret, or in the case of a turretless vehicle, on top of the chassis itself, but it could be mounted on any face of the vehicle. Small turrets may have an effective volume of no more than 10% of the total vehicle volume. If a small turret is to be manned, it must allocate volume for the crewmember equal to one-half the volume of the member's crewstation. Manned small turrets are also called cupolas, unmanned small turrets are referred to as *remote mounts.* Remote mounts are controlled from crewstations within the hull. The equipment necessary to remotely control the mount (periscopes, repeaters, etc.)





is subsumed within the mass and price of the remote turret and crewstation (but see Step 8, Crew, below for fire control requirements).

Both types of turret have front, side, top (or in the case of a belly turret, bottom), and rear armor equal to those values calculated for the entire vehicle.

A pintel mount is a simple post or curved rail on which is mounted a light weapon, such as a machinegun or autocannon. It is usually mounted on top of the chassis or turret, and are particularly popular for open vehicles.

An open weapon is a large weapon mounted in the chassis of an open vehicle. Indirect fire weapons must be in either open mounts or turrets.

Lift vehicles may also mount weapons in any of the mounts listed in the Airborne Weapons Mounts chapter (page 152).

Fixed airborne mounts have no weight or drag. Main turrets have no drag points (as the drag of the turret is already calculated into the lower maximum speed of this chassis configuration). Hardpoints only have drag when ordnance or a bomb rack is mounted. Drag disappears when the weapons are dropped or launched. Airborne turrets from page 152 always incur a drag penalty.

Ordnance hardpoints are generally located on the top and sides of the chassis. Normally, a lift vehicle has room for up to four hardpoints on the hull top, although this is reduced to two hardpoints on turreted vehicles. All hull hardpoints count as inboard hardpoints from the Airborne Weapons Mounts chapter (page 152). Additional hardpoints can be mounted on stub wings, one attached to each of the vehicle's sides. Each stub wing can have one inboard hardpoint, one outboard hardpoint, and one wingtip launch rail.

Inboard wing hardpoints (and vehicle hull hardpoints) can carry up to 1500 kilograms of ordnance, or 7.5% of the total weight of the vehicle, whichever is greater, while outboard hardpoints can carry up to 500 kilograms of ordnance, or 2.5% of the vehicle's loaded weight, whichever is greater.

Multiple bomb/missile racks may be attached to each hardpoint, as well as single weapons.

Fuel drop tanks may be attached to inboard stub wing hardpoints if they have fuel-intake plumbing. Note that the Airborne Weapons Mounts chapter includes different values for plumbed and "dry" hardpoints.

Launch rails for missiles weighing no more than 100 kilograms may be installed on stub wingtips.

Stabilization: Stabilization gear enables a vehicle to fire its weapons while moving; see the Weapon Stabilization rules in the Fire Control chapter (Section 14) for characteristics.

Fixed forward-firing weapons do not require stabilization to fire while moving.

Mechanical Loading Assistance: A gun may reduce its requirement for loaders by having mechanical loading assistance for the gun. Mechanical loading assistance is covered in the actual weapon design sequences. Loading assisters have a volume of 1 cubic meter per ton and must be located with the weapons mount and the ammunition. (Note that with mechanical loading assistance the ammunition must be stored in the same part of the vehicle as the gun mount.)

Autoloader: Guns require one or more crew as loaders in addition to the gunner. All of the weapon's loaders may be replaced by an autoloader; weapons in remote mounts *must* have 1
autoloaders. Autoloader characteristics are calculated during the weapon design sequence. Half of the autoloader's volume is in the part of the vehicle with the weapon mount and the rest is in the part of the vehicle where the ammunition is stored. 2

STEP 7. POWER PLANT

The vehicle needs a power plant to provide electrical energy to various subsystems, as well as to power the lifting agency. A 3
variety of power plants are available and are detailed in the Power Production chapter (Section 8).

Grav and air cushion vehicles also require thrust, as their suspensions serve only to hold them up, not move them forward. The power plant 4
on these vehicles is modified to provide thrust by the addition of propellers, a combustion chamber, or to power a more exotic maneuver drive. The variety of thrusters available is detailed in the Sub-Light (Maneuver) Drive chapter (Section 9). 5

Fuel tankage for the power plant and thruster are also calculated at this time.

STEP 8. CREW 6

Each vehicle crewmember requires a crewstation, and each passenger requires a seat.

Crewstations: Two types of crewstations are possible: cramped and open. Open vehicles may have cramped crewstations while 7
enclosed vehicles must have open crewstations. Both types are listed in the Controls chapter (Section 4). The crewstations must be from the same tech level as the controls installed in Step 3.

Seats: Passenger seats are found in the Optional Features 8
chapter (Section 7).

Each vehicle requires a driver. A vehicle commander is optional, but recommended on enclosed armored fighting vehicles. If the vehicle has a turret, the commander's station must be in the turret. 9

If one or more weapons are installed, a gunner is required, and one or more loaders may be necessary as well, as specified in the weapon design sequence. A gunner may fire more than one 10
weapon, but may only fire weapons controlled from his station (called a *weapon station*). One station may control all weapons mounted on the same side of the chassis or in any part of a turret. One station is required for each small turret unless it is remotely 11
controlled. One station may control any number of remote turrets, but one gunner may only fire one weapon per combat turn. A weapon station must be in the same part of the vehicle as the weapons controlled, except that a turret-mounted weapon 12
may be controlled from the chassis, and remote-mounted weapons may be controlled from anywhere.

Fire Control: During the weapon design sequence, fire control systems are specified for various weapons. However, the designer 13
should note that for vehicle-mounted weapons, fire control systems must be provided for each weapon station, not just for each weapon. For a vehicle with only one weapon and only one gunner, this distinction is immaterial, but if that same vehicle were 14
designed to allow the gun to be fired from two separate weapon stations, each would require a separate fire control system.

If the weapon station controlling a weapon is in a different part of the vehicle from the weapon itself, the volume of the fire control equipment is divided evenly between the two locations.

1 Weapon stations that only control small arms or tac missiles do not require fire control systems. However, tac missile weapon stations are equipped with tac missile control units (see page 149).

2 *STEP 9. CARGO*

All remaining volume may be allocated to ammunition stowage, cargo space, or declared waste volume. Waste volume has no effect on the design.

3 Ammunition stowage has no cost, but adds the weight of the ammunition to the loaded weight of the vehicle.

Cargo volume has no cost, but adds to the loaded weight of the vehicle. Multiply the cargo volume, in cubic meters, by 0.25 to
4 determine the addition, in tonnes, to the vehicle's loaded weight.

DESIGN EVALUATION

5 Once the design is complete, you will need to evaluate it to determine its game ratings.

1. Check Step

Go back and add up the volume, price, surface area, and mass
6 of all the components. This is your chance to check to make sure that its internal occupied volume and area of surface fixtures are within what is allowed by the size of its hull. This step also provides
7 you with a total price and mass.

2. Record Design Features

Most of the evaluation of your design will consist of recording the features already determined by the design, such as armor
8 values, weapon statistics, installed electronics, crew, passengers, etc. Note the volume of the original chassis as its transport volume (the space it takes up in the hold of a starship or transport vehicle).

9 At the same time, total the price of the vehicle and its empty and loaded weights. Empty weight is the vehicle without any ammunition, fuel, cargo, crew, or passengers. This is essentially the weight of the vehicle as it comes off the assembly line, and is also what
10 it weighs when being transported by another vehicle or starship.

Loaded weight includes a full load of ammunition, full cargo (assume 0.25 tonnes per cubic meter), and a weight allowance of 100 kilograms per passenger and crew. This is its typical operating weight.

11 **Suspension Critical Damage Level:** Only air cushion suspensions have a critical damage level (CDL, see **TNE** page 300); contra-grav vehicles simply use their hull armor.

CDL is equal to the air cushion vehicle's chassis volume
12 (selected in Step 1) in displacement tons.

3. Determine Movement

Movement of lift vehicles is based on their thrust. The G rating of
13 a lift vehicle is its total thrust in tonnes divided by 10 times its hull displacement (in displacement tons). Its maximum speed (in kilometers per hour) in an atmosphere is determined as follows:

If G = 1 or less, speed = (G × 3500) × Eff

14 If G = 2 or less, but more than 1, speed = {3500 + [1200(G–1)]} × Eff

If G = more than 2, speed = {4700 + [600(G–2)]} × Eff

Eff = chassis configuration efficiency (from Step 1)

Maximum speed cannot be greater than the maximum design speed of the chassis type. Maximum speed is reduced by drag and size of main turrets. Note the total number of drag points from the weapons mounts installed, again both with and without external stores and add the percent of chassis volume taken up by effective turret volume (see page 23). Reduce the maximum speed by 1% for each point.

Cruising Speed: A lift vehicle's cruising speed is 75% of its maximum speed.

Minimum Speed: Lift vehicles have no minimum speed. Contra-grav vehicles are assumed to have vectored thrust capabilities which allow them to hover.

NOE Speed: Only grav vehicles have an NOE speed. Grav vehicles have a safe NOE speed equal to the maximum allowed by their terrain-following avionics (40 kilometers per hour if no avionics are installed) or one-quarter of their maximum speed, whichever is less.

Combat Move: The safe NOE combat movement of a grav vehicle (in 10-meter grid squares per combat turn) is equal to the vehicle's maximum NOE speed (in kilometers per hour) multiplied by 0.139, rounded to the nearest whole number. The high mode combat movement (in 10-meter grid squares per combat turn) is equal to the vehicle's maximum flight speed (in kilometers per hour) multiplied by 0.139.

Combat move (in meters per combat turn) of an air cushion vehicle is maximum speed (kph) × 0.463 for road speed, and cruising speed × 0.463 for cross-country speed. Cross-country speed is also its water speed.

Travel Move: The high mode travel movement rate (in kilometers per 4-hour period) is equal to the cruising speed (in kilometers per hour) multiplied by 4. The NOE mode travel movement rate (in kilometers per 4-hour period) is equal to the safe NOE speed (in kilometers per hour) multiplied by 6.

Travel moves for an air cushion vehicle (in km per four hours) are 4.32 times its combat move above.

4. Firing Characteristics

Record the firing characteristics of each mounted weapon as well as the effects of installed stabilization and fire control.

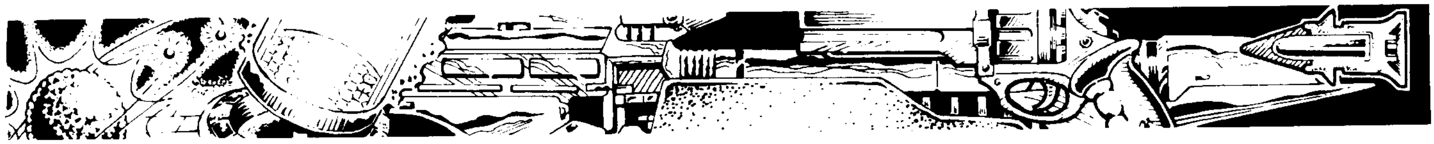
5. Determine Maintenance Points

Divide the loaded mass of the vehicle by the maintenance modifier appropriate to tech level as shown below:

TL	*Maintenance Modifier*
4-5	2
6-7	3
8-9	4
10-12	5
13-15	6
16+	8

Any lift vehicle which has two full-size computers (model St or Fb) installed should divide this result by 4 to get final maintenance points.

Note that maintenance points may be temporarily increased by environment (see "Carrier Aircraft" page 30, "Atmospheric Performance," page 64, and **TNE** page 309). Lift vehicles constantly exposed to saltwater use different multipliers for saltwater corrosion: 3 and 1.5 rather than 5 and 2 (page 30).



CHAPTER 4
Aircraft Design

There are three general types of aircraft: fixed-wing, rotary-wing, and lighter-than-air.

Fixed-wing aircraft depend on their airframes and their associated wings to produce the lift that enables them to fly. Fixed-wing aircraft may be propelled by any power source that produces thrust; unpowered fixed-wing aircraft are called gliders.

Rotary-wing aircraft rely on lift generated by rapidly rotating airfoils—rotor blades—in order to fly. The principal type of rotary-wing aircraft is the helicopter, which uses a power plant to spin its rotor and thus generate lift.

Autogyros are rotary-wing aircraft but with an unpowered rotor. Like fixed-wing aircraft, they generate lift by accelerating laterally and causing air to pass over their airfoil (which in this case happens to be a free-rotating rotor instead of a conventional fixed wing). As their configuration and operation are very similar to a fixed-wing aircraft, they are treated as a special case of fixed-wing design.

Lighter-than-air aircraft, called airships hereafter in this rule, include a range of craft from unpowered balloons to giant airships used as scheduled passenger liners or military reconnaissance and bombardment platforms.

All aircraft follow the same general design sequence outline, although the details differ depending on the type of aircraft being designed.

Step 1: Weight

Weight is the limiting factor in designing all aircraft. Weight is expressed in metric tonnes in one standard gravity (1G).

Fixed-Wing Aircraft: The weight selected by the designer for a fixed-wing aircraft is the aircraft's maximum weight without external stores. This includes the weight of the empty aircraft, a full internal fuel load, the crew, passengers, cargo, weapons, and ammunition.

Externally carried stores may increase the weight and add drag, affecting top speed. Up to 35% of the aircraft's maximum internal weight may be carried as external stores, depending on available *hardpoints*. The maximum internal weight plus its maximum external stores weight equals the aircraft's maximum takeoff weight.

Rotary Aircraft: The weight selected by the designer for a rotary-wing aircraft is its maximum takeoff weight.

Airships: The weight selected by the designer of an airship is its useful lift weight.

Step 1A: Envelope (Airships Only)

Lift generated by lighter-than-air gases and the volume needed to hold the lifting gases are the two constraints on the useful lift of an airship. Once the useful lift has been determined, calculate the envelope needed to produce that lift.

There are two types of envelopes possible, rigid and non-rigid, and three common types of lifting gasses, hydrogen, helium, and heated air.

A rigid envelope is constructed of a metal framework with a fabric (or, at higher tech levels, thin metal) covering. A non-rigid envelope is constructed of fabric without the metal frame. The table below shows the weight of both envelope types per displacement ton (14 cubic meters) of envelope according to tech level.

Hydrogen provides 15 kilograms of lift per displacement ton (14 cubic meters) in a lift envelope. Helium provides 14 kilograms per displacement ton and heated air provides 12 kilograms.

By subtracting the weight of the envelope per displacement ton from the lift of the gas in the envelope, the useful lift per displacement ton is derived. To determine the total volume of the envelope in 1
displacement tons, divide the designed useful lift of the airship by the useful lift per ton of the envelope. The result is the total volume of the envelope in displacement tons.

These values, along with the prices of the envelopes, are summa- 2
rized on the following table:

Type	TL	Wt	MCr	Useful Lift (Atmosphere 6, 7) H	He	HA	SM	
Non-Rigid	3	.007	.00014	.008	.007	.005	0.3	3
	4	.006	.00010	.009	.008	.006	0.5	
	6	.005	.00015	.010	.009	.007	0.7	4
	8	.004	.00020	.011	.010	.008	0.8	
	9	.003	.00025	.012	.011	.009	0.9	
Rigid	4	.010	.00070	.005	.004	.002	0.6	
	5	.009	.00080	.006	.005	.003	0.7	5
	7	.008	.00100	.007	.006	.004	1.0	
	9	.006	.00200	.009	.008	.006	1.1	

Wt: Weight, in tonnes, per displacement ton of envelope. 6

MCr: Price, in millions of credits, per displacement ton of envelope.

H: Useful lift, in tonnes, per displacement ton of hydrogen envelope. 7

He: Useful lift, in tonnes, per displacement ton of helium envelope.

HA: Useful lift, in tonnes, per displacement ton of heated atmosphere envelope.

SM: Speed multiplier. Multiply this value by the maximum speed 8
on the Envelope Configuration table on page 28 to find the maximum speed at that tech level.

The lift values on the previous table are for an atmosphere with 9
standard pressure (Type 6 or 7). Total lift is increased 20% in Atmosphere Types 8 and 9, which changes the useful lift to that shown on the table below. Lift is insufficient to produce a working airship in Atmosphere 5 or less. 10

Type	TL	Wt	MCr	Useful Lift (Atmosphere 8, 9) H	He	HA	SM	
Non-Rigid	3	.007	.00014	.011	.0098	.0074	0.2	11
	4	.006	.00010	.012	.0108	.0084	0.4	
	6	.005	.00015	.013	.0118	.0094	0.6	
	8	.004	.00020	.014	.0128	.0104	0.7	12
	9	.003	.00025	.015	.0138	.0114	0.8	
Rigid	4	.010	.00070	.008	.0068	.0044	0.5	
	5	.009	.00080	.009	.0078	.0054	0.6	13
	7	.008	.00100	.010	.0088	.0064	0.9	
	9	.006	.00200	.012	.0108	.0084	1.0	

14

Gaseous hydrogen costs Cr10 per displacement ton. Gaseous helium costs Cr30 per displacement ton on worlds where it is available. (Gaseous helium is available on about 50% of the worlds in the game.)

Once the type of envelope is selected, the configuration is chosen from the Envelope Configuration table on page 29. Five configurations are available.

Balloon: Balloon configuration is a non-rigid spherical gas bag from which a passenger or cargo compartment is suspended. Many balloons are tethered to the ground and are raised to provide elevated observation platforms. Non-tethered balloons are almost exclusively wind-driven and free-floating. Propulsion is difficult due to their bulky and unstable nature, but thrusters can move the balloon at low speeds.

Cigar: Elongated cigar-shaped envelopes are available in both rigid and non-rigid configurations. Cigar envelopes are equipped with fins for stability and steering, and so are much better suited to powered flight.

Cyclo-Crane: The cyclo-crane is a complex airship configuration in which the cigar-shaped envelope is pierced from front to back by a central shaft. Four (or more) pylons radiate from the central shaft and mount airfoils and engines on their ends (well outside of the envelope itself). These airfoils and engines can be turned to different angles to maneuver the craft or cause the bag to spin around its central axis, thus generating lift from the airfoils. The cabins and payload are suspended from cables attached to the ends of the central shaft.

Magnus Sphere: The Magnus sphere configuration consists of a spherical gas bag pierced through its center from side to side by a central shaft. The engines are mounted on the ends of the shaft and the cabin and payload are carried by conformal arms attached to the shaft. The engines can be rotated to give additional lift for takeoff, but the main lift augmentation comes from powered rotation of the Magnus sphere during flight (from the "Magnus effect," which provides lift to a spinning ball). Due to its compact nature, the Magnus sphere does not tend to weather vane in high winds and so is much safer in bad weather than conventional airships.

Airfoil: An airfoil airship is a rigid envelope constructed in the shape of an aerodynamic lifting body. The airfoil has a minimum speed necessary to gain its lift multiplier. This usually means that airfoil ships take off using conventional runways, but some cargo ships take off vertically without their cargo and then, when they have achieved their minimum speed for aerodynamic lift, snag their cargo from the ground using hook and line retrieval, carrying the cargo as an underslung load.

Note that the maximum speed by envelope configuration type is modified by tech level speed multipliers (and these vary between standard and dense atmospheres).

Envelope Configuration

TL	*Config*	*Type*	*Lift Mult*	*Wt Mult*	*Speed*	*MCr*
3	Balloon	Non-Rigid	1	0.8	0/50	×0.8
4	Cigar	Both	1	1	0/200	×1
8	Cyclo-Crane	Non-Rigid	1.3	1.2	0/300	×2
9	Magnus Sphere	Non-Rigid	1.5	1.1	0/300	×1.5
9	Airfoil	Rigid	1.8	1.3	40/300	×1.3

TL: Tech level of first availability.

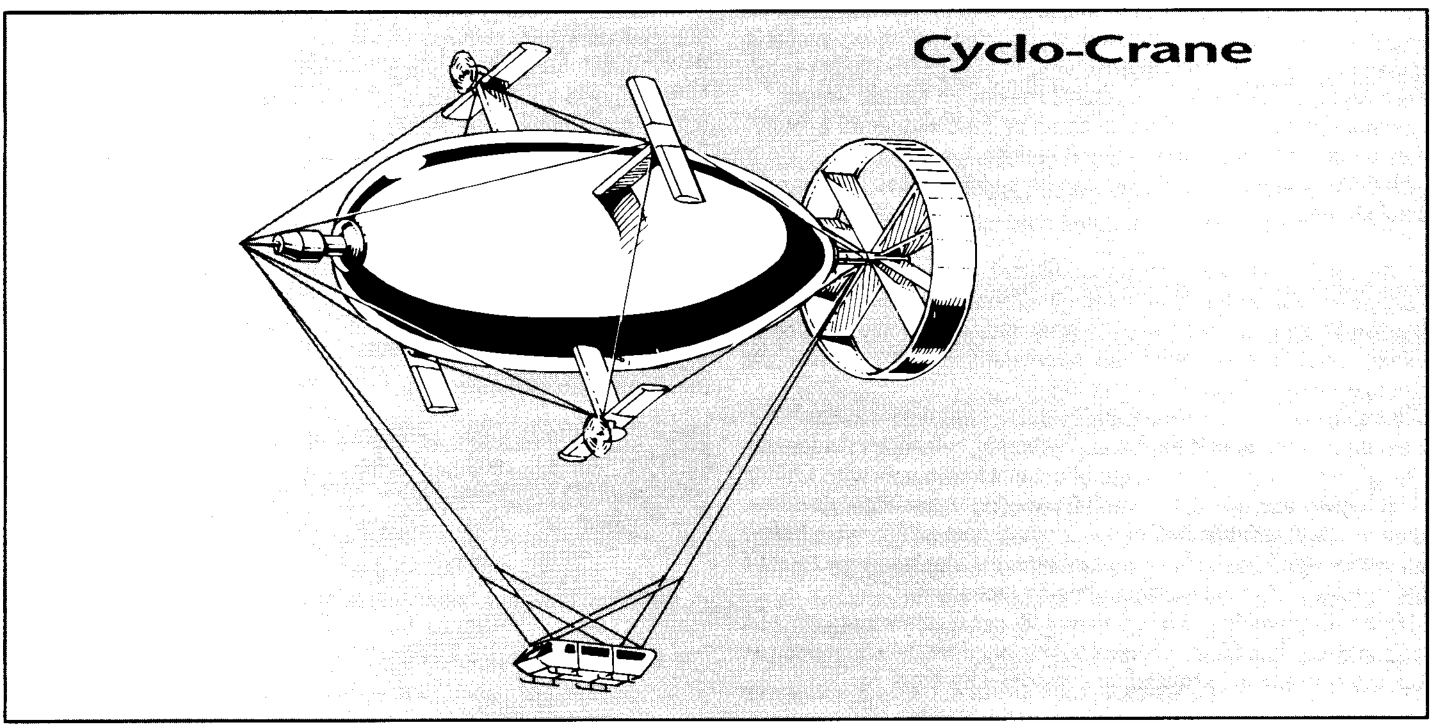
Config: Envelope configuration.

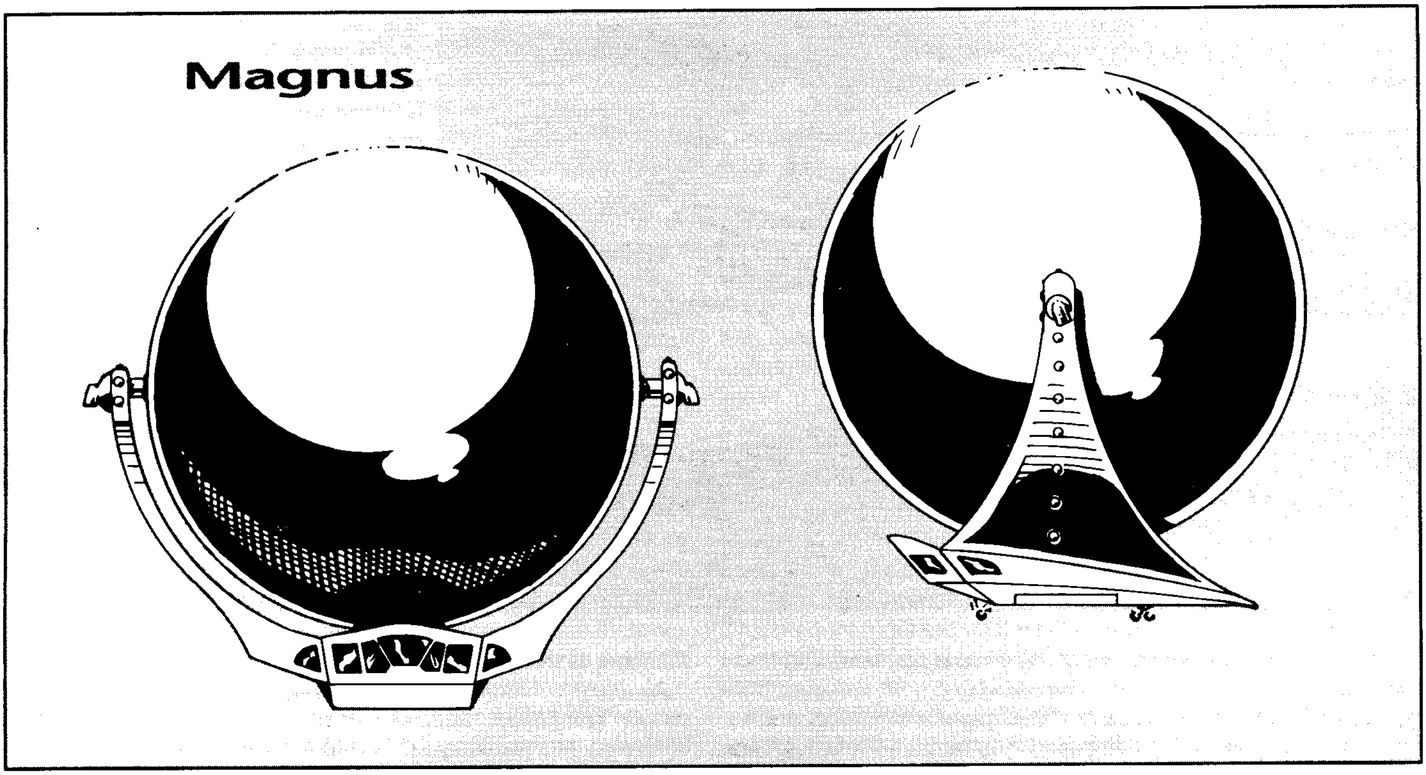
Type: Rigid, non-rigid, or both, indicating the type of envelope which can use this configuration.

Lift Mult: The total normal lift of the envelope is multiplied by this value to determine the maximum takeoff weight of the airship. The multiplier represents additional aerodynamic lift gained by the configuration.

Wt Mult: The total normal envelope weight is multiplied by this value to determine the actual envelope weight. Additions here represent additional internal structure necessary to achieve the indicated configuration. Note that changes in lift and envelope weight will necessitate recalculation of useful lift.

Speed: The minimum speed and maximum speed of the envelope





configuration. Note that maximum speed is adjusted by tech level speed multipliers found on the tables on page 27. Most airships have no minimum speed. The airfoil's minimum speed is that necessary to gain its aerodynamic lift multiplier.

MCr: The price of the envelope is its normal price multiplied by the value shown on the table.

Step 2: Airframe

Once the designer decides upon the aircraft's weight, he must select an airframe from the Airframes table (page 30). Each type of airframe has its own price per metric tonne of aircraft, minimum and maximum flight speeds, and efficiency factor (used in determining the aircraft's cruising and maximum speeds).

Fixed-Wing Aircraft: There is a wide variety of airframes, as there is a great spread in performance between different fixed-wing aircraft.

Autogyros: Autogyros are designed as if they were a special form of fixed-wing aircraft, using a unique airframe type. They are treated as fixed-wing aircraft in all other respects. Autogyro airframes may not incorporate STOL or VTOL capability, although they may incorporate seaplane capability.

Wing-in-Ground: Wing-in-ground (WIG) airframes are unusual airframes which allow truly immense loads to be carried. Wing-in-ground is a contraction of "wing in ground effect." Ground effect refers to the increase in performance experienced by all aircraft when flying within approximately half a wingspan of the ground. For conventional aircraft, long duration cruise in ground effect is not practical, but for specialized WIG craft, using the PAR (Power Augmented Ram) effect, it is, and creates dramatic increases in performance. The WIG airframes here are considered to be PARWIGs (WIG for short). These craft, also called "wingships," blow high-pressure air beneath their wings and use the increased lift resulting from the build-up of this high-pressure air between the ground and their lifting surfaces. This high-pressure air is essentially recycled back to the aircraft by the ground, rather than being dissipated through the air column beneath an aircraft flying at altitude. (Air cushion vehicles trap this air within their sidewalls or "skirts," while WIG aircraft create a rapidly dissipating bubble of high pressure beneath them as they move along.) Although they are able to generate enough speed that they can fly out of ground effect for short periods of time (in effect "hopping"), a WIG craft is distinguished by the fact that it cannot fly for any great distance out of ground effect (multiply fuel use by 5 during these short periods). As this effect can only be maintained over surfaces such as water, icecaps, or level ground, WIG vehicles are of rather specialized utility.

WIG craft may not be combined with STOL capabilities, but may be combined with VTOL and seaplane capabilities.

Gliders: Gliders are unpowered fixed-wing aircraft. Gliders always use simple airframes with STOL capability.

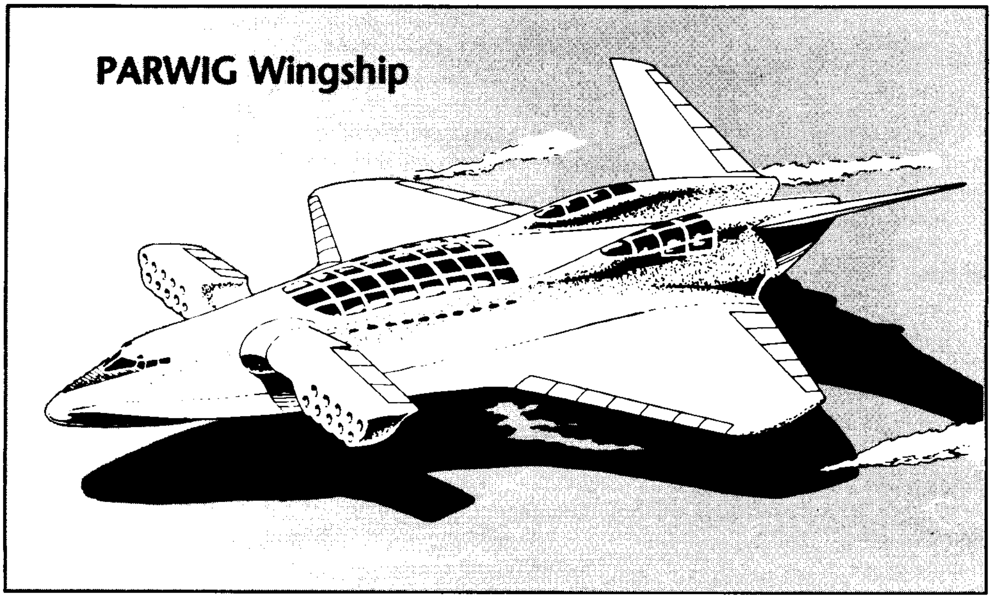
Fixed-Wing Options: Airframes may be modified for VTOL (Vertical Take-Off/Landing), STOL (Short Take-Off/Landing), or seaplane configuration.

VTOL: VTOL airframes incorporate either thrust vectoring gear for jets or tilt engine/tilt wings to allow the aircraft to take off directly upward then switch to normal flight. Add 10% to the weight and 50% to the cost of the airframe.

STOL: STOL airframes have longer, broader wings for greater lift, allowing shorter takeoffs and landings. Add 5% to the weight and 30% to the cost of the airframe. Add 10 drag points to the aircraft.

Seaplanes: Seaplane airframes add 5% to weight and 25% to the cost of the airframe. Seaplanes may only land on water.

Amphibians: Amphibian airframes (which may land on water or land) are built identically to seaplanes up to 350 tonnes aircraft weight. Between 350 and 400 tonnes, add no weight, but add 25% to cost. Above 400 tonnes, subtract 5% from airframe weight and add 25% to cost.



PARWIG Wingship

The key to higher performance is "unloading" the rotor, slowing down stopping it in flight and relying on thrust and lift from other sources (auxiliary jets or propellers, and stub wings, respectively, although a variant called ABC—advancing blade concept—uses stiff coaxial blades to create lift by ensuring that there is always an advancing blade on each side of the helicopter). Such helicopters are called compound helicopters. These can be built starting at tech level 6, and may use fast subsonic airframes. See Step 3, Thrust, for more details.

At higher tech levels, an advanced application of the compound helicopter becomes possible, the "X-wing," in which the stopped blades are heavier and more robust, and allow higher speed.

Helicopters may be designed with seaplane or amphibian airframes, or have floats added. Cost and weight figures are the same as those for fixed-wing aircraft.

Floatplanes: Aircraft which are not designed as seaplanes may have floats added later. Floats may only be added to simple, autogyro, and fast subsonic airframes. Floats added count as external stores, and no fuselage or outboard wing hardpoints may be used while floats are attached. Floats weigh 5% of the total loaded weight of the aircraft, cost MCr0.01 per tonne of float, and add 20 drag points.

VTOL and STOL airframes are mutually exclusive. Seaplane capability may be added to either VTOL or STOL capability.

Carrier Aircraft: Aircraft may have the capability to fold their wings to allow them to be stored at a smaller volume. Add 5% to airframe weight and cost.

Beefing up airframe for aircraft carrier arrested landings costs a percentage of aircraft equal to 8.5% minus the aircraft's agility rating with a minimum percentage increase of 0.5%.

Adding corrosion resistance to aircraft adds nothing to weight and 5% to the cost of the airframe and power plant. Normal aircraft carried aboard ship (or operating in a tainted atmosphere—referee's discretion) require 5 times their normal MP to remain functional due to saltwater ingestion. Corrosion-resistant aircraft only require 2 times their normal MP.

Rotary-Wing Aircraft: Conventional helicopters require only a simple airframe, and indeed, can gain no performance benefits from faster airframes, as they cannot achieve speeds beyond the maximum allowed for a simple airframe. This is because of the particular problems created by the helo's rotor blades, of which two are significant: advancing blade tip speed and retreating blade stall.

Recognizing that the tip of each rotor blade is moving at a very high speed, it is not hard to imagine that a fast helicopter will soon run into the sound barrier with the tips of its forward-moving (advancing) rotor blades, which is an absolute limit on helicopter performance. The flip side of this is that as these same rotor blade tips spin a little farther and begin to move toward the rear of the helicopter (retreating), they begin to stall, losing lift at the same time that the blade tips on the opposite side of the helicopter are reaching the speed of sound.

Thus conventional helicopters are limited to 320 kph, which is the top speed of the simple airframe (even if it were to use a fast subsonic airframe, a conventional helicopter would still be limited to 320 kph).

Airships: In addition to the envelope, airships require one or more cars or "gondolas," inside or suspended beneath the envelope to hold crew and passengers. Airship cars require simple airframes. Weight of the cars is based on the carrying capacity of the car itself, not the total weight of the airship.

Airframes

TL	*Type*	*Aircraft*	*Wt*	*MCr*	*Min*	*Max*	*Eff*
4	Simple	Any	0.01	0.01	150/75	320	0.85
5	Autogyro	Fixed	0.005	0.02	40/—	200	0.65
5	Fast Subsonic	Fixed, Rotary	0.05	0.02	160/80	800	0.90
6	Transonic	Fixed, Rotary	0.10	0.03	180/90	1100	0.95
6	Supersonic	Fixed	0.20	0.04	280/140	2800	1.00
7	Hypersonic	Fixed	0.30	0.1	350/175	5000	2.75
7	Wing-in-Ground	Fixed	0.05	0.02	75/—	400	0.90

TL: Tech level of first availability.

Wt: Airframe weight, in metric tonnes, per tonne of aircraft.

MCr: Price, in millions of credits, per tonne of aircraft.

Min: Minimum speed, in kilometers per hour, of a conventional airframe/STOL airframe. Wing-in-ground and autogyro airframes have a single speed, as they may not be combined with STOL capabilities.

Max: Maximum design speed, in kilometers per hour, of the airframe.

Eff: Airframe efficiency, used in determining maximum and cruising speeds.

Surface Area: Each airframe has one square meter of useful surface area (for electronics and other similar surface installations) per metric tonne of aircraft. This is not true surface area, but is only the portion not already allocated to control surfaces, intakes, landing gear, etc., and therefore not suitable for surface installations.

Step 3: Thrust

Thrust propels an aircraft through the atmosphere. The mechanism by which an aircraft generates thrust is called its thrust agency. There are two general categories of common thrust agencies: propellers and jets.

Propeller-driven aircraft use the output from any power source to turn a propeller (sometimes called an air screw), which either pulls or pushes the aircraft through the atmosphere. Propellers require an atmosphere to function.

Jet-driven aircraft use the actual expanding gas of the combustion of fuel, sometimes combined with high-speed turbines, to create direct thrust. Provided a separate (and sufficient!) source of compressed oxygen is available, a jet thruster will work as well in vacuum as in an atmosphere.

Wing-in-Ground aircraft use either propeller or jet propulsion, but because of the nature of the WIG design and its flight regime, the thrust from these sources is multiplied by 5.

A variety of thrust agencies are discussed in detail in the Sub-Light (Maneuver) Drive chapter (Section 9). Notice that many thrust agents have a limited number of airframe types on which they can be used.

Unpowered fixed-wing aircraft are called gliders. They are usually pulled aloft by another aircraft (of at least twice their weight; these are called *tugs*) and then released to glide to the earth. However, there are other methods, including catapult or even self-powered launch.

Rotary-Wing Aircraft: Helicopters are unique in that they rely on overhead rotors for lift as well as thrust. Helicopters need gearboxes, transmission assemblies, and rotors (all collectively referred to as the *rotor assembly*) to convert engine power to lift. Gearboxes reduce engine speed to rotor speed with reduction ratios of up to 90:1. Transmission assemblies link the power plant to the rotors, and rotors provide lift.

A rotor provides lift for the aircraft in addition to forward thrust. The total lift provided (determined by the size of power plant installed) must be equal to, or in excess of, the maximum take-off weight. The helicopter's thrust, in tonnes, is equal to its lift in tonnes multiplied by 0.1. If additional thrust is desired, an additional thruster (usually a turbojet or turbofan) may be added.

On a conventional helicopter, this added thrust plus the thrust from the rotor blades is limited to 10
the top speed of 320 kph when speed is calculated in the design rating section, below.

Compound helicopters must 11
have an added thrust agency, as their speed is calculated using this added thrust only. This added thrust must yield a speed at least 12
equal to the minimum speed of the airframe. Compound helicopters at tech levels 6 and 7 may only use the MTR rotor con- 13
figuration. At TL 8 they may use the CMR (depicting ABC technology) and MTR configurations.

TL9+ compound helicopters use 14
the X-wing rotor configuration.

Rotors come in several configurations, which in turn affect the number of rotor assemblies needed in a helicopter design. All of these configurations are designed to prevent torque from rotating the helicopter in the opposite direction of the rotor's rotation. The most common rotor 1
configurations include the following:

Main and Tail Rotor (MTR): This assembly is a large, single main rotor and a much smaller anti-torque rotor which is mounted vertically to provide lateral thrust near the end of the tail boom. At 2
higher tech levels, advanced versions of configuration are known as NOTAR, for NO TAil Rotor, in which vectored turbine exhaust takes the place of the anti-torque rotor.

Light MTR rotor assemblies are available for helicopters weighing 3
two tons or less.

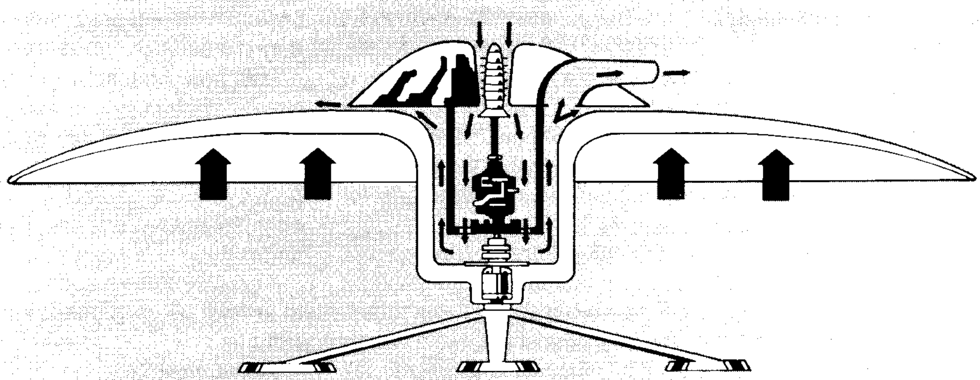
Twin Main Rotors (TMR): Two main rotors (or several pairs of main rotors in the case of really immense helicopters) on separate shafts that spin in opposite directions are mounted in such a way that their rotor blades do not interfere with each other. In some designs, 4
the rotors are at the front and rear of the fuselage, with one rotor set higher than the other. In other designs, the rotors are mounted side-by-side at the ends of long outriggers, or are synchronized to mesh like eggbeaters. 5

Coaxial Main Rotors (CMR): Two main rotors spinning in opposite directions are mounted on the same vertical axis. This combines the advantages of twin counter-rotating rotors in a more compact configuration. 6

Lift Activator Disk (LAD): The "wing" consists of a revolving disk which spins around a fixed central cylindrical hub (which contains the crew, passengers, and power plant). The power plant draws air in from above the craft and then blows it across the top of the disk 7
at high speed, generating lift. The spin of the disk (at about 1000 revolutions per minute) accelerates the air flow, further increasing lift. Part of the air flow is vented to the rear as thrust.

X-Wing: The X-wing helicopter is the ultimate expression of the 8
compound helicopter. Going beyond merely unloading the rotors in flight, advanced materials technology allows a four-bladed rotor to be locked in flight so that its blades—two of them swept forward—now function as fixed lifting surfaces, allowing the aircraft to fly at 9
high speeds, and then transition back to rotary flight for vertical

Lift-Activator Disk



landings. X-wing configurations use the NOTAR system (see MTR, above) to counteract torque when in helicopter mode. X-wing helicopters use transonic airframes.

Ornithopter(ORN): Ornithopters are not rotary-wing aircraft, but their function is best described here. Ornithopters have mechanically articulated wings that flap like a bird's, providing both lift and forward thrust. Constructed of advanced light-weight materials, the ornithopter is still less efficient than a helicopter in rising to altitude, but can then lock its wings and function as a glider, conserving fuel and also allowing silent, stealthy approaches to a target.

Rotor Assemblies

TL	*Type*	*Wt*	*MCr*	*Lift*	*Max Wt*
5	Lt MTR	0.2	0.02	4	2
6	MTR	0.25	0.01	4	60
6	TMR	0.35	0.015	5	—
6	CMR	0.25	0.02	5	60
9	LAD	2.00	0.01	9	—
9	X-Wing	0.25	0.05	5	40
10	ORN	0.15	0.05	2.5	1
12	ORN	0.1	0.03	3	2

Wt: Weight, in tonnes, per tonne of power plant.

Reduce rotor assembly weight by 10% per tech level above its tech level of introduction (i.e., 90% of listed weight at one tech level higher, 80% at two tech levels higher, etc.), but never below 50% of the value shown on the table.

MCr: Price, in millions of credits, per installed tonne of rotor assembly.

Lift: Lift, in tonnes, per MW output of power plant.

Max Wt: Maximum take-off weight of a craft using that type of rotor assembly. This value increases by 10% each tech level above the original tech level of adoption.

Folding Rotors: Any helicopter may be given the capability to fold its rotor blades to reduce its storage volume by doubling the price of its rotor assembly.

Airships: Airships are typically powered by propellers, but may also be powered by jets.

Although airships rely primarily on their aerostatic lift, they may have thrust agencies installed to add additional vertical lift. This allows the airship to operate at weights greater than its useful lift. At tech level 5 and above, installed thrust agencies can be vectorable to assist with lift or to provide thrust. One use of such an installation would be for the airfoil envelope configuration which has a minimum airspeed to gain its lift multiplier. A sufficient quantity of vectored thrust (equal to *one-half* the weight in excess of the useful lift weight, as the vectored thrust takeoff takes place in ground effect, and increases the efficiency of the vertical thrust) would enable the airship to lift vertically off of the ground and transition to its minimum forward airspeed to gain its lift multiplier. Remember that vectored thrust being used for vertical lift cannot be at the same time used for lateral thrust and vice versa.

One interesting application of vertical thrust is the *helistat* concept which combines the features of helicopters and airships. The helistat designer installs rotor assemblies on the airship car, and the rotary-wing assemblies provide vertical lift and thrust in the same way as they do on conventional helicopters (lateral thrust in tonnes equals vertical lift in tonnes times 0.1). Twin main rotor (TMR) is the only rotor assembly type that may be used in this way (in this case, visualize it as one or more pairs of twin rotors).

If additional lateral thrust is desired, propellers or jets may be added in addition. Maximum speed is limited by the airship envelope configuration.

An airship with added vertical lift must have its weight re-defined. It now has a *maximum take-off weight* equal to its useful lift weight plus the value in tonnes of the added vertical lift.

Step 4: Power Plant

Propellers, rotors, and High Efficiency Plasma Recombustion (HEPlaR) thrusters require a separate power plant. Select the power plant or plants to power the aircraft. Available power plants are listed in the Power Production chapter (Section 8).

Certain types of jet thrusters (turbojets, turbofans, ramjets, scramjets, and rockets) are self-contained and do not require a separate power plant. Aircraft with self-contained thrusters will usually require some additional electric power. Each such power plant includes (without additional weight or cost) an electrical generator which will produce MW equal to the thruster's thrust in tonnes times 0.02. If additional power is needed, a small power plant will have to be installed.

Step 5: Controls

Select controls for the aircraft from those listed in the Control Systems chapter (Section 4). The tech level of controls installed must be equal to or greater than the listed tech level of the airframe and any installed thrust agencies, power plant, sensors, or avionics. If a computer is installed, it must have the same tech level as the controls.

Fixed-Wing Aircraft: Certain controls may not be used on certain airframe types, as noted on the Controls table in the Controls chapter (Section 4).

Rotary-Wing Aircraft: Helicopters larger than 10 tonnes require enhanced mechanical controls. All others require only basic mechanical controls, with all the above guidelines.

Airships: Unpowered airships (balloons) do not have controls. Powered airships require simple controls.

Step 6: Crew and Passengers

Crew and passenger accommodations can range from a single seat for a fighter pilot to 500 seats for passengers and four crewstations aboard a jumbo jetliner.

Aircraft crew may be at crewstations, called cockpits for pilots (see the Controls chapter, Section 4). Aircraft with more than three crewmembers (excluding gunners) must have a flight deck, and all crewmembers (excluding gunners) must be provided with open crewstations and are considered to be grouped together. Gunners may still be at cramped crewstations.

The pilot acts as a gunner for fixed forward-firing weapons, bombs, rockets, and missiles.

A sensor operator, or second pilot who can act as sensor operator, is often included on aircraft which employ terrain-following radar, or target acquisition and fire control radar and high-performance, operator-guided missiles. This crewperson may also operate a laser target-designation system.

A bombardier/weapons officer is required if the aircraft is intended to launch air-to-ground attacks from higher than 2000 meters altitude.

Turret-mounted and flexible-mounted guns require a gunner. One gunner may control any number of remote turrets, but may only fire one during a combat turn. A gunner in a simple turret may only fire the guns in that turret. A gunner firing guns attached to a flexible mount may fire only those guns during a combat turn, but may move to a second flexible mount to fire its guns, taking a full combat turn to move there.

A navigator is required if the aircraft's normal mission duration is six hours or longer. Navigators are not required in aircraft with tech level 7 or higher navigational aids and a flight computer.

A flight engineer is required in aircraft with three or more engines, or more than 3.5 MW devoted to propeller thrust, unless a flight computer is installed.

A copilot is required if the aircraft's normal mission duration is four hours or longer. A copilot is required on all commercial aircraft. A copilot is required for any aircraft weighing more than 25 metric tonnes unless a flight computer is installed.

All crew except pilot, copilots, and sensor operators may double as gunners. Passengers are provided with seats as found in the Optional Features chapter (Section 7).

Armor and escape devices listed in the Crew/Passenger Position Additions table may be added to any cockpit or crewstation. Transonic aircraft require ejection seats; advanced ejection seats are required aboard supersonic combat aircraft; and rocket-powered escape capsules are required aboard hypersonic aircraft.

Cockpit armor may negate the minor hit result of "1 crewmember." Check the penetration value of the weapon that hit. If it is less than the armor value, the minor hit becomes no effect.

Crew/Passengers Positions Additions

TL	*Type*	*Mass*	*MCr*
6	**Ejection Seat**	0.1	0.005
7	Adv. Ejection Seat	0.25	0.010
7	**Rocket Escape Pod**	0.50	0.015
4	Cockpit Armor (AV 2)	0.1	0.005
7	**Adv. Cockpit Armor (AV 4)**	0.15	0.010

Mass: Mass in tonnes.

Escape Systems: The mass and price of the ejection seat, advanced ejection seat, and rocket escape pod are the cost to add this feature to each crew and/or passenger station.

Step 7: Life Support

Aircraft flying above 3000 meters in a Standard atmosphere (5000 meters in Dense, 1500 meters in Thin) require life support systems. These range from oxygen tanks and masks to sealed cockpits and full pressure suits aboard combat aircraft to sealed cabins and basic life support (with emergency backup oxygen masks) for civilian airliners.

A variety of life support options are available and are discussed in detail in the Life Support chapter (Section 11).

Step 8: Weapons Mounts

The number of weapon mounts should be determined and the type selected from the Airborne Weapons Mounts chapter on page 152. Fixed mounts have no weight or drag. Hardpoints only have drag when ordnance or a bomb rack is mounted. Drag disappears when the weapons are dropped or launched. Turrets always incur a drag penalty.

Hardpoints are generally located beneath the fuselage and wings. Normally, an aircraft only has room for one fuselage hardpoint—usually the strongest of the hardpoints. Fuselage hardpoints can carry up to 2000 kilograms of ordnance or 10% of the loaded weight of the aircraft, whichever is greater. For large aircraft, assign one 2000kg hardpoint per *complete* 20 tonnes clean weight of aircraft. Hardpoints mounted farther outboard can carry less and less weight. Inboard wing hardpoints can carry up to 1500 kilograms of ordnance, or 7.5% of the loaded weight of the aircraft, whichever is greater, while outboard hardpoints can carry up to 500 kilograms of ordnance, of 2.5% of the aircraft's loaded weight, whichever is greater.

Bomb racks, each carrying up to six bombs, three rocket pods, or 1
three launch rails with their missiles, may be attached to each hardpoint, as well as single weapons.

Fuel drop tanks may be attached to the centerline hardpoint or the inboard wing hardpoints if they have fuel intake plumbing. Note that 2
the Airborne Weapons Mounts table includes different values for plumbed and "dry" hardpoints.

Launch rails for missiles weighing up to 100 kilograms may be installed on each wingtip. 3

Internal bomb and weapon bays hold one tonne of ordnance for each tonne of capacity.

Fixed-Wing Aircraft: Up to two inboard and two outboard hardpoints may be fitted to each wing. 4

Rotary-Wing Aircraft: As combat helicopters are intended for agile operations close to the surface of the ground, fuselage hardpoints are not used. Instead, standard wing hardpoints are mounted on stub wings. Each helicopter stub wing can have one inboard 5
hardpoint, two outboard hardpoints, and sufficient wingtip launch rails to carry 100 kg of missiles. Weight and price of the stub wings is subsumed under the airframe.

Airships: As with helicopters, airships do not use fuselage hardpoints and instead mount their wing hardpoints on short stub wings, each 6
with one inboard hardpoint, one outboard hardpoint, and one wingtip launch rail. Unlike helicopters, airships may have multiple stub wings along their length, allowing them to mount as much ordnance on hardpoints as they can lift. Stub wing weight and cost 7
is subsumed under the gondola airframe.

Rigid airships may also have internal bomb bays: non-rigid airships may only have bomb bays internal to their cars. 8

Step 9: Weapons

A variety of weapons may be installed aboard aircraft. Machine-guns and CPR guns may be installed either in fixed, forward-firing mounts, or in flexible or turret mounts. Lasers and energy weapons 9
may also be installed in fixed, forward-firing mounts.

Bombs may be installed in internal bomb bays. One tonne of bombs may be carried for each tonne allocated for internal bomb bays. They may also be attached to hardpoints either singly or in 10
multiple racks. Rocket pods, gun pods, ECM pods, sensor pods, flare dispensor pods, napalm tanks, and fuel tanks may also be carried by the hardpoints. Missiles and larger free-flying rockets may be carried on missile launch rails that are mounted separately or are attached to hardpoints, and at tech level 7 and beyond they 11
may be carried in retractable internal missile bays.

Ammunition for internally mounted guns is included in the overall aircraft weight. Ammunition for gun pods is included in the pods and 12
counts as part of the external load.

Step 10: Electronics

Electronic systems of any sort may be installed on the aircraft, as detailed in the Electronics chapter (Section 5). Internally mounted 13
systems count toward the total aircraft weight and the antennae must fit within the available surface area of the airframe.

External, pod-mounted systems incur a drag penalty and count toward the aircraft's loaded weight. 14

Step 11: Cargo

Aircraft may have weight allocated to cargo. Each tonne of cargo capacity allows the aircraft to carry one tonne of cargo.

Step 12: Fuel

Fuel capacity is measured in cubic meters. Each cubic meter of fuel masses one metric tonne except for liquid hydrogen (used in HEPlaR thrusters), which masses 0.07 tonnes per cubic meter.

An air-to-air refueling probe may be included in an aircraft's design. This allows the aircraft to refuel in flight from a tanker aircraft or another aircraft carrying a refueling pod as an external store.

Refueling probes cost Cr1000 and weigh 0.1 tonne. Refueling pods include a wind-powered transfer pump attached to an extendable hose and drogue, and a tank holding fuel for transfer. Refueling pods cost Cr5000 and weigh one tonne loaded per 1000 kg of fuel, with a 500 kg fuel minimum.

Step 13: Maneuver Enhancement (Fixed-Wing and Rotary-Wing Aircraft Only)

Designers may allocate any percentage of a fixed-wing or rotary-wing aircraft's weight to maneuver enhancement. There is no cost. The higher the percentage of weight devoted to maneuver enhancement, the more agile the aircraft.

Aircraft with more than 20% of their aircraft weight devoted to maneuver enhancement are assumed to be variable geometry aircraft of some sort. Variable geometry aircraft automatically count as having folding wings for purposes of storage and do not need to devote any additional airframe weight to that feature.

RATING YOUR DESIGN

Once you have designed your aircraft, you need to determine and record its ratings. These include weight, thrust, speed, agility, fuel use, endurance, range, price, and volume.

Weight: A fixed-wing aircraft's full internal weight, a rotary-wing aircraft's maximum take-off weight, and an airship's useful lift weight are the weights determined at the beginning of the design sequence (for helistats and airships with added vertical lift, use the maximum take-off weight discussed in Step 3). Be sure that total weights of all components, including fuel, cargo, ammunition, and ordnance in internal bays, do not exceed the specified weight. This is the aircraft's "clean" weight.

Fixed-wing aircraft also have a maximum gross take-off weight equal to its maximum internal weight multiplied by 1.35. This includes the full internal loaded weight plus externally carried stores attached to hardpoints.

Rotary-wing aircraft and airships may also carry ordnance on external hardpoints, but this does not add to their maximum take-off weight. That is, the weight of these weapons must have been anticipated from the beginning of the design.

Thrust: An aircraft's thrust is determined by its thrust agency and its installed power plant. Remember that a rotary-wing aircraft's thrust in tonnes is equal to its lift in tonnes times 0.1, plus any additional thrust agency incorporated.

Wing-in-Ground Aircraft: Multiply the effective thrust of wing-in-ground aircraft by 5.

Airships: Use thrust in tonnes divided by useful lift weight.

Glide Ratio: Fixed-wing aircraft, including autogyros, and ornithopters have glide ratios. The glide ratio is the number of meters forward an aircraft will glide for every meter it drops. All fixed-wing aircraft start with a glide ratio of 5 and add 1 to the ratio for every 5% of airframe weight devoted to maneuverability. STOL aircraft double their glide ratio. Once the final calculations are complete, subtract 1 from the glide ratio for every drag point (excluding the drag points for a STOL airframe).

All ornithopters have a glide ratio of 20.

Powerless helicopters attempt to "autorotate" to a soft landing, trading altitude for rotor speed, and have no meaningful glide distance. MTR and X-wing configuration compound helicopters calculate their glide ratios as fixed-wing aircraft. They are *not* STOL.

G Rating: An aircraft's G rating helps determine its top speed and agility. Calculate the G rating by dividing the aircraft's total thrust by its total weight (maximum take-off weight or useful lift weight for airships) and multiplying the result by the airframe efficiency factor (listed on the Airframes table, page 30). Airships do not have efficiency factors. For fixed-wing aircraft, calculate the G rating using both the aircraft's clean and maximum take-off weights (for two different G ratings).

VTOL aircraft must have a G rating of 0.5 or greater or they are instead treated as STOL aircraft. VTOL aircraft which have a maximum take-off weight G rating of less than 0.5 but a clean G rating of 0.5 or more are usually called STOVL (Short Take-Off Vertical Landing) aircraft, as they require a short take-off roll but can land vertically once they have released ordnance.

Speed: Maximum speed (in kilometers per hour) in an atmosphere is determined by the vehicle's G rating. Calculate maximum speed (for fixed-wing aircraft, calculate for each of the two G ratings).

If G = 1 or less, speed = G×3500

If G = 2 or less, but more than 1, speed = 3500 + (1200×[G–1])

If G = more than 2, speed = 4700 + (600×[G–2])

Maximum speed cannot be greater than the maximum design speed of the airframe type. Maximum speed is reduced by drag. Note the total number of drag points from the weapons mounts installed, and from use of a STOL airframe, again both with and without external stores. Reduce the maximum speed by 1% for each drag point.

As an example, an attack aircraft carrying four loaded, multiple-bomb racks under its wings and a drop tank under its fuselage would have 17 drag points. This would reduce its maximum speed while carrying these external stores by 17%. Once the bombs and tanks are dropped, the aircraft's maximum speed would increase to its full "clean" loaded speed or maximum airframe design speed, whichever is lower.

Airships: Given the low maximum speeds of airship envelopes, it is easy to overpower an airship. However, this power is not wasted. Airships are very susceptible to wind, and can get into a great deal of trouble in high winds, especially close to the ground. Such operations will require task rolls by the airship's pilot to not lose control of the airship and crash. Excess thrust beyond the airframe's maximum speed can be used by the pilot to reduce the difficulty level of such tests. Compute airship speed normally, and if the result is greater than the maximum speed, take the excess speed and divide it by the maximum speed, dropping fractions. The result is the number of –Diff Mods that can be used by the pilot to maintain control in bad weather.

For example, a tech level 7 non-rigid cigar envelope (standard atmosphere) has a maximum speed of 140 kph, and a useful lift of 10 tonnes. It is fitted with propellers generating 1.2 tonnes of thrust. This yields a G rating of 0.12 and a maximum speed of 420 kph. Maximum speed is limited to 140, so there is excess speed of 280 kph. Dividing this by 140, the result is 2, meaning that the design gives the pilot 2 –Diff Mods for use in difficult weather or maneuvers. Add 1 to this result for cyclo-cranes and Magnus spheres, even if the result was 0.

Cruising Speed: An aircraft's cruising speed is 75% of its maximum speed.

Minimum Speed: An aircraft's minimum speed depends on the airframe type. Note its minimum speed on the airframe table. STOL aircraft have a minimum speed of half this. VTOL aircraft, most airships, and rotary-wing aircraft have no minimum speed. Minimum speed is reduced by 1% for each percent of a fixed-wing aircraft's weight used for maneuver enhancement.

NOE Speed: Only rotary-wing and VTOL fixed-wing aircraft fly the contours of the ground at nap-of-the-earth (NOE) speeds. NOE is defined as flying *around* ground obstacles, not over them, and must have the ability to hover. Airships, which may hover, are not responsive enough for NOE flight, and are too susceptible to wind effects. Aircraft have a safe NOE speed equal to the maximum allowed by their terrain -following avionics (40 kilometers if no avionics are installed) or one-quarter of their maximum speed, whichever is less.

Take-Off and Landing Rolls: All aircraft except for VTOL, helicopters and airships have take-off and landing rolls. These are the distances an aircraft must roll before taking off or after touching down.

To calculate take-off roll, multiply the square root of the actual take-off weight by the aircraft's minimum speed, then multiply the result by .25 and divide the result by the G rating of the aircraft. (However, if the actual take-off weight is less than 1 tonne, use it instead of its square root.) The result is the minimum safe take-off roll of the aircraft in meters.

To calculate landing roll, multiply the square root of the landing weight of the aircraft by the aircraft's minimum speed, then multiply the result by 0.6. (However, if the actual landing weight is less than 1 tonne, use it instead of its square root.) The result is the minimum landing roll of the aircraft in meters, but may never be less (in meters) than the aircraft's minimum speed (in kilometers per hour).

Combat Move: The high mode combat movement (in 10-meter grid squares per combat turn) is equal to the aircraft's maximum flight speed (in kilometers per hour) multiplied by 0.139. For VTOL aircraft, the safe NOE combat movement (in 10-meter grid squares per combat turn) is equal to the aircraft's safe NOE speed (in kilometers per hour) multiplied by 0.139, rounded to the nearest whole number.

Travel Move: The high mode travel movement rate (in kilometers per four-hour period) is equal to the cruising speed (in kilometers per hour) multiplied by 4. The NOE mode travel movement rate for VTOL aircraft (in kilometers per 4-hour period) is equal to the safe NOE speed (in kilometers per hour) multiplied by 6.

Agility: Agility is principally determined by speed.

Speed (kph)	*Agility*
22-42	1
43-85	2
86-171	3
172-343	4
344-687	5
688-1375	6
1376-2751	7
2752-5503	8
5504+	9

Add 1 to agility for every 10% of airframe weight devoted to maneuverability enhancement.

Calculate agility separately for NOE speed, maximum clean speed, and maximum loaded speed (where they are different). Aircraft flying NOE have their agilities doubled.

Agility serves as an increase difficulty modifier for fire against aircraft. An aircraft firing at another aircraft subtracts its agility from the target aircraft's to determine the difficulty modifier used.

Volume: A fixed-wing or rotary-wing aircraft's storage volume, in cubic meters, is equal to its weight in tonnes multiplied by 60. A fixed-wing aircraft with wing-folding capability has a storage volume of its weight in tonnes times 30, and a rotary-wing aircraft with its rotor folded or removed for transport has a volume equal to its weight in tonnes multiplied by 20. An airship has a volume equal to its envelope volume. Non-rigid, non-helistat airships can be disassembled for transport at a volume equal to 3 times its car/gondola mass in tonnes.

Volume determines target size difficulty modifiers, as shown on the table at the bottom of the page.

Fuel Use: The fuel use of each engine and power plant is obtained from the appropriate table in cubic meters per hour. If more than one engine or power plant is installed, multiply fuel use per engine by the number of engines installed to determine total fuel consumption.

Endurance: Endurance is the number of hours an aircraft can remain aloft at cruising speed. Divide the total volume of fuel carried by the fuel use per hour to determine the endurance, in hours, of the aircraft.

Range: Range is the distance an aircraft can fly at cruising speed. Calculate range by multiplying endurance by cruising speed. Do this for both clean cruising speed and loaded cruising speed, when they are different.

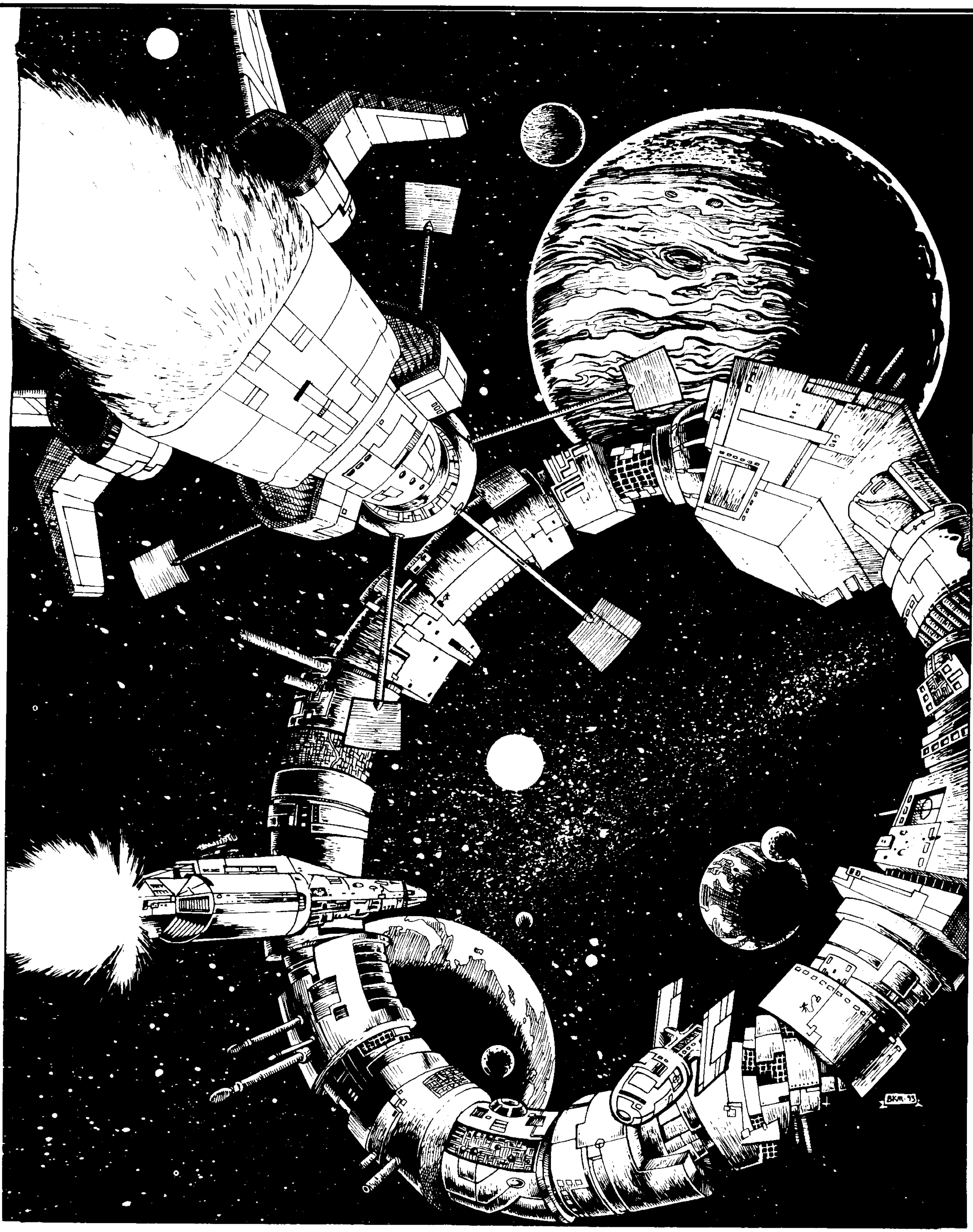
Price: Total the price of the aircraft's components to determine its total price.

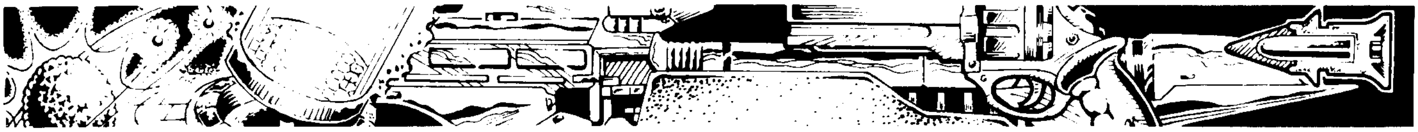
Determine Maintenance Points: Fixed and rotary-wing aircraft determine maintenance points just as spacecraft do, except that aircraft do not subtract their hull mass. Airships use the same system, but have their maintenance points calculated from their *actual mass* (not useful lift), which must first be determined. Multiply the lift envelope volume in displacement tons by the envelope weight from the table on page 27. This is the envelope mass. Add envelope mass to useful lift, and the result is the actual mass.

Note that maintenance points may be temporarily increased by environment (see "Carrier Aircraft" page 30, "Atmospheric Performance," page 64, and **TNE** page 309).

Size	*Displacement Tons*	*Kiloliters/Cubic Meters*	*Target Size Diff Mod*	*Spotting Diff Mod*
Sub-Micro (SM)	0-1	0-13	—	+2
Micro (Mc)	1-9	14-139	—	+1
Very Small (VS)	10-99	140-1399	–1	—
Small (S)	199-999	1400-13,999	–2	–1
Medium (M)	1000-9999	14,000-139,999	–3	–2
Large (L)	10,000-99,999	140,000-1,399,999	–4	–3
Very Large (VL)	100,000-999,999	1,400,000-13,999,999	–5	–4
Gigantic (G)	1,000,000+	14,000,000+	–6	–5

Book 2: Subsystems





CHAPTER 1
Material Technology

Material technology deals with the progressive refinement of materials used in the fabrication of artificial structures. For game purposes, this relates primarily to vehicle, aircraft, and spacecraft hulls, but material technology has a hidden effect on the whole range of subsystem technologies covered in later chapters.

For example, metals with better resistance to fatigue allow the construction of high-speed propellers and fan blades, which simultaneously lead to more powerful aircraft propellers and high-performance turbines. Progressively harder metals form the basis of progressively more effective kinetic energy penetrators in tank gun ammunition.

The earliest metals appear at tech level 1, and consist of bronze (an alloy of copper and tin) and iron. Early iron is hand-forged and of low quality. By tech level 2, foundries are capable of making large solid-iron castings, but are still not capable of fabricating large vehicles or structures from iron subcomponents.

The placement of iron on the Vehicle and Craft Construction Materials table (page 38) at tech level 3 represents the first availability of industrially mass-produced iron from large foundries, along with early steel from the Bessemer process, and the ability to construct large vehicles with it. The first iron-hulled ships, as well as the first armored ships, are built at tech level 3. While steel is used for a number of subcomponents, it is still extremely difficult to use it in large constructions. (Steel is iron with carbon, and sometimes other metals, such as nickel, added for greater toughness and hardness.)

At tech level 4, steel becomes widely used as a replacement for iron in ship hulls, and the first primitive armored land vehicles appear. The first experiments with hardened steel are made, and by tech level 5, hardening techniques become reliable enough that face-hardened armor becomes widespread.

Face-hardened armor is an illustration of two competing values in armor plate which, for purposes of simplicity, we gloss over in **Traveller**, those values being hardness and toughness. Hardness is the ability of armor to resist any deformation at all, and it is usually associated with a certain brittleness. Toughness is the ability of the armor to absorb energy without shattering, and usually is associated with a certain elastic character. By way of illustration, glass is extremely hard but not very tough. Rubber is very tough but not extremely hard.

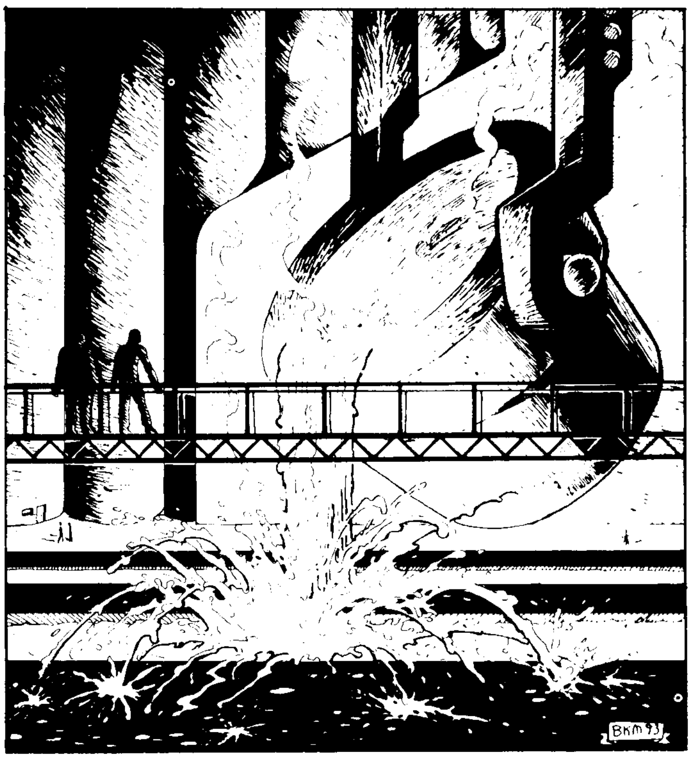
Armor which is very hard will cause small shells to shatter when they hit it and cause no damage, but larger shells will shatter the armor and pass completely through it. Tough armor can often be gouged or damaged by smaller shells, but does not suffer the massive shattering that hard armor does. Face-hardened armor combines both characteristics in one plate by taking a plate of very tough armor and hardening only the face of it. Small shots shatter against it while larger shots crack only the outer surface and are stopped by the more elastic part of the plate.

Although this is an interesting subject with some interesting effects on armor and protection, we have decided for purposes of game simplicity, to lump both characteristics into a generalized "toughness" rating, which represents the ability of armor to resist penetration by all projectiles.

At tech level 6, a number of alloys appear, which are different approaches to toughness and weight issues, as well as fiberglass, the first of the nonmetallic materials strong enough to consider for structural use. Light composites at tech level 7 represent a variety of additional nonmetallic structural materials, such as graphite, boron-carbide, etc. Early chobham armor is an example of light composite armor on vehicles.

Composite laminates at tech level 8 are matrices of different metallic and nonmetallic materials arranged to make the most of each material's strengths. The current version of armor used by US main battle tanks, which incorporates a mesh of depleted uranium in the composite armor, is similar to the level of protection shown on the table.

Crystaliron is a ferrous metal with perfect crystal structure and carefully controlled impurities in order to gain maximum hardness and toughness. Superdense is metal which has had its molecular structure partially collapsed in a massive artificial gravity field (such as might be encountered in a white dwarf star), which increases its density and strength. Bonded superdense has had its electron bonds artificially strengthened, by means of a field similar to that used in damper technology (see the Defenses chapter, Section 6). Bonded coherent superdense armor is dynamically manipulated by input from sensors and the computer so as to polarize the subatomic forces in the hull molecules, thereby presenting maximum penetration resistance to the specific striking weapon.



1. Vehicle and Craft Construction Materials

TL	Type	Toughness	Mass	Price (MCr)
3	Iron	1.5	8	0.0016
4	Soft Steel	1.7	8	0.0016
5	Hard Steel	2	8	0.002
6	Light Alloy	1.7	6	0.004
6	Fiberglass	0.25	1	0.001
6	Titanium Alloy	3	8	0.010
7	Light Composite	4	7	0.007
8	Composite Laminate	6	8	0.008
10	Crystaliron	8	10	0.009
12	Superdense (SD)	14	15	0.014
14	Bonded SD	28	15	0.028
17	Coherent SD	40	15	0.035

The previous materials are those commonly used to build vehicles of various sorts and personal armor. For completeness, we offer the following list of common construction materials used to make buildings and fortifications. Price and weight are omitted as these vary considerably, and in any event are not relevant to the design sequences in this book. They are included so that referees may accurately judge the armor value and resistance to penetration of various field fortifications and civilian structures.

The table following this table lists, for convenience, the armor values of some commonly encountered forms of cover.

Toughness: A measure of the material's resistance to damage. A material's toughness times its thickness in centimeters equals its armor value.

Mass: Tonnes per cubic meter of the material.

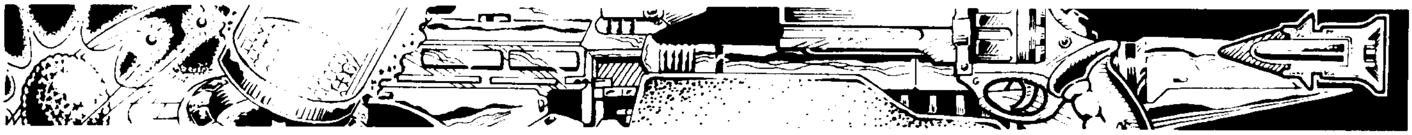
Price: Price in millions of credits per cubic meter of material.

2. Construction Materials

TL	Type	Toughness
1	Loose Dirt	0.04
1	Stone, Packed Dirt	0.2
1	Wood	0.2
2	Masonry	0.3
4	Reinforced Concrete	0.4

3. Common Forms of Cover

Type	Thickness	Armor Value
Sandbag	25cm	1
2" Wooden Plank	5cm	1
Timber House Wall	20cm	4
Cinder Block Wall	30cm	9
Stone Wall	30cm	6
Thick Stone Wall	60cm	12
Reinforced Concrete	25cm	10
Tree Trunk	60cm	12
Brick Wall	10cm	3
Thick Brick Wall	30cm	9



CHAPTER 2
Personal Armor

Personal armor consists of solid or woven protection worn over various body parts. The design sequence deals with three types of armor: rigid, non-rigid, and powered. Rigid armor covers metallic and hard ceramic armors, while non-rigid covers leather, ballistic cloth, and ballistic weave. Powered armor is also called battle dress and consists of rigid all-body armor and a powered exoskeleton.

Rigid Body Armor: The designer will need to specify material, body parts covered, and thickness of protection. The first centimeter of armor can be made particularly tough through the use of surface-hardening, angling of the plates, and other techniques which serve to lower the effective weight of the first layer of armor proportional to its protection. This is reflected in the personal armor tables beginning on page 40, which apply only to the first centimeter of armor thickness.

The Rigid Body Armor table indicates the weight, in kilograms, per armor level of a particular armor type. For example, a soft steel piece of armor covering the chest weighs 7.8 kilograms per armor level. However, these weights apply only to the first centimeter of armor. The extra-tough first centimeter has been reached when the armor value equals the toughness rating of the armor type used. After that, additional armor value additions cost double the weight shown on the table.

In the case of fractional toughness values (such as with iron, soft steel, and light alloy), all armor weighs double after an armor value of 1 is reached.

Due to the need for fine-fitting work, rigid personal armor is fairly expensive. The price column on the table is the price, in credits, per kilogram of armor.

Armor Values: Armor value is determined by the thickness chosen by the designer. Although the armors shown provide information for an armor value of 1, values less than 1 may be selected by opting for thinner (lighter) armor than what is shown on the table.

Armor values of less than 1 but equal to or greater than 0.5 are treated as an armor value of 0. All armor with an AV of 0 has a parenthetical (melee only) value of 2. All armor with an AV of less than 0.5 has no value versus projectiles or energy weapons and has a parenthetical (melee only) value equal to its calculated AV multiplied by 4. Parenthetical melee values are rounded to their nearest increment of 0.5. (Since armor absorbs melee damage equal to twice its armor value, each AV of 0.5 absorbs one hit.) Armor with a parenthetical AV of less than 0.5 provides no protection.

Armor value 1 has a melee armor value of (2). All armor values of 2+ have melee values equivalent to their listed value.

Flexible Body Armor: Flexible body armor imposes fewer agility penalties than does rigid armor, but it is limited in the degree of protection it affords. (If too thick, it ceases to be flexible.) As a result, the flexible body armor lists the absolute armor value offered by that type of armor and the design decision involves selection of body parts to be covered. Price is, as with rigid armor, determined by multiplying the total weight (in kilograms) by the price listed on the Flexible Body Armor table on page 40.

Insert Plates: The Flexible Body Armor table also includes values for insert plates. These plates are inserted in pockets in ballistic cloth and ballistic weave jackets and vests. Plates may only be inserted over the chest and abdomen. When plates are inserted in these vests or jackets, the armor value of the plate is added to the protection of the vest or jacket.

Flak jackets already contain insert plates and their armor values take them into account.

Agility Penalties: Any armor covering the arms and/or legs causes an Agility reduction of 1. Any rigid armor (including flexible armor with plate inserts, which includes all flak jackets) covering part or all of the torso causes an Agility reduction of 1. These two effects are cumulative. Battle dress (see below) is excepted from this rule.

Initiative Penalties: Visored helmets cause an Initiative reduction of 1.

Storage Volume: Storage volume is the space taken up by armor when it is not being worn. This is generally used when a large amount of armor is being carried as cargo. Different pieces of armor have different storage volumes depending on what parts of the body are covered and whether the armor is rigid or flexible. The table below lists storage volumes in liters for different types of armor. Rigid armor consists of solid pieces of armor, usually metallic, although sometimes ceramic, articulated at the joints. Typical rigid armor is plate at lower tech levels and combat armor at higher tech levels. Semi-rigid includes armor which is made up of a large number of connected rigid pieces, and so is somewhat flexible. It includes chain mail, flak jackets, and ballistic jackets and vests with rigid armor inserts. Fabric includes leather, ballistic cloth, and ballistic weave. Note, however, that a ballistic weave helmet is rigid, and so has the same storage volume as listed for rigid helmets.

Armor Storage Volume (in liters)

Type	*Rigid*	*Semi-Rigid*	*Fabric*
Helmet	1	0.5	0.5
Visored Helmet	2	—	—
Arms	5	0.5	0.5
Chest	10	1	0.5
Abdomen	10	1	0.5
Legs	15	0.5	1

Optional Features: Several optional features are possible.

Environmental Control: At tech level 9, environmental control may be added as an option. The environment control option includes an air-tight liner which gives complete protection against most chemical agents, tainted atmospheres, biological agents, and a moderate defense against radiation. A suit equipped with this liner is generally worn open at the neck and wrists, and can be sealed by donning gauntlets and a clear, flexible headpiece. Heat buildup in the suit is handled by a simple solid-state cooling system that is woven into the liner and which eliminates all infrared signature except on the exposed face, hands, and heat exhaust. The heat exhaust is a very pronounced IR source, but this can be dampened by

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inserting a chemical chill can into the cooling system. The chill can completely eliminates the signature from 45 minutes to two hours, depending on the background temperature. At the end of that time, the can is used up and discarded.

When combined with a whole-body protective suit, the complete garment is usually called a combat environment suit. The environmental control option also results in a much more comfortable suit, with lower heat fatigue over time. Incorporation of environmental control reduces any agility penalty suffered by the armor by 1. (Armor with an Agility penalty of –2 becomes –1; armor with an Agility penalty of –1 loses its Agility penalty.)

The environmental control option costs Cr6000.

Helmet Sensor Suite: At tech level 10, compact sensor suites become available with sufficient resolution to negate the Initiative penalty associated with a visored helmet. These suites cost Cr750.

Chameleon Option: At tech level 12, a chameleon surface becomes available for any full-body armor. The chameleon option selectively bleeds heat to match background IR levels and effectively renders the wearer invisible to IR sensors. The chameleon option costs Cr1000.

Looking Glass Option: At tech level 15, a looking glass surface becomes available for any full-body armor. The looking glass surface changes color to match background colors and patterns, rendering the wearer nearly invisible when stationary. The suit adjusts gradually to its background (taking 1D20 combat turns to fully adjust), so while moving the suit has no more effect than camouflage fatigues.

The looking glass option costs Cr50,000.

Psionic Shield Option: At tech level 12, a psionic shield option is available as an addition to helmets. The option costs Cr4000 and adds negligible volume to the armor. At tech level 12, it adds 1 kilogram to the mass of the helmet, but at tech level 13 and beyond, the additional mass is negligible.

In-Helmet Communicators: Communicators may be added to helmets and armor packages by selecting a communicator from the Electronics chapter and adding its mass and price to the cost of the helmet or armor.

Advanced Sensors: Sensor suites may be added to armor by selecting a sensor from the Electronics chapter and adding its mass and price to the cost of the armor. The sensor data is displayed on the inside of the helmet visor or, if the helmet is not equipped with an armored visor, on the inside of a clear plastic faceplate.

ARMOR DESIGN TABLES

I. Rigid Body Armor Table

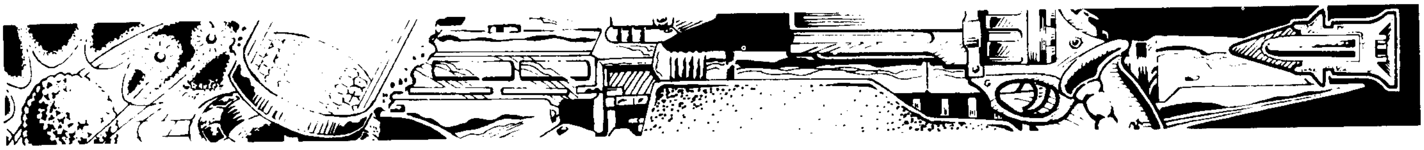
			Hit Location Covered							
TL	*Material*	*Tough*	*Chest*	*Abdmn.*	*Full Torso*	*Arms*	*Legs*	*Helmet*	*Visored Helmet*	*Price (Cr per kg)*
1	**Iron**	1.5	8.8	8.8	17.6	5.9	17.6	1.6	2.9	20
2	Soft steel	1.7	7.8	7.8	15.6	5.2	15.6	1.3	2.6	20
5	**Hard steel**	2	6.6	6.6	13.2	4.4	13.2	1.1	2.2	25
6	Light alloy	1.7	6	6	12	4	12	1.0	2	65
6	**Titanium**	3	4.4	4.4	8.8	2.9	8.8	0.7	1.5	125
7	Light comp.	4	3	3	6	2	6	0.5	1	100
8	**Comp. lam.**	6	2.4	2.4	4.8	1.6	4.8	0.4	0.8	100
10	Crystaliron	8	2.1	2.1	4.2	1.4	4.2	0.35	0.7	90
12	**Super-dense**	14	1.8	1.8	3.6	1.2	3.6	0.3	0.6	95
14	BSD	28	0.9	0.9	1.8	0.6	1.8	0.15	0.3	185
17	**BCSD**	40	0.6	0.6	1.2	0.4	1.2	0.1	0.2	235

Note: Although iron cannot be mass-produced until tech level 3 and the same is true for soft steel at tech level 4, both can be hand-forged in quantities sufficient for armor at two tech levels sooner.

II. Flexible Body Armor

			Hit Location Covered						
TL	*Material*	*AV*	*Chest*	*Abdmn.*	*Full Torso*	*Arms*	*Legs*	*Helmet*	*Price (Cr per kg)*
0	**Leather**	(½)	1	1	2	1	2	.5	10
1	Iron mail	(1)	5	5	10	3.3	10	1	20
2	**Steel mail**	(1)	4.5	4.5	9	3	9	.8	20
5	Flak jacket	1	6	6	12	—	—	—	15
7	**Flak jacket**	1	4	4	8	—	—	—	25
7	Ballistic cloth	1*	2	2	4	1.3	4	—	80
7	**Plate insert**	+1	2	2	—	—	—	—	25
8	Ballistic weave	1	2	2	4	1.3	4	.5	100

* Ballistic cloth is treated as no armor vs. edged melee weapons.



Battle Dress: Battle dress incorporates a powered exoskeleton which, in addition to allowing heavier armor, also doubles the effective strength of a human and moves at regular human speeds. The table below shows a variety of basic exoskeletons available at different tech levels. After selecting an exoskeleton, armor, batteries, and other equipment (e.g., integral weapons, oxygen tanks, etc.) are added up to the maximum allowed mass the exoskeleton can carry.

Each exoskeleton has a listed reduction in Initiative and Agility (except for the light TL-17 exoskeleton).

Designers may overload an exoskeleton if desired, but each additional 10% of mass reduces Agility and Initiative by an additional 1 and reduces movement by 10%. The exoskeleton may not be overloaded by more than 30%.

The rules on pages 39-40 on Agility penalties and benefits of environmental control do not apply to battle dress. Agility penalties and bonuses for environmental control are subsumed into the AGL penalties listed with the exoskeletons. All battle dress exoskeletons automatically include environmental control, as well as filter/respirator fittings which allow the wearer to function in thin and tainted atmospheres, as well as under chemical/biological warfare conditions.

However, battle dress does require an outside source of oxygen. For use in vacuum, portable life support systems must be worn (see **TNE**, page 337).

Powered Exoskeletons

TL	SM	MM	MCr	SV	AGL	INIT
10	0.23	0.42	0.11	100	–3	–2
12	0.1	0.23	0.14	100	–2	–1
12	0.2	0.42	0.20	120	–3	–2
14	0.05	0.3	0.21	100	–1	–1
14	0.1	0.58	0.25	120	–2	–2
17	0.04	0.36	0.26	80	—	—
17	0.08	0.7	0.30	100	–1	–1

TL: Lowest tech level of availability.

SM: Skeletal mass, the mass in tonnes of the rigid exoskeleton (including its power servos and supporting electronics).

MM: Maximum mass of the suit, in tonnes, including the skeletal mass, armor mass, and power supply mass.

MCr: Price (in millions of credits) of the exoskeleton. Total price of the battle dress unit will also include batteries and armor.

SV: Storage volume in liters of the empty armor. This includes space for power packs and armor.

AGL: The Agility penalty of the unit, assuming it is not overloaded.

INIT: The Initiative penalty of the unit, assuming it is not overloaded.

MW: Power requirement, in megawatts, equals the total mass of the unit (including power source and armor) times 0.014.

Sample Battle Dress Designs

Tech Level 10 Battle Dress (AGL –3, INIT –2)

SM	AV	AM	BV	BM	TM	MW	End	SMCr	AMCr	BMCr	TMCr
0.23	4	.042	.0735	.147	.419	.00588	10	.11	.00378	.0002205	.11475

Tech Level 12 Light Battle Dress (AGL –2, INIT –1)

SM	AV	AM	BV	BM	TM	MW	End	SMCr	AMCr	BMCr	TMCr
0.1	6	.054	.0215	.043	.197	.00322	10	.14	.00513	.0001075	.146

Tech Level 12 Heavy Battle Dress (AGL –3, INIT –2)

SM	AV	AM	BV	BM	TM	MW	End	SMCr	AMCr	BMCr	TMCr
0.2	12	.108	.0392	.0784	.3864	.00588	10	.20	.01026	.000196	.2112

Tech Level 14 Light Battle Dress (AGL –1, INIT –1)

SM	AV	AM	BV	BM	TM	MW	End	SMCr	AMCr	BMCr	TMCr
0.05	8	.036	.084	.21	.296	.0042	100	.21	.00666	.00084	.21825

Tech Level 14 Heavy Battle Dress (AGL –2, INIT –2)

SM	AV	AM	BV	BM	TM	MW	End	SMCr	AMCr	BMCr	TMCr
0.1	16	.072	.1624	.406	.578	.00812	100	.25	.01332	.001624	.2657

None of these designs have been fitted with integral weapons, oxygen tanks, or sensors.

AV: Armor value.
AM: Armor mass (tonnes).
BV: Battery volume (cubic meters).
BM: Battery mass (tonnes).
TM: Total mass (tonnes).
End: Endurance of suit battery (hours).
SMCr: Skeleton price in MCr.
AMCr: Armor price in MCr.
BMCr: Battery price in MCr.
TMCr: Total price in MCr.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

CHAPTER 3
Faster Than Light (FTL) Drives

Interstellar drives which allow avoidance of the limits of light speed form the basis of much science fiction. As there is no known way to avoid the light speed barrier, science-fiction authors (including game designers) must find ways to get characters from one star system to another expeditiously and using means which *seem* plausible given current scientific knowledge. After all, we do not yet know everything about the natural universe. Assuming that what we know is reasonably correct, what additional knowledge might enable FTL (faster-than-light) travel?

JUMP DRIVES

"Jump" drives enable starships to bypass the normal laws of time and distance by travelling from star to star through another form of space. The drives push a ship into a tunnel through jump space, or "J-space," a conceptual universe with more elastic dimensions than normal space (N-space). Due to the unique topology of J-space, the fall through the tunnel takes about one week (150 hours), regardless of the distance travelled in N-space. This time spent in the J-space tunnel is referred to as time "in the hole" by experienced travellers.

As gravitational fields interfere with the alignment of the jump drive (and may cause a jump mishap), ships do not usually jump until they are at least 100 planetary diameters away from the nearest world.

Jump drive machinery requirements are tied to the volume of the hull and the maximum distance the drive is capable of jumping the ship. There are upper limits on how many parsecs a ship may jump based on the tech level of the drive. The volume of the jump drives, as a percentage of the total volume of the ship, is equal to 1 plus the maximum jump number (in parsecs). So, for example, a ship capable of jump 4 would have jump drives which filled 5% (1+4) of the internal volume of the ship. If it were a 100-ton ship (1400 cubic meters of volume), the jump drives would take up 70 cubic meters of volume.

The Jump Drive table in the right-hand column lists the maximum allowed jump number, mass, and price of jump drives at each tech level.

Important Note: The smallest jump drive possible, at any tech level, is 2 cubic meters in volume.

Jump drives require fuel, displacement mass, and coolant, all of which are collectively called jump fuel (liquid hydrogen being used for all three functions). The fuel necessary for a jump of 1 parsec is equal to the total volume of the jump drive machinery multiplied by 5 and divided by the drive's maximum jump number. Thus, ships with higher jump performance make more efficient use of fuel at short distances. Jump fuel weighs .07 tonnes per cubic meter.

Fuel tankage itself is under Section 8, Power Production.

To continue the example of the 100-ton jump-4 ship above, it would require $(70\times 5/4=)$ 87.5 cubic meters of jump fuel per parsec jumped (up to a maximum of 4 parsecs, the limit of its drive). The ship would normally have at least 350 cubic meters of jump fuel tankage (enough for its 4-parsec maximum jump).

Jump Drive

TL	*Max Jump*	*Mass*	*MCr*
9	1	3	0.3
11	2	3	0.3
12	3	3	0.3
13	4	3	0.3
14	5	2.5	0.3
15	6	2	0.3

TL: Tech level of construction
Max Jump: The longest allowed jump in parsecs.
Mass: Mass in metric tonnes per cubic meter.
MCr: Price in millions of credits per cubic meter of jump drive.
Surface Area: Surface area in square meters equals cubic meters of jump drive ÷ 3.

ALTERNATIVE TECHNOLOGIES

The means by which FTL travel is accomplished is an important element, perhaps the single most important element, in defining a feel of a science-fiction campaign. The following FTL drives are not available in the Imperial Space campaign of **Traveller,** but instead are presented as alternative means of cracking the C-barrier.

Because the purpose of these alternative technologies is to allow referees to customize the background of their campaigns, the rules below should be seen as guidelines. Referees should feel free to change details to create the proper "look" for their campaigns.

Stutterwarp

Of all the possible forms of FTL travel, stutterwarp comes closest to physical travel though space at trans-light velocities. Stutterwarp is an implementation on the macro scale of the tunneling phenomenon common to electrons. The proper introduction of energy in a field around the ship allows it to move instantaneously from one location to another without passing through the intervening space.

The distances that the stutterwarp can travel in one warp, however, are very small. One cycle of the drive moves the ship less than a few hundred meters. But by cycling the drive very rapidly, the ship can travel vast distances in very short times, even faster than light.

Speed/Efficiency: Actual speed of a stutterwarp ship depends on the output of the power plant, the displacement of the craft that is being moved, and the amount of gravity through which it is being moved. In deep space, where gravity is less than

0.0001G, the warp efficiency is equal to parsecs per day. A warp efficiency 1 ship, for example, would require one week to travel between stars seven parsecs apart.

In the inner system of a star where the gravity becomes greater than 0.0001 G, the efficiency of the stutterwarp drops off enormously (by a factor of proximately 10,000). Ships with stutterwarp in the inner system are still moving at enormous speeds, but no longer at multi-light speeds. Stutterwarp-powered ships travelling between worlds in the inner system can expect travel times ranging from hours to, at most a few days.

Finally, when gravitation reaches about 0.1G, the efficiency of the stutterwarp drives drops off once again. At 0.1G, the stutterwarp has just enough efficiency to maintain orbit; above 0.1G, it cannot overcome the gravitational attraction and some other means of propulsion must be used. The major effect of this is that a stutterwarp drive cannot lift a vessel off of a world's surface or even out of its atmosphere. Some other type of engine is required, or the vessel may carry landing craft.

It is easy for a referee to determine at what distance from a planet or star these cut-off points are. Simply divide the body's surface gravity by 0.1G or 0.0001G (depending on which distance you wish to know), take the square root of that value, and multiply it by the radius of the body in kilometers. The result will be the distance in kilometers from the body's core at which the cut-off points are located.

For Sol, stutterwarp drives will not operate above light speed much beyond the asteroid belt, and they cannot overcome Sol's attraction at all if they are within 11.6 million kilometers of Sol's core (or about 10.9 million kilometers from Sol's surface). For Terra, the cut-off points are at approximately 638,000 kilometers and 20,000 kilometers.

Designing Stutterwarp Ships: Stutterwarps are available at tech level 10 and beyond. Stutterwarps require a separate power plant.

Volume: The volume of a ship's stutterwarp drive in cubic meters is equal to 2 plus the product of five times the square root of the output (in megawatts) from the power plant devoted to the drive.

$$V = 2 + (5\sqrt{MW})$$

Price: The price of the stutterwarp, in millions of credits, is equal to its volume multiplied by 0.3.

Performance: The efficiency of the stutterwarp is equal to the product of the tech level efficiency multiplier times the cube root of the quantity: megawatts (devoted to the drive) divided by 10 times the ship's displacement in displacement tons. The tech level efficiency multiplier of the stutterwarp is equal to the tech level of construction plus 4.

$$E = Tlm \times \sqrt[3]{MW \div 10D}$$

E: Efficiency

Tlm: Tech level multiplier (tech level + 4)

MW: Power input to the drive.

Surface Area: Surface area in m^2 equals volume in $m^3 \div 3$.

Stutterwarp Vessels in Combat: The stutterwarp is so much faster than conventional ships that it can literally "fly rings around" a G-maneuvering vessel. The craft's stutterwarp efficiency multiplied by 4 (rounding fractions to the nearest whole number) is the number of range bands (hexes if playing **Brilliant Lances**) it can move in *one minute.* Since a combat turn is *30 minutes* long, multiply the speed (in hexes per minute) by 30 to find out how many hexes it can move per turn. (This will range from 120 to as much as 500.)

To make the game manageable, divide the turn into several segments. If a stutterwarp ship is facing a conventional vector movement ship, divide the turn into as many segments as the current velocity of the vector-movement ship (or the fastest vector-movement ship if there are several). Divide the stutterwarp ship's movement by the number of segments in the turn. Each segment the stutterwarp ship moves that many hexes (or range bands) and the hostile ship moves 1 (or the fastest hostile ship moves 1 and the slower ones either move or pass, making sure they move the correct total number of hexes in the complete turn).

Ships may fire some or all of their weapons in any segment, but may fire each of their weapons only once per turn. Ships which have increased rates of fire (due to increased power to energy weapons) may use this to make extra shots instead of a blanket lowered difficulty level. This may allow an energy weapon to fire five or even 10 times in turn, but it may fire no more often than once per segment.

Regardless of how many hexes a ship moves in a segment, it may fire or be fired on at any point in its movement. As it moves each hex, the owning player should pause briefly to let any opposing player declare attacks.

If only stutterwarp ships are involved in the combat, divide the turn into 10 segments.

Charge Buildup Limitation (Optional): Stutterwarp as described above is a tremendously versatile drive system. Often the dictates of a game require some limitation on the versatility of a drive, particularly if a military situation is being gamed. The following limitation has been used by us in the GDW **2300 AD**™ future history. Its advantage is that it allows stars with planets to provide important way stations and choke points to travel. Without this option, it is very difficult to have a "frontier" between two powers. The first evidence of an invasion expedition would be the appearance of a hostile fleet in your capital's star system. Therefore, the following is highly recommended.

The structure of the stutterwarp drive imposes some limitations on distances travelled. As a stutterwarp drive tunnels, an energy charge builds up in its components. This charge is related to the total distance tunneled, rather than to the time the drive is in operation. When this charge reaches a critical threshold level, a rapid deterioration of the drive components begins, stalling the drive and releasing lethal radiation. The energy charge is removed by discharging it in a gravity well. If the discharge is not made by the time the ship has travelled its range value in parsecs, the ship will be completely irradiated and the crew killed. The discharge must take place in a significant gravity well of at least 0.1G, and it requires 40 hours to complete.

Note that in order to discharge into 0.1G, a vessel must be orbiting a body while discharging. Although 0.1G is also the limit at which stutterwarp drives drop below the efficiency of conventional drives, stutterwarp drives are sufficient to make any velocity changes necessary to maneuver a ship that is in orbit, as long as the vessel does not drop below the 0.1G distance. Stutterwarp vessels can also leave orbit without using conventional drives.

Also, a stutterwarp vessel can use a planet to change its vector. To do so, the craft begins a shallow drop toward the planet. The velocity it picks up in this drop is sufficient to slingshot it past the planet and beyond the 0.1G limit, where its stutterwarp can be used to maneuver it away.

Wormholes

Wormholes are permanent or semi-permanent naturally occurring tunnels through space. They allow travel from one end of the wormhole to the other, and the hole may conceivably be of any length. Entry and exit points tend to be near large masses, such as stars or black holes. The fact that the wormholes can only be discovered, not created, lends a completely different topology to the universe. Wormholes are defined by two different characteristics: opening and length.

Opening: Wormholes may be open or closed, indicating the degree of difficulty encountered when trying to enter them. Whether all wormholes are open, all closed, or there are a mix of the two types is entirely up to the referee. Open wormholes can be entered without any unusual expenditure of energy, and in fact, are often discovered by accident. Closed wormholes can be entered only by great expenditures of energy and are more difficult to detect. (They are detected using densitometers.)

Ships enter closed wormholes by means of "keyhole" drives.

Keyhole Drive Table

TL	*Mj*	*Vol*
9	3	2
11	2.5	1.75
12	2	1.5
13	1.5	1.25
14	1.25	1
15	1	0.75
16	0.9	0.5
18	0.8	0.25
20	0.7	0.15

Mj: Power, in megajoules, required per displacement ton of craft.

Vol: Volume of drive, in cubic meters, per displacement ton of craft.

Price: All keyhole drives cost MCr0.3 per cubic meter of drive.

Mass: All keyhole drives mass 1 tonne per cubic meter.

Surface Area: Surface area in m^2 is equal to volume in $m^3 \div 3$.

In addition to the keyhole drive itself, the ship will usually have banks of capacitors to store energy from the power plant prior to the jump. Consult the Power Production chapter (Section 8) for a discussion of capacitors.

Length: There are two aspects of wormhole length which are important: endpoint length and apparent length. Endpoint length is the distance between the two endpoints (openings) of the wormhole, and determines the practical real-universe distance travelled through the wormhole. Endpoint length can either be determined randomly or deliberately set by the referee.

Apparent length is the time actually spent in the wormhole while travelling, and is up to the referee. Several options should be considered. One is a constant apparent length. That is, no matter how great or short the endpoint length, a constant amount of time is spent in the wormhole. (This is similar to the time spent in J-space when using a jump drive.) A second is a scaled apparent time, where the time spent in the wormhole is proportional to the endpoint length of the wormhole. A ratio of time to parsecs should be established, and it can be as little as one hour per parsec to a week or more per parsec. A third option is no apparent length: travel is instantaneous. A final option is random apparent length, the assumption being that wormholes are not necessarily straight mathematical constructs and may meander. Wormholes with short endpoint lengths may have very long apparent lengths, and vice versa. This option is perhaps the most interesting as it adds greater variety to the topography of your universe.

Stargates

There are two possibilities for including stargates in a game. One is the tightly closed-door wormhole opening and the other is the artificial (or "drilled") wormhole. Within these general classes there are a number of sub-varieties. When establishing a universe using wormholes as transportation routes, remember that it is not necessary that every variety discussed below be included. Some of the most interesting science-fiction universes are the most restrictive with respect to travel.

Closed Door: This really represents one more type of opening for a wormhole, and assumes that ships cannot easily carry equipment powerful enough to breach the wormhole opening. In this case, large gates are built at the wormhole openings which allow ships to pass through freely.

Drilled Wormholes: These stargates are nothing more than artificially created (rather than naturally occurring) wormhole openings. In some cases, stargates may be relics of long-vanished civilizations. There are two varieties of drilled wormholes: semi-permanent and transitory.

In the case of semi-permanent drilled wormholes, the builders determine entry and exit points, and a gate has to be built at both ends before the wormhole can be activated.

In the case of transitory wormholes, the gate serves as a very large directional-matter transporter which can teleport any object (including a ship) from the gate to any point within its maximum range. It essentially re-drills its wormhole every time it transfers volume. With that exception, all of the below considerations of stargate design must be addressed.

Characteristics: Stargates are usually huge and require tremendous power. If near a star, power is usually supplied by solar collectors, while fusion reactors provide power in other cases. Unlike most forms of technology, we offer few hard guidelines here and instead leave the details up to the referee. However, we will outline what sorts of requirements need to be defined.

Power requirements will be based on the displacement of objects passing though the gate, and will be expressed as Mj per displacement ton. The megajoules, rather than megawatt, notation is used as the gate is not continuously powered, instead only requiring a burst of energy when an object enters the wormhole through the gate. As a result, gates often have capacitor or homopolar generator banks (see Section 8, Power Production) banks which require recharging between ship entries.

Drilled wormholes are somewhat different, as both gates need to be continuously powered to maintain the wormhole between them. This power requirement is in MW per parsec of endpoint length.

The actual gate structure is heavy with complex electronic components, and has a volume equal to one displacement ton (14 cubic meters) per displacement ton capacity. That is, 1000 tons of machinery are required for a gate large enough for a 1000-ton ship to pass through. Gate structure costs between MCr0.001 and MCr1 per displacement ton (at the referee's discretion) and masses 1 tonne per cubic meter (14 tonnes per displacement ton).

Stargate Characteristics Summary

Gate Opening Energy: Mj per displacement ton
Gate Sustaining Power: MW÷parsec endpoint length
Gate Capacity: In displacement tons
Gate Volume: Gate capacity × 1.
Gate Mass: Gate capacity (in displacement tons) × 14.
Gate Price: Gate volume multiplied by the cost constant.

Gate performance is affected by tech level. Tech level can provide both progressive increases in efficiencies and can also impose upper limits on endpoint length. It may also reduce the gate volume to a decimal multiplier of the gate capacity, such as 0.8 or 0.1.

The table below is a sample description of what gate technology might be in a science-fiction universe.

Stargates

TL	*EPL*	*GOE*	*GSP*	*Vol*
10	**6**	**20**	**100**	**1**
11	7	18	100	1
12	**8**	**16**	**100**	**1**
13	9	14	100	1
14	**10**	**12**	**100**	**0.9**
15	12	10	100	0.8
16	**15**	**9**	**100**	**0.7**
18	20	8	100	0.6
20	**25**	**7**	**100**	**0.5**
21	30	6	100	0.4

TL: Tech level of availability.
EPL: Maximum endpoint length in parsecs.
GOE: Gate opening energy in megajoules per displacement ton of transferred volume.
GSP: Gate sustaining power in megawatts per parsec of endpoint length.
Vol: Volume of gate machinery, in displacement tons, per displacement ton of transfer capacity.
Gate Mass: The mass of the gate, in tonnes, is equal to the volume of its machinery in displacement tons multiplied by 14.
Gate Price: The price of the gate, in millions of credits, is equal to the volume of its machinery in displacement tons multiplied by 28.

Subspace

Subspace is a duplicate of our physical universe in smaller scale. Ships which enter subspace can move from point to point at sublight speed, but arrive at their destination sooner than in normal space because the distance travelled is less. In this respect, subspace bears some similarities to J-space (see the discussion of jump drives above), but with some very important differences.

Subspace does not resemble a vacuum, but instead resembles a fluid medium. Continuous energy is required to sustain forward motion through the resisting medium. In addition, each point in subspace has an analogous point in normal space (N-space) and a ship whose subspace drives fail will immediately reappear in N-space at the point corresponding to its previous subspace location. This also means that, although power is usually consumed in relation to speed, a certain amount of energy is consumed simply remaining in subspace, even if absolutely stationary, and this is called the "station-keeping" power level.

Subspace drives require separate power plants. The amount of energy channeled to the subspace drive, coupled with the efficiency of the drive, determines the speed of the craft.

A variable volume of subspace drives may be installed, the volume of the drives limiting the total power that can be used in the drive. The drive's speed is determined by dividing the power (in megawatts) by the displacement (in displacement tons) and multiplying by the tech level efficiency modifier.

$$V = ([MW \div D] \times Eff) \times 0.1$$

V: Velocity in parsecs per hour
MW: Power input in megawatts
D: Displacement of starship in tons
Eff: Tech level efficiency multiplier

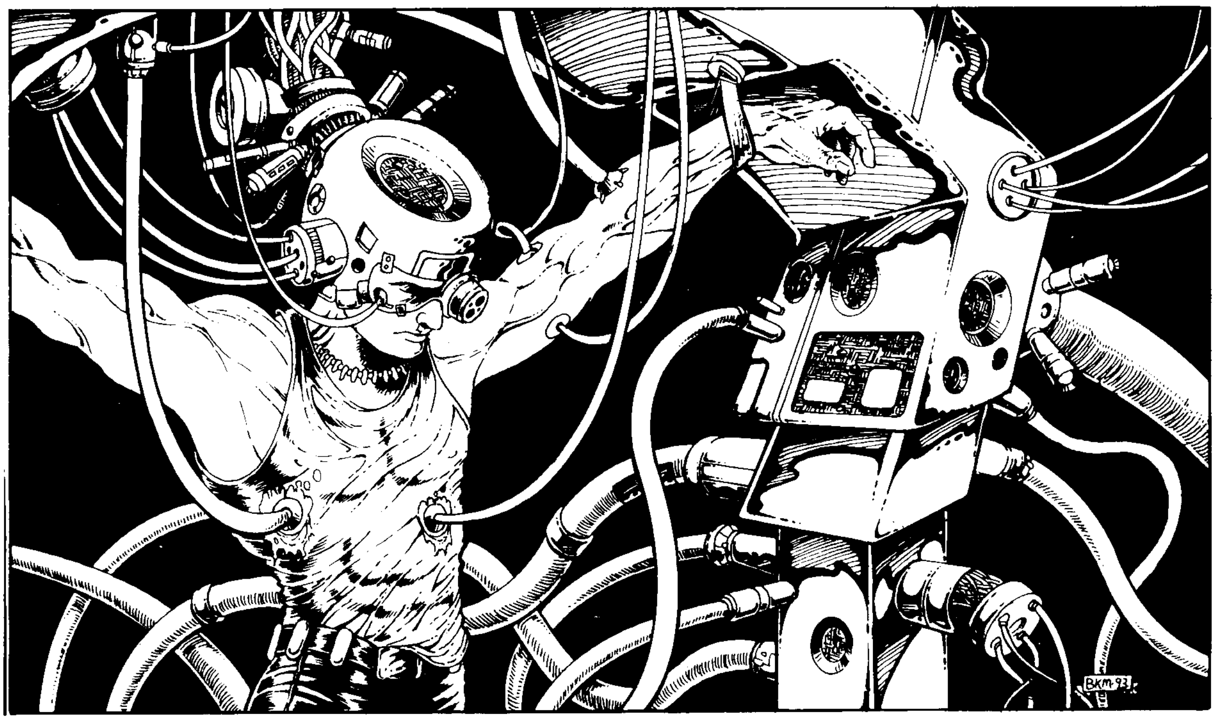
The volume requirements, prices, and efficiency levels should be determined by the referee. As with the case of stargates, we present the following table as one example of subspace drives, but remind referees that they are free to change these values as much as desired.

Subspace Drives

TL	*Vol*	*Eff*
9	**0.50**	**0.60**
10	0.40	0.65
11	**0.30**	**0.70**
12	0.25	0.75
13	**0.20**	**0.80**
14	0.15	0.85
15	**0.10**	**0.90**
16	0.08	0.95
18	**0.06**	**1.00**
20+	0.04	1.10

TL: Tech level of construction
Vol: Cubic meters of drive per MW of power input.
Eff: Drive efficiency multiplier.
Mass: The mass of the drive, in tonnes, is equal to its volume in cubic meters.
Price: The price of the drive, in millions of credits, is equal to its volume, in cubic meters, multiplied by 0.25.
Surface Area: Surface Area in m^2 equals volume in cubic meters ÷ 3.

1 2 3 4 5 6 7 8 9 10 11 12 13 14



Subspace Drive and Combat: Normal **Traveller** starship sensors and communicators are useless in subspace. Consult the Electronics chapter (Section 5) for alternate equipment which is used in subspace. Missiles (unless built with subspace drives), sancasters, and force fields are likewise useless. Lasers, meson guns, and particle accelerators may be used normally. With the exception that different weapons, sensors, and communicators are used, the only other difference is that each range band (hex in **Brilliant Lances**) is 0.01 parsec (0.0326 light-years), approximately 1 million light-seconds. Spacecraft combat speed in range bands (hexes) per turn is equal to their subspace travel velocity (V, calculated on the previous page) multiplied by 50 (rounding fractional results to the nearest whole number).

Psionic Transfer Drive

Psionic transfer (PT) drive uses a conventional power plant to artificially augment the psionic teleportation skill of a psion. This technology normally assumes a cybernetic man-machine interface (usually by neural jack), but it can also be accomplished with computer empathy. Although machinery cannot duplicate the subtlety of a psionic field, it can amplify and strengthen it, which is what the psionic transfer drive does.

The normal requirement that the psion have foreknowledge of the destination is still in effect, which limits the number of psions capable of running a PT drive significantly. Usually both Teleportation and Clairvoyance skills are required. At tech levels 16 and above, the astrogation computer can store direct neural images of the location with sufficient clarity that psions can use them in place of normal sensory input to orient themselves for the transfer.

No one burst of energy characterizes the PT drive, but it must run for a number of hours prior to the transfer equal to the planned transfer distance (in parsecs), and a like number of hours are spent in transfer.

Range is determined by psionic power. The maximum psionic teleportation transfer range, in parsecs, is equal to the square root of the psionic power rolled for the task. Psions may attempt to transfer for distances greater than can be guaranteed (the square root of the psion's Psionic Strength and Teleportation skill level), but if the additional D10 roll is insufficient to reach the destination, a misjump occurs. Consult the **Traveller** main rules for the rules concerning misjumps.

Note that psions often use Psi Booter when conducting PT operations.

The volume requirements, prices, and efficiency levels should be determined by the referee. As with the case of stargates, we present the following table as one example of PT drives, but remind referees that they are free to change these values as much as desired.

PT Drives

TL	*Vol*
9	0.10
10	0.09
11	0.08
12	0.07
13	0.065
14	0.06
15	0.055
16	0.05
18	0.045
20+	0.04

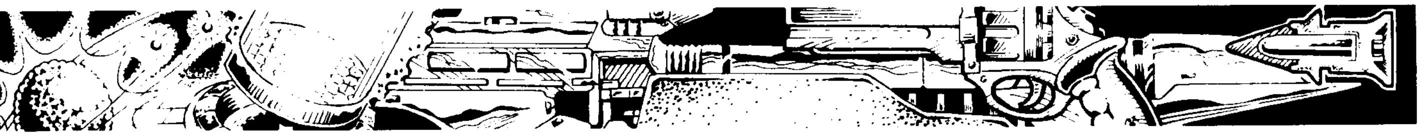
TL: Tech level of construction

Vol: The volume of the PT drive is equal to the volume of the craft multiplied by the value shown on the table.

Mass: The mass of the drive, in tonnes, is equal to its volume in cubic meters.

Price: The price of the drive, in millions of credits, is equal to its volume, in cubic meters, multiplied by 0.25.

MW: The power required for the drive, in megawatts, is equal to its volume in cubic meters.



CHAPTER 4
Controls

Controls, for the purposes of these rules, include control systems proper, navigational aids, computers, and workstations.

CONTROL SYSTEMS

Control systems include control consoles from which the crew of a craft control its systems, and the interior circuitry linking the craft's electrical and mechanical systems to those controls. Installed computers must be from the same tech level as the controls, and avionics and navigation aids may not be installed from a tech level higher than that of the controls.

Controls

TL	Type	Power	Price	Airframe
4	Primitive Mechanical	—	.0001	Simple
5	Basic Mechanical	—	.0002	Fast Subsonic
6	Enhanced Mechanical	0.0002	.0003	Transonic
7	Electronic	0.0005	.0005	Hypersonic
8	Enhanced Electronic	0.0005	.00075	Hypersonic
9	Computer Linked	0.0005	.001	Hypersonic
10-12	Dynamic Linked	0.001	.0015	Hypersonic
13-16	Holographic Linked	0.001	.002	Hypersonic
17-20	Synaptic Linked	0.001	.0025	Hypersonic
21+	Synaptic Fluidic	0.001	.003	Hypersonic

Power: MW per displacement ton of the craft.

Price: MCr per displacement ton of the craft.

Airframe: Maximum airframe type that can be equipped with these controls (for use with aircraft design).

Volume and Mass: Control systems used in vehicles and spacecraft displace 0.014 cubic meters and mass 0.0014 tonnes per displacement ton of the hull.

Aircraft Controls: The values on the Controls table are for spacecraft and vehicles, whose size are calculated in terms of volume. As aircraft calculate size in terms of weight, some modification is necessary. All controls mass 0.014 tonnes per tonne of overall weight of the aircraft. Multiply the power and prices above by 10, and apply them per tonne of overall aircraft weight.

RCV Controls: Vehicles and spacecraft may be designed to function without on-board crews. Such craft require controls, avionics, and sensors, but do not require life support or computers. Vehicles intended specifically for RCV operations are typically reconnaissance vehicles or military vehicles used in very high-threat environments.

Remotely commanded vehicle (RCV) controls may be installed on any aircraft, vehicle, or spacecraft. In the case of aircraft and spacecraft, the RCV option adds 10% to the mass, volume, and price of the controls. In the case of a vehicle, it adds 1% to the mass, volume, and price of the suspension.

RCV controls require a sensor (usually a video camera) in the vehicle and a communication link between the vehicle and the operator. A simple video camera (available at tech level 6 and beyond) masses 2 kilograms, displaces 3 liters (allowing for traverse) and costs Cr100. Communicators are selected from those available in the Electronics chapter.

A number of RCV operators are required equal to the number that the RCV would require if it were manned. (A simple spaceborne sensor drone only requires one operator, as coasting through space does not require the attention of a pilot the way an atmospheric craft does.) Each operator requires a workstation or crewstation (according to where the operators are located, i.e., in a vehicle, aircraft, or spacecraft; ground stations, which have lots of space, are treated as spacecraft and therefore use workstations) of a tech level equal to that of the RCV.

For truly ambitious RCV operations, in which a large, normally manned vehicle or spacecraft is converted to RCV operations, each workstation or crewstation that is to function in the remote operations must additionally have its mass, volume, and price increased by 10%. A number of RCV controllers equal to the normal crew are required to operate it. Each RCV operator requires a workstation or crewstation identical to the one on the vehicle that it is remotely controlling.

In addition, any RCV that would normally (i.e., if it were manned) require one or more computers must have the appropriate number and type of computers installed with the workstations of its operators.

For spaceborne RCV operations, the time lag inherent when RCV and operators are separated by a light-second or more create difficulties (increase the difficulty of all tasks by one level for each light-second apart). Operators of spaceborne sensor drones are therefore often equipped with MFDs to assist with these difficulties. In order to use the MFD's ability to ignore Diff Mods, the RCV must be within the MFD's extreme range (8 × short range listed on the MFD table), so the designer must choose the range of such an MFD accordingly.

WORKSTATIONS AND CREWSTATIONS

Vehicles, aircraft, spacecraft, and many weapons require the allocation of workstations or crewstations to allow crewmembers to control important equipment or machinery. Workstations are used on spacecraft and very large vehicles which perform missions lasting days or more. Crewstations are used on aircraft and vehicles which are typically operated for 24 hours or less at a time.

These are each of two types: normal workstations and roomier bridge workstations, and cramped crewstations and roomier open crewstations. The only difference between these is their volumes. Guidelines for the use of the different types of stations are provided in the vehicle design sequences.

The tech level of workstations/crewstations installed must be the same as the installed controls.

Workstations and Crewstations

TL	Bridge W/S Vol	Normal W/S Vol	Crewstation Crmp/Open	Mass	MCr
4	—	—	2.5/3.5	0.1	0.0001
5	—	—	2.5/3.5	0.1	0.0002
6	—	—	2.5/3.5	0.2	0.0003
7	14	7	2.5/3.5	0.2	0.0005
8	14	7	2.5/3.5	0.2	0.00075
9	14	7	2.5/3.5	0.2	0.001
10-12	14	7	2.5/3.5	0.2	0.0015
13-16	14	7	2.5/3.5	0.2	0.002
17-20	14	7	2.5/3.5	0.2	0.0025
21+	14	7	2.5/3.5	0.2	0.003

Volume: In cubic meters. Under Crewstation, Crmp indicates the volume of a cramped crewstation, Open indicates the volume for an open crewstation.

Mass: In tonnes

MCr: Price in megacredits (millions of credits)

W/S: Workstation

NAVIGATIONAL AIDS

Flight avionics assist spacecraft and aircraft in maneuvering over the ground and making takeoffs and landings, particularly in difficult circumstances (such as night or inclement weather). Terrain following avionics assist lift vehicles, large lift craft (such as spacecraft with G-lifters), helicopters, and VTOL aircraft to fly at high speeds at nap-of-the-earth altitude. Navigation aids assist vehicles in navigating across the surface of world.

Flight Avionics

TL	MCr	Vol	Mass	MW	Description
4	.001	.0001	.0001	—	Magnetic compass
5	.01	.0001	.0001	—	Gyrocompass, barometric altimeter
6	.05	.0001	.0001	.01	Radar altimeter, transponder
7	.10	.001	.001	.1	Weather radar, FLIR, inertial positioning
8	.20	.001	.001	.1	Imaging radar
10	.25	.001	.001	.1	Imaging EMS, inertial/gravitational positioning

MCr: Price in MCr. If at any tech level higher than the level of introduction, price × 0.1; **Vol:** Displacement in cubic meters; **Mass:** Mass in metric tonnes; **MW:** Power requirement in MW; **Description:** TL 6 or better flight avionics necessary for a starship to land on the surface of a planet. Each level of avionics includes all features shown at lower tech levels as well. FLIR = forward-looking infrared, a focused high-resolution thermal-imaging device.

Terrain-Following Avionics

TL/Type	Vol	Mass	MCr	NOE
None	—	—	—	40
8	0.2	0.05	0.010	120
9	0.02	0.04	0.011	130
10	0.15	0.04	0.012	140
11	0.15	0.03	0.013	150
12	0.1	0.03	0.014	160
13	0.1	0.02	0.015	170
14	0.05	0.02	0.016	180
15	0.05	0.02	0.017	190
16	0.03	0.03	0.018	200
17	0.03	0.03	0.019	250
18	0.02	0.04	0.020	300
19	0.02	0.04	0.022	350
20	0.01	0.05	0.024	400
21	0.01	0.05	0.028	450

Vol: Volume in cubic meters (kiloliters); **Mass:** Mass in metric tonnes; **MCr:** Price in millions of credits; **NOE:** Safe nape of the earth (NOE) speed in kilometers per hour; **Power:** Power requirement, in MW is equal to Mass; **Antenna:** Antenna area, in square meters, is equal to Wt × 10.

Navigation Aids

TL	MCr	Vol	Mass	MW	Description
2	.001	.0001	.0001	—	Magnetic compass
5	.001	.0001	.0001	—	Gyrocompass
6	.001	.0001	.0001	.01	Transponder
7	.010	.001	.001	.01	Inertial positioning
8	.020	.001	.001	.01	Satellite positioning
10	.025	.001	.001	.01	Integrates IGS positioning

MCr: Price in MCr. If at any tech level higher than level of introduction, price × 0.1; **Vol:** Displacement in cubic meters; **Mass:** Mass in metric tonnes; **MW:** Power requirement in MW; **IGS:** Inertial gravitational satellite

COMPUTERS

If a computer is desired, select one from the list below. Any orbital or deep-space craft must have at least one computer, and jump-capable craft require an additional computer. Space craft may use either standard or fiber-optic models of computers, or a mix of the two.

Spacecraft generally have at least two computers: one is the primary, the other is a dedicated maintenance troubleshooter and safety backup; starships have three: one primary, one for jump capability/backup, and another for maintenance troubleshooting, which also functions as a backup.

Aircraft with computers may use flight computers (Model Flt). Hypersonic aircraft should have two computers (but are only required to have one); one is a safety backup. Supersonic and slower aircraft are not required to have computers, but may choose to do so to help with long-range sensors and weapons operations.

Important Note: A computer may not be installed which is from a different tech level than the craft's control system. A craft may not have installed sensors or master fire directors from tech levels higher than the installed computer or control system. St or Fb computers are required for any craft fitted with an MFD, or a sensor with a short range greater than 30 kilometers. (Sensors with a short range of 30 kilometers or less do not require a computer.)

Computers Table

TL	Mod	MW	Vol	Mass	MCr	Mult
5	St	0.50	50	10	1.5	1
6	St	0.10	10	2	1.0	0.8
7	St	0.15	5	1	0.5	0.7
8	St	0.20	5	1	0.4	0.6
9	St	0.25	5	1	0.6	0.5
10	St	0.30	6	1.2	1	0.45
11	St	0.35	7	1.4	2	0.4
12	St	0.40	8	1.6	3	0.35
13	St	0.45	9	1.8	4	0.3
14	St	0.50	8	1.6	5	0.25
15	St	0.55	7	1.4	6	0.2
16	St	0.60	6	1.2	10	0.15
17	St	0.60	5	1	11	0.13
18	St	0.60	4	0.8	12	0.11
19	St	0.55	3	0.6	13	0.09
20	St	0.50	2	0.4	14	0.07
21	St	0.45	1	0.2	15	0.05

TL: Tech level of availability.

Mod: Model St = Standard, Fb = Fiber-optic, Flt = flight.

Fiber-optic computers are available from TL 7 on. Multiply MW, volume, mass, and price by 2. Usually one or more of a starship's three computers are fiber-optic.

Flight computers are simplified versions of the above computers optimized to perform a set number of routine flight functions. They may be used in place of standard computers on atmospheric and sub-orbital craft, although full-size computers may be installed as well. Flt computers do not provide maintenance point reduction. Multiply volume, MW, and mass by 0.1 and price by 0.001.

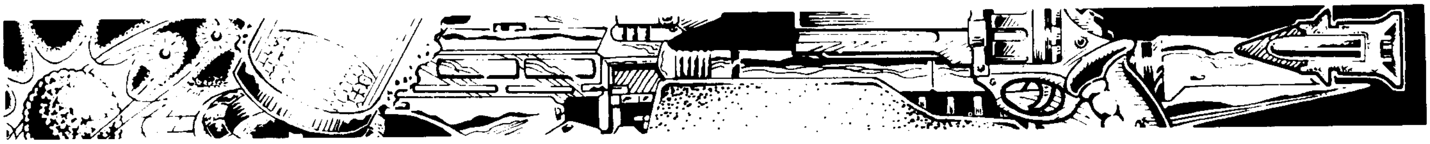
MW: Power requirement in MW

Vol: Displacement in cubic meters

Mass: Mass in metric tonnes

MCr: Price in millions of credits

Mult: Control multiplier



CHAPTER 5
Electronics

Electronics fall into three categories: communicators, sensors, and electronic countermeasures (ECM). The technologies discussed below in each of these categories are those available in the Imperial Space campaign universe. The fourth section in this chapter deals with alternative technologies, most of which are used in conjunction with alternative FTL drives.

Electronics Pods: Any of the electronic systems listed below may be placed in streamlined pods for mounting on hardpoints on aircraft and lift vehicles. Each pod has a shell weight equal to 10% of its final weight. Each pod can mount an antenna with an antenna area equal to 1 square meter per 1000 kilograms (1 metric tonne) of total pod weight.

For all electronic systems which do not calculate antenna price separately, antenna price is equal to 0.25 times the total system cost, for purposes of replacing destroyed antennae.

A. COMMUNICATORS

Communicators can be either broadcast or tight beam. Radio is the principal form of broadcast communications while laser, maser, and meson communicators are tight beam. Tight beam communicators are much more difficult to intercept or jam, but are also somewhat more complex and require that the transmitter know the precise location of the receiver.

Laser Communicators

			Volume at Tech Level						
Range	*MCr*	*MW*	*8*	*9*	*10*	*12*	*15*	*18*	*20*
3	**.0012**	**.005**	**.004**	**.002**	**.001**	**.001**	—	—	—
30	.005	.01	.016	.008	.006	.004	.001	—	—
300	**.011**	**.02**	**.020**	**.010**	**.008**	**.005**	**.002**	—	—
3000	.021	.04	.040	.020	.015	.010	.003	.001	—
30,000	**.036**	**.08**	**.070**	**.035**	**.025**	**.018**	**.005**	**.002**	**.001**
300,000	.056	.15	.110	.055	.040	.028	.007	.003	.002
1000 AU	**.180**	**.3**	—	**.120**	**.070**	**.050**	**.015**	**.007**	**.005**

Range: Short range in kilometers (or Astronomical Units, as indicated by the abbreviation AU)

Range Note: Maximum range in an atmosphere coded Thin or greater is 5000 km

Volume: Cubic meters (kiloliters)

MCr: Price in millions of credits

MW: Power requirement in megawatts

Mass: Mass, in metric tonnes, equals volume × 2

Antenna: Antenna area equals 1 square meter for all versions

> **Radio Receivers**
>
> **All spacecraft are automatically equipped with radio receivers integral to their hulls at no additional cost. These allow radio reception and are destroyed by electronics hits (1h).**
>
> **Vehicles of TL 8+ have the same integral radio receivers at no cost. At lower tech levels, vehicles may add radio receivers at no volume at MCr0.0001.**
>
> **There is no power requirement for any of these receivers.**
>
> **Finally (in the event that these receivers are destroyed in combat), all passive EMS sensors function as radio receivers, even, in the case of folding arrays, when retracted.**

Maser Communicators

			Volume at Tech Level						
Range	*MCr*	*MW*	*8*	*9*	*10*	*12*	*15*	*18*	*20*
3	**.0012**	**.01**	**.010**	**.005**	**.002**	**.001**	—	—	—
30	.005	.02	.030	.015	.010	.002	.002	—	—
300	**.011**	**.04**	**.040**	**.020**	**.015**	**.010**	**.004**	—	—
3000	.021	.08	.080	.040	.030	.020	.006	.002	—
30,000	**.036**	**.15**	**.150**	**.070**	**.050**	**.040**	**.010**	**.004**	**.002**
300,000	.056	.3	.200	.100	.080	.060	.015	.006	.004
1000 AU	**.180**	**.6**	—	**.250**	**.150**	**.100**	**.030**	**.015**	**.010**

Range: Short range in kilometers (or Astronomical Units, as indicated by the abbreviation AU)

Volume: Cubic meters (kiloliters)

MCr: Price in millions of credits

MW: Power requirement in megawatts

Mass: Mass, in metric tonnes, equals volume ×2

Antenna: Antenna area equals 1 square meter for all versions

Meson Communicators

			Volume at Tech Level			
Range	*MCr*	*MW*	*15*	*16*	*18*	*20*
300	**0.25**	**.05**	**.5**	**.3**	**.01**	—
3000	1	.2	2	1.5	.5	.1
30,000	**2.5**	**1**	**30**	**16**	**5**	**.2**
300,000	5	3	150	80	25	15
1000 AU	**20**	**5**	**500**	**220**	**85**	**50**

Range: Short range in kilometers (or Astronomical Units, as indicated by the abbreviation AU)

Volume: Cubic meters (kiloliters)

MCr: Price in millions of credits.

MW: Power requirement in megawatts.

Mass: Mass, in metric tonnes, equals volume × 2

Antenna: Antenna area, in square meters, equals MW × 10, with a minimum of 1 square meter

Radio Communicators

			Volume at Tech Level							
Range	*MCr*	*MW*	*5*	*6*	*7*	*8*	*10*	*12*	*15*	*18*	*20*
3	**.000075**	**.0001**	**.05**	**.01**	**.001**	**.0001**	**.0001**	**.0001**	**.0001**	**.0001**	**.0001**
30	.00025	.001	.1	.05	.01	.001	.0001	.0001	.0001	.0001	.0001
300	**.0005**	**.01**	**.15**	**.1**	**.05**	**.01**	**.001**	**.0001**	**.0001**	**.0001**	**.0001**
3000	.005	.1	.3	.15	.1	.05	.01	.001	.0001	.0001	.0001
30,000	**.030**	**1**	**.7**	**.3**	**.15**	**.1**	**.05**	**.01**	**.001**	**.0001**	**.0001**
300,000	.090	10	—	.7	.3	.15	.1	.05	.01	.001	.0001
1000 AU	**.150**	**20**	—	—	**.7**	**.3**	**.15**	**.1**	**.05**	**.01**	**.001**

Range: Short range in kilometers (or Astronomical Units, as indicated by the abbreviation AU); **Volume:** Cubic meters (kiloliters); **Price:** Price in MCr. If TL 5, ×3. If TL 6, ×2; **MW:** Power requirement, in megawatts; **Mass:** Mass, in metric tonnes, equals volume × 2; **Antenna:** Antenna area, in square meters, equals MW × 10.

B. SENSORS

Sensors detect the presence of targets either by detecting energy emitted by the target or by reflecting energy off of them and detecting the reflection. The first type of sensor is known as a passive sensor, since it does not emit energy of its own. The second type is called an active sensor, since it projects energy and bounces it off the target. Radar, ladar, and active EMS are all active sensors, while passive EMS, high-resolution thermal, densitometers, neutrino sensors, and neural activity sensors are passive.

Aside from signal power, there are two critical issues in sensor design: antenna size and detector element size.

Antenna size is important for two reasons.

First, the absolute size (surface area) of an antenna determines the amount of energy it can collect. The larger a sensor, the more energy that can be collected from a faint target, thus the more sensitive the sensor is. At higher tech levels, the detection elements on the sensor's surface become more sensitive, allowing the absolute size of the sensor to decline with no diminution of sensitivity.

Second, the diameter of a sensor determines its *resolution*, or ability to see detail by separating closely spaced objects into discrete images. Resolution is expressed as the linear dimension that can be resolved, and varies with the wavelength of radiation coming from the target (i.e., short wavelengths allow finer resolution, hence greater detail), but varies inversely with sensor diameter. Thus, very high diameters are required to get good resolution in the infrared wavelengths that are so useful in space combat. This is limited by physics, not technology.

Because most ships cannot carry around huge 800-meter diameter dishes, some way must be found to decouple surface area from diameter. This method is called *aperture synthesis*, in which the effect of a large diameter dish is created by the use of one or more smaller dishes. The way that this is done for spacecraft is to reduce the single large dish (or telescope, or whatever) into an array of several smaller dishes whose signals are processed and combined by a computer to create the effect of one single large dish. The resolution of a synthetic aperture array with a distance X between the outermost edges of its outermost dishes is identical to a single large dish with a diameter of X (although its potential sensitivity is greatly reduced). On starships, these dishes are mounted on folding struts that allow them to be extended out to the required distance. They can also be retracted for atmospheric entry, docking, etc., but cannot be used when retracted.

There is a slightly different use of the synthetic aperture concept that is used for active sensors on planetary vehicles, typically aircraft. Computerized processing allows a fast-moving vehicle to use its own speed to stretch its effective sensor diameter along its flight path. The radar emits pulses at a fixed angle from its flight path (called "staring," as opposed to "scanning" back and forth), and the computer electronically combines the sensor pulses returned during a period of flight time and integrates them into an image as detailed as if the sensor diameter was equal to the aircraft's speed times the period over which the pulses were built up. Naturally, flight must be straight and level to allow accurate computations, and this only works for targets away from the sensor platform's flight path, i.e., it cannot look directly ahead. A variation of this, *inverse synthetic aperture*, uses the target's relative motion, and allows the sensor to look straight ahead, although this has inherently less resolution than normal synthetic aperture systems.

However, this is only practical because of the relatively short ranges between planetary targets compared to the tremendous distances between space targets. In space, the relative speeds of sensor to target are insignificant compared to the distances involved. Only an absolute increase in effective array diameter can address these issues.

These antenna size issues affect all sensors, but are particularly important for passive sensors which must use the energy that is coming off the target. Active sensors pump energy at the target and listen for the echo, so they can make up for lack of antenna size by increasing radiated power, and by decreasing the wavelength of this power.

The second critical issue is detector element size. Each detector element in the receiver represents a fixed proportion of the total area scanned by the sensor. If the signal received from an object is a smaller proportion of the "picture" drawn by the sensor than one detector element, resolution is reduced to a blob with no detail.

Radar

Radar is an active sensor which bounces radio waves off of targets and then detects the returning echoes. A radar requires a processor unit and an antenna.

	Processor Volume by Tech Level				
Short Range	*5*	*6*	*7*	*8*	*9*
0.3 km	0.3	0.1	0.04	0.02	0.01
3 km	3	1	0.4	0.2	0.1
30 km	30	10	4	2	1
300 km	300	100	40	20	10
3,000 km	—	—	400	30	15
30,000 km	—	—	—	40	20
60,000 km	—	—	—	50	30

Volume: Volume in cubic meters (kiloliters) as shown

MW: Power requirement (in megawatts) equals processor volume in cubic meters × 0.2

Mass: Mass of the processor, in tonnes, equals volume × 2

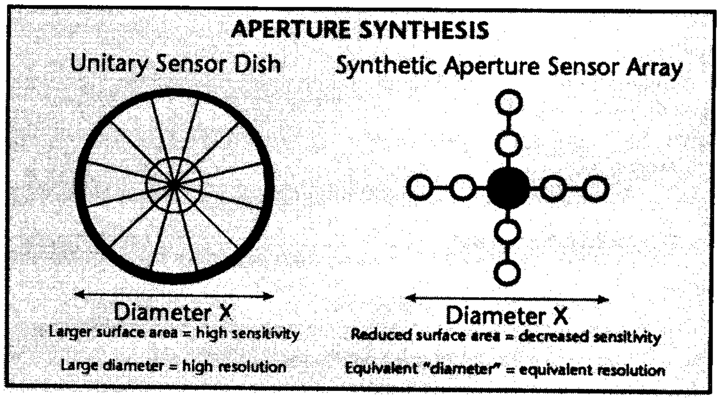
MCr: Price of the processor, in MCr, equals volume × 1

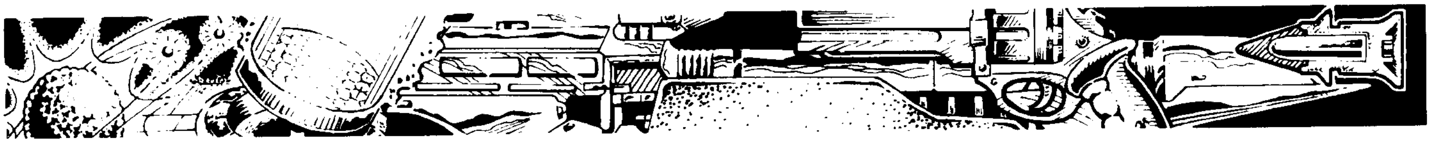
Antenna: Antenna area (in square meters) equals volume times the tech level modifier shown in the following table:

TL	*Modifier*
5	10
6	6
7	4
8	1
9+	0.5

Antenna Volume (cubic meters): Antenna area × 0.1

Antenna Mass (in metric tonnes): Antenna area × 0.1





Active EMS

Active EMS incorporates a variety of active emitters and passive detectors covering most of the electromagnetic spectrum (EMS), making it a much more sophisticated version of radar.

	Volume (kl) by Tech Level						
Short Range	*10*	*11*	*12*	*14*	*16*	*18*	*20*
3 km	0.2	0.1	0.1	0.1	0.1	0.1	0.1
30 km	1.0	0.8	0.6	0.5	0.4	0.3	0.2
300 km	3.0	1.6	1.0	0.8	0.6	0.4	0.3
3000 km	7.0	3.0	1.6	1.0	0.8	0.6	0.4
30,000 km	10	5.0	2.2	1.2	1.0	0.8	0.5
60,000 km	13	6.0	2.5	1.4	1.2	0.9	0.6
120,000 km	16	8.0	3.3	1.8	1.4	1.1	0.7
180,000 km	19	10	4.0	2.2	1.6	1.2	0.8
240,000 km	23	11	4.8	2.6	1.8	1.4	0.9
300,000 km	26	12	5.5	3.0	2.0	1.5	1.0
360,000 km	31	15	7.0	3.4	2.2	1.7	1.1
420,000 km	36	17	8.5	4.2	2.4	1.8	1.2
480,000 km	42	20	10	5.0	2.6	1.9	1.3

Volume: Volume in cubic meters (kiloliters) as shown.
Power (MW): Volume × 5
Price (MCr): Volume × 2
Mass (tonnes): Volume × 2
Antenna (square meters): Volume × 2. Antenna volume, mass, and price are subsumed in the total sensor package above.

Ladar

Ladar is a tight beam active sensor that bounces laser light off of the target and detects the reflection. As the laser can scan a very small area, it is used exclusively to lock onto a target after some other search sensor has detected it.

	Volume (kl) by TL							
Range	*8*	*9*	*11*	*13*	*15*	*16*	*18*	*20*
3	0.1	0.01	0.005	0.001	—	—	—	—
30	0.4	0.04	0.02	0.004	—	—	—	—
300	0.8	0.08	0.04	0.008	0.002	—	—	—
3000	2.0	0.2	0.1	0.02	0.005	0.002	—	—
30,000	5.0	0.5	0.2	0.04	0.01	0.004	0.002	—
60,000	—	1.0	0.5	0.1	0.025	0.01	0.004	0.002
120,000	—	2.4	1.2	0.24	0.06	0.02	0.005	0.003
180,000	—	—	2.5	0.5	0.12	0.05	0.01	0.005
240,000	—	—	—	1.2	0.25	0.1	0.025	0.006
300,000	—	—	—	2.5	0.6	0.2	0.04	0.01

Range: Short range in kilometers
Power Requirement (MW): Volume in cubic meters
Mass (metric tonnes): Volume × 2
Price (MCr): Volume × 10
Antenna Area (square meters): Volume × 1. Antenna weight, price, and volume are subsumed in the above figures.

Densitometer (Grav Shielded)

Densitometers are survey instruments which allow determination of celestial object mass and mapping of mineral deposits and gravitic anomalies.

TL	*MW*	*Vol*	*Mass*	*MCr*
11	2.5	30	10	0.75
12	1	15	5	0.9
13	0.9	12	3	0.95
14	0.5	9	2	1
15	0.4	7	1.5	1.5
16	0.3	4	1	1.5
18	0.2	2	0.8	1.5
20	0.1	1	0.7	1.5

MW: Power requirement in megawatts.
Vol: Volume in cubic meters.
Mass: Mass in tonnes.
MCr: Price in millions of credits.
Antenna Area (square meters): MW × 100.

Neutrino Sensor

Neutrino sensors are useful when surveying a star system. They enable a ship to measure the intensity of fusion taking place within a star as well as determine if any of the gas giants are failed stars.

TL	*Vol*	*MCr*
10	100	1
12	10	2
14	5	3
16	2	4
18	1	5

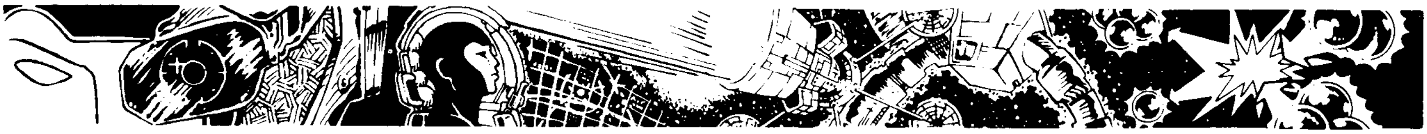
Vol: Volume in cubic meters.
MCr: Price in millions of credits.
MW: All neutrino sensors require 0.01 MW of power for operation.
Mass: All neutrino sensors have a mass in tonnes equal to their volume.
Neutrino sensors have no antennae.

Neural Activity Sensor

Neural activity sensors detect and classify life forms according to their level of brain activity.

TL	*Range*	*MW*	*Vol*	*Mass*	*MCr*
13	0.005	0.004	0.002	0.005	0.02
14	0.025	0.005	0.002	0.005	0.02
15	0.05	0.006	0.002	0.005	0.02
16	0.5	0.007	0.002	0.005	0.02
18	5	0.009	0.002	0.004	0.025
20	50	0.01	0.002	0.003	0.03

Range: Short range in kilometers.
MW: Power requirement in megawatts.
Vol: Volume in cubic meters.
Mass: Mass in tonnes.
MCr: Price in millions of credits.
Antenna Area (square meters) = MW × 100.



High-Resolution Thermal (HRT)

HRT sensors are sophisticated visual sensors sensitive to infrared radiation.

			Volume by Tech Level		
Range	*AD*	*AA*	*7*	*8*	*9*
0.3	0.25	0.05	0.006	0.003	0.001
3	.0.5	0.2	0.06	0.03	0.01
30	.1	1	0.3	0.15	0.05
300	2.25	4	0.6	0.3	0.1
3000	3.5	10	1.5	0.6	0.3
30,000	5	20	—	1.5	0.6
60,000	10	80	—	3	1.5
90,000	20	300	—	5	2.5
120,000	40	120C	—	6	3
150,000	90	6000	—	7	3.5
180,000	200	30,000	—	8	4
210,000	400	125,000	—	9	4.5
240,000	800	500,000	—	10	5

Range: Short range (in kilometers)

AD: Antenna diameter, in meters. If the antenna diameter is greater than the hull length (unmodified by configuration), the antenna must be a folding array.

AA: Surface area of the antenna is square meters. At tech level 9, multiply antenna area by 0.5.

Volume: The volume of the processor in cubic meters (kiloliters) as shown on the table.

Antenna Volume: The volume of the antenna in cubic meters (kiloliters) is equal to the antenna area × 0.05 for a fixed array or × 0.1 for a folding array.

MW: Power requirement, in megawatts, is equal to the processor volume × 0.1.

Processor Price: The processor price, in millions of credits, is equal to the processor volume × 1.

Antenna Price: The antenna price, in millions of credits, is equal to the antenna volume × 1.

Processor Mass: The mass of the processor, in tonnes, is equal to the processor volume × 2.

Antenna Mass: The mass of the antenna, in tonnes, is equal to the antenna volume × 1.

Passive EMS

Passive EMS uses large antenna arrays to detect any electromagnetic emanations from a potential target, such as heat or radio waves, or naturally reflected light waves. It is an extremely sophisticated and precise sensor.

			Volume by Tech Level						
Range	*AD*	*AA*	*10*	*11*	*12*	*14*	*16*	*18*	*20*
3	.25	.02	.03	.02	.01	.005	.003	.002	.001
30	.5	.08	.1	.08	.04	.02	.01	.005	.002
300	1	.4	.2	.1	.08	.04	.02	.01	.005
3,000	2.25	1.6	.3	.2	.1	.08	.04	.02	.01
30,000	3.5	4	.6	.4	.3	.2	.1	.08	.04
60,000	5	8	1.5	1	.6	.4	.3	.2	.1
90,000	10	32	2	1.5	1	.6	.4	.3	.2
120,000	20	120	2.5	2	1.5	1	.6	.4	.3
150,000	40	480	3	2.5	2	1.5	1	.6	.4
180,000	90	2400	3.5	3	2.5	2	1.5	1	.6
210,000	200	12,000	4	3.5	3	2.5	2	1.5	1
240,000	400	50,000	4.5	4	3.5	3	2.5	2	1.5

Range: Short range (in kilometers).

Volume: The volume of the processor in cubic meters (kiloliters) as shown on the table.

AD: Antenna diameter, in meters. If the antenna diameter is greater than the hull length (unmodified by configuration), the antenna must be a folding array.

AA: Base surface area of the antenna in square meters. The actual surface area of the antenna is this value multiplied by a tech level modifier, as shown below:

TL	*Modifier*
10	1
11	0.5
12	0.25
13	0.125
14	0.075
15	0.025
16+	0.01

Antenna Volume: The volume of the antenna in cubic meters (kiloliters) is equal to the antenna area × 0.05 for a fixed array or × 0.1 for a folding array.

MW: Power requirement, in MW, is equal to the processor volume × 0.1.

Processor Price: The processor price, in millions of credits, is equal to the processor volume × 2.

Antenna Price: The antenna price, in millions of credits, is equal to the antenna volume × 1.

Processor Mass: The mass of the processor, in tonnes, is equal to the processor volume × 2.

Antenna Mass: The mass of the antenna, in tonnes, is equal to the antenna volume × 1.

Visible and Infrared Light Sensors

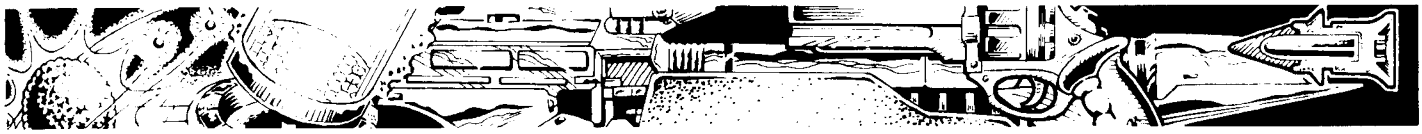
These sensors use visible or infrared light to detect an object, either relying on background light (passive) or illuminating it with a beam of light (active). Due to the short range of these sensors, they are usually used on vehicles rather than spacecraft. See TNE, pages 309-310, for more details. (AIR = active infrared; PIR = passive infrared; LA = light amplification; II = image intensification; WSV = wide-spectrum visual)

Sensors

TL	*Description*	*MW*	*Vol*	*Mass*	*MCr*	*Range*
4	Headlight	.0001	.002	.001	.00005	.03
4	Searchlight	.001	.01	.01	.00010	2.0
5	AIR Searchlight	.001	.01	.01	.00200	1.0
6	AIR Scope	.0001	.001	.001	.00100	.03*
6	PIR Viewer	.0001	.001	.001	.00100	.1
7	AIR Goggles	.0001	—	.0001	.00030	.03*
7	LA Scope	.001	.001	.005	.00500	.1
8	PIR Goggles	.0001	—	.0001	.00050	.1
8	LA Scope	.0005	.001	.001	.00100	.1
8	II Viewer	.001	.001	.005	.00300	.25
9	II Scope	.0005	.001	.001	.00100	.25
9	Imaging Radar	.003	.01	.02	.02000	.3
10	WSV Viewer	.003	.01	.02	.02000	.4
11	WSV Scope	.001	.001	.005	.01000	.4
12	WSV Goggles	.0001	—	.0001	.00500	.4

Volume in cubic meters, Mass in tonnes, Range indicates short range in kilometers. Asset is Observation.

*Range is with integral IR light beams. If working with IR searchlight, use TNE, page 310.



C. ELECTRONIC COUNTERMEASURES (ECM)

Also known as electronic warfare (EW) equipment, ECM is designed to combat enemy sensors and communicators by either disrupting their operation or locating them with an eye toward their destruction.

Radio, Radar, and EMS Jammers

Radio, radar, and EMS jammers have the same characteristics as radios, radars, and active EMS sensors, with three exceptions.

1. Power use and price are multiplied by 2.
2. Antenna size for the radar jammer is divided by 10.
3. Jammers may not be used as sensors or communicators, only for jamming.

Radio jammers may only be used to jam radios; radar jammers may be used to jam radar or active EMS; and EMS jammers may be used to jam radios, radars, or active EMS.

Area Jammers

Area jammers degrade the effectiveness of sensors and communicators that attempt to function in their area of effect. The principal design decision, therefore, is the area of effect of the jammer, all other values being derived from that. The area of effect is defined as the radius of effect in kilometers. (Note that space-based area jammers routinely have an effect radius of 45,000 kilometers.)

TL	*MW*	*Vol*
10	.002	.32
11	.001	.30
12	.00045	.40
14	.00036	.375
16	.00027	.42
18	.00018	.375
20	.00009	.40

TL: Tech level of first availability.
MW: Power requirement, in megawatts, per kilometer of effect radius.
Vol: Volume, in cubic meters, per megawatt of power.
Mass: The mass of an area jammer, in tonnes, is equal to its volume in cubic meters.
Price: The price of an area jammer, in millions of credits, is equal to its volume in cubic meters multiplied by 2.

Sensor Decoys

These require no power and instead are dispensors for decoy material, consisting of flares intended to duplicate the heat signature of the craft, metallic strips, sometimes self-inflating, which mimic the reflected signature of the craft, or anti-laser aerosols to disperse the laser light and prevent it from providing a precise reflection.

Decoys work on ladar (anti-laser aerosols), active radar or EMS (metallic chaff), or passive infrared such as HRT or passive EMS (heat flares). Designers may include different types of decoys on a craft, but each type only works on the specified sensor. A decoy increases the difficulty of a target lock by 1 if of an equal tech level with respect to the sensor and increases it by 2 if from a higher tech level.

The required size of a decoy is 0.002 cubic meters for Sub-Micro size craft. This increases by 0.001 cubic meters per increase in target size, so that a Very Small target requires 0.004 cubic meters per decoy.

All decoys mass 0.5 metric tonnes per cubic meter and cost MCr5 per m³.

Decoys are usually carried in internal automatic dispensers, but aircraft may also carry them using the electronic pods rule at the beginning of this chapter (page 49). They are dispensed one at a time, but a dispenser may launch one decoy per second. More than one decoy does not further decrease the chance of sensor locks.

When used with planetary combat, each decoy lasts one combat turn, and affects all sensor attempts against the owning vehicle, regardless of direction.

When used with **Brilliant Lances**, decoys are "popped" at the end of the Movement Phase, after all movement has been completed. In order to cover the ship as it moves throughout the turn, one decoy must be popped per G-turn expended that turn (0 G-turns expended still requires one decoy) for maneuver, and two per G-turn spent for evasion. This full amount constitutes one "salvo." Each decoy salvo only affects sensors coming in through a single hexside (this includes sensor attempts which are traced across either adjoining hex vertex), but affects all sensor scans made from that direction for the entire turn. Thus, a ship which expended 4 G-turns for maneuver must pop 4 decoys to get protection across one hexside for a turn, 24 decoys to get 360° protection for that turn, or 48 decoys for 360° coverage if it spent 4 G-turns on evasion.

Decoy dispensers are hit by surface hits. They have a surface area of 1 m² and have their hit capacities calculated on their loaded mass. Dispenser volume is equal to 2 times the volume of the decoys it holds, mass is 1 tonne per cubic meter, and cost is MCr0.001 per cubic meter.

Radio, Radar, and EMS Direction Finder

Direction-finding can be added as an option to any radar or active EMS array. (Passive EMS arrays already incorporate radio and radar DF capabilities.) Price is multiplied by 2 for radar, and by 1.5 for the EMS array. Stand-alone direction finders are also available beginning at TL 6. These have the same mass, volume, and antenna size of a radio of the same tech level, but the price is doubled, and the power requirement in MW is equal to the volume at all ranges and tech levels. All direction finders work equally well versus radio, radar, or EMS emissions.

Stealth

Stealth design minimizes a craft's electromagnetic emissions in the most common bands (radio and IR), and uses electromagnetic absorbent material (EMAM) on the hull surface, thus making detection by active and passive sensors (radar and HRT) more difficult.

Stealth design increases the difficulty of an HRT or radar lock on it by one difficulty level (two if from a higher tech level than the sensor), but has no effect on other types of sensors.

Stealth aircraft may not have turrets, hardpoints, or any other feature which produces a drag point. Hypersonic airframes may not incorporate stealth design.

Stealth design is available at TL 8 and higher. The following values are per displacement ton (14 cubic meters) of hull. When applying stealth to aircraft, multiply aircraft mass by 5 to determine effective displacement for purposes of EMM. (Note that this is *not* the same displacement used to calculate the storage volume of the craft.)

Volume (m³)	*Mass (tonnes)*	*Price (MCr)*
0.5	0.1	0.05

Electromagnetic Masking (EMM)

Electromagnetic masking is an advanced form of stealth design, and includes radiators to dissipate immense IR signatures as well as more advanced electromagnetic absorbing material. EMM packages may not be installed in addition to stealth, but rather are used in place of it. EMM effects are +2 Diff Mods vs. HRT or radar, and +1 Diff Mods vs. passive or active EMS sensors.

Unlike stealth design, EMM may be used on hypersonic airframes, and aircraft may carry hardpoint ordnance or other drag-producing features. However, EMM's effect on detection difficulty is reduced by one level if a hypersonic airframe is used, by one level if any drag-producing features are incorporated in the design, and thus is reduced by two levels if both effects are present. (Note, however, that an aircraft whose only drag-producing feature was hardpoint stores could gain back its +1 modifier by dropping its stores.)

EMM packages are available at TL 10 and higher. The following values are per displacement ton (14 cubic meters) of hull. When applying EMM to aircraft, multiply aircraft mass by 5 to determine effective displacement for purposes of EMM. (Note that this is *not* the same displacement used to calculate the storage volume of the craft.)

Power (MW)	*Vol (m³)*	*Mass (tonnes)*	*Rad*	*Price (MCr)*
0.014	0.28	0.14	0.14	0.07

Rad: Hull area used by IR radiators (in square meters).

1 2 3 4 5 6 7 8 9 10 11 12 13 14

D. ALTERNATE TECHNOLOGY

The following electronic devices rely on FTL drive technologies other than the J-space rationale of the Imperial Space campaign.

Subspace Radio

Subspace is explained in the alternate technology section of the FTL Drive chapter (Section 3). Since subspace consists of a resisting medium, it is possible to propagate waves through it and thus achieve FTL communication. Waves travel through the subspace medium at a constant velocity of 1 (N-space) parsec per hour, which imposes a time lag on subspace radio communication.

Subspace radios consist of separate transmitters and receivers. While transmitters are often quite bulky and their power requirements are based on their range, receivers are comparatively simple and can pick up a signal at any range (provided it is from a transmitter capable of sending at that range).

Subspace Transmitter

			Volume at Tech Level							
Range	*MCr*	*MW*	*9*	*10*	*11*	*12*	*14*	*16*	*18*	*20+*
1	0.075	1	5	1	.1	.01	.01	.01	.001	.001
2	0.25	2	10	5	1	.1	.01	.01	.01	.001
3	0.5	3	15	10	5	1	.1	.01	.01	.01
4	1	4	30	15	10	5	1	.1	.01	.01
5	3	5	70	30	15	10	5	1	.1	.01
10	9	10	—	70	30	15	10	5	1	.1
20	15	20	—	—	70	30	15	10	5	5

Range: Short range in parsecs.
Volume: Cubic meters (kiloliters).
MCr: Price in MCr.
MW: Power requirement, in megawatts.
Mass: Mass, in tonnes, equals volume × 2.
Antenna: Antenna area, in square meters, equals volume in cubic meters × 10.

Subspace Receiver

TL	*Volume*
9	2
10	1.5
11	1
12	0.8
13	0.6
14	0.4
15	0.2
16	0.1
17	0.05
18	0.01
19	0.005
20+	0.001

TL: Tech level of availability.
Volume: Cubic meters (kiloliters), including antenna.
Price: Price for a subspace receiver is MCr0.05 at tech level 9 and MCr0.01 at all higher tech levels.
MW: Power requirement is 0.001 megawatts at all tech levels.
Mass: Mass, in tonnes, equals volume in cubic meters.

Subspace Active Sensor (SAS)

Just as waves propagated through subspace can be used to communicate, wave echoes can be used to detect objects in subspace in the same manner as radar or sonar. An active subspace sensor array requires a processor unit and an antenna.

	Processor Volume by Tech Level							
Range	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*18+*
0.01	10	5	2	1	.5	.4	.3	.2	.1
0.02	30	10	4	2	1	.5	.4	.3	.2
0.03	300	100	40	20	10	4	2	1	.5
0.04	—	—	200	30	15	8	4	2	1
0.05	—	—	—	40	20	15	8	4	2
0.06	—	—	—	50	30	20	15	8	4

Range: Short range in parsecs.
Volume: Volume in cubic meters (kiloliters) as shown.
MW: Power requirement (in megawatts) equals processor volume in cubic meters × 0.2.
Mass: Mass of the processor, in tonnes, equals volume × 2.
MCr: Price of the processor, in MCr, equals volume × 1
Antenna: Antenna area (in square meters) equals volume times the tech level modifier shown below:

TL	*Modifier*
9	8
10	6
11	4
12	2
14	1
16+	0.5

Antenna Volume (cubic meters): Antenna area × 0.1
Antenna Mass (in tonnes): Antenna area × 0.1
Antenna Price (MCr): Antenna area × 0.05

Passive Subspace Sensor (PASS)

Subspace radio and active sensor waves may be detected by passive sensors, as may the subspace "wake" of a starship. PASS arrays do not require a great deal of power, but do require extremely sensitive antennae and sophisticated processor units.

PASS arrays can locate the sources of subspace radio or active sensors emissions well enough to provide target solutions, and so are useful combat sensors. Subspace wake sensing cannot detect the approach of a vessel, and so is not useful in combat. Instead the wake-sensing capability of PASS arrays is used as a means of tracking ships through subspace.

PASS arrays consist of a processor and an antenna.

			PASS Processor Volume by Tech Level						
Range	*AD*	*AA*	*9*	*10*	*12*	*14*	*16*	*18*	*20+*
[illegible]	**0.5**	**0.08**	**1**	**0.8**	**0.4**	**0.2**	**0.1**	**0.06**	**0.04**
0.02	1	0.4	2	1	0.8	0.4	0.2	0.1	0.06
0.03	**2.25**	**1.6**	**3**	**2**	**1**	**0.8**	**0.4**	**0.2**	**0.1**
0.04	3.5	4	6	4	3	2	1	0.8	0.4
0.05	**5**	**8**	**15**	**10**	**6**	**4**	**3**	**2**	**1**
0.06	10	32	20	15	10	6	4	3	2
0.07	**20**	**120**	**25**	**20**	**15**	**10**	**6**	**4**	**3**
0.08	40	480	30	25	20	15	10	6	4
0.1	**90**	**2400**	**35**	**30**	**25**	**20**	**15**	**10**	**6**
0.2	200	12,000	40	35	30	25	20	15	10
0.4	**400**	**50,000**	**45**	**40**	**35**	**30**	**25**	**20**	**15**

Range: Short range (in parsecs).

Processor Volume: The volume of the processor in cubic meters (kiloliters) as shown on the table.

AD: Antenna diameter, in meters. If the antenna diameter is greater than the hull length (unmodified by configuration), the antenna must be a folding array.

AA: Base surface area of the antenna in square meters. The actual surface area of the antenna is this value multiplied by a tech level modifier, as shown below:

TL	*Modifier*
9	**1**
10	0.5
12	**0.25**
14	0.125
16	**0.075**
18	0.025
20+	**0.01**

Antenna Volume: The volume of the antenna in cubic meters (kiloliters) is equal to the antenna area × 0.05 for a fixed array or × 0.1 for a folding array.

MW: Power requirement, in MW, is equal to the processor volume × 0.1.

Processor Price: The processor price, in millions of credits, is equal to the processor volume × 2.

Antenna Price: The antenna price, in millions of credits, is equal to the antenna volume × 1.

Processor Mass: *The mass of the processor, in metric* tonnes, is equal to the processor volume × 2.

Antenna Mass: The mass of the antenna, in metric tonnes, is equal to the antenna volume × 1.

Subspace Direction Finders

Direction-finding can be added as an option to any subspace active sensor (SAS) array. (PASS arrays already incorporate DF capabilities.) Price is multiplied by 1.5 for the SAS array.

Stand-alone direction finders are also available beginning at TL 10. These have the same mass and volume of a subspace radio receiver of the same tech level, but the price is doubled, and the power requirement in MW is equal to 0.01 for all versions. All direction finders work equally well versus subspace radio and SAS emissions.

Subspace Jammers

Subspace radio and subspace sensor jammers have the same characteristics as subspace radios and SAS arrays, with three exceptions.

1. Power use and price are multiplied by 2.
2. Antenna size for the sensor jammer is divided by 10.
3. Jammers may not be used as sensors or communicators, only for jamming.

Radio jammers may only be used to jam radios; sensor jammers may be used to jam SAS and PASS arrays.

Tachyons

Tachyons are conceptual particles which travel faster than the speed of light. The term "conceptual" is used advisedly. Tachyons were conceived of, not discovered, as an interesting thought exercise in theoretical physics. What would the properties be, it was queried, of a particle which existed only while travelling faster than light?

Although there is no evidence that such a particle could actually exist (and overwhelming evidence that it does not), it has nevertheless found its way into science-fiction literature, and the same thought exercise leads authors to ask, "what if?" Nevertheless, tachyons should be approached with extreme caution if a hard science game is being played. They, like the Dean Drive (see the Lifters chapter, Section 10) are more at home with science fantasy than science fiction.

Tachyons allow FTL radio and active sensors, generally called "T-band" electronics. The same tables are used as for subspace radio, SAS arrays, ECM, and jammers, but the T-band waves move through N-space, not subspace.

Note that T-band communicators and sensors, alone among the alternate electronics technologies, do not have an associated FTL drive.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

CHAPTER 6
Defensive Systems

Defensive systems refer to advanced technology methods of defeating attacks, methods which go beyond simply making armor thicker and harder.

EXPLOSIVE REACTIVE ARMOR (ERA)

Reactive armor is available at tech level 7 and beyond, and is a cheap alternative to composite and composite laminate armor. Reactive armor consists of a series of blocks of explosive material sandwiched between two metal plates. When a hollow charge (HEAP) warhead penetrates the outer metallic plate and contacts the explosive block behind it, the explosive detonates and blows the front metallic plate away from the vehicle. As the blocks are placed at an angle off of vertical, the plate blows off at an angle as well, removing part of the penetrator stream from the HEAP round. (See the Munitions chapter, beginning on page 135, for a discussion of how HEAP rounds penetrate armor.) This reduces the penetration of the HEAP penetrator jet considerably.

However, reactive armor has no effect on conventional solid penetrators, as the force of the explosion is insufficient to break up the penetrator rod, and so does not reduce either the mass or the velocity of the penetrator. Likewise, reactive armor has no effect on lasers, particle accelerators, or meson guns, but does affect plasma and fusion guns in the same way as it affects HEAP rounds.

Detonation: If the explosive reactive armor (ERA) array of a vehicle is hit by any round with a penetration of 10 or greater, the array detonates. From then on, one-twentieth of the ERA on that vehicle face is missing (having been exploded). Each time a round hits that vehicle side after that, roll 1D20. If the number rolled is equal to or less than the number of times the armor has detonated on that face, the round hits bare armor; if it is greater than that number, the round hits an intact part of the ERA.

For example, a tank is hit in the front by a round capable of detonating its ERA, and so one-twentieth of its ERA detonates. A second round hits and the player owning the vehicle rolls a D20. If a 1 is rolled, the round hits bare armor, but a 7 is rolled, and so the round hits intact ERA and detonates another section. When the next round hits the front of the tank it will hit bare armor on a roll of 2 or less.

Armor Value: ERA never adds its AV unless it detonates, and it never adds its AV against anything other than a HEAP round or a plasma or fusion bolt. If the round is HEAP or a plasma or fusion bolt and the array detonates, the array adds its AV to that of the AV of the structural armor of the vehicle.

Multiple Detonations: Whenever an ERA block explodes there is a chance that there will be a chain reaction of additional multiple detonations. Each type of ERA has a detonation number listed on the chart below. Whenever an ERA detonates, roll 1D20. If the roll is equal to or less than the detonation number of the armor, there is a multiple detonation. If there is a multiple detonation, roll the D20 again and that number rolled is the number of additional hit locations cleared of armor.

For example, a tank with improved ERA (detonation number of 3) is hit for the first time by a plasma bolt on a face protected by ERA. The ERA detonates and adds its armor to the base armor for purposes of stopping penetration by the plasma bolt. However, the owner of the tank rolls a 2 for multiple detonations, and since this is less than the detonation number of 3, there is a chain reaction multiple detonation. The player rolls a D20 again and this time rolls a 12. Twelve additional hit locations are stripped of ERA by the blast, which means that the next time that face is hit by a round, it will hit bare armor on a roll of 13 or less and ERA on a roll of 14 or higher.

Multiple Layers: Up to three layers of ERA may be added to the outside of a vehicle, but each layer after the first adds only half of its AV to the vehicle. The multiple detonation value of the ERA is sum of the detonation values of all the layers.

For example, a vehicle with three layers of Improved ERA would have an AV of (16+8+8=) 32 in addition to its normal armor value, and would have a multiple detonation number of (3+3+3=) 9.

Volume: ERA is seldom applied to the entire surface of a vehicle, and instead is usually applies to only one or two faces. First decide which faces of the vehicle will be covered. Next determine the volume of adding 1 additional centimeter of armor on that face (from the Ground or Lift Vehicle Design chapters). The volume of a single layer of ERA in cubic meters is equal to the volume of 1 additional centimeter of armor on that vehicle face multiplied by 20.

Mass: ERA masses 4 tonnes per cubic meter of volume.

Price: The price of ERA, in millions of credits, is equal to the volume of the array in cubic meters multiplied by 0.007.

Replacement Blocks: ERA is usually custom-designed for each vehicle to fit the vehicle's unique configuration. Replacement blocks may be purchased, but are unique to each vehicle, and in fact each face of each vehicle. Each replacement block has volume, mass, and price equal to that of one complete layer for that face divided by 20, and can replace one layer from a single detonation on that face. Twenty replacement blocks are required to replace one full layer on that face after a complete detonation.

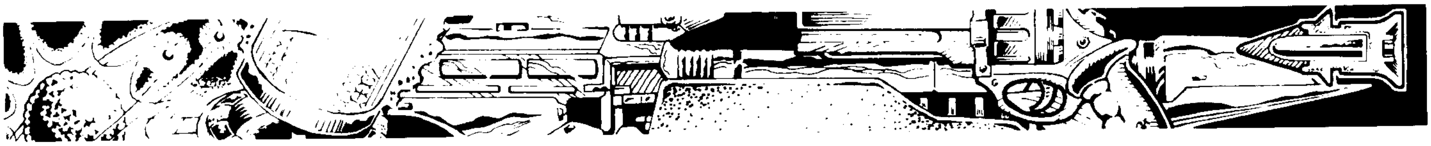
Explosive Reactive Armor

TL	*Description*	*Det*	*AV*
7	Basic ERA	5	12
8	Improved ERA	3	16
9	Advanced ERA	1	20

TL: Tech level of first availability.
Det: Detonation number (per layer) of the ERA.
AV: Armor value added by the ERA when it detonates.

DAMPERS, SCREENS, AND THE STRONG AND WEAK FORCES

In ancient times, people often explained the physical world in terms of four universal elements: earth, air, fire, and water. Our modern understanding of physics revolves around four universal forces: electromagnetism, gravity, the strong, or nuclear, force, and the weak force (although it would now appear that the electromagnetic and weak forces are merely manifestations of the *electroweak* force, and that there is a *color* force underlying the strong—but **Traveller**'s mandate does not take us that far). The strong force is the force that holds the sub-atomic particles (protons and neutrons) of the atom's nucleus together, and the weak force is related to the decay of subatomic particles.



Manipulation of electromagnetism became possible at tech level 3, but control and manipulation of the other forces has proven more difficult to master. Much of the advances in technology postulated in **Traveller** result from an ability to manipulate the strong and weak forces, and this ability is most directly used in the design of nuclear dampers and meson screens.

Nuclear Dampers

The creation of nuclear dampers is allowed by the understanding and manipulation of the strong and weak forces which control the stability of atomic nuclei. Nuclear damper units create interference fields in these forces, resulting in strong positive and negative nodes where the wave patterns intersect and interact. At negative nodes the forces are reduced, and at positive nodes they are reinforced. By selectively projecting these nodes onto a material, the atomic nuclei can be made more or less stable, depending upon the needs of the user. For example, by projecting a strong force negative node, the nucleons (particles of the nucleus: protons and neutrons) are held together less powerfully, allowing nucleons to escape (at early tech levels this use is imprecise, creating random transmutations, at higher tech levels it allows more reliable transmutation, albeit very expensively) at low energy levels. On the other hand, nodes can be projected that "freeze" a radioactive nucleus by preventing its decay and eliminating dangerous radiation.

The latter effect allows the manufacture of damper boxes that permit the transport of radioactive material without the need for heavy shielding.

Nuclear damper screens are created by projecting these fields at a distance to inhibit the function of nuclear warheads. By sufficiently strengthening the strong force with a positive node, a nuclear damper can prevent fission chain reactions from beginning by eliminating the spontaneous fission in a supercritical mass that begins the chain reaction. The projection of negative nodes, causing the shed of nucleons, can be dangerous at early tech levels, as the release of low-energy neutrons initiates the fission of common nuclear warhead materials. However, at higher tech levels, the effect can cause large numbers of nuclei to dissociate so rapidly into non-fissile elements that there are insufficient nuclei to maintain a chain reaction. This is fortunate because it is also this effect of the screen that is necessary to inhibit fusion warheads. While early dampers inhibit fusion warheads by disabling their fission triggers, pure fusion can only be prevented by reducing the strong force that permits the fusion to occur.

Nuclear Damper Screens: Unlike most weapons, damper screens only have a single range. Targets within that range may be attacked and targets outside of that range may not. All attacks by nuclear dampers are Difficult tests for success, a successful attack rendering the warhead inert.

When designing a nuclear damper, the designer specifies the range of the weapon in kilometers. All other values are derived from the Nuclear Damper Design table below. Space-based nuclear dampers must have a range of 30,000 kilometers in order to successfully intercept in-coming missiles.

Nuclear dampers require a beam pointer with a short range equal to the damper's absolute range. They also require a normal workstation for local control (or they may be controlled by an MFD which may control a number of dampers equal to its Diff Mod rating—this rating only allows the MFD to control multiple dampers, but does not allow it to apply its Diff Mod negations to damper tasks). Dampers may also be fitted with sensors which allow them to make their own target locks if the vehicle's main sensors are knocked out.

Nuclear Damper Design

TL	*MW*	*Vol*	*MCr*
12	.00050	5	0.13
13	.00030	8	0.3
14	.00020	10	0.67
15	.00010	11	1.5
16	.00008	13	2
18	.00006	16	4
20	.00003	18	6

TL: Tech level of construction.

MW: Power, in megawatts, equals the range in kilometers multiplied by the value shown on the table.

Vol: The volume of the damper, in cubic meters, is equal to its power in megawatts multiplied by the value on the table.

MCr: The price of the damper, in millions of credits, is equal to the power in megawatts multiplied by the value on the table.

Mass: The mass of the damper, in metric tonnes, is equal to its volume in cubic meters.

Antenna Area: The antenna area of the damper, in square meters, is equal to its volume multiplied by 0.1.

Nuclear Damper Boxes: Nuclear damper boxes are used to transport radioactive materials safely. Damper boxes are available at tech levels 11 and higher. Damper box design depends on the capacity of the box, which is expressed in tonnes of fissionable material. All other values are derived from the capacity of the box, as indicated below.

Mass: The mass of the box, in metric tonnes, is equal to its capacity multiplied by 0.3.

Volume: The volume of the box is equal to its capacity multiplied by 1.2.

Price: The price of the box, in millions of credits, is equal to its capacity multiplied by 0.33 unless the capacity of the box is 1 tonne or greater, in which case the price is equal to the sum of 0.9 plus the product of the capacity of the box multiplied by 0.03. (MCr = 0.9 + [0.03×Cap])

Power: The power requirement of the box, in megawatts, is equal to its capacity in tonnes multiplied by 0.001.

Meson Screens

A meson screen is another application of the ability to manipulate the strong force, which is transmitted by mesons. A meson screen projects an energy field surrounding the screen generator which slows and prematurely detonates high-energy mesons. The designer specifies only the power requirement (in MW) of the meson screen; all other values are derived from the power requirement, tech level, and volume of protected space.

Vol: The meson screen generator's volume, in cubic meters equals MW × 20.

Mass: The meson screen generator's mass, in metric tonnes, equals Vol × 0.75.

AA: The meson screen generator's antenna area, in square meters, equals MW × 10.

MCr: The meson screen generator's price, in millions of credits, equals Vol × 0.1.

Performance: The meson screen generates a Protection Value for the target which is used against incoming meson guns. The Protection Value is derived by the following formula:

$$PV = TLM \times \sqrt{MW+TSM}$$

PV= Protection value
TLM = Tech level multiplier
TSM = Target size modifier

Tech Level Modifiers

TL	TLM
12	50
13	60
14	70
15	80
16	90
17	100
18	105
19	110
20	115
21	120

Target Size Modifiers

Size	TSM
Small or less	1
Medium	2
Large	4
Very Large	8
Gigantic	16

Each meson screen requires crew equal to the mass of the screen (in tonnes ÷ 100, times the computer control multiplier (round to the nearest whole number, but must be at least 1). Each crewmember requires one normal workstation installed as part of the screen installation.

SANDCASTERS

All sandcaster turrets fit in the standard turret hardpoint socket. Each turret weighs 50 tonnes and requires 1MW of continuous power while in operation.

The table below lists the price of the turret in megacredits, the number of sand cannisters carried in the turret, and the beam reduction made per successful beam interception. Additional sand cannisters may be stored in cargo, but it takes one hour to resupply a turret. Individual sand cannisters have a volume of 0.5m³, mass 0.5 tonnes, and have a cost in credits as indicated on the table.

TL	MCr	Cannisters Carried	Beam Reduction	Cann Cr
8	0.6	16	1D6×5	400
9	0.65	18	1D6×5	400
10	0.7	20	1D10×5	600
11	0.75	24	1D10×5	600
12	0.8	30	1D10×5	600
13	0.85	35	2D6×5	800
14	0.9	40	2D6×5	800
15-16	1	50	2D10×5	1000
17-18	1.2	54	2D20×5	1500
19-20	1.4	58	2D20×5	1500
21	1.6	62	3D20×5	2000

Sandcasters fire cannisters of ablative crystals, commonly called "sand." Each sandcaster also contains a generator which creates a field used to manipulate the location and shape of the cloud of crystals. At early tech levels, these fields are electromagnetic, and require magnetic sand. More advanced systems supplement, then supplant, the magnetic manipulation with gravitic manipulation, which allows the use of more effective nonmagnetic crystals.

These clouds are placed in the path of incoming beam weapons, and the beams expend their energy burning through the cloud. The sandcaster operator uses integral laser warning sensors to detect fire control locks and anticipate incoming beam fire. Each successful sandcaster hit reduces the beam by the indicated amount, and requires that another cannister be expended to replace the burned sand.

ELECTROSTATIC ARMOR (ESA)

Electrostatic armor is, until the development of the meson screen, the closest realistic analog to the classic "force field" of science fiction. The protected target (usually a vehicle or aircraft) is surrounded by a low-power static field linked to a fully charged high-energy capacitor. When an object enters the field (and provided it falls within fairly narrowly defined parameters for mass and velocity) the capacitor discharges its energy which vaporizes the foreign object.

The massive power discharge is triggered by entry of detectable mass in the field, and so it has no effect on lasers and no significant effect on particle accelerator weapon systems (PAWS). It was originally designed as a counter to hyper-velocity tank rounds, but it is difficult to generate sufficient power to completely vaporize the dense penetrators of most large-caliber CPR guns and mass drivers. As a result, electrostatic armor is usually used as an adjunct to, rather than a replacement for, a conventional armored envelope. Due to the low mass of the penetrator stream of a HEAP round or a plasma bolt, however, electrostatic armor is extremely effective against HEAP rounds and both plasma and fusion guns.

ESA systems will have an armor value which is usually added to the base armor value of the protected target. The full AV is added versus HE, HEAP, plasma bolt, and fusion bolt attacks. Half the AV is added versus KEAP attacks. No AV is added versus laser and PAWS attacks.

ESA Design: The ESA system itself consists of a field generator and a homopolar generator. The designer specifies the discharge power, in megajoules, of the field generator. All other values are derived from the field generator's discharge power. The homopolar generator must have a discharge capacity equal to the discharge power of the field generator.

Field Generator

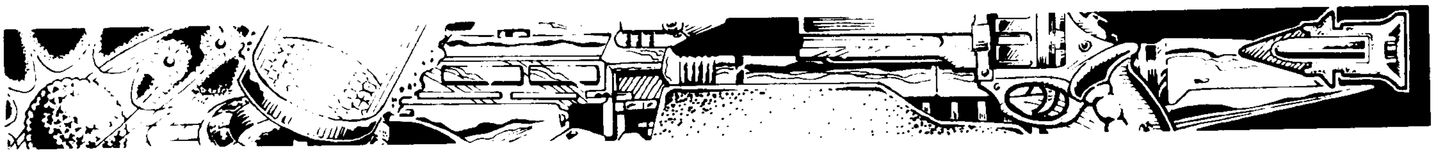
TL	Vol	MCr	AV
9	0.4	1	4
10	0.3	0.8	5
11	0.2	0.6	5.5
12	0.15	0.5	6
14	0.1	0.4	7
16	0.075	0.3	8
18	0.05	0.25	9
20	0.025	0.2	10

TL: Tech level of construction.

Vol: The volume of the field generator, in m³, is equal to its discharge power in megajoules multiplied by the value shown on the table.

MCr: The price of the field generator, in MCr, is equal to its discharge power in megajoules multiplied by the value shown on the table.

AV: The armor value of the system is equal to the discharge power (in megajoules) multiplied by the value shown on the table, multiplied by the target size AV multiplier (see table below). This value is used versus HEAP rounds and both plasma and fusion guns. Half this value is used against KEAP rounds.



Target Size AV Multiplier

Size	Multiplier
Small or less	1
Medium	.5
Large	.25
Very Large	.12
Gigantic	.06

Mass: Generator mass, in tonnes, is equal to volume in $m^3 \times 2$

Homopolar Generator: Direct electrical power requires the installation of a homopolar generator (HPG), see the Power Production chapter (Section 8). The HPG must be of sufficient size to store the ESA's one-shot energy output as defined immediately above. Calculate the volume of HPG needed by multiplying the ESA's discharge energy (DE) in MJ by the value on the HPG table.

Rate of Fire: Define the ESA's rate of fire (ROF). As ESAs have no effect on lasers and PAWS, they are used almost exclusively in planetary combat and so ROF is calculated on the basis of a five-second combat turn. The rate of fire is equal to the continuous power input from the power plant, in megawatts, multiplied by 5 and divided by the discharge power in megajoules. The result is the number of times per five-second combat turn that the ESA will add its value to the vehicle's basic armor.

Note that in many cases the ROF value will be less than 1. In this case, the ESA homopolar generator requires one or more turns to recharge before it can be used again. Divide 1 by the ROF result, rounding all fractional results up, to determine how many turns the homopolar generator must recharge before it can fire again.

Explosive Power Generation: Some ESA systems are not tied to a continuously running power plant, and instead rely upon explosive generation of power to recharge the homopolar generator. See the Power Production chapter (Section 8) for details of explosive power generators.

TRACTORS AND REPULSORS

Both tractors and repulsors are advanced devices based on artificial gravity technology. Tractors are large, focused artificial gravity attractors. When directed at other craft, they draw them in or restrict their agility. Repulsors are large, focused but negatively polarized artificial gravity projectors available at very high tech levels. When directed at incoming missiles or other foreign objects, they deflect them away from their target.

The performance of both tractors and repulsors is expressed in terms of tonnes of thrust per cubic meter of projector. If a tractor or repulsor operator makes a successful task roll, the power of the weapon may be applied to the target, either as acceleration toward (tractor) or away from (repulsor) the projector.

The manipulator is a combination tractor/repulsor which allows fine control over the object being targeted. Because a tractor can only pull objects toward itself, it cannot stop them once they are close aboard. A manipulator can apply tractor and repulsor thrust to an object to place it beside the projector at a relative net vector of zero. Manipulators are often installed in large, otherwise empty bays which they load with large, unwieldy cargoes, and then unload at the destination.

The table in the next column shows the tonnes of thrust generated per kiloliter (cubic meter) of tractor or repulsor projector installed.

			Tonnes per kiloliter of projector at tech level				
Type	*Price*	*Power*	*12*	*14*	*16*	*18*	*20*
Tractor	.1	.01	3	30	300	600	1500
Repulsor	.2	.02	—	—	200	400	800
Manipulator	.3	.02	—	—	200	400	800
Range Modifier			.1	.01	.001	.0001	.00001

Price: Millions of credits per cubic meter of projector.

Power: Power requirements are in megawatts per tonne of applied thrust.

Mass: Mass in tonnes of any gravitic projector is equal to its volume in cubic meters.

The system requires a workstation and a beam pointer to function. The beam pointer determines the range of the weapon for purposes of achieving a hit. However, power drops dramatically with range. Divide power by the the product of the range in kilometers multiplied by the tech level range modifier, shown on the bottom line of the table. However, any product of range times modifier less than 1 is rounded up to 1.

FORCE FIELDS

True force fields are a result of an increased ability to manipulate subatomic particles as well as a deeper understanding of the sensitivity of those to electromagnetic radiation. The earliest force fields are called black globes, due to the fact that they are effectively opaque to all forms of matter and electromagnetic energy encountering the field from both the inside and outside. Since they absorb all light, from both the inside and outside they look completely black.

The field itself is a cloud of free electrons held in place by an electromagnetic field. Free electrons are those which are not bonded to an atomic nucleus, and are therefore capable of absorbing and emitting electromagnetic energy of any wavelength. Early descriptions of black globes as "free electron lasers in reverse" are not entirely accurate, but it is true that the same characteristics of free electrons which make FELs possible are utilized in the force field.

Since early versions of the field were omnidirectional, ships with the field up were unable to sense targets, fire, or maneuver. At short range, this presented tremendous tactical problems, since the lack of maneuverability made the target solution by hostiles trivial and allowed an enemy to simply pump energy into the globe (by means of any and all directed energy weapons) until the field collapsed. The solution was to "flicker" the black globe, allowing the ship to maneuver, sense, and fire while absorbing a portion of the incoming energy of weapons. While maneuver was limited, firing by energy weapons was at full effectiveness: The pulses of the ship's energy weapons were timed to the flicker of the shield much as with the interruptor gears on primitive propeller-driven fighter aircraft. Higher tech levels allowed a more rapid flicker rate.

The next step beyond the black globe, however, was the white globe, a unidirectional force field that allowed a ship to maneuver and fire while completely shielded from enemy fire. Because the field is unidirectional, energy can pass freely out through the barrier, but this still poses difficulties for incoming communications and sensor data. As a result, white globes are tuned to allow certain narrow wavelengths of energy through. These are usually wavelengths which are not particularly useful for weaponry, particularly space-based weaponry. White globe-equipped ships thus tend to rely heavily on infrared wavelength radiation for sensors and make extensive use of masers for tight beam communication.

A critical concern in force field architecture is what to do with the energy the field absorbs. Black globe-equipped ships store it in HPG
1 banks and in combat often shut down their power plants, substituting energy from the HPG banks to power critical ship systems. Some vessels mount additional large lasers or particle weapons which are not normally powered by the ship's power plant, and instead are fed
2 solely by intercepted incoming energy from hostile fire.

White globes have less problem with radiating energy, as the electron globe of the field can radiate energy outward as easily as it can absorb it (which is why it glows white while in use). The energy
3 is first cycled through the system's HPG bank, however, and is then discharged back to an unengaged part of the electron cloud for transmission outward. As a result, white globes are not limited in the total amount of energy they can absorb, but only in the volume of
4 energy they can process in a given amount of time. This is determined by the size of the HPG banks and engineers refer to this limit as the "traffic flow ceiling."

Important Note: If an erected force field comes into contact with
5 large quantities of matter (a vehicle of 50 displacement tons or greater, a large asteroid, planet, etc.), the generator is immediately overloaded and destroyed, and its HPG sink immediately suffers a catastrophic detonation, causing 1D20 critical hits. As the field attempts to drain all of the kinetic energy of the large mass, cooling
6 it to absolute zero, energy is drawn from the entire mass to be drained by the globe, rapidly overloading the generator, as it cannot possibly contain all of the energy in a system that large.

7 DESIGNING FORCE FIELDS

Force field defensive systems consist of two subcomponents: the force field generator and the homopolar generator/energy sink. Force field generators are described on the following table.

8

Force Field Generators

	TL	Type	Flicker	Power	Vol	MCr
	15	Black	10%	15	135	400
9	15	Black	20%	20	200	600
	15	Black	30%	25	270	800
	15	Black	40%	30	350	1000
	16	Black	50%	35	300	500
10	16	Black	60%	40	400	700
	17	Black	70%	45	450	900
	18	Black	80%	45	250	500
	19	Black	90%	45	250	500
11	20	White	—	50	300	900
	21	White	—	50	400	910

TL: Tech level of first availability.
12 **Type:** Black globe or white globe.
Flicker: Operational flicker rate.
Power: Megawatts of power input required for operation of the generator.
13 **Vol:** Volume in cubic meters of the generator.
MCr: Price in millions of credits of the generator.
Mass: All generators mass 1 tonne per cubic meter.

14

Protected Volume: Power requirements increase as the volume of the protected target increases. Multiply those values by the ship's target size multipliers shown in the Target Size Multiplier table:

Target Size Multipliers

Size	*Multipliers*
VS and smaller	×1
S	×2
M	×3
L	×4
VL	×5
G	×6

Note that deployed folding HRT or Passive EMS arrays increase the effective target size of a ship for purposes of force field protected volume. On the following chart, use the diameter of the deployed sensor to find the minimum protected volume required, which reads out in target size as used on the Target Size Multipliers table above. This will require a greater amount of power to run the force field. If insufficient power is provided to run the field at the larger volume required for the extended array, the sensor must be retracted, and may not be used while the force field is on.

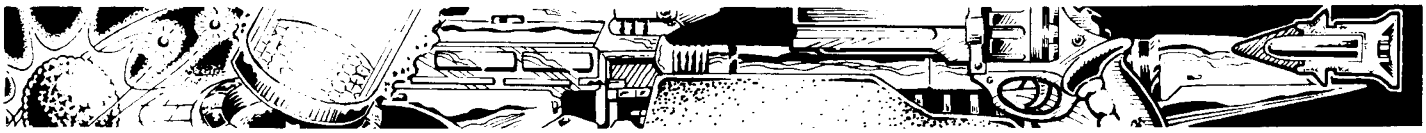
Sensor Array Minimum Volume

Antenna Diameter	*Min Vol (Target Size)*
10 or less	SM
20	Mc
40	VS
90	S
200	M
400	L
800	VL
1200+	G

HPG Bank: Any size homopolar generator may be selected for the system. The storage capacity of the HPG subcomponent (or HPG bank) is the maximum power which may be stored by a black globe before catastrophic discharge. White globes are continuously discharging, so there is considerably less danger of an overload. However, incoming power is still cycled through the system and the peak power per 30-minute starship combat turn which can be processed by the field is equal to the power of the installed HPG system. The peak power per five-second planetary combat turn which can be processed by the field is equal to the above value divided by 360.

Note that 35% of the volume of a jump drive consists of capacitor/HPG banks. The jump drive capacitors may be used to store energy along with/in lieu of specifically installed HPGs. Multiply the jump drive volume by 0.35, and divide the result by the correct TL entry on the Homopolar Generator Energy Capacity table. This is the capacity of the jump drive HPG/capacitors in megajoules. Add this to the capacity of the specially installed HPGs to get the total traffic flow ceiling.

Solar Array: Black globes function as excellent solar arrays for ships with power plant damage. Look on the Sensor Array Minimum Volume table, and find the number in the "Antenna Diameter" column corresponding to the chosen protected volume. A full-up black globe in the habitable zone of a star produces power in megawatts equal to 0.1 times the Antenna Diameter figure squared (multiply this value by 10 in the inner zone, and by 0.01 in the outer zone). If the globe is set to flicker, multiply this result by the flicker rate.



CHAPTER 7
Optional Features

These items are used almost exclusively on spacecraft, and constitute an assortment of features which do not fall into any other major category.

Fuel Scoops

Fuel scoops may be added to any design. These allow a vessel to skim the free raw materials for liquid hydrogen (LHyd) fuel from oceans or gas giant atmospheres. They do not consume any volume or add to the mass of the vessel. Fuel scoops do consume surface area. Each 5% of a craft's total surface area given to fuel scoops allows the craft to scoop fuel equal to 20% of its total volume per hour (i.e., a 100-ton ship with fuel scoops covering 10% of its surface can scoop 40 displacement tons of fuel per hour). Cost to add fuel scoops to a design is MCr0.000075 per cubic meter of hull.

Fuel Purification Plant

TL	*MW*	*Vol*	*Mass*	*MCr*	*MinVol*
8	**0.01**	**0.7**	**1.5**	**0.0002**	**135**
9	0.009	0.6	1.2	0.00019	120
10	**0.008**	**0.55**	**1.1**	**0.00018**	**105**
11	0.007	0.45	0.9	0.00017	95
12	**0.006**	**0.4**	**0.8**	**0.00016**	**80**
13	0.005	0.35	0.7	0.00015	65
14	**0.005**	**0.25**	**0.5**	**0.00014**	**55**
15	0.005	0.2	0.4	0.00015	40
16	**0.005**	**0.15**	**0.3**	**0.00016**	**25**
17	0.005	0.1	0.2	0.00017	15
18+	**0.005**	**0.05**	**0.1**	**0.00018**	**5**

Vol: Volume in cubic meters.
Mass: Mass in tonnes.
MCr: Price in millions of credits.
MW: Power requirement in megawatts.
All values are per kiloliter of fuel processed per 6 hours.

Special Facilities

Description	*Vol*	*Mass*	*MCr*	*MW*
Electronics Shop	**84**	**40**	**1**	**0.6**
Machine Shop	140	120	2	1
Laboratory	**112**	**50**	**5**	**0.8**
Sick Bay	112	50	5	0.8

Vol: Volume in cubic meters (kiloliters).
Mass: Total mass in tonnes.
MCr: Price in millions of credits.
MW: Power requirement in megawatts.

Vehicle Service Facilities

Description	*Vol*	*Mass*	*MCr*	*MW*
Internal Hangar (Minimal)	**×2**	**0.2**	**.0002**	**—**
Internal Hangar (Spacious)	×4	0.2	.0002	—
Docking Ring	**×1**	**0**	**.0002**	**—**
Launch Tube	×25	0.5	.00015	.01
External Grapple (USL)	**×0.1**	**1.0**	**.001**	**—**
External Grapple (SL)	×0.3	1.0	.002	—
External Grapple (AF)	**×0.5**	**1.0**	**.003**	**—**

Volume: Multiply the craft or vehicle volume by the value shown to determine the facility volume.

Mass: The mass in tonnes per cubic meter of installation.

MCr: The price, in MCr, per cubic meter of installation.

Surface Area: All of the facilities require surface area except for the hangars (which require launch ports, below). The launch tube requires area in m² equal to $2 \times L^2$ where L equals the basic length as taken from the Hull Size table, unmodified by hull form, of the largest craft that will use the tube.

Grapples require area equal to the square of the final length of the craft carried by the grapple.

MW: Power requirement per cubic meter of installation.

Hangar Space: Spacious hangars allow all repair and maintenance

tasks to be conducted at normal difficulty levels. Minimal hangars increase the difficulty level of all such tasks by one level. Docking rings allow no maintenance or repair.

External Grapple: Types listed are for unstreamlined (USL), streamlined (SL), and airframe (AF) hulls of the carrying ship, not the carried craft. Note that the volume of craft carried in external grapples is not subtracted from the available hull volume of the carrying ship, although the volume of the grapple is. Remember that the volume of the carrying ship plus all externally carried craft is used when calculating the required amount of maneuver drive and jump drive.

By selecting the type of grapple that corresponds to its hull streamlining, the vessel may carry externally mounted craft without compromising its streamlining configuration, so long as the externally mounted craft also meets that configuration. If the grapple or craft's configuration is lower than that of the overall hull, the ship is limited to the lower configuration if it is carrying the craft. If the craft is detached, the hull's configuration may be used.

Access Ports

Description	*Area*	*MCr*
Launch Port	L^2	0.001
Large Cargo Hatch	20 m²	0.02
Small Cargo Hatch	12 m²	0.012

Area: Hull surface area required.

L^2: The square of the craft's basic length as taken from the Hull Size table, unmodified by hull form.

MCr: Price in MCr per square meter of launch port, or per each cargo hatch.

Launch Port: At least one launch port is required if craft or vehicles are carried. More launch ports allow craft to be launched more rapidly.

Cargo Hatches: All craft require at least one large cargo hatch per 350 m³ (25 tons) of cargo capacity. Vessels with under 100 m³ of cargo space can get by with a single small cargo hatch.

For air locks, see page 77.

Seats

Short-haul vehicles will require passenger seats.

Seats

Access	*Vol*	*Mass*	*MCr*
Restricted	1.5	0.02	.0001
Cramped	2.5	0.02	.0001
Adequate	3.5	0.02	.0001
Roomy	7	0.02	.0001

Vol: Volume in m³ per position/seat.

Mass: Mass in tonnes per position/seat.

MCr: Price in megacredits per position/seat.

These entries are simple seats with no controls. Paying passenger seats must be Adequate or better; seats for troops must be Cramped or better. "Restricted" access is the minimum possible accommodation for special purposes only.

Drop Tanks

Ships may be fitted with drop tanks if desired. A drop tank is an additional hull section filled entirely with fuel. Its material volume and mass are calculated just as if it were a separate ship, and it must use the same hull form and configuration modifiers as the ship it will be fitted to, and must be armored and have internal structure bracing sufficient to withstand the ship's rated acceleration.

If a drop tank is fitted to a ship with electromagnetic masking (EMM), the tank(s) must also be so fitted, with the volume and surface area taken out of the tank itself. Power requirements are assumed to be met by the carrying ship, which must allow for them in its own design. If any EMM-fitted ship is carrying non-EMM drop tanks, the ship loses all of its EMM benefits until the tanks are dropped.

A drop tank is designed to be released once it is drained, allowing improved performance by the ship.

Collapsible Tanks

Insulated fuel bladders may be carried in the cargo hold to carry additional fuel. This fuel may not be used directly, but must be pumped into the normal fuel tanks for use. Collapsible tanks cost Cr100 per cubic meter of fuel capacity, and when empty can be stored at 5% of their full volume.

Dismountable Tanks

Dismountable fuel fuel tanks may be carried in the cargo hold to carry additional fuel. Fuel from these rigid tanks may be used directly, without requiring transfer to the permanent tanks. Dismountable tanks cost Cr200 per cubic meter of fuel capacity, but must be stored at their full volume when empty. Modified versions costing Cr500 per cubic meter function the same, but may be disassembled to store at 25% their full volume.

Internal Armor

Valuable internal systems may have additional armor added around them. Any time a hit is rolled against such a system, the remaining damage value must first penetrate this internal armor before it can damage the system.

Calculate the volume of the system(s) to be protected, and then design the armor as if it were a separate hull, using the same procedure used to calculate the hull shell (or chassis armor material volume, if it is a vehicle) volume, weight, and price of the ship. Select the armor thickness desired, and use the hull form modifier as used by the main hull. Do not, however, use the minimum armor level based on G performance, and do not apply the airframe configuration modifier. There is no internal structure requirement for internal armor.

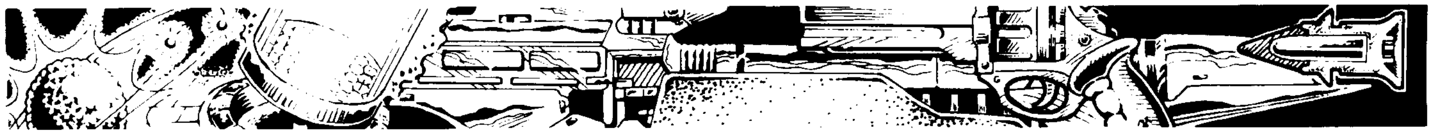
Spacecraft Deckplans

Each displacement ton is drawn as a grid square 2 meters by 2 meters, with a vertical height of 3.5 meters. Much of this vertical height is taken up by deck thickness, lighting, environmental ducting, etc., so that free height is only about 3 meters.

When allocating space within the craft, assume that only a portion of the specified volume for staterooms, bunks, etc., is used for those fittings *per se*; the remainder should be used for common areas and other accommodations for the crew, such as recreation areas, eating spaces, and so on.

When comparing the final number of grid squares used on the deckplan to the rated tonnage of the vessel's design, allow a 10-20% leeway. If the plan comes within 20% of the stipulated volume, it is acceptable.

When drawing passenger seats, Roomy seats fit two per grid square; Adequate seats fit four per square; Cramped seats six per square; and Restricted seats nine per square.



CHAPTER 8
Power Production

The extraction of energy from fuel and conversion of that energy to a useful form is the heart of the industrial revolution of tech level 3.

FUELS

All early fuels are organic in origin. The earliest fuel, of course, was wood, and even early steam engines used wood as a fuel. As the industrial revolution required more energy, and a more portable energy supply, coal became a more common fuel due to its greater energy density. Coal is, of course, also organic in origin, the fossilized remains of long-dead life forms (hence the term "fossil fuels"). Coal is also a hydrocarbon fuel. As demand for portable fuel sources increased, high-energy density distillates of hydrocarbon fuels (either oil or gassified coal) replaced coal as the standard hydrocarbon fuel.

As all hydrocarbons are fossil fuels, worlds without a biosphere are unlikely to have them in significant quantities. Even worlds with biospheres may not have had the right biological and geological history to produce significant quantities of fossil fuels. On these worlds, alcohol distillates are used at early tech levels, but these rely on organic material as well, and so are also unavailable on worlds without biospheres.

The most plentiful fuel in the galaxy is probably hydrogen, and it is free for the taking in the atmospheres of most gas giants. It exists in plentiful quantities in oceans and icecaps as well, but in a less useful form. While hydrogen can be burned in most high-tech hydrocarbon power plants, the energy released by simple hydrogen combustion is exactly the same as the energy required to separate it from the oxygen in water. As a result, worlds with other plentiful but less portable energy sources (such as geothermal, tidal, wind, or solar) may use these "free" energy sources to crack hydrogen from water and thus have a useful portable fuel. Energy-poor worlds, however, will not gain anything by using scarce energy to crack hydrogen, since they gain no energy in the process.

They gain nothing in the process assuming, of course, that they are burning hydrogen in a chemical power plant. If they are using it in fusion reactors, the story is considerably different. Once fusion power is available, worlds with considerable water have solved the worst of their energy problems.

The interim step between chemical power plants and fusion is fission. Fission relies upon naturally occurring radioactive elements for fuel, and these are scarce enough throughout our region of space to make them high-priced and highly sought-after.

Fuel

Type	*Mass*	*Price*
Wood	2.0	.000050
Alcohol	1.0	.000200
Coal	2.0	.000100
Hydrocarbon Distillates (HCD)	1.0	.000250
HG Hydro Distillates	1.0	.001000
Liquid Rocket Fuel (LRF)	1.0	.001000
Solid Rocket Fuel (SRF)	1.0	.002000
Hydrogen Rocket Fuel (HRF)	0.3	.001000
Liquid Hydrogen	0.07	.000035
Radioactives	19	.075000
Antimatter	0.07	.200000

Mass: In tonnes per kiloliter (m^3).

Price: In millions of credits per kiloliter (m^3).

HG Hydro Dist.: High grade (highly refined to reduce impurities) hydrocarbon distillates. These are used almost exclusively in fuel cells.

Wood, alcohol, and coal are substitutes for hydrocarbon distillates in various engines. Each of these fuels has a different output multiplier and fuel use multiplier as compared to burning pure hydrocarbon distillates.

Fuel	*Output Mult.*	*Fuel Use Mult.*
Wood	0.5	3
Alcohol	0.75	1
Coal	1	1.5

Chemical Power Plants

The term *reciprocating* refers to the back-and-forth motion of the piston. Not only do reciprocating engines need a flywheel to smooth out the uneven application of power, they are inherently inefficient and limited in the power and speed they can develop. As the engine works faster and faster, the forces on the pistons will eventually shake apart the vehicle or destroy the engine.

Steam engines are usually called external combustion, as the fire is outside of the confines of the boiler and engine itself. The internal combustion engine differs in that the fuel is burned inside the engine and the expanding gas of the fuel explosion is itself used, in place of high-pressure steam, to drive reciprocating pistons which turn a drive shaft. As with any engine, the spinning drive shaft can be connected directly to a mechanical contrivance, such as a winch or axle, or it can turn an electrical generator and produce power to run other systems.

Turbines are engines which use spinning fan blades in place of the less mechanically efficient reciprocating pistons.

The most advanced form of chemical power plant is the magnetohydrodynamic (MHD) turbine, which works on a fundamental principle of electromagnetism called Fleming's Left Hand Rule. This principle states that the confluence of a magnetic field and an electrical current passing through a fluid will cause the fluid to be propelled in one direction. When combined with a high-energy turbine, an MHD field produces an extremely efficient power source.

Although the thrust effect is very weak at low levels of magnetism, the efficiency of the turbine increases with the square of the increase in the power of the magnetic field. As a result, efficient MHD power plants become practical only when large superconducting magnets are economically feasible.

Chemical Power Plants

TL	*Description*	*MW*	*Mass*	*MCr*	*Min Vol*	*Kl/Hour*	*Fuel Type*
3	Early Steam	0.10	2	0.0005	0.25	0.2	Hydro. Dist.*
4	Steam	0.20	2	0.0005	0.15	0.15	Hydro. Dist*
4	Int.-Comb.	0.30	1	0.001	0.05	0.2	Hydro. Dist
5	Steam Turbine	0.35	2	0.002	1	0.15	Hydro. Dist
5	Imp. Int. Comb.	0.40	1	0.002	0.01	0.25	Hydro. Dist
7	Gas Turbine	0.50	1	0.005	0.5	0.3	Hydro. Dist
8	MHD Turbine	0.60	1	0.01	1	0.2	Hydro. Dist

MW: Output in megawatts per cubic meter of power plant.

Mass: Tonnes per cubic meter of power plant.

MCr: Price in MCr per cubic meter of power plant.

Min Vol.: Smallest possible power plant in cubic meters.

Kl/Hour: Kiloliters (cubic meters) of fuel consumed per hour per MW output.

Fuel: The type of fuel burned. All chemical power plants burn hydrocarbon distillates, but some substitutes are possible.

Alcohol distillates may be substituted for hydrocarbon distillates in all power plants listed, but energy output is multiplied by 0.75.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

All power plants from tech level 7 and higher may be designed to burn LHyd (liquid hydrogen) instead of hydrocarbon distillates at no energy penalty.

*Asterisked power plants may substitute wood or coal for hydrocarbon distillates. If wood is used, energy output is multiplied by 0.5 and fuel consumption is multiplied by 3. If coal is used, energy remains the same but fuel use is multiplied by 1.5.

Atmospheric Performance: The figures above are for power plants built to function in a standard atmosphere (code 6 and 7). All of these power plants are "air breathers," i.e., require oxygen to function. These power plants may function without penalty in thin atmospheres (codes 4 and 5), but require intake compressors to function in very thin atmospheres (codes 2 and 3). Intake compressors add 20% to the volume of the power plant (and mass and price are figured on this increased volume). Dense atmospheres (codes 8 and 9) require no modifications.

All power plants include fittings for filters for use in tainted atmospheres at no additional cost. (Certain environments, such as sandy deserts, may also require such filters.) When fitted, these filters cost 0.01 times the cost of the power plant and have negligible mass and volume. While these filters are fitted, multiply maintenance points (pages 21, 26, 34) by 1.2.

Air-breathing power plants do not function in vacuum, trace, exotic, corrosive, or insidious atmospheres except by using their own on-board oxygen supply. Any air-breathing vehicle using liquid hydrogen for fuel may modify its fuel tankage to carry half liquid oxygen and half liquid hydrogen. Such a vehicle may then operate in vacuum, trace, exotic, corrosive, or insidious atmospheres, or in tainted atmospheres without filters, as it has no need for external sources of oxygen. However, its rate of fuel consumption is doubled.

This modification costs Cr50 per cubic meter of fuel capacity, and does not prevent the vehicle from using the full tank for liquid hydrogen for normal external oxygen operations.

Fuel Cells

Fuel cells burn fuel and take energy from the energetic electrons transferred between the various products of the chemical reaction. Fuel cells, like batteries (page 65) are electrochemical cells and work on similar principles, except that fuel cells are open systems which continue to process fuel and convert it to energy.

Fuel cells are more efficient than most chemical power plants, but are not as economical as the electrodes become contaminated by fuel impurities and require frequent replacement. Only with ultra-pure fuels is this problem avoided, and the added cost of these fuels generally makes them uneconomical. Only where size and fuel efficiency are more important than cost (as with a spacecraft) are they generally cost-effective.

Fuel Cells

TL	*Description*	*MW*	*Mass*	*MCr*	*Min Vol*	*Kl/Hour*	*Fuel Type*
7	Fuel Cell	0.5	1	0.02	.01	0.3	HG Hydro. Dist.
12	Fuel Cell	0.75	1	0.02	.01	0.25	HG Hydro. Dist.
14	Fuel Cell	1.5	1	0.02	.01	0.2	HG Hydro. Dist.
16	Fuel Cell	1.75	1	0.02	.01	0.2	HG Hydro. Dist.

MW: MW output per cubic meter of power plant.
Mass: Tonnes per cubic meter of power plant.
MCr: Price in MCr per cubic meter of power plant.
Min Vol.: Smallest possible power plant in cubic meters.
Kl/Hour: Kiloliters (cubic meters) of fuel consumed per hour per MW output.

Nuclear Power

Nuclear power relies on the energy released by the fission or fusion of atoms in a controlled nuclear chain reaction. Nuclear fission is the splitting of an atom of "fissionable" material, usually a refined isotope of uranium or plutonium. When the atom is split, energy is released. Nuclear fusion is the combination of two atoms, usually hydrogen atoms, into a single atom, also releasing energy in the process. (See

Common Fusion Reactions

The only achievable fusion reaction on Earth is deuterium and tritium fusion. Thus far, it has only been achieved in H-bombs, but it is hoped that these reactions will eventually be harnessed for controlled fusion power production.

The reaction takes place in three steps:

1) Two deuterium (${}_1H^2$) nuclei (each with one proton and one neutron) fuse to form one helium-3 (${}_2He^3$) nucleus (two protons, one neutron) and a free neutron.

2) Two deuterium (${}_1H^2$) nuclei fuse to form one tritium (${}_1H^3$) nucleus (one proton, two neutrons), and a free proton.

3) One deuterium (${}_1H^2$) nucleus and one tritium (${}_1H^3$) nucleus fuse to form one helium-4 (${}_2He^4$) nucleus (two protons, two neutrons), and a free neutron.

The total reaction is summarized as:

Five deuterium (${}_1H^2$) yield one helium-3 (${}_2He^3$) plus one helium-4 (${}_2He^4$) plus one proton plus two neutrons plus energy.

However, the most common fusion reaction in our solar system is the one which powers our sun, and is known as the proton-proton chain. It requires temperatures and pressures far in excess of what can be created on Earth. Like the deuterium-tritium chain above, it too proceeds in three steps:

1) Two hydrogen (${}_1H^1$) nuclei (one proton each) fuse to form one deuterium (${}_1H^2$) nucleus (one proton, one neutron) plus a positron and a neutrino (the positron collides with a nearby electron almost instantaneously, annihilating both particles, releasing energy). Note that one of the protons has decayed into a neutron, positron, and neutrino.

2) One hydrogen (${}_1H^1$) nucleus and one deuterium (${}_1H^2$) nucleus fuse to form a helium-3 (${}_2He^3$) nucleus.

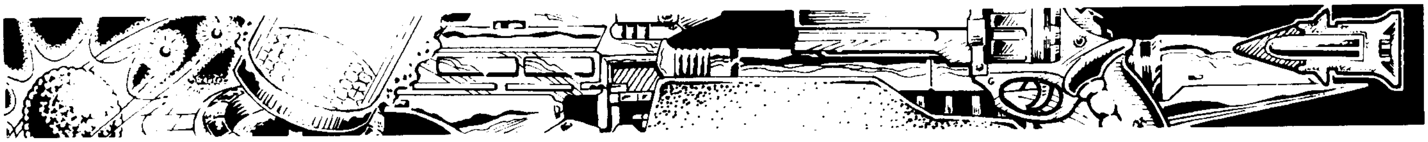
Each of steps 1 and 2 take place twice to create the material for the last step:

3) Two helium-3 (${}_2He^3$) nuclei fuse to form one helium-4 (${}_2He^4$) plus two hydrogen (${}_1H^1$) nuclei, which start the cycle again.

The total equation is:

Six hydrogen (${}_1H^1$) yield one helium-4 (${}_2He^4$) plus two hydrogen (${}_1H^1$) nuclei, two neutrinos, and energy, or, simplified:

Four hydrogen (${}_1H^1$) yield one helium-4 (${}_2He^4$) plus two neutrinos and energy.



the sidebar on common fusion reactions.) In both cases, much of the energy released is in the form of heat. Fission and fusion reactors use the heat to boil water to turn a high-pressure turbine to generate electrical power.

Nuclear Power Plants

TL	Description	MW	Mass	MCr	Min Vol	Kl/Year	Fuel Type
6	**Fission**	**0.30**	**10**	**0.1**	**30**	**0.75**	**Radioactives**
7	Fission	0.60	8	0.1	20	0.25	Radioactives
8	**Fission**	**1.00**	**6**	**0.1**	**10**	**0.1**	**Radioactives**
9	Fusion	2.00	4	0.2	100	0.15	LHyd
10	**Fusion**	**2.00**	**4**	**0.2**	**50**	**0.15**	**LHyd**
11	Fusion	2.00	4	0.2	20	0.15	LHyd
12	**Fusion**	**2.00**	**4**	**0.2**	**10**	**0.15**	**LHyd**
13	Fusion	3.00	3	0.2	1	0.1	LHyd
14	**Fusion**	**3.00**	**3**	**0.2**	**0.25**	**0.1**	**LHyd**
15	Fusion	6.00	2	0.2	0.1	0.1	LHyd
16	**Fusion**	**7.00**	**1**	**0.2**	**0.075**	**0.1**	**LHyd**

MW: MW output per cubic meter of power plant.
Mass: Tonnes per cubic meter of power plant.
MCr: Price in MCr per cubic meter of power plant.
Min Vol.: Smallest possible power plant in cubic meters.
Kl/Year: Kiloliters (cubic meters) of fuel consumed per year per MW output.

Matter-Antimatter Annihilation

Antimatter is a collective term for the *antiparticles* that correspond to all subatomic particles. A particle and its antiparticle have the same mass but are opposite in electric charge or some other elementary characteristic. The anti-electron, for example, is called the *positron*, and has a positive charge rather than a negative. The difference between matter and antimatter is that, although they both respond in the same way to gravitation, electromagnetic forces, etc., if a particle and its antiparticle collide, they will be completely converted to energy. In fact, this is responsible for part of the energy of a fusion reaction. When hydrogen atoms fuse, one of the byproducts are single positrons which almost immediately collide with an electron, annihilating both and generating energy. One positron is generated for every three atoms of hydrogen which fuse, and the annihilation of this positron accounts for 7.7% of the total energy of the fusion reaction, and a higher percentage of its useful energy.

This quality of complete annihilation of matter and conversion to energy makes matter-antimatter the most energy-dense fuel system possible in the physical universe. It is the only fuel which gives over its entire mass to Einstein's classic equation: $E = mc^2$.

Antimatter is naturally occurring, but not in useful quantities. However, it can be created in high-energy particle accelerators. Antimatter is, therefore, not a natural fuel, but rather a manufactured one. (The distinction is less important than it may at first sound, however, as virtually all high-grade fuels require considerable processing before being used.)

MAA (Matter-Antimatter Annihilation) Power Plants

TL	Description	MW	Mass	Price	MinVol	Kl/Year	Fuel Type
17	**Antimatter**	**50**	**6**	**0.5**	**8.000**	**0.005**	**Antimatter**
18	Antimatter	100	5	0.5	1.000	0.002	Antimatter
19	**Antimatter**	**250**	**4**	**0.5**	**0.250**	**0.001**	**Antimatter**
20	Antimatter	500	3	0.5	0.100	0.0005	Antimatter
21	**Antimatter**	**1000**	**2**	**0.5**	**0.020**	**0.0002**	**Antimatter**

MW: MW output per cubic meter.
Mass: Tonnes per cubic meter
Price: Price in millions of credits per cubic meter
Min Vol: Smallest possible power plant in cubic meters.
Kl/Year: Kiloliters (cubic meters) of fuel consumed per year per MW output.

Solar Arrays

Solar arrays consist of solar collectors, which collect solar radiant energy, and solar cells, which convert radiant energy to electrical energy. Each cubic meter of solar cells requires 10 square meters of solar array if deployed in the inner zone of a star system, 100 square meters of solar collectors if deployed in the habitable zone of a star system, and 10,000 square meters of solar collectors if deployed in the outer zone of a star system.

Solar Collector Panels

TL	Vol	Mass	MCr
6	**0.3**	**0.008**	**0.005**
7	0.2	0.006	0.004
8	**0.15**	**0.004**	**0.003**
9	0.1	0.003	0.002
10	**0.06**	**0.002**	**0.001**
11+	0.04	0.001	0.001

Vol: Cubic meters of volume required per square meter of installed collector panels, if permanently installed.
Mass: The mass of the collector, in tonnes, per square meter of panel.
MCr: The price of the collector, in millions of credits, per square meter of panel.

Retractable Array: The values on this table are for rigid, permanently installed solar collectors. If the solar collector is designed to be retracted and deployed at various times, double the price, mass, and volume.

Solar Cells

TL	MW	MCr
6	**0.01**	**0.5**
7	0.015	0.4
8	**0.02**	**0.3**
9	0.025	0.25
10	**0.03**	**0.2**
11	0.035	0.15
12+	**0.04**	**0.1**

MW: Output, in megawatts, per cubic meter of solar cell.
MCr: Price, in millions of credits, per cubic meter of solar cell.
Mass: All solar cells mass 2 tonnes per cubic meter.
Minimum Volume: The smallest allowed solar cell is 0.01 cubic meters.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Batteries

Batteries are not a means of generating power, but rather of storing it. However, the same might be said for artificially generated fuels, such as antimatter. Batteries are often used as surrogate power plants and fuel supplies when the device does not warrant a full-fledged power plant.

Batteries

TL	Description	MW	Mass	MCr
4	Storage Batteries	0.04	2	0.001
5	Storage Batteries	0.06	2	0.001
6	Storage Batteries	0.08	2	0.0008
7	Storage Batteries	0.1	2	0.0008
8	Storage Batteries	0.2	2	0.001
9	Storage Batteries	0.4	2	0.002
10	Storage Batteries	0.8	2	0.003
11	Storage Batteries	1	2	0.004
12	Storage Batteries	1.5	2	0.005
13	Storage Batteries	2	2.5	0.008
14	Storage Batteries	2.5	2.5	0.01
15	Storage Batteries	3	2.5	0.015
16	Storage Batteries	3.5	2.5	0.02
17	Storage Batteries	4	2.5	0.025
18	Storage Batteries	6	3	0.03
19	Storage Batteries	8	4	0.04
20	Storage Batteries	10	5	0.05
21	Storage Batteries	12	6	0.1

MW: Maximum output, in megawatts, at the one-hour discharge rate, per cubic meter of battery.
Mass: Mass of the battery, in tonnes, per cubic meter
MCr: Price, in millions of credits, per cubic meter

Battery Discharge Rate: The battery's discharge time is the time it takes to drain the battery's charge. The energy output on the table above assumes a discharge time of 1 hour. If the output is lowered, the discharge time is increased, as shown below. Note that some discharge times are only available at higher tech levels.

Output	Time	Price	TL
×15,625	0.0036 seconds	×25	9
×3125	0.036 seconds	×16	8
×625	0.36 seconds	×9	7
×125	3.6 seconds	×4	6
×25	36 seconds	×2	5
×5	0.1 hour	×1	4
×1	1 hour	×1	4
×0.1	10 hours	×1	4
×0.02	100 hours	×1	5
×0.004	1000 hours	×1	6

Capacitors and Homopolar Generators

Like batteries, capacitors and homopolar generators (HPGs) are not means of generating power, but rather of storing it. They are included here because they are usually used in conjunction with some means of generating energy.

Capacitors and HPGs are treated together because both perform the same function. They hold very large amounts of energy (usually for fairly short periods of time) and then discharge the energy very quickly. Capacitors are used at the earliest tech levels, but are quickly replaced (over the course of tech level 8) by HPGs for larger jobs. The table below represents the best performance at tech level and assumes designers will use the most appropriate technology.

Capacitors store electricity directly as an electromagnetic charge; HPGs convert electricity to kinetic energy, storing it in a rapidly spinning flywheel. When a charge is passed through the generator, the flywheel slows rapidly, converting energy to electricity in a powerful discharge.

The following table shows volume of capacitors and HPGs per Mj of stored energy.

Homopolar Generator Energy Capacity

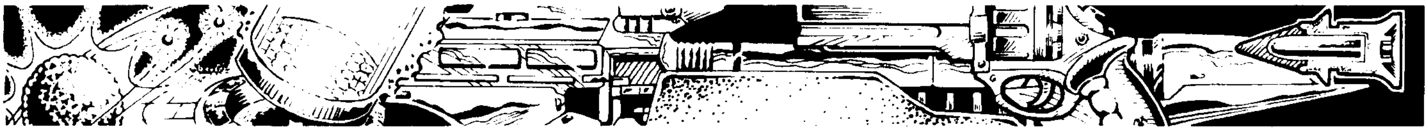
TL	Cubic Meters of HPG per Mj
7	0.25
8	0.125
9	0.1
10	0.08
11	0.06
12	0.05
13	0.045
14	0.04
15	0.035
16	0.03
17	0.025
18	0.02
19	0.015
20	0.01
21	0.005

Vol: Volume, in cubic meters, is equal to megajoules of stored energy multiplied by the value shown on the table.
Mass: Mass in tonnes is equal to volume in cubic meters × 2.
Price: Price, in millions of credits, is equal to volume in cubic meters multiplied by 0.01.

Explosive Power Generators (EPG)

EPG is a means of generating a large amount of power quickly, and it is useful for systems requiring quick surges of power. It was first used to generate large power surges by the Soviet Union in the 1980s as part of their beam weapon research program. By tech level 9, field versions become reasonably practical, and by tech level 12 pulse plasma cartridges (PPC) make it an extremely efficient means of generating quick surges of power.

Each EPG system consists of a homopolar generator and power cartridges. EPG output is generally expressed as pulse energy and measured in megajoules. The homopolar generator is modified slightly to enable it to convert the energy of the power cartridge to electrical energy. This modification increases the cost of the homopolar generator by 10% but has no effect on volume or mass.



Each EPG system requires five seconds (one combat round) to eject a spent cartridge and load a new one, giving the generator a normal cycle time of one pulse per combat turn. This may be increased by building a multiple feed generator (one which holds more than one cartridge at the same time). Each additional cartridge held increases the mass, volume, and price of the generator by 5% and adds 1 to the number of pulses allowed per combat phase.

Explosive power cartridges are designed using the table below. Cartridges are usually cylindrical in shape and are three times as long as their diameter. They usually have a thin metallic covering and a ceramic liner.

TL	*Description*	*Vol*	*MCr*
[illegible]	**Chemical Explosive Cartridge (CXC)**	.001	.001
10	Chemical Plasma Cartridge (CPC)	.0006	.0001
12	**Pulse Plasma Cartridge (PPC)**	.0003	.000025
14	Pulse Fusion Cartridge (PFC)	.0002	.000008
16+	**Gravitic Compression Fusion Cartridge (GCFC)**	.0001	.000004

TL: Tech level of availability

Vol: The volume of the cartridge, in cubic meters, is equal to its output in megajoules multiplied by the value shown on the table.

MCr: The price of the cartridge, in millions of credits, is equal to its output in megajoules multiplied by the value shown on the table.

Mass: The mass of the cartridge, in tonnes, is equal to its volume in cubic meters multiplied by 8.

Dimensions: The dimension [illegible]e cartridge can be calculated using the following formula:

Radius (r) = $0.376 \times \sqrt[3]{Vol}$ (Volume in m³, r in meters)

Diameter = 2r

Length = 6r

ALTERNATE TECHNOLOGY

The above range of power-generating means is a reasonable surface coverage of the most important means of power generation likely to be open to mankind over the next few centuries. One important alternate technology is not included in the Imperial Space technological background, and that is piezo-nuclear fusion, which we present here as an alternative.

Piezo-Nuclear Fusion

This type of fusion may never be available, or it may be available long before any of the above advanced forms of power generation. Piezo-nuclear fusion, more popularly known as "cold fusion," was the subject of some controversial scientific research, and sensational news reporting, in 1989. As far as the public was concerned, it all began with a press conference in March of 1989 in Salt Lake City when Drs. Martin Fleischman and B. Martin Pons announced that they had discovered a cold-process for fusion.

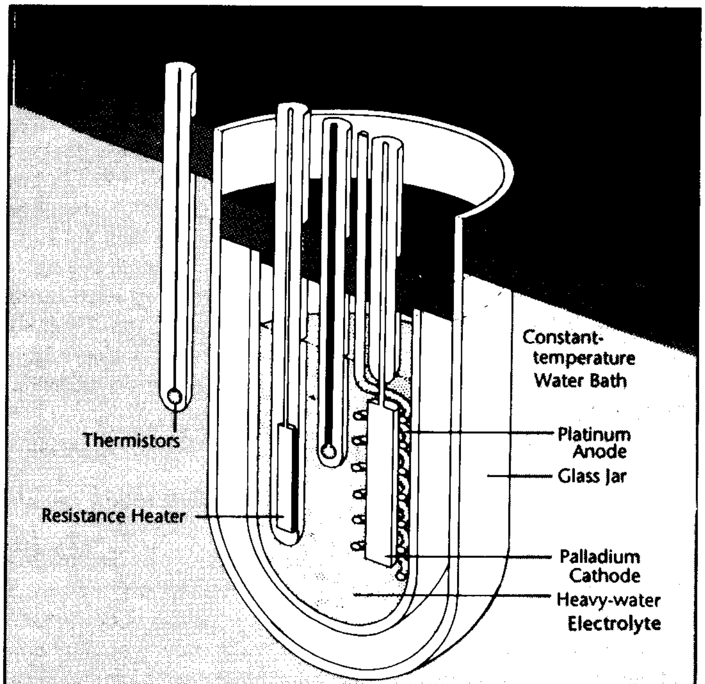
The apparatus used a platinum anode and palladium cathode in a bath of heavy water. Electricity separated the deuterium (a heavy isotope of hydrogen) from oxygen in heavy water and then attracted the deuterium to the palladium cathode. The hydrogen then penetrated the palladium and under high pressure (hence the term *piezo*, or "squeeze") began to fuse, heating the cathode and giving off about four times as much heat energy as was used to run the machine.

Or so they reported. There was an immediate flurry of activity as skeptical researchers across the world made duplicates of the apparatus and hundreds of experiments were soon running, trying to replicate the results reported by Fleischman and Pons. They were, almost without exception, unable to produce any results. Fleischman and Pons were not physicists but were instead electro-chemists and were, it was speculated, unfamiliar with the rigorous experimental protocols necessary for controlling and measuring energy levels this small. The results they reported were well within the error margin of poorly calibrated instruments.

Within months, the verdict of the scientific establishment was in. The cold fusion process was a dead end. The US patent office refused to issue any patents on cold fusion, citing numerous experimental disproofs of the process. Prestigious scientific journals declined to accept further articles on the subject. Research funding disappeared. End of story.

Almost. The statement above—that attempts to replicate the effects experimentally were "almost without exception" unsuccessful—is significant. A few researchers, both in the United States and abroad, achieved results, and these results remained unexplained. A few scientists continued research on the process, with funding from various sources. Some private money was made available. Some researchers controlled discretionary funding and used it to continue cold fusion experiments. At some labs today, even as this is written, experiments continue using funding diverted from other projects.

But the main source of funding has been Japanese. The powerful Ministry of International Trade and Industry (MITI) funded a three-year project beginning in 1992. Fleishmann and Pons are now working in France at a special laboratory provided by IMRA Europe, the European branch of Toyota's scientific research institute. Nippon Telephone and Telegraph (NTT) has also become a major player in the unfolding research.



Cold Fusion Apparatus

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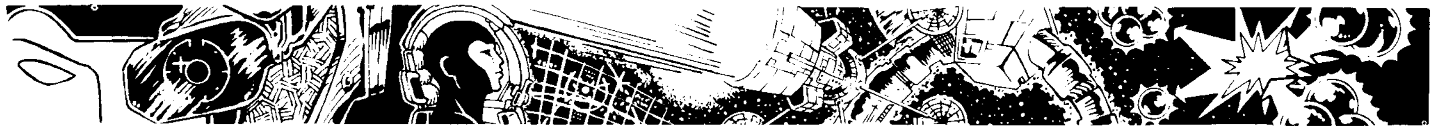


Why had only a handful of researchers been able to replicate the
results of the original experiment when the majority had not?
1 Although the answer isn't certain, one possible explanation lies with
the characteristics of the palladium cathode. Dr. Edmond Storm at
Los Alamos, when examining the cathodes of a number of successful
experiments, noted that the surfaces were smooth and unblem-
2 ished, while the cathodes used in many unsuccessful experiments
were covered with a network of hairline cracks.
Whatever the reason, by the middle of 1991 there had been over
40 successful replications of the original cold fusion experiment, and
3 repeated successes brought more understanding of the procedures
needed to replicate the results on a consistent and predictable basis.
In the autumn of 1992, Dr. Michael C. H. McKubre of SRI Interna-
tional reported that 11 of the previous 12 cold fusion experiments at
4 the SRI labs had produced excess heat. Critics remained skeptical,
and pointed out that there could be no claim of fusion without fusion
byproducts.
When deuterium fuses, it often produces tritium (a triple-heavy
form of hydrogen appearing only as a byproduct of nuclear
5 reactions) and eventually helium-4 (a byproduct of deuterium-
tritium fusion). Without tritium and helium-4 it is difficult to believe
that fusion is taking place. Dr. John Bockris of Texas A&M has now
reported detecting tritium in the heavy-water bath of a cold fusion
6 device which reached 10,000 times the normal background con-
centration. Other researchers have begun to find tritium as well,
and Bockris has reported from 2 to 100 times more helium-4 in the
palladium cathodes of experimental devices than found in samples
7 of palladium from the same production batch but not used in
experiments. Helium-4 residue has also been reported by experi-
menters at the University of Hawaii, the University of Texas, and the
Naval Weapons Center at China Lake, California.
8 Intriguing as these results are, they do not demonstrate conclu-
sively that the helium-4 was actually produced by a fusion reaction.
If fusion is taking place, it should be possible to observe the
production of helium-4 while the reaction takes place. Dr. Eiichi
9 Yamaguchi of NTT's Tokyo basic research lab has apparently done
exactly that. He has taken a piece of palladium, coated on one side
with gold, saturated it with deuterium gas, enclosed it in a vacuum
chamber, and run an electric current through it. After two or three
10 hours, the palladium begins to heat up, generating excess heat for
about 15 minutes, and then releases a burst of helium-4. At the
Nagoya, Japan, cold fusion conference in October of 1992, Yamaguchi
reported: "The amount of produced helium-4 gas was strongly
11 correlated to the excess heat evolution."
But at the same conference, a demonstration of an even more
revolutionary nature was made. Reiko Notoya of the Catalysis
Research Center at Hokkaido University demonstrated an electrolytic
12 cell which put out three times as much energy as it consumed. What
made the demonstration extraordinary was that the cell did not use
heavy water—it used regular (or "light") water salted with potassium
carbonate.
13 What's so extraordinary about that? Controlled fusion, as we
understand it on Earth, requires deuterium to take place, as the
principle fusion reactions are deuterium-deuterium and deuterium-
tritium. (See the sidebar on page 63 on common fusion reactions.)
14 Heavy water is water containing a high concentration of deuterium
in place of conventional hydrogen. Light water, however, contains
no deuterium, and so cannot sustain a conventional fusion reaction.

There seems to be little question that something is going on here. Light water reactions were first reported by Dr. Randall Mills, a private researcher living in Lancaster, Pennsylvania. Since then, and in addition to Notoya's repeated demonstrations, Bush and Eagleton of California Polytechnic have built and operated 19 light water cells and the Bhabha Atomic Research Center of India has run 29 different light water cells. But is it fusion?

Obviously it cannot be fusion as we expect to find it on Earth if there is no deuterium present. However, the light water cells use potassium carbonate as a salt in the water. If a hydrogen nucleus (a single proton) were to fuse with a potassium nucleus, the result would be calcium. Both Bush in California and Notoya in Japan have detected calcium in the electrolyte after the cell has operated for an extended length of time. The excess energy produced by the cell is greater than can be explained by mechanical or chemical reactions. It may not be fusion—but what is it?

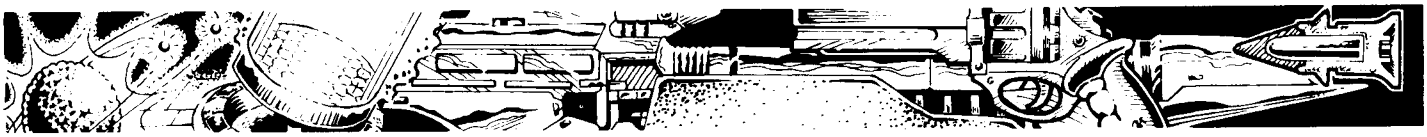
Are we on the verge of a dramatic breakthrough in power-generating technology or will this latest round of experimental results turn out to be scientifically intriguing but of little practical value? It is impossible to tell, but it makes for an interesting optional power source with more than a little basis in fact.

The advantages of piezo-nuclear fusion are staggering. There are no bottom limits on the size of the device. It is lightweight, since it does not need heavy shielding (it is not "hot" in a radioactive sense). It is not dangerous. It can conceivably run off of water, without too much preliminary fuss. For campaigns that require very portable, very long-lived power sources, piezo-nuclear fusion is the perfect answer.

Piezo-Nuclear Fusion (PNF) Power Plants

TL	*Description*	*MW*	*Mass*	*MCr*	*Min Vol*	*Kl/Hour*	*Fuel Type*
9	PNF	0.40	1	0.005	—	0.002	H_2O
10	PNF	0.50	1	0.005	—	0.002	H_2O
11	PNF	0.60	1	0.005	—	0.002	H_2O
12	PNF	0.80	1	0.005	—	0.002	H_2O
13	PNF	1.00	1	0.005	—	0.002	H_2O
14	PNF	1.25	1	0.005	—	0.002	H_2O
15	PNF	1.50	1	0.005	—	0.002	H_2O
16	PNF	2.00	1	0.005	—	0.002	H_2O

MW: Power in megawatts produced per cubic meter of plant.
Mass: In tonnes per cubic meter of plant.
MCr: Price in millions of credits per cubic meter of plant.
Min Vol: Minimum volume, in,cubic meters.
Kl/Hour: Kiloliters (cubic meters) of fuel consumed per hour per MW output.
Fuel Type: Water.



CHAPTER 9
Sublight (Maneuver) Drives

Traveller is scientifically based for much of its technology, but is not strictly speaking a "hard science" game. Instead, it is a reasonable compromise between hard science and science-fiction adventure literature, and this shows up in the mathematics of maneuver drives among other places. This compromise is represented in two aspects of maneuver drive design: thrust requirements and fuel consumption.

Thrust requirements are abstracted by tying thrust energy requirements to hull displacement rather than craft mass. This is an obvious abstraction, but one which is necessary for ease of design. Too many variables affect ship mass throughout the design process, and tying thrust to mass would require you to continually re-design and re-design to get a workable craft. In our opinion, the thrust-to-mass formula is a workable compromise, especially since spacecraft tend to have the same general density. The correction factor for very high mass-to-volume designs takes care of any important distortions.

The fuel requirements for the TL-10 maneuver drive reaction mass are considerably lower than for current or projected technology thrusters. The standard maneuver drive in **Traveller**, which appears at tech level 10, is called the High-Efficiency Plasma Recombustion (HEPlaR) drive, which uses hydrogen as propellant/reaction mass, super-heating it to a plasma state in an ignition chamber and expelling it out the back of the vessel. Note that this is not a fusion rocket, and while the exhaust is a super-heated plasma, it is not radioactive. While the principle of the drive is scientifically sound, its game representation is extraordinarily fuel-efficient.

By way of comparison, take a look at NASA's space shuttle. It is almost all fuel tank, and that is just to boost a modest payload into low Earth orbit (LEO). It is not capable of escaping Earth orbit or conducting interplanetary travel. A first possible alternate universe would be to ignore the HEPlaR maneuver drive and stick with lower-tech drives. Ships built based on that earlier level of thruster fuel efficiency would be much different than **Traveller** ships, and the economics and logistics of interplanetary travel and exploration would be completely different. It would not be the **Traveller** universe, but it would still be an interesting universe.

Maneuver Drive Design

Thrust requires both energy and reaction mass, and so additional fuel tankage will be required as well. Thrust is measured in tonnes. Spacecraft require (for the sake of simplicity) 10 tonnes of thrust per displacement ton to achieve an acceleration of 1G. Spacecraft with a final mass of more than 15 times (rounding fractions to the nearest whole number) their hull rate (in displacement tons) should recalculate their acceleration based on the actual thrust-to-mass ratio, dividing thrust (in tonnes) by mass (in tonnes) to determine acceleration in Gs (round fractions *down*). Most spacecraft, however, will mass less than 15 tonnes per displacement ton.

Aircraft, which are designed around their weight rather than their volume, require 1 tonne of thrust per tonne of craft weight to achieve 1G of acceleration. Most aircraft, particularly at early tech levels, will have less than 1G of acceleration.

Thrust is produced in one of two ways: either by means of a thrust agent added to an existing power plant or by means of a dedicated self-contained thruster.

A thrust agent is a mechanical means of converting the power produced by a power plant (either electrical power from a dynamo, heat from combustion, or the physical power of a turning drive shaft) into thrust.

Propellers: A propeller is the most common thrust agent at lower tech levels.

Note that aircraft engines used to drive propellers have only half the volume per output power as conventional engines, for three reasons. First, virtually no volume is used for maintenance access. The next time you open the hood of your car, look at how much of the volume of the engine compartment is consumed by open space. This open space serves a purpose—maintenance access. If the engine is too compactly installed, mechanics cannot get to various parts of the engine to check them or replace components. An aircraft engine, however, is mounted at the end of the fuselage or in a wing nacelle, and in either case no internal volume is used to provide access. Instead the entire engine is accessible from outside the aircraft. Second, the engine drives the propeller directly without need for any complicated drive shafts, differentials, etc. Third, there is less volume and weight consumed by cooling apparatus. Many aircraft engines are air-cooled, and even liquid-cooled engines gain considerable efficiency from the high speed air flow.

Because aircraft design is based on weight and does not use volume, the only impact of this rule on aircraft design is to cut the final weight of such a propeller-driving engine in half. However, a designer may wish to install a propeller onto a lift vehicle, in which case the one-half volume rule would apply, which would also reduce the engine's final mass by half.

The characteristics of propellers are shown below. Propellers that are driven by turbine engine (TL-7 gas turbine or TL-8 MHD turbine) are known as turboprops.

Propellers

TL	*Th*	*MCr*	*MaxP*	*Airframe*
4	0.5	×1.5	0.6	Simple
5	0.7	×2	1.2	Fast subsonic
6	0.8	×2.5	1.4	Fast subsonic
7	0.9	×2.5	1.6	Fast subsonic
8	1.0	×2.5	2.0	Fast subsonic

TL: Tech level of first availability

Th: Thrust in tonnes per MW of power

MCr: Propellers have no price of their own, but instead increase the cost of the power plant to which they are mounted. The price of the power plant is its normal price multiplied by the value shown on the table. This price modifier is applied to the full volume of engine *before* it is cut in half for aircraft.

MaxP: Maximum power per engine.

Airframe: The fastest airframe type on which the thrust agent may be used.

Volume: Aircraft power plants used to drive propellers have their volumes multiplied by 0.5.

Mass: Propellers themselves do not alter the mass of the power plant to which they are attached. (Note however that mass is calculated based on a smaller overall volume, which will make power plants only half as massive as normal.)

HEPlaR: The other thrust agency, high efficiency plasma recombustion (HEPlaR), becomes available at tech level 10. It may be added to any power plant by adding a heat exchanger recombustion chamber to the plant. Hydrogen is injected into the recombustion chamber and the power generated by the engine heats the hydrogen to a plasma state. The plasma is then released as a high velocity stream of reaction mass, providing thrust.

HEPlaR requires a recombustion chamber of 0.1 cubic meters in volume per megawatt of power devoted to thrust, and in turn generates 20 metric tonnes of thrust per megawatt. The recombustion chamber masses 1 tonne per cubic meter of recombustion chamber and costs 0.001 million credits per megawatt of power. It consumes 0.25 cubic meters of liquid hydrogen (LHyd) per hour per megawatt of power and may be used on any type of airframe. Hull surface area (used for spacecraft only) in square meters is equal to thrust (in tonnes) ÷ 200.

Self-Contained Thrusters: As an alternative to thrust agencies coupled to separate power plants, some power plants, such as turbojets and rockets, are much more efficient at generating direct thrust than electrical energy. These power plants have their output measured in terms of tonnes of thrust rather than MW. These plants are called self-contained thrusters.

Self-contained thrusters have auxiliary generators which generate electrical power for other systems. Generator output, in MW, is equal to thrust, in tonnes, times 0.02.

Self-Contained Thrusters

TL	*Type*	*Th*	*MCr*	*MaxT*	*FC*	*FT*	*Airframe*
5	Turbojet	3	0.15	6	0.5	HCD	Super
5	Ramjet	6	0.25	10	2.5	HCD	Hyper
5	LF Rocket	6	0.25	15	7.5	LRF	Hyper
5	SF Rocket	*	—	10	10.5	SRF	Hyper
6	Turbojet	3.6	0.15	6	0.25	HCD	Super
6	Afterburners	×1.5	×1.1	—	×2	HCD	—
6	Ramjet	7.5	0.30	12	2	HCD	Hyper
6	LF Rocket	7.5	0.30	1500	7.5	LRF	Hyper
6	SF Rocket	*	—	1000	9	SRF	Hyper
7	Turbofan	3.9	0.175	6	0.12	HCD	Super
7	HF Rocket	7.5	0.30	—	4.5	HRF	Hyper
7	SF Rocket	*	—	2500	7.5	SRF	Hyper
8	HBT	3	0.0625	20	0.1	HCD	Super
8	SF Rocket	—	—	5000	5.5	SRF	Hyper
8	AZHRAE (TJ)	3.6	0.50	—	0.5	HCD	Hyper
	AZHRAE (RJ)	6			2	HCD	
	AZHRAE (Rckt)	9			4.5	HRF	
9	EAPlaC	—	×2	100**	0.225	[illegible]RF	Hyper
9	Fusion Rocket	9	0.35	100**	0.000[illegible]	LHyd	Hyper

TL: Tech level of first availability

Type: Description of thruster. HBT = High Bypass Turbofan SF = solid fuel. LF = Liquid Fuel. EAPlaC = Electrothermal Augmented Plasma Combustion.

Th: Thrust, in tonnes, per cubic meter of engine.

*Note that solid fuel rockets have no engine volume *per se*; the fuel volume is the engine volume. Solid rocket fuel (SRF) mass in tonnes equals its volume in cubic meters. See FC note below to calculate solid rocket thrust.

MCr: Price, in millions of credits, per cubic meter of engine. Note that solid fuel rockets have no engine price beyond the fuel. The fuel is in effect the engine. Solid fuel costs twice its normal amount for EAPlaC engines.

MaxT: Maximum thrust, in tonnes, of a single engine. For more thrust, install multiple engines. **The values shown for the EAPlaC and fusion rockets are the *minimum* thrust ratings per engine.

FC: Fuel consumption, in tonnes, per hour per tonne of thrust. To determine volume in cubic meters, multiply by the volume of the fuel type. For solid rockets, simply pick a fuel mass. Divide the mass by the FC value. The result is thrust in tonne-hours. Select either the thrust or the duration, and the other is determined from that. For example, 18 tonnes of TL-6 SF rocket fuel could have 2 tonnes of thrust for one hour, 4 tonnes for 30 minutes, 1 tonne for two hours, or any other combination desired, as limited by the maximum allowed thrust (MaxT column).

Size Efficiency: Solid-fuel rockets with less than 500 kg of propellant (fuel) mass suffer from inefficient fuel combustion. To determine the fuel consumption inefficiency of a solid-fuel rocket, divide 500 by the fuel mass (in kilograms). The result is the final fuel use multiplier. Multiply the calculated fuel consumption of the engine by this number. However, any multiplier less than 1 is treated as 1 and any multiplier greater than 10 is treated as 10.

FT: Fuel type burned. Note that at TL 7+, any thruster which burns hydro-carbon distillates (HCD) may be designed to burn liquid hydrogen (LHyd) at no cost or energy penalty (the penalty is the vastly greater volume needed by LHyd).

Fuel Volume: The volume of fuel (in m³) used per hour per tonne of thrust is equal to the mass (in metric tonnes) consumed per hour per tonne of thrust divided by the density of the fuel, as shown below.

Type	*Density*	*Price*
HCD (Hydrocarbon Distillates)	1	250
LRF (Liquid Rocket Fuel)	1	1000
SRF (Solid Rocket Fuel)	1	2000
HRF (Hydrogen Rocket Fuel)	.3	1000
LHyd (Liquid Hydrogen)	.07	35

Fuel Price: In credits per cubic meter (m³).

Air-Breathing Engines: Air-breathing engines include turbojets, ramjets, turbofans, and AZHRAE when operating in its turbojet and ramjet modes. These are subject to the same limitations in vacuum, thin and tainted atmospheres as air-breathing power plants are, and have compressors, filters, and liquid oxygen added using the same rules. See "Atmospheric Performance" on page 64. An AZHRAE-equipped aircraft can get around these restrictions simply by using its rocket mode at all times. Note that all rocket fuels (LRF, SRF, and HRF) contain their own oxidizers and ignore these air-breathing penalties.

Airframe: Fastest airframe (for aircraft design) or chassis configuration (for vehicle design) type on which the thruster may be used. Super = Supersonic, Hyper = Hypersonic.

Mass: All self-contained thrusters mass 1 tonne per cubic meter.

Surface Area: When installed on spacecraft (only), air-breathing self contained thrusters (turbojets, turbofans, ramjets, AZHRAE) take up surface area in square meters equal to thrust in tonnes ÷100. Non-air breathers take up area equal to tonnes of thrust ÷200.

Afterburners: An afterburner (also called *reheat*) is available at tech level 6. It may be added to any turbojet or turbofan engine. When in use, it increases thrust by 50% and fuel use by 100%. An afterburner increases engine volume (and thus price and mass) by 10%.

Rockets: Rocket fuel consumption includes both fuel and oxidizer (usually liquid oxygen).

Ramjets: Ramjets must reach a speed of 800 kph before the ramjet will start. This is usually achieved either with a booster rocket, but is sometimes accomplished by carrying the aircraft aloft attached to another aircraft. This type also includes the scramjet (supersonic combustion ramjet).

AZHRAE: Advanced Zero speed to Hypersonic Regime Air-breathing Engines include a wide variety of exotic engine types designed, unlike turbine engines and ramjets, to function at low (takeoff and landing) speeds, where they function as turbojets, at hypersonic speeds for high-altitude operations, where they function as ramjets, and in suborbital/orbital insertion profiles, where they close off their intakes and function as rockets. These include applications of such concepts as PDWE (Pulsed Detonation Wave Engines), RBCC (Rocket-Based Combined Cycle) ramjets, SER (Supercharge Ejector Ramjet), ATR (Air-Turbo-Ramjet or turbo-rocket), TSHE (Twin-Spool Hydrogen Expander) engines, and rocket fans. As a group, these are also referred to as "ducted rockets," and are the preferred engines for trans-atmospheric craft (TAC). The first AZHRAE line gives the tech level, weight, cost, airframe characteristics for the entire engine, and the thrust and fuel characteristics when operating in turbojet mode. The second line gives the thrust and fuel characteristics of the same engine when operating in ramjet mode. The third line gives the thrust and fuel characteristics in rocket mode.

Fusion Rocket: A fusion rocket is not much more than a fusion reactor with a steady stream of hydrogen going in and a hole in one end. Super-heated hydrogen plasma expelled at tremendous velocities forms the reaction mass. Because of the nature of the drive, the exhaust is extremely dangerous. It cannot be used within planetary atmospheres.

Ships passing through its hydrogen wake will generally do so quickly enough that they will not suffer any ill effects unless within very short range (~200km, referee's discretion). In this case, each crewperson must make a Difficult roll versus Constitution to avoid incapacitation by radiation (Average if wearing radiation-protective clothing) and each system on the ship suffers a minor damage result.

All crew will require blood and bone-marrow therapy over the next several months to avoid long-term health problems.

ALTERNATIVE TECHNOLOGIES

1. Realistic Thrusters

Our first alternative technology is "realistic" thrust and fuel requirements. This is not so much an alternative technology as it is the abandonment of HEPlaR thruster technology and reliance on the more primitive rocket thrusters. Even these fuel requirements have been simplified for playability, but they come much closer to duplicating the sorts of real-world design trade-offs current and near-future spacecraft designers face. While these can be used as described in the tables above, we recommend a slightly different method of calculating Gs of thrust.

Calculating Gs: Craft with the huge fuel requirements listed above require a separate mechanism for calculation of Gs, because the mass of the vessel is continually changing as fuel is consumed. As a result, thrust is measured not in Gs, but in tonnes of thrust (the thrust necessary to give 1 tonne of mass an acceleration of 1G).

Once the craft is designed, calculate its G value when fully loaded with fuel, and then calculate its G value at each 10% increment of fuel consumption. G value is calculated by dividing the thrust in tonnes by the total mass of the craft (including fuel) in tonnes. By dividing the total fuel endurance of the craft by 10, you can arrive at a useful approximation of its performance, which may, for example, be 10 minutes at 1.2Gs, 10 minutes at 1
1.4Gs, 10 minutes at 1.6Gs, etc.

Next, determine how much thrust in G-hours each 10% increment of fuel generates. To do so, divide the minutes of the increment (10 minutes in the example above, but it can be any 2
length) by 60. The resulting value is multiplied by the G value of that increment to determine the total G-hours generated.

Using the example above, the increment is 10 minutes. Dividing 10 by 60 yields a value of 0.167. Therefore, the first 10-minute increment 3
will generate 0.2004 G-hours (which we'll round down to 0.20), the second will generate 0.2338 G-hours (rounded down to 0.23), the third will generate 0.2672 G-Hours (rounded up to 0.27), etc.

The total G-hours of thrust required to reach orbit can be found 4
by consulting the Time to Orbit table on page 225 of the basic game and looking at the Fuel G-Hrs column. Progressively, add the G-hours of thrust from each 10% fuel increment to find how much fuel is burned to reach orbit. Smaller increments of fuel 5
(1%) can be assumed to be one-tenth of the value of a single 10% increment, rather than calculating the slight differences in thrust between the start and end of the increment.

For example, the ship above is taking off from a size 8 planet 6
(say, Terra), and requires 0.64 G-hours to reach orbit. After the second increment, it has generated 0.43 G-hours, and does not require all 0.27 G-hours of the third increment to reach orbit. It needs 0.21, with is about 80% of the third increment. Therefore 7
after 2.8 increments (28 minutes), the craft has reached orbit and has 2 minutes of its third fuel increment remaining.

No CG Lifters: All of the above is quite correct assuming the craft has CG lifters to negate the gravitational pull of the world 8
and can devote all of its thrust to reaching orbital velocity. If not, part of thrust is consumed just counteracting the pull of the planet, not thrusting it up. If the craft does not have contra-grav lifters, subtract the world gravity from the thrust value of the craft when calculating its effective thrust between the surface of the world and orbit. If the craft has an airframe hull, subtract 0.5x world gravity from the thrust value. Once in orbit, ignore the effects of planetary gravity on thrust and use the 100 Diameters Travel Times 10
and Interplanetary Speed tables (pages 225 and 227) normally.

Multiple Stages: Most rocket-propelled craft use multiple stages to reach orbit. As each stage exhausts its fuel, it is jettisoned to fall back to the planet surface. (If the planet has an atmosphere 11
code of 4 or higher, the jettisoned stage may be recovered and reused.) Stages are numbered in the order in which they are jettisoned (thus the First Stage is the first one jettisoned).

A multiple-stage spacecraft must have its performance calcu- 12
lated separately for each different configuration. For example, consider a three-stage rocket. The first configuration is with all three stages and powered by the first stage engine. The second configuration is with only the second and third stages and 13
powered by the second-stage engines. The third and final configuration is only the third stage powered by its own engine. Each of these configuration would have different gross weights, different thrusts, and thus different G ratings. 14

2. Ion Drives

This method of thrust is not really an alternative technology. It might better be described as a marginal technology. Ion drivers

can be freely added to any **Traveller** campaign without fear of doing damage to it. They are not discussed in the main section of the rules because most games will have superior technologies which will render them superfluous. That is not to say, however, that isolated pockets of intelligent life might not be forced to use ion drives, or that even an advanced space-faring civilization might not find some use for them.

Ion drives create thrust by electrochemically reducing fuel to a stream of charged particles (ions) which creates a very low thrust. Ion engines are usually made up of a large number of very low-thrust units mounted in clusters. The advantages of these drives are their endurance, low power requirements, and reliability. But the low thrust generated by this sort of drive limits its utility to moving low-priority cargos around inside a star system. Interplanetary trips by ion drive typically take months rather than days or weeks.

The fuels used for this system are known as "ionizates." This one term includes mercury, cesium, and a variety of liquified noble gases (argon, neon, krypton, etc.) The values given for this fuel represent an average since some of these substances would be heavier than indicated and others lighter. Ionizates are found as trace elements in most Earth-like atmospheres, but are more frequently gathered from gas giants and their moons, which sometimes boast large concentrations of noble gases.

Design: Each cubic meter of ion drive requires .03MW of power from a separate power plant and generates .003 tonnes of thrust, consuming .0000067 cubic meters of ionizates per hour. The drive masses 1 tonne and costs MCr0.013 per cubic meter of drive.

Ionizates mass 1.5 metric tonnes and cost MCr0.0001 per cubic meter.

Because of the low power requirements, ion drive ships are often equipped with large solar panels and draw on solar energy to power their drives.

3. Dean Drive

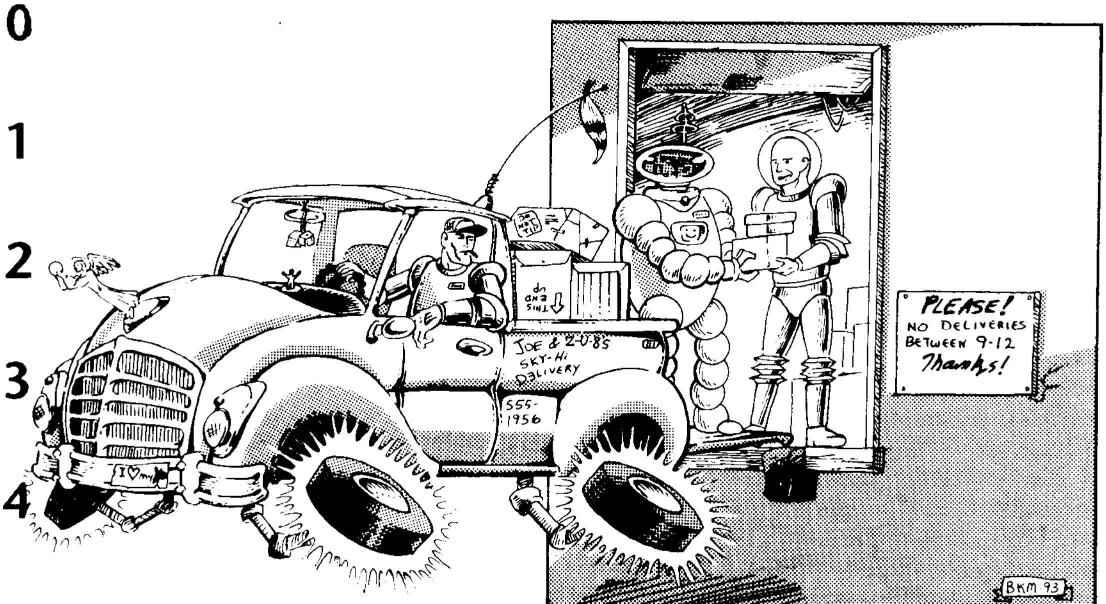
Over 30 years ago, John W. Campbell popularized a supposed invention by a fellow named Dean. His invention, the Dean Drive, was a simple device which converted rotational momentum to linear momentum. Never mind that that violated the laws of conservation of momentum, he claimed he could do it. He wasn't able to convince the patent office, however, and never could provide a convincing public demonstration of the device, and so interest faded.

But had the drive worked, it would have had an extraordinary effect on travel, and is a perfect substitute for both CG and all thrusters. It is a reactionless means of efficiently converting electricity to thrust. The electric motor (or any other sort of engine) spins a dense shaft, thus creating rotary momentum. The Dean Drive (or, for purposes of the game, the Dean Converter) then changes this rotary momentum to linear momentum, or thrust. The standard illustration of a Dean Drive at work shows a cargo truck unloading at a second-story window, its Dean Drive converting the momentum of its drive shaft to upward momentum.

Very nice. But why does this violate conservation of momentum? Think of the solar system as a closed system spinning with a fixed average velocity. Everything in it is spinning, although at different velocities, and each of the individual bodies has angular momentum. The sum of the angular momentum of all of the individual components of the solar system equals the total angular momentum of the system.

Now, suppose something changes velocity. Assuming that its mass stays the same, its momentum changes, since momentum is a combination of mass and velocity. Does this change the total momentum in the system? No, it doesn't, because the only way things can change velocity within the system is to change the velocity of something else at the same time. Remember, "for every action there is an equal and opposite reaction." So if a rocket accelerates in one direction, reaction mass (the rocket exhaust) is accelerating in the opposite direction, and with equal force, so the net change in momentum in the system overall is exactly zero. The sum of the momentum of all the bodies in the system is still equal to exactly the same total.

But that is not true with a Dean Drive. The Dean Drive manages to change the momentum of the object it accelerates without changing the momentum of any other component of the solar system (or the galaxy, or the universe), and thus alters the total momentum in the system, hence violating the law of conservation of momentum. For the Dean Drive to work, our current understanding of the physical universe has to be seriously flawed.



On the other hand, who is to say, especially in a science-fiction game, that our understanding of the physical universe *isn't* seriously flawed? Certainly not us, and in that spirit we offer the Dean Converter as an alternative to conventional thrusters.

Design: The Dean Converter is an extremely efficient reactionless drive which requires only electric energy to operate. Each cubic meter of Dean Converter machinery converts 1 megawatt of power to 100 metric tonnes of thrust. There is no lower or upper limit on the

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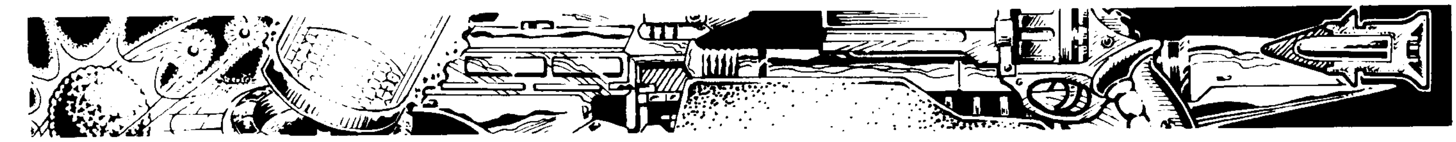


size of Dean Converter machinery. Each cubic meter of Dean Converter machinery masses 2 metric tonnes and costs MCr0.1. Tech level of initial availability is left entirely up to the referee.

4. Thruster Plates

Maneuver drives in previous editions of **Traveller** were explained as related to the same body of theoretical physics which allowed artificial gravity and damper fields, which is to say manipulation of gravitational force and the strong nuclear force. Artificial gravity was defined as a force which could either push or pull and which acted on the gravitational field of a mass. Clearly, this would not be an efficient means of travel outside of a gravity well, and so a further advance was postulated which allowed the force generated by the drive to push on the actual thruster plates of the ship itself, propelling it through space and achieving a true reactionless drive.

The problem with this approach is that it runs into the same wall as does the Dean Drive (see above). A drive can be reactionless without violating the law of conservation of momentum if it moves a craft around without changing its velocity. ("Huh?" No, this is not a typo. Consider the jump drive. It moves a ship from point A to point B, and does so without pushing it through the intervening space. It is a reactionless drive, but when the ship arrives at point B it has exactly the same momentum in the form of a vector as it had when it left point A. Thus, its velocity has not changed, nor has the momentum in the system overall been altered.) But a reactionless drive which changes the physical velocity of the craft shatters the law of conservation of momentum.

As indicated in the discussion of the Dean Drive, referees of science-fiction games should not be too shy about breaking the laws of physics. The *fiction* in the genre's name gives you license to do so. But the *science* in the genre's name requires you to at least know what you are doing and have a pretty good reason for doing it. In the case of reactionless drives in general, the best reason is that the sort of campaign you are running requires a cheap, efficient, no-hassle way of getting from here to there. It is best suited to campaigns with a strong space-opera flavor. (Don't sneer; those can be the most fun sometimes.)

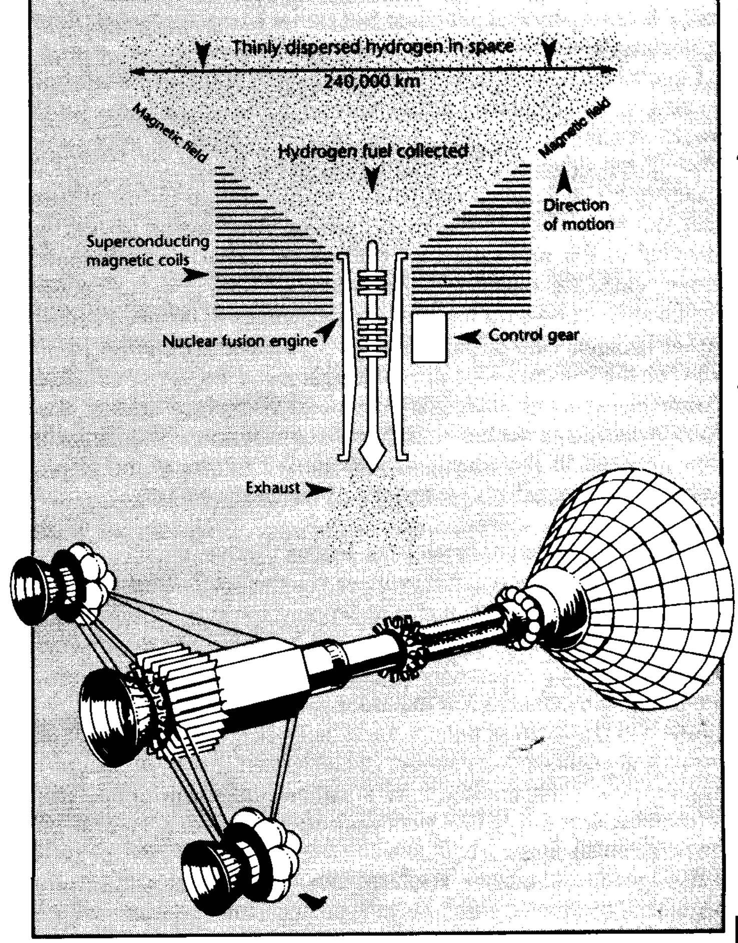
Design: Thruster plate technology becomes available around tech level 11 (due to the fact that it is tied closely to many of the other theoretical breakthroughs that occur at about that time). Each cubic meter of installed thruster plate drive generates 40 metric tonnes of thrust, masses 2 tonnes, requires 1 MW of power, and cost MCr1. Surface area (used by spacecraft only) in square meters is equal to thrust in tonnes ÷ 200.

5. Bussard Hydrogen Ram

The Bussard ram (so called after Dr. Robert Bussard, who first proposed it in 1960) was once thought to be scientifically and technologically feasible. Greater knowledge of the workings of superconducting magnets and deuterium fusion now seem to have relegated the Bussard ram to the arena of science fantasy. Even if technologically feasible, Bussard rams are not generally used in the **Traveller** universe because jump drives make them irrelevant. This is because Bussard rams are drives designed to bridge the distance between stars at sublight velocities.

The biggest single problem in tackling interstellar distances is fuel. You have plenty of distance between stars in which to accelerate and get up to really healthy fractions of light speed, but as hard as it is to find room for several G-hours of acceleration, imagine trying to carry several G-*years* of fuel—then imagine slowing back down.

Bussard Ram



The Bussard ram beats this problem by using the thin interstellar atmosphere for fuel. What atmosphere, you say? You thought space was a vacuum? Well, for most purposes it is. There is insufficient atmosphere to have any measurable pressure, but there is the odd hydrogen atom floating around. The problem is gathering enough of "the odd hydrogen atoms" (one or two atoms per cubic centimeter of space) to constitute useful fuel for a hydrogen fusion rocket.

The answer is twofold. First, the faster the ship moves, the more volume of space it passes through, and thus the more atoms of hydrogen it can collect for fuel in a given amount of time. Second, if the ship has a sufficiently large fuel scoop, it can gather a larger volume of hydrogen. In round numbers, a ship needs a scoop area of about 35,000 square kilometers per metric tonne of ship's mass per G of constant acceleration, and needs to reach about 1% of light speed before it is scooping enough hydrogen for the ram to sustain a continuous fusion reaction. By way of illustration, this means that a fairly tiny ship, of about 1000 tonnes mass, would require a scoop over 2000 kilometers in diameter.

It is clearly not feasible to build a solid scoop that large, given the weight limitations of the craft. The answer is instead to use a

network of superconducting magnets as the base of the scoop and use their magnetic fields as the scoop itself. That is, the ship's
1 scoop is not a physical presence but rather a large magnetic field projecting from the front of the ship.

To accelerate the ship to 1% of light speed (3000 kilometers per second, or 180 **Brilliant Lances** hexes per 30-minute game turn)
2 would require a separate drive, probably either a very fuel-efficient ion drive or a thermonuclear pulse drive.

Design: The Bussard ram uses a conventional fusion rocket coupled to an electromagnetic scoop. The fusion rocket is
3 identical to the one noted on the self-contained thruster table above, with the exception that while operating in ramscoop mode, it consumes no fuel. Each cubic meter of installed fusion rocket requires one cubic meter of superconducting magnetic
4 coils for the ram scoop. Magnetic coils mass 1 tonne per cubic meter and cost MCr0.5 per cubic meter. Surface area of the thruster in square meters equals thrust in tonnes + 200. Surface area devoted to the scoop is equivalent to 25% of the ship's
5 surface area (i.e., all of the surface of hit locations 1-5).

6. Daedalus Thermonuclear Pulse Drive

The Daedalus drive was first proposed by the British Interplanetary
6 Society in the mid-1970s, and in its simplest terms consists of a fuel tank and an ignition chamber. Hydrogen fuel is fed into the ignition chamber and super-heated by lasers or high-energy electron beams. The resulting thermonuclear explosion pushes the ship forward.

7 Fuel is in the form of pellets. Each fuel pellet masses about 1.5 grams and consists of a mixture of deuterium (heavy hydrogen) and helium-3, all enclosed in a superconducting shell. The detonation of a single fuel pellet produces between 15 and 20
8 tonne/seconds of thrust.

The ignition chamber and supporting electronics (electron guns and magnetic fields which protect the ship as well as directing thrust) give the engines a lower thrust-to-mass ratio
9 than a conventional fusion rocket, but provide fuel efficiency about one order of magnitude higher. For long interstellar voyages, fuel efficiency is critical.

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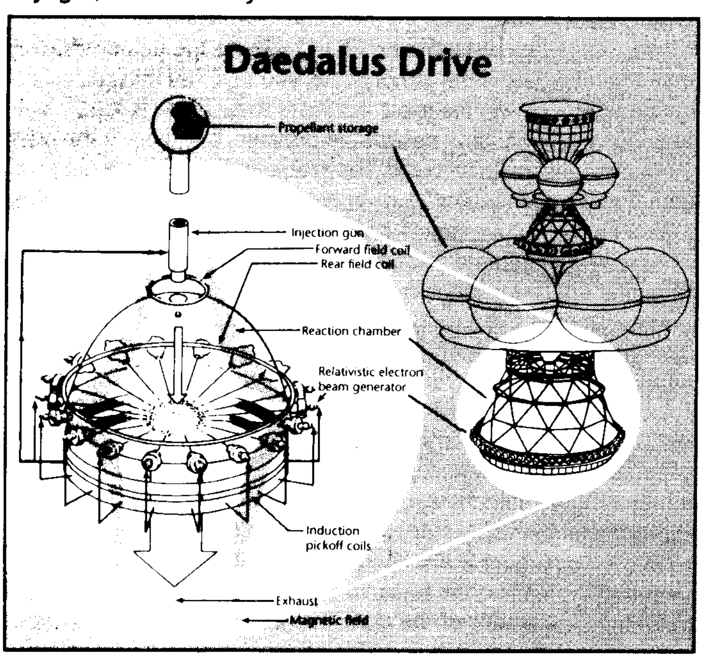


Design: Daedalus drives are available at tech level 9 and above. Each cubic meter of engine masses 1 tonne, generates 1.5 tonnes of thrust, and consumes 0.0005 tonnes of fuel per hour. Price is MCr0.5 per cubic meter of engine. Surface area of the ignition chamber in square meters is equal to tonnes of thrust + 200. Because of the exacting manufacturing requirements, fuel for the Daedalus drive costs 100 times as much as conventional hydrogen fuel.

7. Solar Sails

Solar sails are extremely leisurely ways of moving around in a solar system. Solar sails are extremely large, lightweight reflective surfaces which rely on the physical pressure of photons in sunlight for thrust.

The almost-universal first instinctive reaction to solar sailing is that the sail can only carry the craft away from the sun, but in fact the sail can be used to tack (to borrow a yachtsman's term) and use thrust to move back toward the sun. How is this possible?

The solar sail is not a stationary object with straight-line vectors. As it is an object in the solar system, it is in orbit (although it may be a very distant orbit) around the sun. As the sail can be angled, it can be used to either add to the orbital velocity or decrease orbital velocity. As orbital velocity increases, the sail assumes an orbit farther away from the sun, and so moves away from it. As orbital velocity decreases, however, the sail assumes a closer orbit and so actually moves toward it. In both cases, however, movement is gradual due to the extremely low thrust generated by the sail.

The pressure of sunlight on the sail inside the habitable zone of a star system generates 0.5 kg of thrust (or 0.0005 tonnes) per square kilometer of sail. As a square kilometer of solar sail, complete with its rigging, weighs 0.5 tonnes, or 1000 times as much as the thrust generated, and that is without any payload, it is immediately obvious that the sail generates minute acceleration. However, that minute acceleration is constant and free (with respect to fuel), and so is very economical for long voyages if you aren't in any particular hurry.

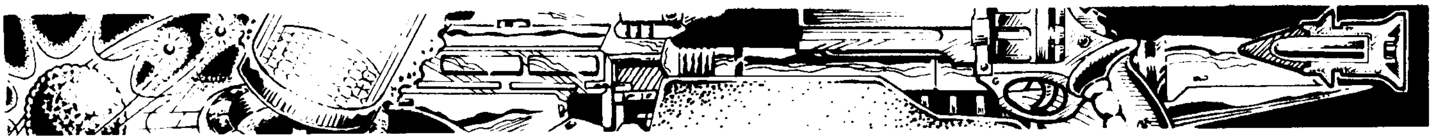
To calculate G-hours of thrust generated by the sail, divide the total mass of the spacecraft (including the mass of the sail) by the sail's thrust in tonnes (square kilometers of sail area multiplied by 0.0005). The result is the number of hours of acceleration needed to achieve one G-hour of acceleration.

Thrust is multiplied by 10 in the star's inner zone and by 0.01 in the star's outer zone.

Solar Sails

TL	*Mass*	*MCr*
8	0.5	.001
9	0.4	.0005
10	0.3	.0004
12	0.2	.0003
14	0.1	.0002
16	0.05	.0001

TL: Tech level of first availability.
Mass: Mass, in tonnes, per square kilometer of sail surface.
MCr: Price, in millions of credits, per square kilometer of sail surface.
Vol: Stored volume of 1 square kilometer of solar sail is 10 cubic meters.



CHAPTER 10
Lifters

By lifters we mean unconventional methods of levitating a craft (conventional means including lifting gasses, airframes, rotors, and conventional thrusters). The standard lifter used in **Traveller** is the contra-gravity device found on most spacecraft. Several alternative lifters are described later in the chapter.

It should be noted that two other alternative lifter technologies—the Dean Drive and thruster plates—are included in the Sublight Drive chapter (Section 9) as they are also useful for interplanetary travel.

Contra-Grav

Many spacecraft have contra-grav (CG) lifters as fuel-efficient means of landing and taking off from a planet surface, and CG lifters are also used on grav vehicles. CG lifters do not provide thrust and so cannot physically lift a craft or vehicle. Instead, they neutralize most of the gravitational attraction of a world (approximately 99% of gravitational force, beyond which power use becomes prohibitive). This, combined with atmospheric pressure, will provide buoyancy in very dense atmospheres and so allow the craft to float at low altitudes, but usually CG is used only as an adjunct to the ship's thrusters. By neutralizing most of a world's gravitational field, a ship with only 1G of thrust can still escape the world's gravity well.

Note that CG does not reduce the mass of the ship, and so a 1G thruster will still only produce 1G of acceleration; CG merely negates the gravitational vector of a world.

Surface area below (used for starships only) includes space for landing gear/skids.

CONTRA-GRAV LIFTERS

Type	*TL*	*MW*	*Kl*	*Mass*	*MCr*	*Min Vol*
Standard	**9**	**0.3**	**0.5**	**0.4**	**.02**	**1**
Improved	10	0.2	0.3	0.3	.025	0.3
High Efficiency	**12**	**0.1**	**0.3**	**0.2**	**.03**	**0.03**

TL: Tech level available.

MW: Power requirement per displacement ton (14 kl) of hull.

Kl: Volume, in kiloliters (cubic meters), per displacement ton (14 kl) of hull.

Mass: Mass, in tonnes, per displacement ton (14 kl) of hull.

MCr: Price, in millions of credits, per displacement ton (14 kl) of hull.

Min Vol: Smallest installation volume allowed.

Surface Area: 10% of total hull surface area, used for spacecraft only. Surface area is not calculated separately for lift vehicles, as it is subsumed into their standard surface area calculation.

1. Ducted Fans

Although ducted fans are currently capable of lifting small payloads, the technology presented below relies on material breakthroughs that allow much stronger fan blades as well as some minor bending of aerodynamic laws.

Ducted fan lifters work on principles similar to those used by helicopters. Instead of a single (or sometimes twin) large-diameter rotor, however, ducted fan craft have a larger number of smaller multiple-blade propellers, almost identical to turbine fans, imbedded in the craft's hull. These high-speed fans suck air in from overhead intakes and vent it beneath the craft, providing lift. The power plant also injects fuel directly into the air flow and combusts it, effectively turning the fan assemblies into very large diameter turbofans. As with helicopters some of this lift can be vented for thrust.

Because of the ability to angle atmosphere flow inward from the ducts along the outer edges of the vehicle, ducted fan lifters create a ground effect cushion directly under the vehicle when operating at very low altitude (less than four or five meters), and it is at these altitudes that ducted fan craft are most efficient. Above these altitudes, lift declines dramatically and increasing amounts of engine thrust have to be switched to lift instead of thrust.

Design: Ducted fan technology becomes available at tech level 8, when light composites make stronger fan blades possible. The thrust characteristics of ducted fan assemblies are shown below. Thrust generated by ducted fans may be devoted to either lift or lateral thrust (and may be switched from one to the other during flight). Speed is calculated based on lateral thrust. Thrust devoted to lift must be equal to the mass of the vehicle. All thrust devoted to lift at NOE altitude, however, produces double lift. That is, each tonne of thrust produces 2 tonnes of lift.

Characteristics of ducted fan assemblies are shown below.

TL	*Thrust*	*MCr*
8	**1**	**0.5**
10	1.5	0.4
12	**2**	**0.3**
14	2.5	0.2

TL: Tech level of first availability.

Thrust: Thrust, in tonnes, is equal to the power plant output devoted to thrust, in megawatts, multiplied by the value shown on the table.

MCr: Price, in millions of credits, per cubic meter of fan assembly.

Vol: Volume, in cubic meters, is equal to the power plant output in megawatts devoted to the ducted fan multiplied by 0.5.

Mass: Mass of the fan assembly in tonnes is equal to its volume in cubic meters.

Afterburn: All ducted fans have the ability to inject fuel and burn it in the air stream, which works similar to the afterburner on a jet. This increases thrust by 50% and increases fuel consumption by 0.2 kiloliters per hour per MW of power devoted to thrust. Afterburners are generally used only at high altitudes or for bursts of speed.

2. Maglev

Current magnetic levitation (maglev) research is concentrated on making near-frictionless trains, which ride on (or actually over) magnetized rails. This is not what we are talking about here, however. Maglev here is defined as a means of free levitation by riding the magnetic field of a planet. One obvious limitation of this form of lifter is that it is useless on a world which does not have a magnetic field, or which has a very weak one.

Aside from the fact that they function only in a strong magnetic field, maglev lifters are built and function in the same way as CG lifters.

Maglev Lifters

TL	*MW*	*Kl*	*MCr*
10	0.3	0.5	.02
12	0.25	0.4	.025
14	0.2	0.3	.03
16	0.15	0.25	.035
18	0.1	0.2	.04
20	0.05	0.1	.05

TL: Tech level available.

MW: Power requirement, in megawatts, per displacement ton (14 kl) of hull.

Kl: Volume, in kiloliters (cubic meters), per displacement ton (14 kl) of hull.

Mass: Mass, in tonnes, is equal to volume in cubic meters.

MCr: Price, in millions of credits, per displacement ton (14 kl) of hull.

3. Gravitic Displacement

The contra-grav lifters described in the game are far from the only imaginable means of manipulating gravity, and of the various types imaginable, one of the more interesting we call a gravitic displacement (GD) field. A GD field displaces the potential energy of a mass toward the closest gravity source without moving the mass itself, thus circumventing gravity with respect to the physical mass. This allows a massive object to rise and hover, and has much the same effect as contra-grav. The technical requirement of GD fields are similar enough to those of contra-grav that the same design procedure can be used. The only important difference is in the actual operation of the lifters.

Since a GD field displaces the potential energy of a mass toward the nearest gravity field, GD lifters have to be used with great care. A ship massing 1000 tonnes and hovering at a dozen meters or so will have the same effect on the ground surface directly beneath it as if it were resting physically on the ground. Light structures, plant life, and animal life alike would be crushed.

Craft at higher altitudes cause less surface disruption as their potential mass is spread over a wider area, but there are strict altitude and traffic regulations for even small craft flying near metropolitan areas. Large craft have very rigidly controlled landing and takeoff patterns, and these are over water whenever possible. (The ship will make a huge depression in the surface as it pulls over the water at low altitude.)

Grav vehicles, such as grav tanks, can again make crushing overrun attacks on enemy personnel, but pressure-sensitive mines (some of which are angled to fire charges directly up at the belly of grav vehicles) will also be triggered by their passing. In short, GD lifters are identical in gross effect to CG lifters, but add a number of interesting additional detailed interactions with a planet surface.

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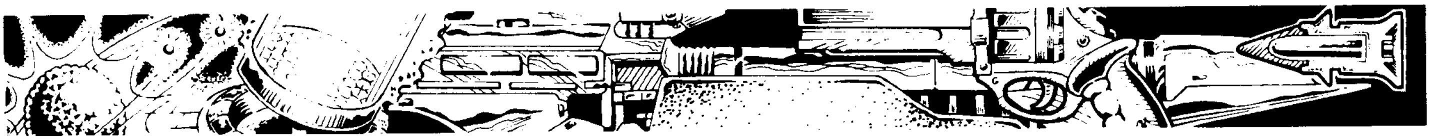


CHAPTER 11
Life Support

Spacecraft, high-altitude aircraft, and all vehicles intended for use in a hostile environment require some sort of life support equipment. Specific design sequences provide guidance on minimum required levels of life support.

Life Support Equipment

Oxygen tanks and masks allow breathing at high altitudes or in a hostile atmosphere. Overpressure consists of a compressor and filter for use on worlds with tainted atmospheres or in a chemical, biological, or radiologically contaminated environment. It draws air in, filters any contaminants out of it, and pumps it into the craft at a higher pressure level than the outside. This allows an unsealed vehicle to remain contaminant free, as there is a constant flow of air outward, preventing contaminated air from entering.

All powered vehicles include some form of heating and internal lighting.

Basic life support provides sealed environment, air, and water. Extended life support adds waste disposal/recycling and food, and is required for all craft that are operated for 8+ hours at a time, or vehicles in a hostile environment intended to operate for a day or more away from base. Craft with extended life support substitute this for basic life support.

The most common types of life support are shown on the table below.

Life Support Equipment

TL	*Description*	*MW*	*Vol*	*Mass*	*MCr*
5	**Air Lock**	**0.001**	**3.000**	**0.200**	**0.005**
5	Oxy. Tanks & Masks	—	0.010	0.010	0.0001
5	**Overpressure**	**—**	**0.001**	**0.001**	**0.0001**
5	Basic Life Support	0.0001	0.005	0.005	0.0003
6	**Extended Life Spt.**	**0.0002**	**0.008**	**0.008**	**0.0005**
8	G Tanks (pass)	—	2	2	0.01
8	**G Tanks (crew)**	**—**	**2**	**2**	**1**
10	Artificial Gravity/ G Compensators*	0.005	0.010	0.020	0.0005

TL: The tech level of availability.

MW: The energy requirement, in millions of watts, per cubic meter of enclosed hull volume (except that the requirement listed for air locks is per installed air lock).

Vol: The volume of life support equipment, in cubic meters, per cubic meter of enclosed hull volume (except that the requirement listed for air locks is per installed air lock and for oxygen tanks and masks is per passenger and crewperson).

Mass: The mass of life support equipment, in tonnes, per cubic meter of enclosed hull volume (except that the requirement listed for air locks is per installed air lock and for oxygen tanks and masks is per passenger and crewperson).

MCr: The price of life support equipment, in millions of credits, per cubic meter of enclosed hull volume (except that the requirement listed for air locks is per installed air lock and for oxygen tanks and masks is per passenger and crewperson).

Aircraft: For aircraft, the enclosed hull volume, in cubic meters, for purposes of life support requirements, is defined as the total number of passengers and crew multiplied by 2.

Airlocks: The minimum number of airlocks required on a spacecraft is equal to the hull number (displacement in tons) divided by 100, rounding all fractions up. Each air lock requires 2 square meters of hull surface area.

G Compensation

Ships with a G rating greater than 1 may only use the acceleration for limited periods of time, unless they have G compensators or G tanks installed. (Prolonged periods of high acceleration will otherwise injure the crew.)

G tanks are large fluid-filled tanks that passengers and crew are immersed in during high-G maneuvers. As crew workstations require secure means of interacting with controls and monitors while immersed, crew (workstation) G tanks are extremely expensive.

Artificial gravity G compensators create an artificial gravity field in direct opposition to the axis of acceleration, thus negating the acceleration (up to the limit of the artificial gravity field). Compensated Gs is the number of acceleration or evasion Gs negated by the compensator. The amount of Gs which can be compensated vary by tech level as shown on the table below.

All crews can automatically withstand 1G, so the maximum acceleration without degrading crew performance is actually 1G above this level, as shown in the Max Accel column to the left of the slash. Evasion Gs, however, are applied erratically, and so cannot be withstood by crews without degrading performance, as shown in the Max Evade column to the left of the slash. Beyond these levels, all tasks are performed at one difficulty level higher (+1 Diff Mod) per G-turn applied.

Starship crewmembers who are strapped into workstations (for **Traveller** space combat, this is assumed to be everyone except damage control parties, maintenance crew, stewards, medics, and ship's troops) can withstand 1G additional of acceleration or evasion before their performance is degraded. These figures are shown to the right of the slash in the Max Accel and Max Evade columns.

G tanks always compensate 1G and all passengers and crew in -tanks are treated as strapped into a workstation (and so use that column). Note that damage control parties cannot use G tanks while working, and so such a ship may only accelerate at 1G while making repairs and may not evade at all.

TL	*Compensated Gs*	*Max Accel/ Workstation*	*Max Evade/ Workstation*
10	1G	2G/3G	1G/2G
11	2G	3G/4G	2G/3G
12	3G	4G/5G	3G/4G
13	4G	5G/6G	4G/5G
14	5G	6G/7G	5G/6G
15	6G	7G/8G	6G/7G
16	7G	8G/9G	7G/8G
18	8G	9G/10G	8G/9G
20	9G	10G/11G	9G/10G

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Extended Accommodations

Craft which will house passengers and crew for more than 24 hours require extended accommodations. Passengers and crew require bunks for short trips of several days, provided they understand that accommodations are to be austere. Staterooms are required for paying passengers. Each High Passage passenger requires one stateroom (large or small). Middle Passage passengers require one stateroom (large or small) in the Regency, but are placed two to a large stateroom in the Wilds (never two to a small).

Civilian crew are usually accommodated two to a large stateroom, or one to a small stateroom in the case of officers.

Military crew are usually accommodated at best like civilian crews, but will often be carried at double occupancy (two per small, four per large stateroom) or greater, or even housed in bunks. Bunks may be multiple-occupied by "hot bunking," by sleeping in three shifts per 24-hour period.

Officers will not sleep in bunks, nor accept worse than double occupancy.

All values on the table below are per installation.

Extended Accommodations

Description	*MW*	*Vol*	*Mass*	*MCr*
Bunk	—	14	0.5	.005
Low Berth	0.001	14	1.0	.05
Emergency Low Berth (for 4)	0.002	28	2.0	.1
Small Stateroom	0.0005	28	2.0	.04
Large Stateroom	0.001	56	4.0	.1

Environmental Gravity

On trips lasting longer than one week, the absence of gravity in deep space will begin to have harmful physiological effects, principal among them being loss of muscle tone and, eventually, loss of bone calcium. Regular exercise can only reduce these effects, it cannot prevent them. Prevention requires some form of artificial gravity. Ships equipped with artificial gravity generators (covered above under G compensators) automatically have a steady 1G environment. Ships without grav compensators must instead generate gravity by means of spin.

Ships which rely on spin habitatsto provide gravity do not have to spin the entire vessel (although sometimes this is done). Instead, only that part of the vessel occupied by accommodations need be spun.

There are several varieties of spin habitats, broken into the following general categories. The several designs of spin habitats are differentiated more for purposes of deck plans than for the particulars of design. The requirements for volume and additional machinery actually vary very little between most of these. Their descriptions should help visualize your ship during design.

Spun Hull: This is the simplest, but usually largest, spin habitat. In it, the hull is a large cylinder that spins around its long axis, thus providing centrifugal gravity in the outer part of the cylinder. Due to Coriolis effects, the central part of the cylinder (within a radius of 10 meters) is unusable for quarters or workstations, and thus is usually used for fuel, cargo, and low-maintenance machinery. More often the hull is built like a doughnut, and the central core is left empty. The basic game's lab ship is an example of a ship built in this configuration.

Only open structures and cylinder hullforms may use this type of spin habitat.

No additional machinery is required for a spun hull.

Double Hull: In this design, the outer hull spins but surrounds an enclosed inner hull which does not. Again, this design is most useful for very large ships as the enclosed central hull is at least 10 meters in radius.

Only cylinder hullform ships may use this type of spin habitat.

Double hulls require a volume of machinery equal to 1% of the enclosed volume of the *outer* hull. Mass is 1 metric tonne per cubic meter and price is MCr0.001 per cubic meter.

Hamster Cage: The hamster cage consists of a cylindrical module that is at 13 meters in radius, and that spins to create artificial gravity. Unlike other designs, the hamster cage is often set at right angles to the axis of the ship and generally installed in counter-rotating pairs (to eliminate torque effects on the ship's attitude).

Any ship hullform may use hamster cages, but the ship may not have an airframe configuration.

Hamster cages require a volume of machinery equal to 1% of the enclosed volume of the modules. Mass is 1 metric tonne per cubic meter and price is MCr0.001 per cubic meter.

Spin Capsule: The most common spin habitat in use is the spin capsule. In this design, two or more quarters modules of the desired size are placed at the ends of pylons that rotate around a common axis. (Usually, but not always, this is also the long axis of the ship). The spin capsules have a rotational radius of at least 10 meters. Access to the capsules is by way of the pylons, which contain ladders or powered lifts. Power and atmosphere is also supplied through the pylons.

All spin capsules are designed to retract against the ship's hull during violent maneuvers or atmospheric travel, and so any hullform and configuration can have spin capsules.

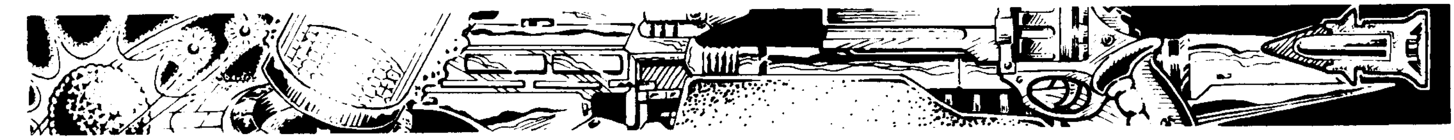
Spin capsules require a volume of machinery equal to 5 percent of the enclosed volume of the capsules. Mass is 1 metric tonne per cubic meter and price is MCr0.001 per cubic meter.

Two Body: Two ships can attach themselves together using a pylon and spin around a central point to provide gravity. The chief disadvantages of this design are that both ships must be present in order to spin and neither ship may maneuver or change vectors while linked.

All that is required for a two-body spin habitat (aside from the two ships) is a pylon made of hull material (hard steel or a material of greater hardness) that is at least 1% of the combined mass of the two ships. Volume and price are determined by the material used to construct the pylon.

Custom Life Support Design

Fuel tankage volume does not require life support or artificial gravity. However, without these, the tankage is more difficult to repair and maintain, and cannot be used for emergency or expedient measures (such as the installation of modular quarters).



CHAPTER 12
Cybernetics

The core **Traveller** universe does not concentrate heavily on cybernetic enhancements. Although there is no reason not to include this sort of technology in an on-going campaign, its effects on both the style and substance of play are so powerful as to completely dominate the game. Therefore, referees should give some serious thought to the sort of game they wish to run before deciding on how much cybernetics will be used.

The Imperial Space campaign will not be dominated by cybernetic issues, but will deal with these issues only on the level that they provide futuristic "realism."

Cybernetics is the science of electronic, mechanical, and biological enhancement of living organisms. Its most primitive antecedents are the peg legs and hooks used to replace missing legs and hands, inferior substitutes for the originals. Engineering advances made prosthetic limbs progressively more effective replacements for missing body parts, until eventually the replacements became superior to the original organic component.

Once elective cybernetic enhancement becomes a reality, each society has to face a number of ethical issues which are not easily resolved, and which invariably turn separate societies in different directions. Some embrace cybernetic enhancement whole-heartedly, others reject it completely, and still others find an uneasy middle ground. How a particular society reacts to cybernetic enhancement is up to the referee, but is an issue which should be considered carefully before cybernetics are incorporated into a campaign.

Virtually all societies view cybernetically enhanced humans in different terms than "natural" humans, and a wide variety of slang (some derogatory) inevitably grows up to help define that difference. The most common slang for a cybernetically enhanced human is "ironman" (or "iron maiden"), while unenhanced humans are called "slicks." By the same token, cybernetic enhancements which are visually indistinguishable from original organic components are called "slickware," as opposed to hardware or cyberware.

As general rule, it is a good policy to impose some penalty on visible cybernetic enhancements, usually to a player's Charisma attribute, and usually amounting to a –1 per visible cybernetic modification.

A typical outline progress of cybernetics by tech level is shown on the following table.

TL	*Type*
5	**Primitive prosthetics (artificial limbs)**
6	Reconstructive surgery
7	**Advanced plastic surgery**
8	Full-function prosthetics
9	**Direct brain-machine interface allows prosthetic eyes and ears and neural jacks. Early controlled chemical manipulation of body systems**
10	Enhanced-performance prosthetics and subdermal armor
11	**Direct computer implantation**
12	Advanced chemical manipulation of body systems
13	**Genetic manipulation, enhancement, and replacement of selected tissues**

A wide variety of cybernetic modifications and enhancements are discused below. These are broken into four broad categories: head jobs, body implants, peripherals, and therapy.

Head jobs, as the name suggests, have to do with cybernetic modifications to the character's head, usually to the principal sensory organs (eyes and ears).

Body implants include large systems which cannot easily be fit into the head and which are instead mounted in the abdominal or thoracic cavity, sometimes replacing or displacing internal organs.

Peripherals are modifications to the arms and legs, either for improved performance or adaptation of limbs to special functions.

Therapy consists of organic modification of the character's body, either through drugs, genetic manipulation, or surgical procedures.

Power

Many of the cybernetic enhancements detailed require the input of electrical power to function. This power is produced in one of two ways.

Items that need only small amounts of power, such as various passive sensor eyes, are powered by tiny thermoelectric generators that produce the needed electrical power from body heat. These generators are subsumed within the volume, weight, and price of the item.

Other items, particularly those which transmit energy (active sensors and radio or video transmitters) and enhance strength, have thermoelectric power supplemented by tiny long-life batteries, also subsumed within the volume, weight, and price of the item. These batteries must be periodically recharged by a specialized adaptor which can convert standard current into a form suitable to the batteries.

Some systems require no power at all. These systems are completely passive, as in the case of subdermal armor, completely biological, as in the case of aquatic skin, or have their mechanical functions connected to the host's muscles, which operate the mechanism as if it were any normal skeletal component, as in the case of the hard hand. All of the respiratory implants are treated as being completely biological, even though they may include the insertion of various synthetic components.

Head Jobs

Head jobs all require delicate surgery to the head, and most deal with very sensitive nerve connections. These procedures can be extremely dangerous if not done properly, and so they tend to be the most expensive of the cybernetic enhancements.

Cyber Eyes: Direct electronic/nerve interface at tech level 9 opens the way for a wide variety of cybernetic enhancements to eyesight. Early cyber eyes are single-function eyes, and are easily recognizable as mechanical implants, but at higher tech levels a wider variety of functions are available and they become less obvious.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

The following table shows the general development of cyber eyes over time. In all cases, the cyber eye includes basic visible light vision, and the table indicates the number of additional features which can be added. A dash indiactes that a cyber eye is not available at that tech level and a "0" indicates that no extra function can be added to basic visible light spectrum vision. Note that some additional options count as more than one feature for purposes of the capacity of the eye.

"Hard" eyes are immediately recognizable as cybernetic enhancements, while "slick" eyes appear normal to casual observers.

	Functions	
TL	*Hard*	*Slick*
9	0	—
10	1	—
11	2	0
12	3	1
13	4	2
14	5	3
15	6	4
16	7	5
17	8	6
18	9	7
19	10	8
20	11	9

A number of options available for cyber eyes are listed below. In all cases, skill tests to detect objects using cyber eyes are made with the Observation asset. For additional details, see **TNE**, page 310.

Telescopic: Telescopic vision allows magnification similar to a telescope or binoculars, with zoom controlled by eyeball pressure (which is manipulated by squinting). This provides a +1 to the character's Observation asset.

Active Infrared: A beam of infrared light is projected either from forehead-mounted lights (in the hard version) or through the eye itself (in slick versions). Active infrared is a useful sensor at night, but will not penetrate smoke, dense fog, blowing sand, etc. It has a short range of 60 meters. Slick active IR eyes are sufficiently bulky that they count as two options instead of only one.

Passive Infrared: The eye is extremely sensitive to infrared radiation and can "see" heat. Most living creatures and machines have very distinct heat signatures, while inanimate objects can usually be seen by the amount of heat that they absorb from the sun. Nevertheless, objects after sundown which have completely cooled off become almost invisible to passive IR. It has a short range of 100 meters.

Star Eyes (Light Amplifiers): Star eyes use light-amplification techniques to allow normal vision in low light conditions (primarily nighttime using starlight, hence the name). Smoke, blown sand, and any sort of atmospheric conditions will interfere with star eyes. They have a short range of 100 meters. Star eyes are sufficiently bulky that they count as two options instead of only one.

Color Enhancement: Color enhancement, originally developed to aid color-blind patients, is useful for resolving detail at long distances and for detecting camouflage. Color hue and intensity is adjusted by increasing or decreasing eyeball pressure. (This can be accomplished by squinting.) Color enhancement is useful only in daylight and clear visibility, and adds +1 to the owner's Observation asset.

Thermal Viewer: The thermal viewer, also called HRT (for high-resolution thermal), is an advanced form of passive infrared with a short range of 400 meters. HRT can see clearly through most forms of smoke, but is affected by rain or snow. HRT eyes are sufficiently bulky that they count as two options instead of only one.

Imaging Radar: The eye contains a millimeter wave radar transmitter and processor unit with fine enough resolution for image formation. Imaging radar has a short range of 300 meters and is not degraded by any atmospheric effects. Imaging radar is sufficiently bulky that it counts as three options instead of only one.

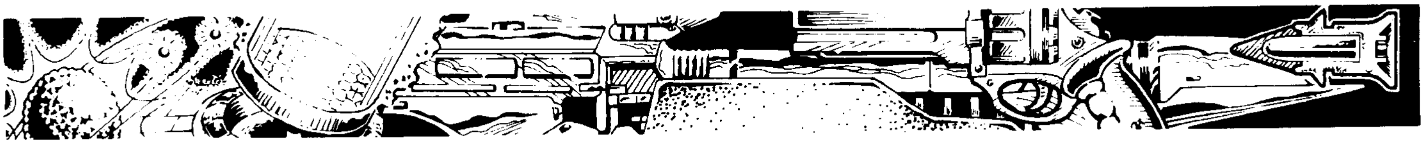
Image Intensifier: Image intensification not only magnifies but also sharpens focus and contrast, making visual recognition easier. Image intensification also adds the light-amplifying ability of star eyes. Image intensifiers add 2 to the Observation asset of the character, and have a short range of 250 meters. Image-enhancement eyes are sufficiently bulky that they count as two options instead of only one.

Wide-Spectrum Visual (WSV): This eye combines magnification and image enhancement with sensitivity to light across a broad spectrum, from ultraviolet through infrared. As such, it combines most of the advantages of earlier sensor eyes in a single package. Its adds 2 to the character's Observation asset and has a short range of 400 meters. WSV is sufficiently bulky that it counts as three options instead of only one.

Target Link: Only characters with a neural jack may use a target-linked eye, and only with weapons designed for target interface (so-called "smart" weapons). The weapon's bore sensor, when engaged, projects a target image in the middle of the user's vision field, showing what the weapon "sees" rather than the actual image. An alternative shows a distinct colored line along the weapon's line of fire if the line of fire is within the user's field of vision, and a colored arrow prompt showing what direction to look to find the line if it is out of the user's field of vision. This line is invisible to anyone else, since it exists only inside the user's eye.

Any small arm or heavy weapon may be modified by the addition of a "smart sight." Available at TL 10, it has a volume of 1.5 liters, masses 0.2 kilograms, and costs Cr5000. The smart sight also has the features of an electronic sight (see page 97).

Recorder: This option allows the user to make a one-hour video recording and play it back at a later time. The recording can be transferred to hard video by means of a small laser viewer that fits over the eye. The video image on the organic recording will begin to deteriorate after 48 hours. The recorder feature is sufficiently bulky that it counts as three options instead of only one.



Holo-Recorder: As the recorder described above, but the recording is a three-dimensional hologram. The holo-recorder feature is sufficiently bulky that it counts as four options instead of only one.

Eyeball Display: This allows projection of information in readable form in the user's field of vision, much like the heads-up display of a fighter aircraft. It is particularly useful if a computer implant is used, but can is also useful with chronometer or inertial navigation implants.

Rangefinder: This option may only be installed if the user also has an eyeball display. The rangefinder projects a low-energy infrared laser beam and determines range from the reflection. It is accurate to within 1% of range out to 5 kilometers.

Cyber Ears: Cybernetic augmentation of hearing is available considerably sooner than is visual augmentation. Early cyber ears are simple amplifiers, often worn externally, which are later replaced by implants inside the hearing canal, all but invisible. At higher tech levels, a wider variety of functions are available.

The following table shows the general development of cyber ears over time. In all cases, the cyber ear includes basic hearing, and the table indicates the number of additional features which can be added. A dash indiactes that a cyber ear is not available at that tech level and a "0" indicates that no extra function can be added to basic hearing.

"Hard" ears are immediately recognizable as cybernetic enhancements, while "slick" ears appear normal to casual observers.

	Functions	
TL	*Hard*	*Slick*
6	0	—
8	1	0
10	2	1
12	4	2
14	5	3
16	6	4
18	7	5
20	8	6

A number of options available for cyber ears are listed below.

Amplified: This allows amplified hearing and clear audio resolution of faint sounds at distances of 100 meters or more.

Low Frequency: This allows hearing of low-frequency sounds, sounds which are more often felt or sensed than heard. Hearing these sounds makes it easier to pinpoint the direction of origin. Early versions of this ear tend to be oversized.

High Frequency: This option allows a person to hear sounds above the aural range of normal humans. Early versions of this ear tend to be made from very dense material, such as plastic or even metal.

Sound Dampening: Although loud or irritating sounds won't damage bionic ears, they can be annoying, distracting, or even painful to the user. This option enables the owner to dampen out specific ranges from the sonic spectrum, allowing sound to be dampened, which can also make it easier to hear a specific sound (such as a human voice) in a noisy environment.

Recorder: This option allows the user to record one hour of sound and play it back at a later time. The recording can be accessed at any point and can be recorded over.

Sonar: Sonar ears may only be used in conjunction with a computer implant. An omnidirectional variable-tone ultrasound transmitter in the ear sends out ultrasound waves and then determines distance to the nearest objects by means of echo-ranging. A continuous low tone in the ear when the system is engaged provides information to the user as to range based on pitch and volume of the tone. If an eyeball display is available, the sonar can also build up an ultrasound map of the space around the user and overlay it on the visual image of the eye. If only one ear is installed, the head must be moved around to build up a full sonar map. If both ears have sonar features, no such "scanning" is necessary.

Comm Receiver: Communicators are normally too bulky to install in the ear itself, but the speaker for the communicator is generally located there. See the Body Implants section (page 82) for details of communicators available.

Eye-Ear Combination Suite: This is a special cybernetic combination suite available at tech level 10 and higher. It is available as a hard option only and replaces both the eye and ear on one side with a clearly visible synthetic housing. No attempt at cosmetic disguise is made. The suite allows the standard number of hard options for the eye and ear plus two additional options added to either, or split between them. Cost is the sum of the options selected, but the suite lowers Charisma by 4 instead of the normal 2 (1 each for a replacement eye and ear).

Other Options: A number of other head options are available, some of which can be used in conjunction with options already covered.

Neural Jack: This is a socket, usually mounted in the temple or (for cosmetic reasons) at the base of the neck, and is used to establish direct electronic contact between the human brain and electronic equipment. It allows the brain to receive and decode electronic data as well as transmit commands directly to linked equipment.

When "jacked in" to machinery, all tasks using that machinery become one level easier. When jacked in to memory bank and educational programs, the Education attribute is increased by 3.

Chronometer: This is an installed day, date, and elapsed time recorder linked to an eyeball display.

Inertial Navigation System: This is an installed inertial positioning and navigation system. A eyeball display must be installed for this option to be used. The navigation system will display current magnetic bearing and will also show the bearing to any of five previously recorded positions.

Psionic Shield: This serves the same function as a psionic shield helmet, but is permanently built in (and usually undetectable).

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Power Jaw: This option involves complete replacement of the upper and lower jaw and teeth with synthetic material. Strength is mechanically enhanced which allows the user to bite through a variety of materials and inflict 1D6 hits if used to bite a hostile character.

Jaws of Death: This is a hardware-only option consisting of oversized jaws with enlarged teeth (so-called "jaws of death") which allows the user to use them to make armed melee attacks in the same way as do large predators. Jaws of death inflict 2D6 hits, but cause a –2 CHR penalty due to their (deliberately) grotesque appearance.

Subdermal Armor: This option surgically layers thin synthetic armor protection below the skin surface but over the skull.

The following table summarizes the important information concerning cybernetic head modifications.

Cyber Head Options

TL	*Type*	*Number of Spaces*	*MCr*
9/11	**Visible Spectrum Eye**	**0**	**0.01**
10/12	Telescopic Eye	1	0.01
10/14	**Active IR Eye**	**1 or 2**	**0.03**
11/14	Passive IR Eye	1	0.05
12/14	**Star Eye**	**2**	**0.10**
12/13	Color Enhancement Eye	1	0.005
13/16	**Imaging Radar Eye**	**3**	**2.0**
14/16	HRT Eye	2	0.1
14/16	**Image Enhancement Eye**	**2**	**0.1**
15/18	WSV Eye	3	0.5
10/11	**Target Link Eye**	**1**	**0.01**
11/12	Eyeball Display	1	0.01
11/15	**Rangefinder Eye**	**2**	**0.02**
12/16	Recorder Eye	3	0.05
14/18	**Holo-Recorder Eye**	**4**	**1.0**
6/8	Replacement Ear	0	0.001
8/10	**Amplified Ear**	**1**	**0.001**
8/10	Comm Receiver Ear	1	0.001
9/11	**Sound Dampening Ear**	**1**	**0.03**
9/12	Low Frequency Ear	1	0.02
9/13	**High Frequency Ear**	**2**	**0.02**
10/12	Recorder Ear	2	0.04
12/14	**Sonar Ear**	**3**	**0.1**
9/10	Neural Jack	—	0.8
11/12	**Chronometer**	**—**	**0.0001**
11/12	Inertial Nav	—	0.001
13/14	**Psionic Shield**	**—**	**0.04**
9/11	Power Jaw (1D6 damage)	—	0.005
9/—	**Jaws of Death (2D6 damage)**	**—**	**0.01**
10/11	Subdermal Armor AV (1)	—	0.25
12/13	**Subdermal Armor AV 0 (2)**	**—**	**0.2**
14/15	Subdermal Armor AV 1	—	0.2
17/18	**Subdermal Armor AV 2**	**—**	**0.15**

TL: Tech level of first availability. The first number is the tech level at which the feature is available as a hard option, the second the level at which it is available as a slick option.

Number of Spaces: The number of features the particular option counts as when determining the total capacity of the cyber eye or ear.

MCr: The price, in millions of credits, per feature, at the tech level of introduction. This price is halved at all higher tech levels. Note, however, that slick options cost the full printed price at their first tech level of availability, even though hard options of the same sort are by then less expensive.

Body Implants

Larger systems cannot usually be fit inside the skull and so are placed in the thoracic or abdominal cavity, usually anchored to the skeleton, and sometimes replacing part or all of an organ. Body implants include four general areas: respiratory implants, electronics, dermal alteration, and computer implants.

Respiratory Implants: These devices deal with respiration and affect the ability of the user to function under physical stress of in a hostile environment.

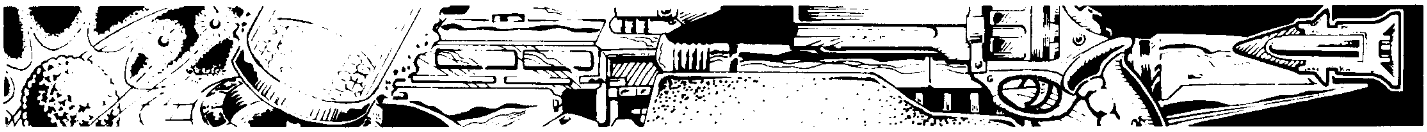
Supercharger: This is a device used to store some of the endorphins that the character's body naturally produces. The endorphin is saved for reintroduction into the body when needed to add extra oxygen to, and remove fatigue toxins from, the character's bloodstream. The supercharger is installed in a space made available by removal of half of a kidney. A supercharger increases a characters CON attribute by 2. No more than one supercharger may be installed.

Hypercharger: A larger and more advanced form of the supercharger, the hypercharger requires removal of an entire kidney and increases a character's CON attribute by 3. No more than one hypercharger may be installed, and it may not be installed in addition to a supercharger.

Filter Lungs: Filter lungs implant filters and scrubbers in the character's lungs which allow breathing of tainted atmosphere without harmful effects. Early versions rely on extensive pre-lung filters (mostly near the surface, and physically replacing the nose). When this version is installed, the users have to blow their "noses" frequently while operating in hostile environments to clear the filters.

"Slick" versions use filters and scrubbers actually in the lung. The impurities scrubbed from the air are flushed through the normal body waste system, but can strain the system severely. Characters must have both kidneys intact to use slick filter lungs and should drink large quantities of fluids while in a hostile environment.

Gill Implants: Gill implants allow the character to extract oxygen from water. Gil implants usually require enlargement of the thoracic cavity, and the gills themselves are clearly visible on the user's neck. "Slick" versions of the gill implant place the gill slits on the sides of the ribcage and reduce the amount of thoracic cavity increase by use of a hypercharger. (The hypercharger is not included in the price of the implant and must be installed separately.)



Electronics: The following items include communicators and sensors too bulky to emplace in the skull.

Radio Communicator: Communicators are generally attached to the spine and linked to the speaker and/or microphone in the head by means of the spinal cord. The earliest radio communicators are receivers only and are limited to a single band. Multiband receivers soon become available followed by transmitter/receivers of varying power.

Video Transmitter: Video transmitters are available one tech level after audio radio transmitters for twice the price of an audio transmitter of the same range. For example, a hardware 30-kilometer video transmitter is first available at tech level 13 and costs MCr0.02. Use of this transmitter requires either a recorder eye or a camera jacked into the transmitter.

Neural Activity Sensor (NAS): Neural activity sensors are an outgrowth of the same technology that permits electronic psionic shields. They detect and classify life forms according to the level of brain activity, but are extremely short-ranged. NAS requires an eyeball display.

Dermal Alterations: The following options deal with modifications to the user's skin. Some of these are all-body modifications (meaning they include modifications to the limbs and head as well), but they are included here for the sake of simplicity.

Aquatic Skin: Aquatic skin involves chemical and genetic alteration of the outer skin to a form resembling that of marine mammals (such as dolphins and whales), which allows prolonged immersion in water without need for a protective wet suit. Aquatic skin must be kept moist at all times, however, or it will begin to dry and crack, and the user will begin to suffer symptoms of severe dehydration within two or three days, usually dying within a week if access to water is continually denied.

Vac Skin: Vac skin is synthetically grown skin which is permeable at normal pressure differences but becomes non-permeable at pressure differences approaching 1 atmosphere. This allows characters to function in vacuum with only a breathing helmet and some sort of personal heating/cooling system.

Subdermal Thoracic Armor: This option surgically layers thin synthetic armor protection below the skin surface but over the ribcage. It covers the chest only. The hard (as opposed to slick) version of this armor is not only more noticeable, but it is also heavier. As a result, hardware versions of thoracic armor lower the CON attribute by 1.

Subdermal Abdominal Armor: This option surgically layers thin synthetic armor protection below the skin surface. Given the absence of a rigid bone structure to anchor the armor to, abdominal armor is inherently less effective than thoracic armor. The hard (as opposed to slick) version of this armor is not only more noticeable, but it is also heavier. As a result, hardware versions of thoracic armor lower the CON attribute by 1.

The following table summarizes the important information concerning the above cybernetic body implants.

Body Implant Options

TL	*Type*	*MCr*
—/11	Supercharger	0.030
—/12	Hypercharger	0.040
9/11	Filter Lungs	0.200
11/13	Gill Implants	0.300
8/9	Single-Band Radio Receiver	0.005
9/10	Multiband Radio Receiver	0.005
10/12	3-km Radio Transmitter	0.005
12/14	30-km Radio Transmitter	0.01
15/17	300-km Radio Transmitter	0.03
17/18	3000-km Radio Transmitter	0.05
15/17	5-meter NAS	0.05
16/18	25-meter NAS	0.05
17/19	50-meter NAS	0.05
18/20	500-meter NAS	0.05
11/15	Aquatic Skin	1
15/18	Vac Skin	2
10/12	Thoracic Armor AV (1)	0.025
12/14	Thoracic Armor AV 0 (2)	0.020
14/17	Thoracic Armor AV 1	0.020
17/20	Thoracic Armor AV 2	0.015
12/14	Abdominal Armor AV (1)	0.020
14/17	Abdominal Armor AV 0 (2)	0.020
17/20	Abdominal Armor AV 1	0.015

Computer Implants: Beginning at tech level 12, it is possible to have a computer surgically implanted and cybernetically linked to the conscious brain centers. The lightest of these computers still mass one kilogram and so are too large to implant in the skull. Instead, the computer consists of a series of a half-dozen or more small subcomponents which are fused to individual vertebrae of the spine (on the inner sides) in such a way that they do not interfere with articulation. They are linked to each other and the organic brain by way of the spinal cord. Output from the computer can be accessed either by way of an eyeball display, an in-ear speaker, or direct machine-brain interface, if the user also has a neural jack installed.

Computer implants serve several functions:

First, some cybernetic systems require a computer implant to achieve their full potential. For example, a cybernetic sensor suite consisting of an HRT eye and an amplified hearing ear, when linked to a computer implant, will allow a character to determine the emotional state of the person they are conversing with and have a reasonable chance (80%) of determining if they are lying or telling the truth.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Second, and assuming the character has a neural jack, implant computers can substitute for regular computers on a limited basis. While they are not powerful enough to carry out all functions of a larger computer of the same type, they allow the player to conduct specific tasks one at a time. For example, a character's implant computer cannot replace the general systems diagnostic function of a ship's computer (which reduces the maintenance requirements of the ship), but it can allow the character to calculate jump parameters, or run a master fire director, of pilot the ship through the atmosphere for a landing.

Third, it allows the character to store background and technical information for later recall. The character can query the computer about specific information during an adventure and receive a reply. Since memory in the computer is not infinite, the referee must impose some limits on the information available. Very general questions (such as basic questions about physical laws and the outline history of the Imperium) will almost always be answerable by the computer. Specific questions about local history or a scientific specialization will be answered only 40% of the time. Very specific questions about individuals, recent discoveries, or obscure historical facts (and assuming that the referee considers the computer implant to have ever had access to this information) will be available only 20% of the time.

Before an adventure begins, however, characters should be allowed to pick one or more subjects and optimize the computer's data base around that subject. This doubles the chances the question will be answered by the computer (40% becomes 80%, 20% becomes 40%) but reduces the chance of an off-topic question being answered by 10% (40% becomes 30%, 20% becomes 10%).

The number of subjects a character can select is equal to the computer model number minus 6. In other words, a Model 10M computer can be optimized for four subjects. If the number of subjects chosen for optimization is half or less of the total allowed number of subjects, the off-topic penalty is not suffered.

Virus: If cybernetics are added to an Imperial Space campaign, one recurring hazard of a computer implant is that it may become infected with Virus. Only implanted computers of model 10M and higher are powerful enough to serve as a host for Virus, although any computer can be a carrier.

Since the computer is permanently jacked into the character's conscious brain, a viable infection by Virus is potentially fatal to the character. However, some strains of Virus will cause the implanted computer to become self-aware but not necessarily homicidal or suicidal, and may just give it a bizarre personality. The nature of the infection and its effects are up to the referee, but assuming that an infected implant computer has some similarities to a robot brain, referees are directed to the discussion of sentient robots on page 98 of the basic game rules for guidance.

Implant Computers

TL	*Mod*	*Wt (tonnes)*	*MCr*
12	7M	.001	0.5
13	8M	.001	0.4
14	9M	.001	0.4
15	10M	.0012	0.6
16	11M	.0014	1.0
17	12M	.0016	1.2
18	13M	.0018	1.8
19	14M	.0016	2.4
20	15M	.0014	3.0
21	16M	.0012	4.5

Model "M" computers are micro-computers suitable for implantation.

Peripherals (Arms and Legs)

Peripherals are modifications to the arms and legs, either for improved performance or adaptation of limbs to special functions.

Upper Limbs: These cybernetic modifications are to the arms and hands, mostly the hands.

Chainsaw Hand: This attachment is a 30-cm chainsaw, useful for light construction work and brush clearing and a devastating melee weapon. There is no slick version of this attachment. Attacks with a chainsaw hand count as armed melee attacks.

Grapple Hand: This hand can be fired up to 20 meters in any direction, connected to the user's arm by means of a length of fine but extremely strong cable, capable of holding 200 kg of weight safely, 400 kg if attached to a cyber utility arm). The hand contains 50 meters of cable (100 meters if attached to a utility arm) which can be reeled in or out at will. The hand can function as a grappling hook wherever there is a handhold capable of supporting it, and can be used to descend as well as ascend. The user does not have fine manipulative control of the hand while it is extended at the end of the cable, but can close and open the hand at will to grasp or release handholds.

Hand Socket: A hand socket allows the character to use a variety of different cyber hands. If a character does not have a hand socket, then whatever cyber hand is chosen is permanently mounted to the hand. If a hand socket is mounted, then any socket hands may be used.

Any cyber hand option may be purchased as a socket hand by increasing the price by 50%. Hand sockets may be installed on organic arms; utility arms come with hand sockets already installed and are included in the price.

Hardfist: This is a cybernetic replacement hand with specially reinforced bones and heavy knuckles, allowing the character to deliver much more powerful blows. Melee strikes delivered with a hardfist do double damage.

Movement of the fingers is somewhat restricted by the modifications. Tasks performed using the hand which rely on agility are performed with a –1 modification to the character's Agility attribute.

Knuckle Blades: Knuckle blades can be added to a cybernetic hand or an organic hand. The telescoping 10-cm blades are normally retracted into sheaths in the back of the hand, but when the fist is clenched in a particular manner the blades emerge from their sheaths out from over the knuckles.

Movement of the hand is somewhat restricted by the modifications. Tasks performed using the hand which rely on agility are performed with a –1 modification to the character's AGL attribute.

Pistol Hand: This hand is built around a small automatic pistol. Hard (as opposed to slick) versions of the hand do not have functioning fingers. Slick versions have working fingers and thumb, although the index finger is rigid.

The actual pistol is designed using the small arms design sequence, but with several limitations on the design. Hard versions may not have a weight greater than one kilogram (including ammunition). Soft versions may not have a weight greater than 0.4 kilograms (including ammunition), and may not have a bore diameter greater than 7.5mm. The design must include the weight of a pistol grip, although this component is shaped like the hand, not a conventional pistol grip.

The price listed below for the pistol hand is for the attachment equipment and frame only. The design price of the installed pistol is added to this.

Power Hand: This hand has up to 10 times the normal gripping strength, but retains the normal sensitivity of the human hand. While this does not allow the character to lift any greater loads, it enables him or her to exert crushing pressure on objects and to lock the hand in place, thus allowing the character to hang suspended for long periods of time without suffering fatigue. (The character may even sleep while the hand is locked in place.)

Protected Cyber Components: Arms and hands completely replaced by cybernetic prosthetics are considerably easier to armor. In order to use the ratings for protected cybernetic components, a character must have a utility arm (see below).

Subdermal Armor: Given the limited space available, it is extremely difficult to add effective subdermal armor to the hand and arm. This is reflected in the fairly low protection levels available. In addition, hard (as opposed to slick) subdermal armor lowers the character's AGL attribute by 1.

Tentacle Hand: On this hand, the thumb and fingers functions normally but can be telescoped to form tentacles up to three meters in length. Each tentacle has the strength of a normal human hand, and the hand can be used for climbing, grappling, reaching through small openings, and hundreds of other uses.

Movement of the fingers when the tentacles are retracted is somewhat restricted by the modifications. Tasks performed using the hand which rely on agility are performed with a –1 modification to the character's AGL attribute. When extended, the tentacles do not suffer this penalty.

Torch Hand: This hand is an electric cutting/welding torch incorporating an internal battery which contains power enough for two minutes of operation. Thirty seconds of use is regained for every six hours of recharging. Hard versions of the hand do not have movable fingers and cannot be used as conventional hands, but slick versions do and can.

Torque Hand: This hand is capable of rotating at high speed in either direction on its socket, and the fingers can be locked in place to grip small objects securely, making the hand useful as a torque wrench. When not used as a torque device, the hand functions normally.

Utility Arm: This is a standard cybernetic replacement for a human arm, originally developed as a prosthetic replacement for limbs lost due to injuries. It mimics the function of a human arm extremely well, suffering some loss in sensitivity but making up for that with greater strength. All tasks performed exclusively or primarily with a cybernetic utility arm are done with an attribute modification of –1 to AGL and +2 to STR.

The arm is equipped with a human analog hand, but the hand is mounted in a socket and can be removed and replaced with other options. The arm also has a small hidden compartment in which documents or small objects can be concealed.

Legs: The following replacements and enhancements for legs are available.

Power Legs: Power legs are complete cybernetic replacement legs with power enhancement and shock absorbers. Power legs allow the character to conduct tasks as if the character's strength was 16, provided the task relies solely on the legs. This usually involves lifting objects (provided the character can lock his or her back and rely solely on legs to lift it), or forcing open doors (again by bracing the character's back and relying solely on leg power). Power legs also allow the character to leap four meters straight up in 1G (and proportionately more or less in different gravity fields) and jump down twice that distance without injury.

Characters with hard power legs may not run; then may only trot. Characters with slick power legs may run normally.

Speed Legs: Speed legs increase the character's running speed from 30 meters per turn to 50 meters per turn.

Dynalegs: Dynalegs combine the effects of power legs with those of speed legs. Hard (as opposed to slick) versions do not have the prohibition on running that normally accompanies hard power legs.

Subdermal (SD) Armor: Given the limited space available, it is extremely difficult to add effective subdermal armor to the leg. This is reflected in the fairly low protection levels available.

Protected Cyber Component (PCC) Armor: Legs completely replaced by cybernetic prosthetics are considerably easier to armor. In order to use the ratings for protected cybernetic components, a character must have either power or speed legs.

The following table summarizes the important information concerning the above cybernetic peripherals.

1

Peripheral Options

	TL	Type	MCr
	9/10	Hardfist	0.003
2	9/12	Knuckle blades	0.01
	9/13	Pistol Hand	0.001
	10/—	Chainsaw Hand	0.002
	10/12	Hand Socket	0.01
	10/12	Utility Arm	0.08
3	10/12	Grapple Hand	0.02
	10/12	Power Hand	0.02
	11/13	Torque Hand	0.03
	12/14	Torch Hand	0.05
4	14/17	Tentacle Hand	0.1
	12/14	SD Arm Armor AV (1)	0.01
	14/17	SD Arm Armor AV 0(2)	0.008
	17/19	SD Arm Armor AV 1	0.006
5	10/12	PCC Arm Armor AV (1)	0.001
	12/14	PCC Arm Armor AV 0 (2)	0.001
	14/17	PCC Arm Armor AV 1	0.001
	17/19	PCC Arm Armor AV 2	0.001
	10/13	Power Legs	0.4
6	11/14	Speed Legs	0.6
	12/15	Dynalegs	0.7
	12/14	SD Leg Armor AV (1)	0.02
	14/17	SD Leg Armor AV 0 (2)	0.02
7	17/19	SD Leg Armor AV 1	0.01
	10/12	PCC Leg Armor AV (1)	0.002
	12/14	PCC Leg Armor AV 0 (2)	0.002
	14/17	PCC Leg Armor AV 1	0.002
8	17/19	PCC Leg Armor AV 2	0.002

Melee Effects

Several peripheral attachments have melee effects, some counting
9 as armed and some as unarmed attacks. Hit Mods are added to character's asset.

Unarmed Melee Attacks

	Type	Attack	Hit Mod	DV
10	Hardfist	Hand Strike	—	×2
	Tentacle Hand	Grapple/Strangle	+2	×2
	Power Legs	Kick	+2	×2

11

Armed Melee Attacks

	Type	Range	Hit Mod	DV
	Knuckle Blade	Short	+2	1D6+(STR÷2)
	Chainsaw Hand	Short	—	2D6+STR
12	Power Hand	Short	—	2D6+STR
	Torch Hand	Short	—	3D6

Therapy

Therapy consists of organic modification of the character's body,
13 either through drugs, genetic manipulation, or surgical procedures.

Muscle Implants: This technique involves taking a muscle tissue sample from the character, cloning it, then grafting these new muscles into the existing tendon/ligament system of the character.
14 The technique will increase a character's STR attribute by up to 6, but for every point of strength gained the character will temporarily lose 1D6 points from the AGL attribute until the character is used to working with the additional muscle mass. Characters regain lost AGL attribute points by expending experience points, just as if improving a skill rating.

Installing muscle implants is time-consuming, demanding one month of physical inactivity from the patient. It is also expensive, costing Cr12,000 per point of Strength gained. Available at TL 10+.

Tesseron Beta: This is a drug that stimulates the endocrine system, causing increased production of strength-producing hormones. It is administered in a weekly dose and must be taken continually to keep up its effect. When a character first takes T-Beta, there is no immediate effect.

With the second dose (the second week of the therapy), the character must make a Difficult test against CON to avoid violent muscle contractions. If the test fails, the character suffers 1 hit to each body part and must discontinue the therapy. If the test is successful, the character may continue the therapy without further risk of mishap.

With the third dose (the third week of therapy), the character will gain from 1 to 3 points of STR (1D6÷2, rounding fractions up). This added Strength level will remain in effect so long as the T-Beta treatment is continued. Once it is terminated, the STR attribute declines by 1 point per week until it reaches its original pre-therapy level. At the same time, T-Beta withdrawal will also cause an AGL decline of 1 point per week, due to muscle twitches, until STR reaches its original level. After that, AGL will increase by 1 point per week until it reaches its original level.

T-Beta prices vary. Typical costs are 1D6×Cr50. Available at TL 9+.

Neural Sheathing: This technique utilizes viruses which have been engineered to manufacture and deposit certain organic chemicals around the nerve fibers of a character. The plastic-like sheath decreases the electrical resistance of the nerves and various outside electrochemical interferences to neural communication. To perform the process, a doctor takes samples of blood, nerve tissue, and spinal fluid from the patient and determines what support chemicals are required for the virus to perform properly. The process must be monitored for one full month, with a medical appointment every three days to update the support solution.

The doctor must make a successful Average task roll using Diagnosis as an asset for the procedure to succeed. If the task roll fails, the procedure is not successful, but may be attempted again later. If the task roll is a Catastrophic Failure, the process cannot be retried and the character permanently loses 1 point from the AGL attribute due to induced nerve hypersensitivity.

If the procedure is successful, the character's AGL attribute is increased by from 1 to 3 points (1D6÷2, rounded up). The price of the treatment is Cr30,000. Available at TL 11+.

Vassopressin-Y: This drug allows the human brain to modify its electrical pathways, which will make it easier for a character to learn new things and recall things already learned. Due to its addictive effect, this drug is usually used by people who are beginning major projects (preparation for a special mission, for example) and can quit after the project's completion. The drug must be taken in daily doses for two full weeks for any effect to occur, at which time the character's INT attribute is increased by 1D6 points.

If the character remains on the drug for a month or less, there are no side effects. For every month thereafter that the character remains on the drug, the character's Willpower skill is reduced by 1 (regained at a rate of 1 point per week after Vassopressin-Y is no longer taken). Characters whose Willpower is reduced to 0 (or who suffer a Willpower reduction when they have no Willpower skill to begin with) slip into a catatonic state for 1D6 weeks and then recover.

In order to voluntarily terminate Vassopressin-Y therapy, a character must make a successful roll for an Average task using Willpower as an asset. This roll is made once per day at the time the normal dose would be taken. A character must be successful on each of seven consecutive days for the addiction to be broken.

The price for a daily dose of the drug on any given world is Cr3D6. Available at TL 12+.

CHAPTER 13
Teleportation

Matter transporters make use of the same principles of tunneling that are used in most FTL drives, but do so on a micro instead of macro level. Most teleporters are short range (less than 10,000 kilometers) and handle comparatively small masses (tonnes, as opposed to hundreds of tonnes).

Teleporters require only a transmitter, not a transmitter and receiver, the main facility serving both functions. That is, it can teleport objects from its own location to a distant target or it can teleport objects from a distant target to its own location. Although only the one teleporter is required, one endpoint of the operation must be the machine itself.

Objects being teleported have vectors which must be dealt with during the teleportation process. For example, an object in space has its vector of travel which will probably be quite different from that of the teletransmitter it is being teleported into. Even "stationary" objects on a world's surface have vectors: a vector toward the center of the world due to gravity (also called "potential energy"), and a lateral vector tangential to the world's surface caused by planetary rotation. Both of these vectors will vary with altitude.

In order for objects arriving at the teleported destination to not go crashing through a wall or floor, their vectors must be adjusted to match those of their destinations (although this need not be done if this is the effect that the teleporter operator is seeking). The energy required to do this (or the excess energy released in doing this) is subsumed into the boost energy calculated below. The homopolar generators which form part of the teleporter also serve as sinks or reservoirs for the energy consumed or released by this vector adjustment.

In order to "teleport in" an object (i.e., pick it out of space and bring it to the teleporter), the teleporter must be hooked into a system (such as a starship or ground installation) which has a target lock on the object to be teleported. At the long ranges available at TL 19 and 20, this target lock will usually be obtained by another sensor closer to the target which is "handed off" to the teleporter, usually via tight-link communicators. In some cases, a "teleporter booth" is constructed which is simply a passive sensor which locks onto the booth's contents and hands off that lock to the teleporter some distance away, which then plucks out those contents.

As a practical limit, without FTL communicators (see Section 5), TL 21 teleporters can only be used to "teleport out" objects at their maximum range, as it would require faster-than-light communications to receive the target lock hand off necessary to teleport in an object from a parsec away. There is one exception to this, which is a pre-arranged pick-up from a site carefully surveyed in advance and fed into the teleporter's controls. This of course requires that the teleporter have absolutely perfect data on all of the variables of this pick-up site, such as a world's orbital and rotational data, diameter, topology, etc., in the case of a site on a planetary surface.

All teleporters must also be hooked into a full-size computer (model St or Fb) of the same tech level.

Teleporter performance is defined by several critical characteristics.

Range: The maximum range of the teleporter in kilometers at that tech level.

Volume: The cubic meters of teleporter machinery required per metric tonne of capacity. In other words, if a designer wishes to build a teleporter of seven metric tonnes capacity and at that tech level the volume requirement is four, the teleporter would require 28 cubic meters of machinery.

Boost Energy: This is the amount of energy required per tonne/kilometer to teleport an object. To determine the total energy required, multiply the mass (in tonnes) of the object to be teleported by the distance (in kilometers) it is to be teleported by the boost energy value.

HPGs: In addition to teleporter machinery, a teleporter must have homopolar generators installed, and the peak power of the homopolar generators is the upper limit on teleporter performance. For example, even if a teleporter is built with sufficient capacity to teleport 20 tonnes of mass and is of a tech level capable of teleporting it 1,000,000 kilometers, if the homopolar generators are not large enough to provide the necessary boost energy then it cannot achieve that level of performance.

The homopolar generators also serve as potential energy reservoirs and sinks for vector adjustment.

Teleporters

TL	*Range*	*Vol*	*Boost*
18	2500	5	4
19	2,500,000	4	2
20	200 AUs	3	0.5
21	1 Parsec	2	0.001

TL: Tech level of availability.

Range: Maximum range of teleporters at this tech level. 200 AUs is approximately 2.5 billion kilometers. 1 parsec is approximately 2.5 trillion kilometers.

Vol: Volume of teleporter machinery, in cubic meters, per metric tonne of transfer capacity.

Boost: The energy, in millions of joules (MJ), required per kilometer/tonne to teleport an object.

Mass: The mass of the teleporter, in metric tonnes, is equal to the volume of its machinery in cubic meters.

Price: The price of the teleporter, in millions of credits, is equal to the volume of its machinery in cubic meters multiplied by 200.

CHAPTER 14
Fire Control

1 Fire control equipment is designed to assist weapons in hitting a target. A wide variety of fire control equipment is available to cover the range of weapons included in the game. In general, fire
2 control equipment is used for heavy and vehicle-mounted weapons. The equivalents of fire control equipment for small arms are called sights and are included in the actual design sequences for the weapons.

3 DIRECT FIRE CONTROL

Direct fire control is used by projectile weapons (CPR guns and electromagnetic mass drivers) and high-energy weapons (plasma
4 and fusion guns). Both fire an amount of high-speed matter—on the one hand a slug of metal, on the other a slug of plasma—at their targets. Since either way the projectile is unguided, the actual target solution obtained before firing is the critical element
5 in successfully hitting the target.

Two types of fire control equipment are available to help make this target solution. The first type is called sights and rangefinders, since most primitive sights either have some form of rangefinder on
6 them or are calibrated for different ranges. All direct fire projectile weapons must have a sight/rangefinder.

The second type is a ballistic computer. This device allows the gunner to incorporate corrections for target movement, atmospheric
7 conditions, tilt of the firing weapon, and so forth, thus negating difficulty modifiers to the to-hit task. Ballistic computers are optional, but are usually added to larger weapons.

Point Defense: Ballistic computers may also be modified to serve
8 as point-defense computers. Point-defense computers are used to enable a weapon system to shoot down incoming bombs and artillery projectiles. A ballistic computer may be modified as a point-defense ballistic computer by doubling its mass, volume, and price.

9 Point-defense computers function the same as an unmodified computer of that tech level except when firing at ballistic projectiles. Ballistic projectiles are those which are not maneuvering and are following a fixed trajectory (such as an artillery round,
10 a bomb, or an unguided missile or rocket). When a weapon equipped with a point-defense computer fires at ballistic projectile, the projectile's speed modifier is halved (rounding fractions
11 down).

1. Sights and Rangefinders

	TL	*Type*	*Range*	*Mass*	*MCr*
12	4	**Iron Sight**	0.2	.005	.00025
	5	Telescopic Sight	0.4	.01	.0005
	6	**Optic Rangefinder (RF)**	0.6	.02	.001
	7	Laser RF	0.8	.04	.005
13	8	**Imaging Radar**	1.6	.06	.01
	10	EMS RF	3	.08	.02

TL: Tech level of first availability.
Range: Upper limit on short range in kilometers.
Mass: Mass in tonnes.
MCr: Price in millions of credits.
Vol: Volume in cubic meters is equal to mass in tonnes.

2. Ballistic Computers

TL	*Type*	*Mass*	*MCr*	*Diff Mod*
6	**Analog**	0.01	.002	1
8	Digital	0.02	.005	2
10	**Digital**	0.04	.02	3
12	Digital	0.04	.1	4
14	**Synaptic**	0.03	.5	5
16	Synaptic	0.02	1	6
18	**Fluidic**	0.02	2	7

TL: Tech level of first availability
Mass: Mass in metric tonnes
MCr: Price in millions of credits
Diff Mod: Number of increases in difficulty ignored.
Note: Ballistic computers may be purchased from one tech level higher than level of manufacture of the weapon by multiplying price, weight, and volume by 10.

INDIRECT FIRE CONTROL

Indirect fire control consists of on-carriage sights and off-carriage fire-direction centers.

Indirect fire may be conducted by projectile weapons (CPR guns and electromagnetic mass drivers) and meson guns. While projectile weapons loft their rounds over obstructions to hit their targets, meson guns simply fire through obstructions to hit unseen enemies.

In order to conduct indirect fire, a weapon must have an on-carriage indirect fire sight, which in its simplest form amounts to precise calibration of elevation and traverse enabling the gunner to make exact corrections. More advanced forms allow more precise corrections or access to computerized fire control assistance. This is reflected in the fact that the tech level of the installed fire control equipment is the upper limit on the tech level of fire direction center (FDC) that may be used by that weapon.

Indirect fire sights on mortars have half the weight and cost of those for CPR guns.

Fire direction centers coordinate the fire of several guns at a single target, convert correction requests from forward observers into precise elevation and traverse commands, and calculate the effects of a wide variety of factors on gun accuracy (such as atmospherics, different elevations between the firing guns and the target, and so on). While fire direction centers are not required to conduct indirect fire, they increase the effectiveness of that fire dramatically.

For fire conducted through a fire direction center, the task roll to hit the target is a Difficult (instead of Formidable) task.

Fire direction centers substitute the appropriate weapon skill/asset of the main operator (usually the most skilled gunner in the FDC) for the weapons skills of the gunners of all the weapons controlled by the FDC (called "the battery"). All weapons in the battery must have a communication link to the FDC.

FDCs have a correction delay time (in combat turns) and an effective indirect fire range (in kilometers). The more sophisticated the FDC, the shorter the correction delay and the longer the effective range. Indirect fire at ranges beyond the effective range of the FDC is allowed, but the task roll to hit to hit is Formidable instead of Difficult.

Indirect Fire Sights

TL	Mass	MCr
4	.05	0.004
5	.05	0.006
6	.075	0.008
7	.1	0.01
8	.2	0.02
9	.2	0.1
10	.2	0.15
11-13	.2	0.2
14-15	.1	0.25
16-17	.1	0.3
18-20	.05	0.35
21+	.05	0.4

Mass: Mass of sights in tonnes
MCr: Price of sights in millions of credits

Fire Direction Centers

TL	Delay	Km	MCr
4	10	10	0.1
5	6	20	0.2
6	5	25	0.3
7	4	30	0.4
8	3	35	0.5
9	2	40	0.75
10	1	50	1
11-13	0	60	1.5
14-15	0	80	3
16-17	0	100	5
18-20	0	150	8
21+	0	300	10

Weapon Stabilization

As a vehicle moves, the weapons mounted on it move as well, and since the ground over which the vehicle travels is uneven, the movement of the weapons will be almost as uneven (the vehicle's suspension compensates for this somewhat). That makes it almost impossible to aim and fire a weapon while the vehicle is moving.

The answer is stabilization. A stabilized weapon has its power traverse and elevation linked to a gyrostabilizer which automatically adjusts the position of the weapon to match the movement of the vehicle, allowing aimed fire on the move. As stabilization becomes more effective, vehicles are able to aim and fire their weapons at higher speeds. The three types of stabilization are shown in the Stabilization table.

Stabilization gear stabilizes all weapons in a single mount. The Stabilization table expresses the mass of the gear as a percentage of the weight of the weapon being stabilized. The mass of the weapon includes the mass of its fire control/sights, its mechanical loading assistance, and its ammunition if it is a magazine-fed automatic weapon or autocannon. If it has an autoloader, half of the mass of the autoloader is included in the mass of the weapon, but not the ammunition mass. The gear is located on the mount; however, the stabilization gear for an open mount is located in the chassis. The minimum weight is that for 1 tonne of weapon, even if the weapon's weight is much less than a tonne.

Stabilization

TL	Type	Mass	MCr	Fire if Move
6	Basic	0.05	0.02	Full safe speed
7	Good	0.075	0.04	Twice safe speed
8+	Advanced	0.1	0.05	Any speed

TL: Tech level of first availability.
Mass: The mass, in tonnes, of the stabilization gear is equal to the mass, in tonnes, of the stabilized weapon times the listed decimal.
MCr: Price, in millions of credits, of the stabilization gear is the mass, in tonnes, of the stabilized weapon times this decimal.
Fire if Move: The limit to vehicle movement while firing with that stabilization gear. Safe speed is safe road or safe off-road speed, whichever mode the vehicle is in.
Vol: The volume of the stabilization gear in cubic meters is equal to its mass in tonnes.

Beam Pointers

All heavy (non-small arms) lasers, particle accelerators, and meson guns require beam pointers, which represent the integral fire control capabilities installed on the mount. Beam pointers may only be used on these classes of weapons.

Select a beam pointer from the table on the following page based on the weapon's tech level and the range performance desired. Note that range is given in kilometers and 30,000-km hexes/range bands for space combat. The listed range in km/hexes of the selected beam pointer will be the weapon's short range for purposes of combat.

Special Note on Planetary Combat: Weapons equipped with beam pointers receive the Diff Mod benefits of a ballistic computer of the same tech level (see facing page) when they use direct fire in planetary (ground) combat. This is because these weapons are effectively ballistically perfect and arrive virtually instantaneously at their targets at planetary ranges.

This is for planetary combat *only*; beam pointers allow no Diff Mods to be negated in space combat, only master fire directors (MFDs, see next page) may do this.

Any beam pointer-equipped weapon linked to an MFD which conducts direct fire under MFD control in planetary combat receives the benefits of a point defense computer (see facing page) of the same tech level (beam pointer or MFD, whichever is lower).

When a weapon has its performance adjusted for atmosphere,
remember that its atmosphere-adjusted ranges are for purposes
1 of damage calculation only. Its short range (and medium, long,
and extreme ranges which are derived from it) based on installed
beam pointer are still used for resolving hits.

Range below is given in km and in space combat hexes/range
2 bands.

Beam Pointers

	Range (in km/hexes)	8	9	10	12	14	15	17	19
3		*Volume in m³ at Tech Level*							
	0.3/0*	**0.1**	**0.05**	**0.04**	**0.03**	**0.02**	**0.01**	**0.006**	**0.004**
	3/0*	0.2	0.1	0.08	0.06	0.04	0.02	0.01	0.006
4	**30/0***	**0.4**	**0.2**	**0.15**	**0.12**	**0.08**	**0.04**	**0.02**	**0.01**
	300/0**	0.8	0.4	0.3	0.24	0.15	0.08	0.04	0.02
	3000/0†	**1.5**	**0.8**	**0.6**	**0.5**	**0.3**	**0.15**	**0.08**	**0.04**
	30,000/1	3	1.5	1.2	1	0.6	0.3	0.15	0.08
5	**60,000/2**	**6**	**3**	**2.4**	**2**	**1.2**	**0.6**	**0.3**	**0.15**
	90,000/3	9	4.5	3.7	3	1.8	0.9	0.45	0.25
	120,000/4	**12**	**6**	**5**	**4**	**2.4**	**1.2**	**0.6**	**0.3**
	150,000/5	15	7.5	6	5	3	1.5	0.75	0.4
6	**180,000/6**	**18**	**9**	**7**	**6**	**3.6**	**1.8**	**0.9**	**0.45**
	210,000/7	21	10.5	8	7	4.2	2.1	1.0	0.5
	240,000/8	**24**	**12**	**9**	**8**	**4.8**	**2.4**	**1.2**	**0.6**
	270,000/9	27	13.5	10	9	5.4	2.7	1.3	0.65
7	**300,000/10**	**30**	**15**	**11**	**10**	**6**	**3**	**1.5**	**0.75**

*Weapon cannot be used in space combat, even in same hex.
**Use extreme range (base difficulty of Impossible) for task
8 difficulty in same hex; task is not possible outside of same hex.
†Use long range (base difficulty of Formidable) for task difficulty in same hex; task is not possible outside of same hex.

9 **Volume:** The volume of the beam pointer in cubic meters.
Mass: The mass of the beam pointer, in tonnes, is equal to its volume in cubic meters.
Price: The price, in millions of credits, is equal to the volume in
10 cubic meters multiplied by 0.1.

Master Fire Directors

Spacecraft may be equipped with master fire directors (MFDs)
11 which enhance the performance of installed weapons. While
many small ships with only one or two turrets rely on local turret
control and do not contain MFDs, warships will want several
directors. Each MFD must be provided with a pencil-beam active
12 sensor of its own, with a short range equal to the listed range of
the fire director. The values for this sensor must be chosen from
the Radar table (for TL 8-9 fire directors) or Active EMS table (for
TL 10+) in the Electronics chapter (Section 5), except that the
13 power requirement and antenna size listed are multiplied by 0.1
and the cost is multiplied by 0.5. Volume and mass figures are
unchanged. These numbers are added to those of the MFD, as
they constitute one piece of equipment. The sensor is not used

separately under any circumstances, but is necessary for the
normal functioning of the MFD.

If an MFD is to have the capability to control missiles, it must have a laser or maser communicator from the same tech level installed with it as well. Like the pencil-beam sensor above, it is considered part of the MFD and may not be used for any other purpose, but its full cost, power, and antenna size are used. This communicator should be the same type as installed on the missiles that will be used with the MFD, as the short (automatic contact) range will be limited to that of the MFD or the missile, whichever is shorter. The number of missiles that can be simultaneously controlled by an MFD is equal to the "Diff Mod" listing. When the missile detonates and fires, the missile can only use the MFD's ability to ignore Diff Mods if it is within the MFD's extreme range (8 times the short range shown on the table). Designers should choose the range of their missile control MFDs accordingly.

Note that the task-range performance of weapons that are being fired by an MFD is limited to the range of the MFD if that is shorter than that of the weapon. Therefore, players should take care to install MFDs whose range performance matches that of the installed weapons. A vehicle equipped with an MFD must also be equipped with a St or Fb model computer of equal or higher tech level (see Section 4). MFD crew are not handled at this step. MFD crew are allocated workstations on the bridge or flight deck and are handled in that portion of Major Systems.

Master Fire Directors

Range	8	9	10	12	14	15	17	19
	Volume at Tech Level							
0.3	**0.2**	**0.1**	**0.08**	**0.06**	**0.04**	**0.02**	**0.01**	**0.006**
3	0.4	0.2	0.16	0.12	0.08	0.04	0.02	0.01
30	**0.8**	**0.4**	**0.3**	**0.24**	**0.16**	**0.08**	**0.04**	**0.02**
300	1.6	0.8	0.6	0.48	0.3	0.16	0.08	0.04
3000	**3**	**1.6**	**1.2**	**1**	**0.6**	**0.3**	**0.15**	**0.075**
30,000/1	6	3	2.4	2	1.2	0.6	0.3	0.15
60,000/2	**12**	**6**	**4.8**	**4**	**2.4**	**1.2**	**0.6**	**0.3**
90,000/3	18	9	7.4	6	3.6	1.8	0.9	0.45
120,000/4	**24**	**12**	**10**	**8**	**4.8**	**2.4**	**1.2**	**0.6**
150,000/5	30	15	12	10	6	3	1.5	0.75
180,000/6	**36**	**18**	**14**	**12**	**7.2**	**3.6**	**1.8**	**0.9**
210,000/7	42	21	16	14	8.4	4.2	2.1	1.05
240,000/8	**48**	**24**	**18**	**16**	**9.6**	**4.8**	**2.4**	**1.2**
270,000/9	54	27	20	18	10.8	5.4	2.7	1.3
300,000/10	**60**	**30**	**22**	**20**	**12**	**6**	**3**	**1.5**
Diff Mod	1	2	3	4	5	6	7	8

Range: Short range in kilometers/space combat hexes.
Diff Mod: The number of cumulative adverse difficulty modifiers to hit the fire director ignores, also the number of missiles it may control at one time.
Mass: Mass in tonnes equals volume × 1.
MCr: Price in millions of credits equals volume × 1.
MW: Power requirement, in megawatts, equals volume × 0.01.

Book 3: Weaponry

1 CHAPTER 1
Small Arms Design

This design sequence is aimed at designing "modern" firearms, by which we mean firearms using a fixed cartridge
2 consisting of a bullet (or bullets), propellant, and primer. The ability to manufacture this type of ammunition appears at middle tech level 3, with the near-simultaneous development of advanced metal-working technology (for cartridge cases) and more stable and reliable primers, and becomes widely available at tech level 4.

As classic firearms are defined almost as much by their ammunition as by their own construction, small arms design
3 consists of two parts: ammunition design and weapon design.

4 *PART 1: AMMUNITION DESIGN*

Ammunition is defined by four characteristics: the tech level, the diameter of the bullet in millimeters (also referred to as caliber), the length of the cartridge case in millimeters, and the type of cartridge
5 case (straight, necked, or shotgun). In some cases, the type of cartridge case is further defined as ETC (Electrothermal Chemical) indicating that it is fired from a specially designed ETC gun with an electric pulse which both enhances the power of the propellant and
6 smooths out its energy curve to increase its efficiency. Ammunition for gauss weapons is handled in the gauss weapon design sequence.

Tech Level: Modern ammunition (propellant and bullet carried in a metallic cartridge case and fired by means of a primer in the base
7 of the cartridge case) becomes available at mid tech level 3 and becomes universally used at tech level 4. Electrothermal-chemical (ETC, see page 137) cartridges are widely available at tech level 9, and all non-ETC cartridges are by then caseless. By tech level 12,
8 conventional small arms have mostly been supplanted by gauss and directed energy weapons.

Bullet: The diameter of the bullet in millimeters is called its caliber, and weapons are commonly referred to by their caliber, such as 9mm. Although standard weapons listed in the game are usually in
9 increments of 0.5 millimeters (such as 5.5mm, 7.5mm, etc.), weapons may be designed in any caliber desired, such as 11.43mm or 4.71mm. Small arms may be made in any caliber up 20mm. (Weapons of 20mm and above are usually considered to be cannons.)

10 If the round is to be a shotgun shell, it should be specified at this point, as should the number of bullets in the shell. The number of bullets in the round must either be one (a single large slug) or any multiple of four.

Cartridge Case Length: The longer the cartridge case, the more
11 propellant contained in it and the more powerful the ammunition. Ammunition is often referred to by two numbers, the caliber followed by the cartridge case length, which helps distinguish it from other ammunition of the came caliber. Sometimes the ammunition
12 will also have a common name under which it is sold to the public. For example, 7.62x25mm pistol ammunition is today commonly called 7.62 Tokarev, since it is usually fired from a Tokarev pistol, while 7.62x51mm rifle ammunition is commonly called 7.62 NATO,
13 since it is the standard large-caliber NATO rifle cartridge. In the case of shotgun shells, the length includes the container for the bullets as well, and so 12-gauge shotgun shells (the most common current shotgun round) is also called 18.5x70mm round.

14 **Cartridge Case Type:** For our purposes there are three general types of cartridges: straight, necked, and shotgun.

Straight cartridges have a cartridge case approximately the same diameter as the bullet along its entire length, while necked cartridge cases are larger in diameter than the bullet and then "neck down" at the end to fit the bullet. Necked cartridge cases are considerably more powerful than straight cases and are usually fired from rifles, while straight cartridges are usually fired from pistols and submachineguns. Necked cartridges carry a longer, heavier bullet than do straight cartridges, and the cartridge case must be at least 35mm long in order to be necked. (There do exist some short pistol rounds that are slightly necked, but these are included under straight rounds because their performance is not sufficiently different from straight rounds to justify a distinction.) Shotgun cases are straight cases with fairly light powder charges and either multiple small bullets or a single large slug.

Necked cartridges are not available until tech level 4. Because all non-ETC cartridges at TL 9+ are caseless, it is the cartridge dimensions which are specified here, and not the case.

Note: In the sequences below, unless otherwise instructed, round all results to the nearest whole number.

Ammunition Evaluation

Once the ammunition round has been designed, determine its length, weight, magazine weight, and average muzzle energy.

Length: The ammunition length is determined using the following formulae:

$$Lasg = Lcc$$
$$Las = Lcc + d$$
$$Lan = Lcc + 2d$$

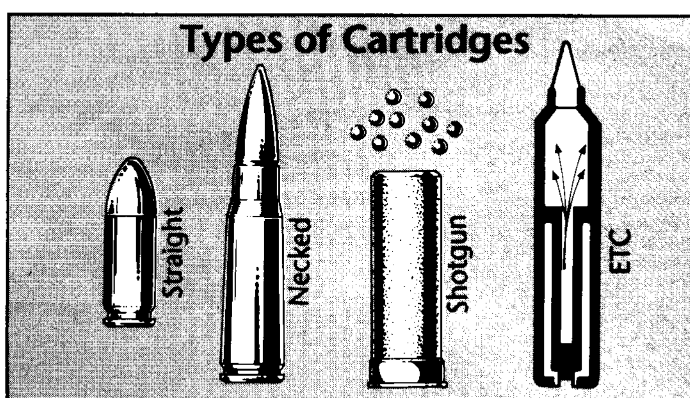
Lasg: Length (in millimeters) of shotgun ammunition.

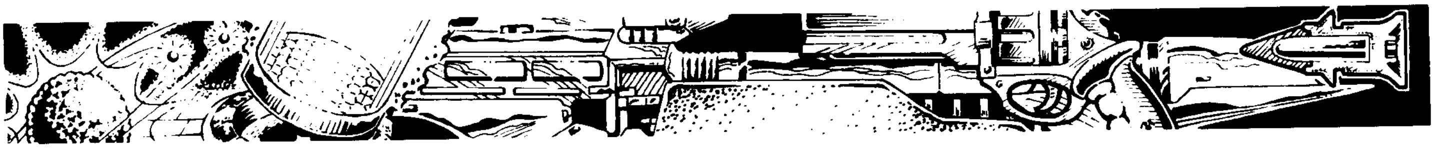
Las: Length (in millimeters) of ammunition with a straight cartridge case.

Lan: Length (in millimeters) of ammunition with a necked cartridge case.

Lcc: Length (in millimeters) of the cartridge case.

d: Diameter (in millimeters) of the bullet.





Weight: The ammunition weight is determined using the following formula:

$$Wa = AwmLcc\,\pi\,r^2$$

r: Radius (in millimeters) of the bullet (half the diameter).
π: 3.1416
Wa: Weight (in grams) of a complete round of ammunition.
Lcc: Length (in millimeters) of the cartridge case.
Awm: Ammunition weight multiplier, which depends on whether the ammunition is a conventional round or a shotgun shell, as shown below.

Ammo Type	*Awm*
Shotgun shell	**0.003**
Straight	0.008
Necked	**0.01**

Average Muzzle Energy: The average muzzle energy of conventional and ETC ammunition is determined using the following formula. (The actual muzzle energy will be affected by the design of the weapon itself.)

$$Ea = TmCmLcc\,\pi\,r^2$$

Ea: Average muzzle energy (in joules) of a cartridge.
Lcc: Length (in millimeters) of the cartridge case.
r: Radius (in millimeters) of the bullet (half the diameter).
π: 3.1416
Tm: Tech level modifier, as shown on the table below

TL	*Tm*
3	**0.6**
4	0.7
5	**0.8**
6	0.9
7	**1**
8	1.1
9+	**1.3**

Cm: Cartridge modifier, as shown on the following table:

Cartridge Type	*Cm*
Shotgun	**0.2**
Shotgun ETC	0.3
Straight	**0.4**
Straight ETC	0.8
Necked	**1.6**
Necked ETC	3.2

Price: The price of the ammunition is determined by the following formula:

$$Cr = WTm$$

Cr: Price in credits
W: Weight of the round in grams.
Tm: Type multiplier, as determined below:

Type	*Tm*
Shotgun	**0.01**
Mass-produced military ammo	0.02
Conventional	**0.04**
High-powered (Ea = 10,000+)	0.05

Special Ammunition

The above design sequence deals with solid slug ammunition (usually called "ball" ammunition). A variety of special small arms ammunition is available as well.

Shotgun: Shotgun shells are the standard ammunition for shotguns, just as ball is for slug-firing rifles. Shotgun shells contain a quantity of round shot which expands in a pattern to allow greater 1
hit probability. The number of rounds in a shell (which must be a multiple of four), determine the way that the shell's fire is resolved. A four-round shell is resolved as a three-dice burst, an eight-round shell as a five-dice burst, and a 12-round shell as a 10-dice burst (see TNE, page 2
279). More rounds than these use combinations of the above, for example, a 16-round shell is resolved as a 10 dice and a three-dice burst fired at the same time, a 24-round burst as two 10-dice bursts, etc.

Like ball, shotgun shells are calculated above and do not have a 3
further price multiplier.

HE: HE, or high-explosive, ammunition (also variously called shredder or exploder) is hollow and contains an explosive filler that detonates on impact. 4

HE rounds are not available before TL 6. Price for HE rounds is multiplied by 2.

DS: DS, or discarding sabot, ammunition (also called SLAP, for saboted, light armor-piercing) is a high-velocity bullet designed to 5
penetrate armor.

DS small arms rounds are not available before tech level 8. Price for DS rounds is multiplied by 2.

HEAP: HEAP, or high-explosive armor-piercing, bullets are hollow, as with HE bullets, but have small shaped charges for penetrating armor. 6

HEAP small arms rounds are not available before tech level 9. Price for HEAP rounds is multiplied by 3.

Tranq: Tranq rounds are nonlethal means of subduing adversaries.

Tranq small arms rounds are not available before tech level 6. Price 7
for Tranq rounds is multiplied by 2.

Flechette: Flechette rounds are like shotgun shells, except that the multiple rounds are carefully machined, finned darts with superior penetrative and ballistic performance. The number of flechettes in a 8
round and the way that their hits are resolved are identical with the method for shotgun shells, above.

Flechette rounds are not available before tech level 5. Price for Flechette rounds is multiplied by 5. 9

PART II: WEAPON DESIGN

1. Barrel 10

The barrel of a firearm carries the bullet after the cartridge is fired. The barrel is usually rifled, and so imparts a spin on the bullet, giving it stability (and thus accuracy) in flight. (Shotguns, intended for very short ranges, fire their bullets through a smooth bore.) In addition, 11
the barrel provides a gas-tight constricted space within which the expanding gas of the exploded propellant can act on the bullet, accelerating it. Once the bullet leaves the muzzle of the barrel, however, it begins decelerating. In general, the longer the barrel the 12
higher the muzzle velocity, up to the point where the bullet reaches its greatest possible velocity.

Average Barrel Length: First, determine the average barrel length for the ammunition being used by the weapon. The following 13
formula is used:

$$Bla = (Ea+d^2)Rm$$

Bla: Average barrel length (in centimeters)—the length of the barrel which allows the ammunition to achieve its average muzzle 14
energy.
Ea: Average muzzle energy (in joules) of the ammunition.
d: Diameter (in millimeters) of the bullet.
Rm: Rifling multiplier, as shown on the following page:

	Type	*Rm*
	Smoothbore	**4**
1	Smoothbore ETC	3
	Rifled	**1**
	Rifled ETC	0.5

Note: Regardless of the results of the above calculations, average
2 barrel length is never less than 10cm.

Actual Barrel Length: The actual barrel length can be any length desired down to a minimum of 20% of the average barrel length and up to a maximum of 230% of the average barrel length.

3 **Type of Barrel:** Two types of barrels are possible: heavy barrels and light barrels. Heavy barrels are required for machineguns or other weapons intended to be used at a high sustained rate of fire, any weapon intended to mount a bipod, and any weapon with firing a
4 cartridge with an average muzzle energy greater than 5000 joules. Light barrels may be used for all other weapons, including shotguns.

Barrel Weight: The weight of the barrel is determined using the following formulae.

5

$$Wbl = .02Lb$$
$$Wbh = .03Lb$$

Wbl: Weight (in kilograms) of a light barrel.
Wbh: Weight (in kilograms) of a heavy barrel.
Lb: Length (in centimeters) of the barrel.

6 **Barrel Price:** The price of the barrel is determined using the following formula:

$$Cr = WbBtm$$

Cr: Price of the barrel in credits.
7 *Wb:* Weight of the barrel in kilograms
Btm: Barrel type multiplier, as determined by the following table:

	Type	*Btm*
	Smoothbore	**100**
8	Light rifled	200
	Heavy rifled	**400**

Actual Muzzle Energy: Once the barrel length is decided on, the
9 weapon's actual muzzle energy can be determined using the following formula.

$$E = Ea\{1 + (0.5[Blp-1])\}$$

E: Actual muzzle energy (in joules) of the weapon
10 *Ea:* Average muzzle energy (in joules) of the ammunition
Blp: Actual barrel length (cm) divided by Average barrel length (cm): Bl÷Bla.
Bl: Actual length (in centimeters) of the barrel of the weapon.
11 *Bla:* Average barrel length (in centimeters) for the ammunition used.

If a multiple-bullet round (i.e., shotgun shells and flechette rounds) is fired from the weapon, divide the actual muzzle energy of the round by the number of bullets in the round to determine the
12 energy of each bullet. This is the figure used when calculating damage, penetration, and range for multiple-round bullets.

If the round fired is Tranq, multiply the muzzle energy by 0.6.

Damage: Once muzzle energy is known, it is possible to calculate
13 damage and using the following formula.

$$D = (\sqrt{E}) \div 15$$

D: Damage value (if D = less than 0.8, damage is 1D6–1)
E: Muzzle energy (in joules)

With a multiple bullet round damage is calculated separately for each
14 bullet. The result is the *medium* range damage of each bullet. The short range damage *of the entire round* is determined by the following formula:

$$Dr = .75NDb$$

Dr: Damage value of the round.
Db: Damage value of a single bullet.
N: Number of bullets in the round.

Note that damage for shotgun shells loaded with a single slug is calculated in the same way as any other single bullet round.

HE and HEAP bullets cause additional damage from the explosion of the round. The explosive energy is determined by adding the diameter of the bullet (in millimeters) to the tech level of the bullet and subtracting 7, then cubing the resulting number. The result is the explosive energy of the bullet. When calculating damage, the value for E in the formula becomes the sum of muzzle energy and explosive energy.

All Tranq rounds have a damage value of –1* (1D6–1 damage points) where the "*" refers to their tranq effects as determined by the rules for Tranq rounds found on page 350 of the basic **Traveller** rules.

Penetration: It is also possible to determine penetration once muzzle energy is known by consulting the following table.

E	*Pen*
0-600	**Nil**
601-2000	1-Nil
2001-3000	**2-Nil**
3001-5000	2-3-Nil
5001-10,000	**2-4-6**
10,001-20,000	2-3-4
20,001-50,000	**2-2-3**
50,001+	2-2-2

Shotguns are an exceptions to this, as their bullets tend to be heavier but slower-moving. All shotgun bullets (both single slugs and multiple-projectile bullets) have a penetration of 3-4-5. (Note, however, that since multiple-projectile shotgun rounds cannot fire beyond medium range, buckshot penetration is effectively 3-NA-NA.) This applies only to shotgun slugs or shells. Flechettes (even those fired from shotguns) calculate penetration normally using the per-flechette energy.

(Note that the very high short-range damage of multiple-bullet shotgun shells and flechette rounds is caused by multiple-bullet hits, each with a lower damage value. In most cases the penetration of multiple bullets from a shotgun will be Nil because the penetration of each individual bullet is Nil, but see the discussion of penetration four paragraphs below for possible special cases.)

For DS ammunition, subtract 1 from each penetration number of the penetration value of the weapon. For example, a penetration of 2-4-6 would become 1-3-5. If one of the values is already 1, it remains 1. If one of the values is Nil, it becomes 1 higher than the previous value and Nil is added after it. For example, a penetration of 1-Nil would become 1-2-Nil. Ammunition with a listed penetration of Nil becomes 1-Nil instead.

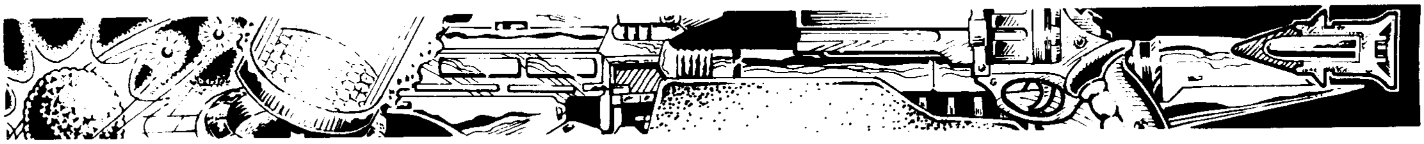
For HEAP ammunition, penetration is always 2-2-2.

For HE and Tranq ammunition, penetration is always Nil.

For multiple bullet rounds, calculate the penetration of each bullet separately. If this results in a penetration other than Nil, it will be necessary to calculate the damage of each bullet at short range. Rather than being resolved as one single round at short range, a rolled hit means that 75% of the bullets have hit the target and are each resolved with their individual damage and penetration performance.

2. Receiver

The receiver is the mechanical heart of a firearm. It "receives" the cartridge from the magazine, places it in the chamber, holds it in place with the bolt, and fires it with the firing pin. Some receivers, such as in bolt-action rifles, are manually operated, while others, such



as in automatic and semiautomatic weapons, are operated by gas from the fired round or direct recoil energy.

Weapons which fire ammunition with high muzzle energy require heavier and longer receivers, as do weapons intended for high sustained rates of fire. Sometimes weapons are given heavier receivers simply to absorb additional recoil, and thus allow more accurate fire.

Receiver Type: There are a number of different types of receivers which define the method of operation of the weapon. All receivers are divided into two general categories: heavy and light.

In the case of self-loading receivers (automatic and semiautomatic weapons), both light and heavy receivers are available. Weapons intended to operate primarily or exclusively on the automatic setting (machineguns) should have a heavy receiver. All belt-fed or cassette-fed weapons must have a heavy receiver. Weapons intended to operate only in semiautomatic fire, or which are selective fire weapons, may use a light receiver (but are not required to).

At tech level 9 and above, any receiver may be constructed as an ETC receiver by so designating in the design process.

TL	*Action*	*Weight*
3	Individually loading	Light
3	Revolver	Light
3	Lever-action	Heavy
4	Bolt-action	Light
4	Pump-action	Light
4	Heavy self-loading	Heavy
5	Light self-loading	Light

Rate of Fire: Individually loading, lever-action, bolt-action, and pump-action weapons have rate of fire (ROF) codes of SS (single shot), LA (lever action), BA (bolt action), and PA (pump action) respectively.

Revolvers from tech level 3 have an ROF code of SAR (single-action revolver) while those from tech level 4 or higher have a code of DAR (double-action revolver).

Weapons with light self-loading receivers may be either semiautomatic (ROF code of SA) or selective fire, with a full automatic rate of fire of either 3 or 5 shots per burst, at the designer's option (selective fire always includes the single-shot SA option).

Heavy self-loading receivers may be either semiautomatic (ROF code of SA) or selective fire (ROF code of either 3, 5, or 10).

With selective fire, the designer must specify how many rates of fire are available (single-shot SA is always available in all self-loading receivers). That is, a selective fire weapon may have a listed ROF of 5/10, meaning that it can be fired as a semiautomatic weapon, an automatic weapon with an ROF of 5, or an automatic weapon with an ROF of 10.

Receiver Length: Receiver length is determined by the following formula:

$$Lr = Tm(\sqrt{Ea})$$

Lr = Length (in centimeters) of the receiver
Tm = Tech level multiplier, as shown below
Ea = Average muzzle energy (in joules) of the ammunition

TL	*Tm*
4-5	.55
6-7	.5
8-9	.45
10+	.4

Receiver length must always be at least as long as the cartridges it fires.

Receiver Weight: Once the type of receiver is known, its weight can be calculated using the following formulae:

$$Wrl = .001Ea$$
$$WrlET = .0005Ea + 0.3$$
$$Wrh = .002Ea$$
$$WrhET = .001Ea + 0.3$$

Wrl: Weight (in kilograms) of a light receiver.
WrlET: Weight (in kilograms) of a light receiver of an ETC gun.
Wrh: Weight (in kilograms) of a heavy receiver
WrhET: Weight (in kilograms) of a heavy receiver of an ETC gun
Ea: Average muzzle energy (in joules) of the ammunition.
For shotguns, multiply receiver weight by 0.6.

Receiver Price: The price of the receiver is based on its weight and type of action, according to the following formula:

$$Cr = WrAm$$
$$CrET = WrAm+200$$

Cr: Price in credits
CrEt: Price in credits of ETC receiver
Wr: Weight (in kilograms) of the receiver
Am: Action multiplier, as shown below

Action	*Am*
Individually loading	50
Revolver	150
Lever-action	300
Bolt-action	300
Pump-action	300
Self-loading SA	200
Self-loading selective	250
Self-loading deluxe	300

Notes: A self-loading selective receiver is a selective fire receiver with semiautomatic fire and one automatic ROF. A self-loading deluxe receiver is a selective fire receiver with, in addition to semiautomatic fire, more than one automatic rate of fire option (regardless of how many).

Doubles

Any weapon using an individually loading receiver may have more than one barrel if the designer wishes (this is common in shotguns and large-bore rifles). Each barrel must have its own individually loading receiver, but only one stock/grip is needed. These barrels need not be identical in caliber, but they must be identical in length.

It remains for the designers and users of such weapons to discover the practical limit on the number of barrels to be incorporated into such a design, but such weapons normally only include two (hence the name), and seldom more than three. Double-barreled shotguns are the most common, but it is not uncommon to combine a smoothbore shotgun barrel with a rifle barrel, or two rifle barrels. Double weapons are primarily used for hunting, and are seldom used for military purposes due to their obvious drawbacks (low magazine capacity, lengthy reloading time, and relatively heavy weight).

3. Stocks

Stocks refer to rifle stocks and pistol grips. The desired stock for the weapon is selected from the following table. Note that carbine stocks are generally fitted to rifles with short barrels (up to 80% of the average barrel length for the cartridge) or sport versions of rifles. They are not considered sturdy enough for full-length rifles in military use. If a weapon (such as a machinegun) is to be used exclusively from a tripod or a vehicle, it only needs a pistol grip instead of a stock.

TL	Type	L (cm)	M (kg)	Cr
4	Wood pistol grip	0	0.2	5
5	Hollow pistol grip	0	0.1	25
4	Wooden stock	25	1	25
4	Carbine stock	25	0.7	20
6	Folding stock	5/25	0.5	50
7	Plastic stock	25	0.5	30
7	Bullpup	5	0.1	10

Range: Once the type of stock is known, the weapon's range can be calculated according to the following formula:

$$SR = (\sqrt{E})\ CmBlm$$

SR: Short range (in meters) of a weapon.

E: Muzzle energy (in joules)

Cm: Configuration modifier, as shown below. If two configuration descriptions apply to the same weapon, multiply them together to determine the total configuration multiplier.

Configuration	Cm
Bullpup	0.9
Bolt-action	1.1
One-handed	0.4
Two-handed*	1.3
Smoothbore single-shot**	0.5

*Two-handed refers to weapons specifically designed to be fired with two hands, and thus including a stock instead of simply a pistol grip. However, all vehicle- or tripod-mounted weapons are considered to be two-handed, even if equipped with only a pistol grip.

**Shotgun single-slug rounds, but *not* multiple-shot rounds.

Blm: Modification to short range for barrel length. The barrel length modifier is determined by the following formula:

$$Blm = 1 + ([Blp-1]\times C)$$

Blm = Barrel Length Modifier

Blp = Actual barrel length (cm) divided by Average barrel length (cm): Bl÷Bla

Bl = Barrel Length

Bla = Average Barrel Length (for the cartridge)

C = Constant. If Blp–1 is a negative number, the constant is 1.2. If Blp–1 is a positive number, the constant is 0.75.

DS Ammunition: Multiply range by 1.2 for DS ammunition.

HE and HEAP Ammunition: Multiply range by 0.75.

Tranq Ammunition: Multiply range by 0.6, but short range is never more than 30 or less than 4 meters regardless of the calculated value.

Limits on Short Range: Regardless of any modifications made in this step or later (through additions of sights or mounts), the upper limit on the short range of small arms is 300 meters. Even direct line-of-sight energy weapons (such as lasers) are constrained by the physiological limitations of the operator.

Final Short Range: Once short range is computed (after all modifications for sights, mounts, etc.), if it is greater than 20 meters, round it to the nearest 10 meters. (However, retain the "iron sight" range without rounding—see "Advanced Sights," page 98.) Short ranges less than 20 meters are retained without rounding.

4. Feed System

The feed system is the method by which individual rounds are stored in the weapon fed to the receiver.

Breach-Loaded: Breach-loaded weapons have no magazine, as the individual bullets are loaded directly into the receiver.

Cylinder: A cylinder is the magazine of a revolver, but its weight is included in the weight of the receiver. The capacity of the cylinder is 19 divided by the square root of the bullet diameter.

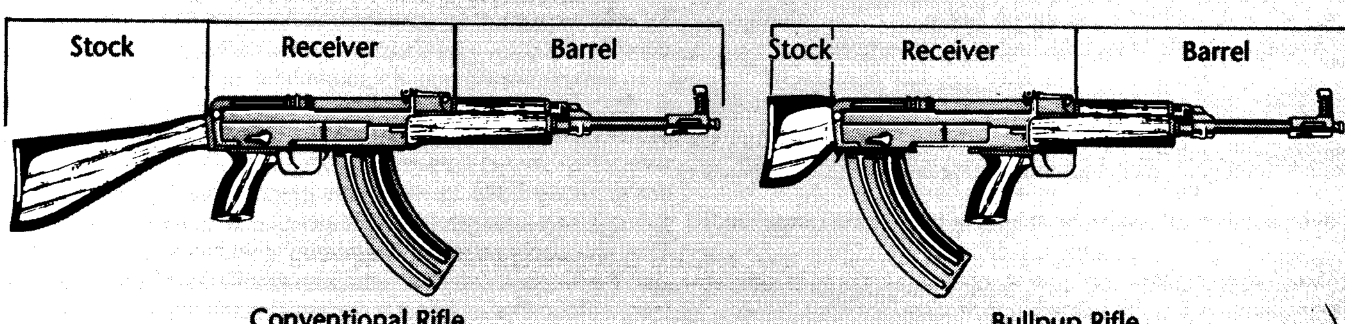
Belt: Belts are linked rounds fed directly into the receiver. Only heavy self-loading receivers may be belt-fed. Belts usually hold 100 rounds, although they may hold more or less if desired. The weight and price of the links are negligible.

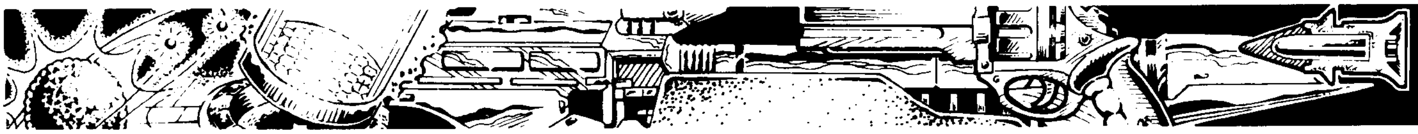
Bullpup Configuration

The basic configuration for small arms weapons is a barrel, receiver, and stock. The receiver has to be in the middle, for obvious reasons, and has to be long enough to accommodate the trigger mechanism (usually in the form of a pistol grip) and the feed system (usually a box magazine). The trigger mechanism must be far enough forward from the base of the stock for the firer to comfortably hold it to steady the weapon while aiming. Given these requirements, there doesn't seem to be much room for rifle designers to improve on the classic arrangement of the parts. That being the case, the only way to get a shorter rifle is to shorten the barrel, which adversely affects muzzle energy and range.

The bullpup configuration is a way to partially circumvent the problem. The barrel and receiver are just as long as with a conventional rifle, but the trigger mechanism and feed assembly are placed at opposite ends of the receiver. This allows most of the receiver length to be used for the stock, with only a small recoil pad added to the end. Without sacrificing any critical component, the overall weapon length is reduced.

There are two drawbacks to the bullpup configuration. First, it is more difficult to build the receiver, and make it jam-proof, in this configuration than in the more common one. By tech level 8, however, these engineering problems have been overcome. Second, the sight radius is shorter than on a conventional rifle of the same barrel length, and this reduces accuracy slightly when using iron sights. (This is why there is a configuration modifier to range of 0.9 for a bullpup rifle.) This can be overcome by mounting optical sights, which do not depend upon a long sight radius for accuracy, on the weapon.





Cassette: A cassette is a pre-packaged container of ammunition attached to an endless link feed system which moves the ammunition to the weapon. Only heavy self-loading receivers may be cassette-fed. Cassette feed systems are usually electrically powered, either by batteries or by an engine. Cassette feed systems are available at tech level 7 and above.

A cassette feed system masses 2 kilograms plus the mass of the ammunition contained in it. Due to the basic overhead cost of the power and feed system, cassettes seldom hold fewer than 1000 rounds. The price of an empty cassette is equal to the price of a single round of ammunition for the weapon multiplied by 500.

Grip Magazine: Grip magazines are small box magazines inserted through a hollow pistol grip.

Grip magazines may not hold necked cartridges.

The maximum length of bullets in grip magazines, as well as the number of rounds which can be carried in a grip magazine, varies with tech level, as shown in the table below. The capacity, however, applies only to magazines which fit completely inside the pistol grip. Weapons which are never holstered (such as submachineguns) may have longer magazines. The maximum ammo length still applies, but the capacity of the magazine otherwise is determined as for a box magazine.

TL	*Max Al*	*Cap*
4	30	80+d
6	40	100+d
7	50	120+d
8+	60	140+d

TL = Tech level
Max Al = Maximum ammunition length
Cap = Maximum number of rounds in the magazine
d = Bullet diameter

Box Magazine: A box magazine is a spring-loaded metallic or plastic box which is attached to the receiver. A weapon may only be fed by a box magazine if its receiver is at least 150mm longer than the length of the cartridge fired by the weapon. Maximum box magazine capacity is 200 for rounds massing 15 g or less, and 100 for heavier rounds.

Clip: A clip is a thin piece of metal holding a group of rounds together. The clip is pushed into the receiver, and the rounds enter a nonremovable internal magazine. The clip is either discarded at that point or ejected by the weapon when the last of the rounds are expended. A weapon may only be clip-fed if its receiver is at least 150mm longer than the length of the cartridge fired by the weapon. The clip itself has negligible mass and price. Clips may not hold more than 10 cartridges.

Tubular Magazine: A tubular magazine is a hollow, spring-loaded metallic tube into which individual rounds are loaded. Tubular magazines are long, must be mounted parallel to the barrel, and so can only be mounted under the barrel, over the barrel, or in the stock.

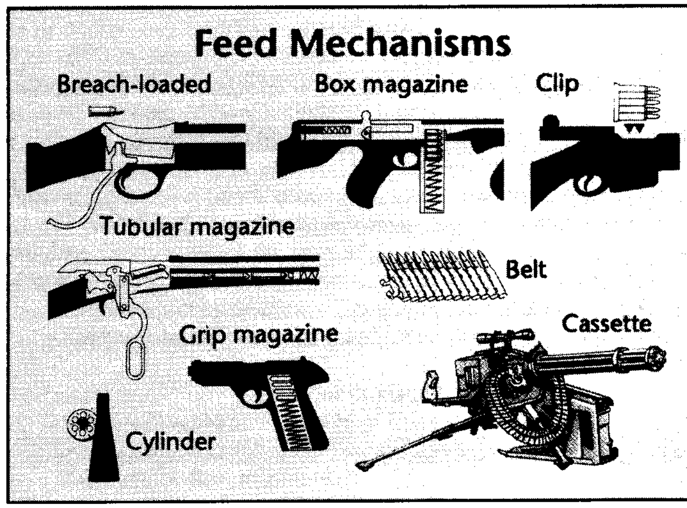
The maximum capacity (number of rounds) in a tubular magazine is its length divided by the length of a single cartridge, rounding fractions down. The maximum length of the magazine is the barrel length or, if mounted in the stock, 25cm.

Magazine Weight: The weight of an empty magazine (grip magazine, box magazine, clip-fed internal magazine, or tubular magazine) is determined by the following formula.

$$Wm = .0006(N+4)Wa$$

Wm: Weight (in kilograms) of an empty magazine.
Wa: Weight (in grams) of a complete round of ammunition.
N: Number of rounds the magazine is designed to hold.

A loaded magazine weighs this plus the weight of the individual rounds loaded into it. Note that in the case of tubular and clip-fed internal magazines, the empty magazine is a permanent part of the weapon and so forms part of its empty weight.



Empty magazines cost Cr10 per kilogram, rounding fractions up.

Electrothermal Chemical Feed Systems: ETC weapons may only be fed by box magazine, grip magazine, belt, or cassette. In all cases, the power source (a fast-discharge battery) is included in the feed device. Belts usually come in ammunition boxes which also contain the battery pack necessary to fire the belt of ammunition. The table below shows the price and weight addition to the feed device *per round* at each tech level.

TL	*Kg*	*Cr*
9	.027	5
10	.019	5
11	.013	5
12	.011	5

In addition, the internal volume available for ammunition is reduced in a grip magazine. When calculating the number of cartridges which can fit in the magazine, add 1 to the effective diameter of the bullets.

Note: The battery packs in ETC magazines are rechargeable and reusable.

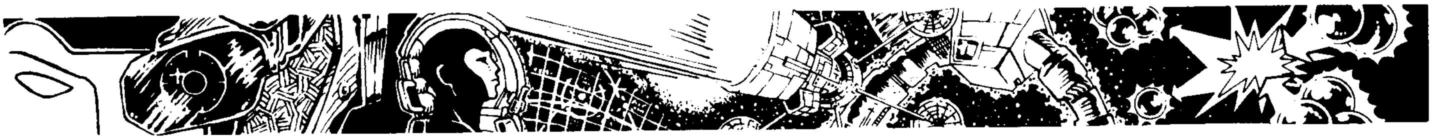
5. Options

Sights: The basic ranges calculated above assume traditional iron sights. Optic sights may be fitted instead of iron sights. Optic sights are rugged military versions of telescopic sights, which do not provide the same long-range benefits of those sights but which do improve accuracy. Optic sights increase the weapon's short range as noted below.

Optic Sights

TL	*Range (Mult)*	*Mass (kg)*	*Price (Cr)*
7	x1.05	0.1	150
8	x1.1	0.1	150
9+	x1.15	0.1	150

Laser Sights: A laser sight may be substituted for or added to any other sight. A laser sight allows up to three shots fired during a turn to count as aimed shots (instead of only the first one). All other shots fired during the turn count as quick shots. The sight may only be used at ranges up to its maximum listed range.



Laser Sights

	TL	Mass (kg)	Range (m)	Price (Cr)
1	8	1	40	400
	9	1	240	1000
	10	0.5	240	300

Advanced Sights: For two-handed weapons, the basic (iron sight) range
2 should be calculated as well, even if an optic sight is installed. This is necessary since an advanced sight may be installed later, and an advanced (either telescopic or electronic) sight adds 15 or 20 meters to the weapon's basic (iron sight) range, not the enhanced optic range.
3 Advanced sights may not be fitted to one-handed weapons.

Advanced Sights

	Type	TL	Range (m)	Vol (liters)	Mass (kg)	Price (Cr)
4	Telescopic	6	+15	0.8	0.1	200
	Electronic	9	+20	1.5	0.2	2000

Mounts: Bipods and tripods may be provided for weapons.
5 Tripods may be of any weight desired, but the highest base recoil number of the weapon (usually attained when firing a burst) may not be greater than the weight of the tripod in kilograms. Bipods are usually custom built for weapons, and their weight is determined
6 using the following formula.

Wbp = .0005E (but never less than 1 kg)

Wbp: Weight (in kilograms) of the bipod
E: Muzzle energy (in joules)

7 *Recoil:* The recoil of a weapon (calculated below after final mass is established) when fired from a bipod is the standard value times 0.5. The recoil of a weapon when fired from a tripod is the standard value times 0.25. Weapons fired from moving vehicle mounts have
8 negligible recoil.

The price of tripods is determined by the following formula:

Cr = 100 + (10W)

Cr: Price in credits.
9 *W:* Weight in kilograms.

The price of bipods is determined by the following formula:

Cr = 50 + (10W)

Cr: Price in credits.
10 *W:* Weight in kilograms.

Range: Bipods and tripods extend the range of the weapon, as shown on the following table (all vehicle-mounted weapons also
11 receive the tripod modifier).

Mount	Range
Bipod	×1.3
Tripod	×2.0

12 **Bayonet Lugs:** Bayonet lugs are simple standardized brackets at the end of the weapon barrel. A bayonet lug costs nothing and has negligible mass, but must be specified as part of the design.

A bayonet is less useful than a hand-held knife unless it is mounted
13 on a well-balanced weapon with sufficient length to allow it to be used as a spear point. As a result, only weapons with a bulk (see below) of 4 or more may profitably benefit from a bayonet lug. Shorter weapons may have them, but the mounted bayonet counts
14 as a short range (instead of long range) melee weapon and suffers a +1 Diff Mod for its chance to hit in armed melee combat.

Grenade Adapter: A grenade adapter allows the firing of rifle grenades and adds 5 cm to the length of the weapon and costs Cr50.

Non-Metallic Weapons: Weapons may be made from all non-metallic components to make them easier to conceal. Multiply price of *all* components (including ammunition, magazines, sights, recoil reduction equipment, etc.) by 3.

Recoil Reduction: There are three types of devices used to reduce recoil: muzzle brakes, shock absorbers, and compensators. No more than one of each type may be added to the weapon. Some weapons enjoy lower recoil because of the type of action employed, and these are treated as a separate fourth type of recoil reduction.

Muzzle Brakes

TL	Type	L	W	Rcm	Cr
6	Muzzle Brake	4	.2	.9	50
7	Muzzle Brake	4	.2	.85	50
7	Long Muzzle Brake	8	.4	.7	200
8	Muzzle Brake	4	.2	.8	50
8	Long Muzzle Brake	8	.4	.65	200
9	Muzzle Brake	4	.2	.75	50
9	Long Muzzle Brake	8	.4	.6	200

Shock Absorbers

TL	Type	L	W	Rcm	Cr
5	SA Stock**	0	.1	.95	50
7	SA Stock**	0	.2	.9	75
9	Folding SA Stock**	0	.2	.9	150
9	SA Stock**	0	.2	.85	75

Compensators

TL	Type	L	W	Rcm	Cr
10	Gyroscopic Compensator	0	.5	.5	300
14	Inertial Compensator***	0	1	.3	1000

Action

TL	Type	L	W	Rcm	Cr
4	Auto or Semiauto*	—	—	.95	—
9	Electrothermal Chemical*	—	—	.6	—

TL: Tech level
L: Length in centimeters
W: Weight in kilograms
Cr: Price in credits
Rcm: Recoil compensator modifier
SA: Shock-absorbing

*Automatic and semiautomatic weapons have a limited built-in recoil compensation system, as some of the weapon's recoil is used (and absorbed) operating the mechanism of the weapon itself. By the same token, electrothermal chemical guns have lower recoil than their muzzle energy would normally indicate and so have what amounts to a built-in recoil reduction. This is automatically included in the weapon and has no additional cost or weight.

**The prices and weights for an SA (shock-absorbing) stock represent the cost to add this mechanism to a conventional stock, and so are in addition to the cost and weight of the stock already fitted. The shock-absorbing feature may usually only be added to solid stocks, not folding stocks. When the folding shock absorbing stock becomes available (TL 9) it may be added to either type of stock.

***The inertial recoil compensator is worn as a harness and the gun is attached to it by a flexible arm. The arm becomes rigid when the weapon is fired and the recoil compensator in the harness pack absorbs much of the force of the recoil. Unlike all other recoil reduction devices, the weight of the inertial compensator is not added to the weight of the weapon (Ww) for purposes of determining recoil weight below.

If a weapon has more than one Rcm, multiply them together to get a single combined value.

If a weapon has no recoil modifiers, its Rcm is 1.

Recoil: Once any recoil compensators have been installed, the weapon's recoil when firing a single shot can be calculated. (Include the weight of a bipod, but *not* a tripod.)

$$R = \{[(0.15\sqrt{E})+Ww] + Em\} \times Rcm$$

R: Recoil number

E: Muzzle energy

Ww: Weight, in kilograms, of weapon (use empty weight for belt- and cassette-fed weapons, loaded weight for all others)

Rcm: Recoil compensator modifier.

Em: Modifier for high muzzle energy. If the weapon has high muzzle energy, add to the final recoil as shown on the chart below.

E	*Em*	*E*	*Em*
1001+	1	10,001+	4
2501+	2	20,001+	5
5001+	3	50,001+	6

When calculating the recoil energy of a burst of shots, the following formula is used:

$$R = (\{[(Bn+2)(0.15\sqrt{E})]+Ww\} + \{[Bn+2]Em\}) \times Rcm$$

Bn = number of shots in the burst.

Bulk: Weapon length is calculated by adding the lengths of all of the individual components. Once the final length of the weapon has been determined, the bulk can be calculated. Bulk is equal to the weapon length (in centimeters) divided by 15, rounding all fractions down.

Volume: Weapon volume, for purposes of installation in a vehicle, is one liter per kilogram of mass (or one cubic meter per tonne).

6. Tinkering the Design

Most of the specifications for the weapon are minimum specifications, and so a weapon can always be heavied up (to reduce its recoil, for instance). This is usually done by adding weight to the receiver. If the weapon has a light receiver, its weight can be increased until it reaches the weight of a heavy receiver for a weapon of that muzzle energy. Once it reaches the weight of a heavy receiver, its weight can only be increased by increasing the length of the receiver. The percentage increase in weight over the weight of a heavy receiver is the percentage increase in length produced by that extra weight.

By the same token, a designer may wish to increase the length of a receiver (to make it possible to use a box magazine, for example). In this case the percentage increase in receiver length is the percentage increase made in receiver weight.

Silencers and Sound Suppressors

True "silencers" are very difficult to construct because, although the sound of the cartridge firing can be muffled, the sound of a supersonic bullet passing through the air cannot, and it is this crack (a mini sonic boom) that is usually heard by hostiles. In fact, many combat soldiers report that they have never heard any weapon firing but their own while in combat, so completely does the mind filter stimuli in a desperate situation, but they regularly hear the passage of hostile bullets.

Sound suppressors effectively muffle the sound of the weapon firing while leaving the sonic crack of the bullets unmodified. This will have no effect on the ability of target personnel to realize that they are under fire or in determining the direction of the fire. What it does do is make it more difficult for personnel not part of the firefight to notice that it is going on. Firefights conducted with suppressed weapons will seldom be heard beyond 500 meters in open countryside or 100 meters in urban areas.

Truly silenced weapons not only muffle the sound of the cartridge firing but also slow the bullet (usually by bleeding off muzzle gas) to 1
sub-sonic speeds. This reduces the sound of the bullet but also considerably reduces muzzle energy. Silenced weapons will not be heard beyond 25 meters in open countryside or five meters in urban areas.

A silenced weapon has its muzzle energy (and as a result its range, 2
damage, and penetration) reduced to that of a weapon of the same caliber but a 15mm straight non-ETC cartridge case. Mounting a standard noise suppressor on a weapon which already fires low-powered cartridges (15mm or less straight non-ETC) and which have
a noise suppressor mounted are considered silenced. 3

Silencer

Length: 1cm per 25 joules of muzzle energy
Weight: 0.025 kg per cm of length 4
Price: Cr5 per cm of length

Suppressor

Length: 1cm per 100 joules of muzzle energy
Weight: 0.025 kg per cm of length 5
Price: Cr5 per cm of length

Flash Suppressors

A flash suppressor reduces or eliminates muzzle flash. All firearms 6
have a muzzle flash at night. Weapons with a muzzle energy of 1000 joules or more have a visible daytime muzzle flash when firing from cover or darkened areas (such as woods, buildings, etc.) All weapons with a muzzle energy of 1000 joules or more and a barrel length which 7
is 80% or less have a bright visible muzzle flash in all light conditions.

A flash suppressor will reduce or eliminate muzzle flash, moving the weapon down one "category" for a regular flash suppressor and down two "categories" for a long flash suppressor. A long flash
suppressor is twice the length of a regular suppressor. 8

Flash suppressors may be combined with muzzle brakes by adding the cost of the two together. The total length of the assembly is the length of longer of the two attachments.

9

Flash Suppressor

Length: 1cm per 300 joules of muzzle energy
Weight: 0.01 kg per cm of length
Price: Cr 1 per cm of length. 10

Multiple-Barrel Rotary Guns

The design system does not allow for a rate of fire of higher than 10 per barrel due to overheating. However, it is possible to design a 11
multi-barrel weapon which can deliver a higher overall rate of fire. The design sequence follows the above sequence except where specifically noted below.

1. Barrels: The weapon may have as many barrels as desired, but 12
all of them must be identical.

2. Receiver: Rotary guns must have a heavy receiver, and the weight of the receiver is increased by an additional 10% for every barrel. So, for example, a three-barreled gun would have a receiver
130% as massive as a normal heavy receiver of that caliber. This does 13
not increase receiver length, however.

Rate of fire is always equal to 10 times the number of barrels minus 1.

$$ROF = 10 (Bn–1)$$

Firing characters roll 10 dice for hits at short range, but each rolled 14
hit causes actual hits equal to one less than the number of barrels (Hits = Bn–1). See the **Traveller** rulebook for automatic fire rules and attenuation with range.

3. Feed System: Rotary guns must be cassette- or belt-fed.

Gunshot Wounds

There are few rule mechanics in roleplaying that have generated as much heated discussion as the subject of gunshot wounds and how best to simulate them in a game. The principal reason for this is that, despite the long history of gunshot wounds, interior wound ballistics (the study of what a bullet actually does once it enters a human) have only been subject to careful and systematic study for a few years.

Prior to the last decade, almost all of what we knew about gunshot wounds was anecdotal in nature, based partially on autopsy results (when the wounds were fatal) and partially on the reports of surgeons who treated gunshot wounds, particularly military surgeons. Recently, however, much more systematic study has been done using high-speed photography, test-firing of bullets into blocks of ballistic gelatin (with the same consistency as human tissue), and test-firing into animal carcasses. The U.S. Wound Ballistics Laboratory (WBL), under the direction of Dr. Martin Fackler, has pioneered in this study.

These controlled experiments have gone a long way toward explaining what happens when a bullet enters the human body, and have relegated many of our most cherished beliefs about gunshot wounds to the status of old-wives' tales. A couple of key issues are worth talking about.

Bullet Tumble: Here is a subject about which a huge amount of misinformation has been published. Just recently I picked up an otherwise-reputable source on modern warfare and was told that small-caliber assault rifle bullets (such as from an AK-74 or M-16) actually tumbled through the air, thus causing more dramatic wounds when they hit. Another source didn't go to quite this extreme, but did report that the bullet of the Soviet AK-74 (the 5.45×39mm) is of a very complex design and incorporates an air bubble in the tip of the steel jacket to push the center of gravity back and make it more likely to tumble when it hits its target.

Rubbish.

To begin with, assault rifle bullets do not tumble through the air. Because they are fired from "rifles," they are spin-stabilized and fly straight along their ballistic path. If they tumbled, they would be wildly inaccurate and would lose velocity and energy very quickly.

Second, *all bullets tumble once they hit an obstruction.* I witnessed a convincing demonstration of this conducted by firing various small arms through two paper targets perhaps a meter apart, with the area between them filled with light brush and branches. After firing, the two target were compared. The first target had a perfectly round hole. The second target had an elongated hole (called "key-holing"), meaning that the bullet was beginning to tumble as it passed through it. The demonstration started with small-caliber assault rifles (which everyone knows tumble when they encounter foliage), then demonstrated the same effect with heavier 7.62mm NATO rounds, and wrapped up the show with a Barret .50-caliber sniper rifle. All of the rounds, including the .50-caliber round, began tumbling after hitting the brush.

Third, the impression most people have is that when a bullet tumbles, it does so end-over-end repeatedly. Not so. Dr. Fackler at the WBL has shown repeatedly that when a bullet enters a resisting medium, it will tumble through 180 degrees and then become stable again, exiting the target backwards.

So why does the Russian 5.45×39mm bullet have an air bubble in the tip? About five or six years ago, I had the chance to talk to a representative from the European ammunition firm Dynamit Nobel at a small arms conference. As we talked, it turned out that he had been one of the researchers present when the first examples of 5.56×39mm ammunition captured in Afghanistan had been examined. After carefully cutting open several rounds, their conclusion was that the air bubbles were the result of poor manufacturing techniques. The Soviets simply hadn't been able (or hadn't thought it worth the trouble) to force all of the air out of the tip of the steel jacket when forcing in the lead. From such little things are legends born.

Hydrostatic Shock: For a while it was widely thought that bullets with a sufficiently high muzzle velocity would cause a massive hydrostatic overpressure in the human circulatory system and (in some versions of the theory) explode the heart. Other versions claimed somewhat less dramatic results, but still argued that high-velocity bullets caused massive tissue damage from hydrostatic shock.

Again, the WBL and Dr. Fackler convincingly disproved this. But how can that be? Everyone has seen convincing demonstrations of hydrostatic shock when a bullet is fired into a sealed tin can or sealed water jug and it explodes from the overpressure. Why doesn't the human body behave the same way? Because it is not a tin can.

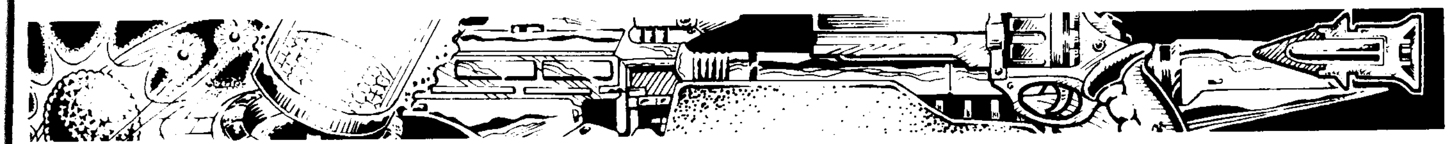
Instead of being rigidly contained, the human body is extremely flexible and can easily absorb sudden transitory pressure surges. The one place this is less true is the head which, because of the skull, is much less elastic and much more susceptible to hydrostatic shock. Aside from head shots, however, hydrostatic pressure is not the killer it was once thought to be.

Size, Velocity, Energy: What actually injures people? Is it the size of the bullet, its velocity, or its energy? The answer, unfortunately, is "it depends."

Let's start by looking at simple tissue damage. A bullet passing through a target destroys tissue along its path, and it destroys that tissue no matter how fast or how slow it goes (assuming it has enough energy to pass completely through the target). The actual amount of damage done is the volume of the wound cavity, which at first glance might seem to be equal to the diameter of the bullet times the length of the cavity. Not quite. Since all bullets tumble, at some point the bullet actually is travelling sideways and it is at that point that most of the serious damage is done. A better measure of a bullet's damage is found by multiplying its diameter by its length. Long bullets (such as those fired from rifles) are much more damaging than the shorter bullets fired from pistols.

But if all that matters is bullet dimensions, what's all the fuss about muzzle energy? The answer is that bullet dimensions are important determinants of *tissue* damage, assuming that's all that the bullet hits. But if the bullet hits bone, bullet energy becomes critical. A low-energy bullet will often ricochet off the bone, sometimes exiting the wound and doing very little damage. A high-energy bullet, on the other hand, will shatter the bone, continue on its course, and send bone fragments through the body as additional tissue-destroying projectiles.

We wanted a fairly simple means of calculating bullet damage, and so chose to base it exclusively around muzzle energy, for three reasons. First, whenever bone is hit (which is fairly often), energy is the main cause of damage. Second, when tissue is hit, a certain minimum muzzle energy is necessary to force the bullet through the target and cause maximum tissue damage, and so even here energy serves as a cap on damage. Third, bullet dimensions (the main cause of tissue damage) are directly related to bullet mass, and, except in very unusual cases, larger bullets have higher muzzle energies.



CHAPTER 2
Gauss Weapons

Conventional small arms accelerate projectiles using the force of expanding gases from an explosion. These weapons are inherently limited by the rate of expansion of the exploding gases and, as noted before, have a practical upper limit on muzzle velocity of about 2000 meters per second.

Electromagnetic weapons, however, have no such limits. These weapons use electric energy to power electromagnets which accelerate projectiles down the barrel of the gun. For these weapons, the practical upper limit of muzzle velocity in the atmosphere is 6400 meters per second. Projectiles moving faster than that will burn up from atmospheric friction. There is no real limit to muzzle velocity in a vacuum, but most electromagnetic weapons are designed for work on a planetary surface and so are designed within the limits of atmospheric operation.

Electromagnetic small arms (2cm and smaller in bore) are called gauss weapons (as opposed to mass drivers, which refers to larger-bore electromagnetic weapons). Gauss weapons can be built in the same configurations as other small arms: pistols, carbines, rifles, and autoguns.

One additional advantage that gauss weapons have over conventional small arms is the lack of barrel friction. Conventional small arms push the bullet out of the barrel by means of expanding explosive gases (or an expanding plasma in the case of ETC rounds). The bullet must be a tight fit in the barrel in order to contain the high-pressure gases behind it, and this means that there is considerable friction between the bullet and the barrel wall. Not only is this energy-inefficient, it generates a great deal of heat. In fact, very little barrel heat is generated by the heat of the propellant explosion; almost all of it is simple friction.

Since a gauss weapon does not rely on a tight gas seal to push the round, the bullet is in only light contact with the barrel as it moves down it and so generates very little friction. This allows a weapon to sustain a much higher rate of fire and to do so without resorting to multiple gun barrels. As a result, most gauss autoguns are usually called VRF gauss guns, the VRF standing for very rapid fire.

Gauss weapons consist of four principal components: a barrel, power source, homopolar generator, and stock or mount. 1

The barrel consists of a series of concentric metallic rings which are the actual magnetic propellers for the round. These magnets are fired in sequence and accelerate the bullet down the barrel. The ring magnets are usually covered with a protective housing. 2

The weapon's power source can be any conventional supply of electricity, and is dictated more by the size of weapon and its likely use than by any unique requirements of the electromagnetic process. Weapons mounted on vehicles often draw on the vehicle's power 3
plant for energy, while man-portable weapons rely on batteries.

Regardless of the means of power generation, a homopolar generator is necessary to store the energy until it reaches sufficient density to power the gun (and until the gunner wishes to fire), and 4
then feeds the energy back in one rapid burst of power. One advantage of the tremendous torque generated by the rapid discharge of the HPG is that it can be used to gyroscopically counter part of the weapon's powerful recoil.

Gauss weapons use stocks and mounts similar to conventional 5
small arms, and are very similar in appearance to such weapons.

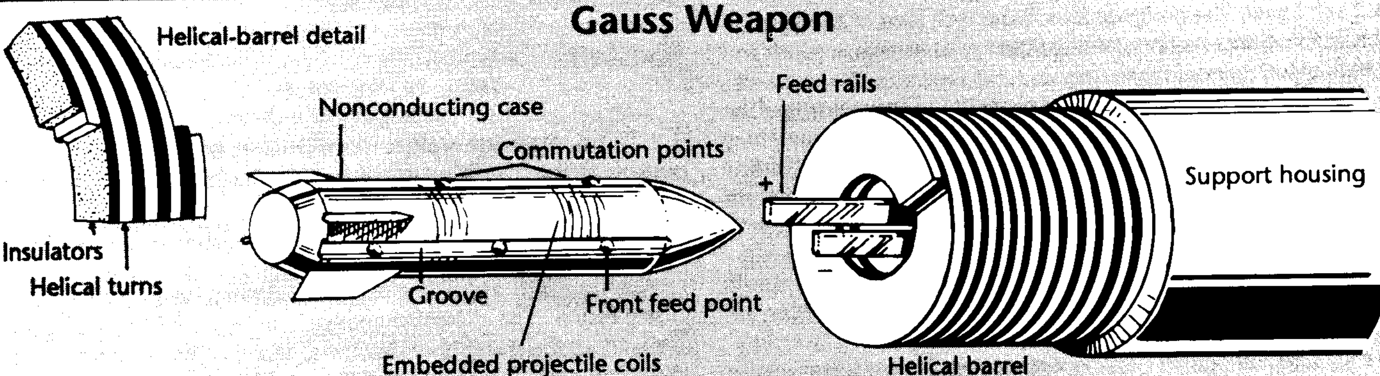
Gauss Ammunition Design 6

Like other small arms, the first step in designing a gauss weapon is to design its bullet. As the bullet is a simple finned dart, however, this is much simpler than with other small arms ammunition.

The only defining characteristic of gauss ammunition is its caliber, 7
expressed in millimeters. Although standard weapons listed in the game are usually in increments of 0.5 millimeters (such as 5.5mm, 7.5mm, etc.) weapons may be designed in any caliber desired, such as 11.43mm or 4.71mm. Small arms gauss weapons may be made 8
in any caliber up to 20mm. (Weapons of 20mm and above are usually considered to be cannons and are covered under Mass Drivers, pages 110-111.) All gauss bullets have a length equal to their diameter multiplied by 5.

Once the size of the round has been specified, determine its weight. 9

Gauss Weapon



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11
12

A slotted copper alloy coil magnet is arrayed to form the barrel of the gauss gun so that current flows through the entire array along one continuous helical path. 13

The bullet (or, more often, a discarding sabot wrapped around a slimmer round) has two projectile coils set into its outer casing (which is itself nonconducting), grooves in the side to fit electrical rails which run along the inside sides of the gun barrel, feed contact points in the grooves, and commutation contact points attached to the coils. The feed contact points set in the bullet grooves allow direct current to pass from the positive left rail into the rear projectile coil and then exit the bullet through the rear coil's commutation contact point into the main magnetic coil. The current then flows along the coil of the magnet until it reenters the bullet's front coil by way of the front coil's commutation contact point and exits the bullet by way of the front feed contact point into the negative rail. In this way, the current moves up the barrel with the projectile, continuously accelerating it. 14

Weight: The ammunition weight (Wa) in grams is determined using the following formula:

1 $$Wa = .02\pi r^3$$

r: Radius (in millimeters) of the bullet (half the diameter).
π: 3.1416

Price: The price of the ammunition is determined by the following
2 formula:

$$Cr = WaTm$$

Cr: Price in credits
Wa: Weight of the round in grams
3 *Tm:* Type multiplier, as determined below:

Type	*Tm*
Mass-produced military ammo	0.02
Conventional	0.04

4 Special Ammunition

The above design sequence deals with solid slug ammunition, called "dart" ammunition for gauss weapons. A variety of special
5 small arms ammunition is available as well.

HE: HE, or high-explosive, ammunition is hollow and contains an explosive filler that detonates on impact.

Price for HE rounds is multiplied by 2.

HEAP: HEAP, or high-explosive, armor-piercing, bullets are hollow, as
6 with HE bullets, but have small shaped charges for penetrating armor.

Price for HEAP rounds is multiplied by 3.

Tranq: Tranq rounds are nonlethal means of subduing adversaries. These are fired at lower-than-usual velocities, to avoid lethality.
7 Price for Tranq rounds is multiplied by 2.

8 *WEAPON DESIGN*

1. Barrel

The barrel of a gauss weapon is a major component of the weapon and is much more sophisticated in design and construction that the
9 barrel of a conventional small arm. Once ammunition has been selected, two design decisions determine everything else about the barrel: tech level and muzzle velocity.

A. Tech Level: The designer selects the tech level of the weapon
10 at this point. Gauss weapons can be designed at tech level 10 and any higher tech level.

B. Muzzle Velocity: The designer selects the muzzle velocity of the weapon. Muzzle velocity is expressed in meters per second and may
11 be any velocity up to a maximum of 6000 meters per second. As a practical matter, gauss small arms rarely have muzzle velocities less than 1500 meters per second or much in excess of 3000 or 4000 meters per second.

12 **C. Evaluation:** Based on ammunition size, tech level, and muzzle velocity, a number of important variables are determined for the weapon that are used in later steps.

1. Barrel Length: The length of the barrel is a function of
13 tech level and muzzle velocity. Higher velocities require longer barrels to provide the necessary acceleration, while advances in technology allow higher acceleration in shorter distances (thus allowing shorter barrels). Barrel length is determined using the
14 following formula:

$$Lb = V \div 100TLm$$

Lb: Length of barrel in centimeters.
V: Muzzle velocity in meters per second. (Step 1-B)
TLm: Tech level multiplier, as shown in the next column:

TL	*TLm*
10	1.6
11	1.3
12	1.0
13	0.8
14	0.6
16+	0.4

2. Barrel Weight: The weight of the barrel is determined using the following formula:

$$Wb = .03Lb$$

Wb: Weight (in kilograms) of a barrel.
Lb: Length (in centimeters) of the barrel. (Step 1-C-1)

3. Barrel Price: The price of the barrel is determined using the following formula:

$$Cr = Wb600$$

Cr: Price of the barrel in credits.
Wb: Weight of the barrel in kilograms (Step 1-C-2)

4. Muzzle Energy: The muzzle energy of the weapon is determined using the following formula:

$$E = (0.5MV^2) \div 1000$$

E: Muzzle energy in joules
M: Bullet mass in grams
V: Muzzle velocity in meters per second (Step 1-B)

Tranq rounds are assumed to have lower muzzle velocities, but this is handled in the Damage Value (Step 1-C-6) and Range (Step 3-A) sections below, and so is not calculated separately.

5. Required Energy: The energy required to accelerate the bullet to the desired muzzle velocity is a function of the total generated muzzle energy, and the efficiency of the weapon in converting electrical power quickly to magnetic force (which is a function of tech level). The required energy (in joules) is equal to the weapon's muzzle energy multiplied by the weapon's tech level efficiency, as shown on the following table.

TL	*Efficiency*
10	3
11	2.4
12	2
13	1.8
14	1.6
16+	1.4

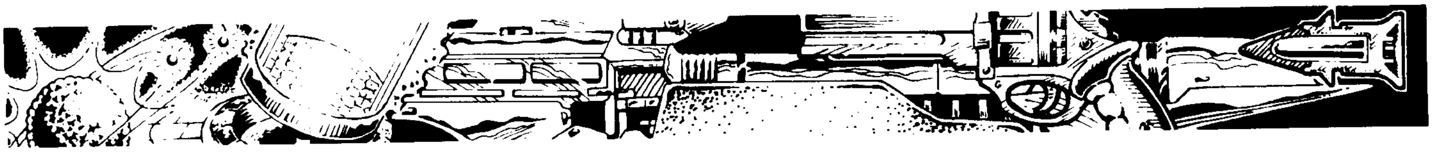
6. Damage Value: Once muzzle energy is known, it is possible to calculate damage and using the following formula.

$$D = (\sqrt{E}) \div 15$$

D: Damage value
E: Muzzle energy (in joules) (Step 1-C-4)

HE and HEAP bullets cause additional damage from the explosion of the round. The explosive energy is determined by adding the diameter of the bullet (in millimeters) to the tech level of the bullet and subtracting 7, then cubing the resulting number. The result is the explosive energy of the bullet. When calculating damage, the value for E in the formula becomes the sum of muzzle energy and explosive energy.

All Tranq rounds have a damage value of –1*, indicating that they do 1D6–1 points of damage plus the special tranq effect discussed on page 350 of the basic **Traveller** rules.



7. Penetration: It is also possible to determine penetration once muzzle energy is known by consulting the following table:

E	*Pen*
0-1000	**Nil**
1001-3000	1-Nil
3001-5000	**1-2-Nil**
5001-10,000	1-3-5
10,001-20,000	**1-2-4**
20,001-50,000	2-2-3
50,001+	**2-2-2**

For HEAP ammunition, penetration is always 2-2-2.

For HE and Tranq ammunition, penetration is always Nil.

2. Receiver

The receiver of a gauss weapon serves a function somewhat different from that of a conventional small arm. As in a conventional weapon, the gauss weapon's receiver "receives" the bullet from the magazine and aligns it with the barrel for firing. There is no mechanical bolt, firing pin, or ignition chamber, however, as the acceleration of the round takes place exclusively in the barrel. Therefore, the receiver houses only the magazine feed system and the internal homopolar generator.

A. Receiver Type: All gauss receivers are of the self-loading variety. The receiver may be semiautomatic (single shot, ROF code of SA) or selective fire (capable of semiautomatic and full automatic fire) at the designer's option.

B. Rate of Fire: If selective fire, designer must specify the automatic rate of fire, 5, 10, or 50. If either ROF 5 or 10 is chosen, the weapon is normal selective fire. If both 5 and 10 are chosen, it is a multi-selective fire weapon. If the rate of fire is 50, the weapon is called a VRF (very rapid fire) gauss weapon.

A listed ROF of 5/10 means that the weapon is multi-selective fire and can be fired as a semiautomatic weapon, an automatic weapon with an ROF of 5, or an automatic weapon with an ROF of 10.

C. Evaluation: Based on receiver type and barrel information, a number of important variables are determined for the weapon.

1. Receiver Weight: The receiver weight is dependent largely on the energy of the weapon and the efficiency of homopolar generators available at that tech level. Receiver weight is determined by the following formula:

$$Wr = PTm$$

Wr: Weight of the receiver in kilograms

P: Required power joules (Step 1-C-5)

Tm: Tech level modifier as shown below.

TL	*Tm*
10	**0.00016**
11	0.00012
12	**0.00010**
13	0.00009
14	**0.00008**
15	0.00007
16	**0.00006**
17	0.00005
18	**0.00004**
19	0.00003
20	**0.00002**
21	0.00001

If capable of fully automatic fire (with a rate of fire of either 5 or 10), multiply the receiver weight by 1.1. If multi-selective fire (capable of both automatic ROFs 5 and 10), multiply the receiver weight by 1.2. If a VRF weapon (rate of fire of 50), multiply the receiver weight by 5.

2. Receiver Length: The length of the receiver is determined by the following formula:

$$Lr = \sqrt{1000Wr}$$ 1

Lr: Length of the receiver in centimeters

Wr: Weight of the receiver in kilograms (Step 2-C-1)

However, the receiver may never be shorter than the length of one bullet. 2

3. Receiver Price: The price of the receiver in credits is equal to its weight in kilograms (Step 2-C-1) multiplied by 100. If capable of selective fire (one automatic rate), multiply price by 1.2.

3. Stocks 3

Stocks refer to rifle stocks and pistol grips. The desired stock for the weapon is selected from the following table. Weapons intended to
fire exclusively from vehicle mounts and/or tripods only require a 4
pistol grip.

TL	*Type*	*L (cm)*	*M (kg)*	*Cr*
4	**Pistol grip**	**0**	**0.2**	**5**
5	Hollow pistol grip	0	0.1	25
7	**Rifle stock**	**25**	**0.5**	**30**
7	Bullpup rifle stock	5	0.1	10

5

A. Range: Once the type of stock is known, the weapon's range
can be calculated according to the following formula: 6

$$SR = (\sqrt{E})\ Cm$$

SR: Short range in meters of a weapon.

E: Muzzle energy in joules (Step 1-C-4)

Cm: Configuration modifier, as shown below. If two configuration 7
descriptions apply to the same weapon, multiply them together to determine the total configuration multiplier.

Configuration	*Cm*
Bullpup	**0.9**
One-handed	0.5
Two-handed*	**1.6**

8

* Two-handed refers to weapons specifically designed to be fired
with two hands, and thus including a stock instead of simply a pistol 9
grip. However, weapons with only a pistol grip but fired exclusively from a tripod or fixed/vehicle mount count as two-handed weapons.

Tranq Ammunition: Multiply range calculated above by 0.6 for 10
tranq ammunition, but short range is never more than 30 or less than 4 meters regardless of the calculated value.

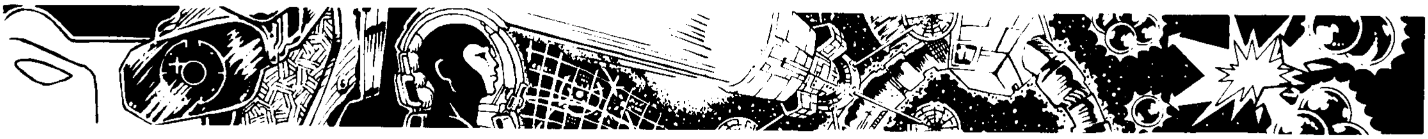
HE and HEAP Ammunition: Multiply range calculated above by 0.75
for HE and HEAP ammunitions. 11

Maximum Range: Regardless of the results of this calculation or any modifications made later (through the addition of sights or mounts), the upper limit on the short range of gauss weapons is 300 meters.

Final Short Range: Once short range is computed (after all 12
modifications for sights, mounts, etc.), if it is greater than 20 meters, round it to the nearest 10 meters. (However, retain the "iron sight" range without rounding—see "Advanced Sights," page 98.) Short
ranges less than 20 meters are retained without rounding. 13

4. Feed System

The feed system is the method by which individual rounds are stored
in the weapon fed to the receiver. Gauss weapon magazines are more 14
complex than conventional small arms magazines since they hold, in addition to the bullets themselves, a battery capable of powering the weapon for the number of shots contained in the magazine.



A. Battery Weight: The weight of the battery in a magazine is a function of the number of rounds in the magazine, the required energy of the weapon, and the weapon's tech level. The battery weight is determined using the following formula:

$$Wb = NErTm$$

Wb: Weight of battery in kilograms.
N: Number of rounds the magazine is designed to hold.
Er: Required energy in joules.
Tm: Tech level modifier, as shown below:

TL	*Tm*
10	.00001
11	.000009
12	.000006
13	.0000055
14	.000004
15	.0000035
16	.000003

B. Magazine Type: Gauss weapons can be fed by grip magazines, box magazines, or cassettes. VRF weapons are usually fed from cassettes, but it is possible to design a large-capacity box magazine which can also feed such a weapon.

Grip Magazine: Grip magazines are small box magazines inserted through a hollow pistol grip.

The maximum length of bullets in a grip magazine is 60mm. The maximum number of rounds that can be carried in a grip magazine is equal to 140 divided by the diameter (in millimeters) of an individual round. The capacity, however, applies only to magazines which fit completely inside the pistol grip. Weapons which are never holstered (such as submachineguns) may have longer magazines. The maximum ammo length still applies, but the capacity of the magazine otherwise is determined as for a box magazine.

Box Magazine: A box magazine is a spring-loaded metallic or plastic box which is attached to the receiver. A weapon may only be fed by a box magazine if its receiver is at least 150mm longer than the length of the cartridge fired by the weapon. Maximum box magazine capacity is 200 for rounds weighing 15 g or less, and 100 for heavier rounds.

Cassette: A cassette is a pre-packaged container of ammunition attached to an endless link feed system which moves the ammunition to the weapon. Cassette feed systems are usually electrically powered either by the batteries or by a vehicle engine.

C. Magazine Evaluation: Once the battery weight and magazine type have been determined, the following information can be determined:

1. Magazine Weight: The weight of an empty magazine (grip magazine or box magazine) is determined by the following formula.

$$Wm = .0006(N+4)Wa + Wb$$

Wm: Weight (in kilograms) of an empty magazine.
Wa: Weight (in grams) of a complete round of ammunition.
N: Number of rounds the magazine is designed to hold.
Wb: Weight of battery.

An empty cassette feed system weighs 2 kilograms plus the weight of the battery for the ammunition contained in it. Due to the basic overhead cost of the power and feed system, cassettes seldom hold fewer than 1000 rounds.

2. Magazine Price: Empty box or grip magazines cost Cr2 per kilogram, rounding fractions up. Empty cassettes cost Cr10 per kilogram, rounding fractions up.

3. Loaded Magazine Weight: A loaded magazine weighs the amount shown above plus the weight of the individual rounds loaded into it.

5. Options

Once the basic mechanical components of the weapon have been designed, a number of optional features may be added.

A. Sights: The basic ranges calculated above assume traditional iron sights. All of the more advanced sights listed below are available at all tech levels at which gauss weapons may be constructed.

Optic sights are rugged military versions of telescopic sights, which do not provide the same long-range benefits of those sights but which do improve accuracy. Optic sights provide a multiplier to the weapon's short range, as shown on the chart below.

Telescopic or electronic sights may only be installed on two-handed weapons and provide a base addition to the short range instead of a multiplication. This short range is the weapon's short range *before* being multiplied by the optic sight modifier.

A laser sight allows up to three shots fired during a turn to count as aimed shots (instead of only the first one). All other shots fired during the turn count as quick shots. The sight may only be used at ranges up to its maximum listed range.

Advanced Sights

Type	*Range (m)*	*Mass (kg)*	*Price (Cr)*
Optic	×1.15	0.1	150
Telescopic	+15	0.1	200
Electronic	+20	0.2	2000
Laser	240	0.5	300

B. Recoil Reduction: There are two types of devices used to reduce recoil on gauss weapons: shock absorbers and compensators. No more than one of each type may be added to the weapon. Some weapons enjoy lower recoil because of the type of action employed, and these are treated as a separate fourth type of recoil reduction.

Shock Absorbers

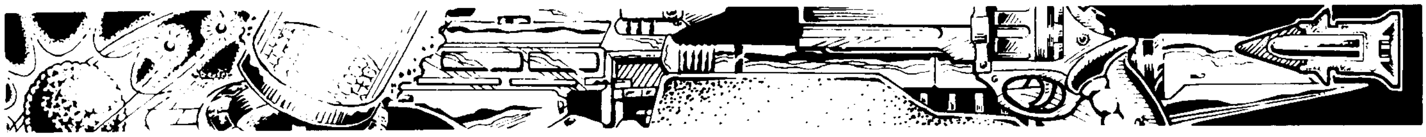
TL	*Type*	*L*	*W*	*Rcm*	*Cr*
9	Folding SA Stock*	0	.2	.9	150
9	SA Stock*	0	.2	.85	75

Compensators

TL	*Type*	*L*	*W*	*Rcm*	*Cr*
10	Gyroscopic Compensator	0	.5	.5	300
14	Inertial Compensator**	0	1	.3	1000

TL: Tech level
L: Length in centimeters
W: Weight in kilograms
Cr: Price in credits
Rcm: Recoil compensator modifier
SA: Shock-absorbing

* The prices and weights for an SA (shock-absorbing) stock represent the cost to add this mechanism to a conventional stock, and so are in addition to the cost and weight of the stock already fitted.



** The inertial recoil compensator is worn as a harness and the gun it attached to it by a flexible arm. The arm becomes rigid when the weapon is fired and the recoil compensator in the harness pack absorbs much of the force of the recoil. Unlike all other recoil reduction devices, the weight of the inertial compensator is not added to the weight of the weapon (Ww) for purposes of determining recoil weight below.

If a weapon has more than one Rcm, multiply them together to get a single combined value.

If a weapon has no recoil modifiers, its Rcm is 1.

C. Mounts: Bipods and tripods may be provided for weapons. Tripods may be of any weight desired, but the highest base recoil number of the weapon (usually attained when firing a burst) may not be greater than the weight of the tripod in kilograms. Bipods are usually custom-built for weapons, and their weight is determined using the following formula.

$$Wbp = .0005E \text{ (but never less than 1 kg)}$$

Wbp: Weight (in kilograms) of the bipod

E: Muzzle energy (in joules)

The price of tripods is determined by the following formula:

$$Cr = 100 + (10W)$$

Cr: Price in credits.

W: Weight in kilograms.

The price of bipods is determined by the following formula:

$$Cr = 50 + (10W)$$

Cr: Price in credits.

W: Weight in kilograms.

Recoil: The recoil of a weapon when fired from a bipod is the standard value (as determined below) times 0.5. The recoil of a weapon when fired from a tripod is the standard value times 0.25. When calculating the weapon's weight to compute recoil in F-1 below, the weight of a bipod (if the weapon is equipped with one) is added into the weapon's weight, but not the weight of a tripod.

Range: Bipods and tripods extend the range of the weapon, as shown on the following table (all vehicle-mounted weapons also receive the tripod modifier).

Mount	*Range*
Bipod	×1.3
Tripod	×2.0

D. Bayonet Lugs: Bayonet lugs are simple standardized brackets at the end of the weapon barrel. A bayonet lug costs nothing and has negligible mass, but must be specified as part of the design.

A bayonet is less useful than a hand-held knife unless it is mounted on a well-balanced weapon with sufficient length to allow it to be used as a spear point. As a result, only weapons with a bulk (see below) of 4 or more may profitably benefit from a bayonet lug. Shorter weapons may have them but the mounted bayonet counts as a short-range (instead of long-range) melee weapon and suffers a +1 Diff Mod for its chance to hit in armed melee combat.

E. Grenade Adapter: A grenade adapter allows the firing of rifle grenades and adds 5 cm to the length of the weapon and costs Cr50.

F. Silenced: A gauss weapon makes very little sound normally as there is no explosive detonation of propellant. The only sound is the sound of the bullet travelling at supersonic speeds. Consequently, all 1
gauss weapons are treated as having sound suppressors. In addition, a gauss weapon can be designed with the capability to reduce barrel coil power sufficiently to fire at subsonic velocities and thus be truly silenced. This option doubles the cost of the weapon's receiver, but 2
has no effect on weapon weight or length.

If this option is selected, it is necessary to recalculate weapon muzzle energy, damage, penetration, and range, all based on a muzzle velocity of 300 meters per second. 3

The weapon can fire either standard ammunition or special low-powered ammunition designed to meet the lower power requirements that come with the lower muzzle velocity.

G. Tinkering: Most of the specifications for the weapon are 4
minimum specifications, and so a weapon can always be heavied up (to reduce its recoil, for instance). This is usually done by adding weight to the receiver. Receiver weight can only be increased by increasing the length of the receiver. The percentage increase in weight over the design weight of a receiver is the percentage 5
increase in length produced by that extra weight.

By the same token, a designer may wish to increase the length of a receiver (to make it possible to use a box magazine, for example). In this case the percentage increase in receiver length is the percentage increase made in receiver weight. 6

These changes in receiver weight and length do not change the price of the receiver.

H. Evaluation: Once the above optional features have been 7
decided on two additional items of information can be determined.

1. Recoil: The weapon's recoil when firing a single shot can be calculated using the following formula:

$$R = \{[(0.15\sqrt{E})+Ww] + Em\} \times (0.5Rcm)$$ 8

R: Recoil number

E: Muzzle energy

Ww: Weight, in kilograms, of weapon (use empty weight for belt- and cassette-fed weapons, loaded weight for all others) 9

Rcm: Recoil compensator modifier.

Em: Modifier for high muzzle energy. If the weapon has high muzzle energy, add to the final recoil as shown on the chart below.

10

E	*Em*	*E*	*Em*
1001+	1	10,001+	4
2501+	2	20,001+	5
5001+	3	50,001+	6

11

When calculating the recoil energy of a burst of shots, the following formula is used:

$$R = (\{[(Bn+2)(0.15\sqrt{E})]+Ww\} + \{[Bn+2]Em\}) \times (0.5Rcm)$$ 12

Bn = number of shots in the burst.

Mounts: The recoil of a weapon when fired from a bipod is the standard value times 0.5. The recoil of a weapon when fired from a tripod is the standard value times 0.25. 13

2. Bulk: Determine the final length of the weapon by adding together the lengths of the individual components. Bulk is equal to the weapon length (in centimeters) divided by 15, rounding all fractions down.

14

CHAPTER 3
1 Chemically Propelled Round (CPR) Guns

CPR guns are the large-bore equivalent of conventional small
2 arms. They work using the same physical laws and have many of the same physical limits, although on a grander scale. The principle is simple: An explosion is contained at one end of a tube. The expanding gases of the explosion escape the only direction pos-
3 sible—down the tube, forcing a solid projectile out ahead of them. The tube is often (but not always) rifled, imparting spin to the projectile to stabilize it in flight. Modern CPR guns which are not rifled fire projectiles which rely on small fins at the rear of the
4 projectile for stability, much like a rocket does. Current armor-piercing ammunition fired by the smoothbore gun of the M1A1 tank is called APFSDS, or armor-piercing, fin-stabilized, discarding-sabot ammunition.

In general terms, designing CPR guns is a simple proposition. The
5 longer the barrel, the greater the muzzle velocity possible, up to the practical limits of the round. The greater the muzzle velocity, the greater the range and, given a constant projectile weight, the greater the muzzle energy. The greater the muzzle energy, the more recoil
6 generated, and hence the more massive a carriage required to absorb that recoil. There are a number of sticky design problems which gun designers have had to overcome over the course of time.

Muzzle Energy: As muzzle energy is a recurring theme in gun
7 design, now is a good time to discuss it. Muzzle energy is simply the energy of a projectile at the moment it leaves the muzzle of a gun. We chose that particular instant because it is the peak energy of the projectile. All the time it is travelling down the barrel, it is accelerating. The instant it leaves the barrel, the expanding gases of the
8 exploded propellant charge cease acting on it and it immediately begins to slow due to atmospheric drag (or, in a vacuum, continues to coast at a constant velocity). Therefore, the projectile will never have more energy than it has at the instant it leaves the muzzle.

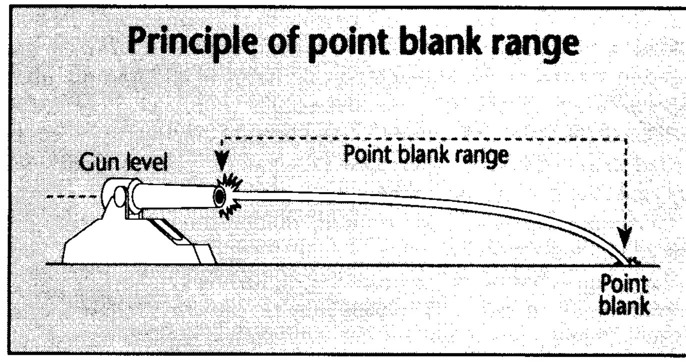
9 Muzzle energy is very easy to calculate if the projectile mass and the muzzle velocity are known, as energy is a simple function of mass and velocity. The formula is: Energy equals one-half mass times velocity squared.

10 $$E = (0.5M)V^2$$

Traveller uses the metric system of measurements, and so the units used in this equation are joules (energy), kilograms (mass), and
11 meters per second (velocity). Since most calculations in CPR gun design use megajoules (1 million joules), convert the result of the above equation to megajoules (Mj) by dividing by 1,000,000.

Effective Range: There are a number of ways of measuring
12 effective range, and as good a way as any is the range at which a gun will hit its intended target more than half the time. Since modern ammunition experiences very little deflection, hitting a target is largely a function of correctly determining the range.

Just as a round begins to decelerate as soon as it leaves the muzzle,
13 so also does it begin to fall (assuming it is fired in a gravity well). If the weapon is pointed straight ahead and level to the ground, the distance at which a shot fired will impact the ground is dependent on the muzzle velocity of the round. This is so because a round dropped
14 from muzzle level and a round fired at the same time will both hit the ground at the same time, since both are falling toward the ground at exactly the same rate. Therefore, the higher the muzzle velocity, the farther the round will travel from the gun before hitting the ground.



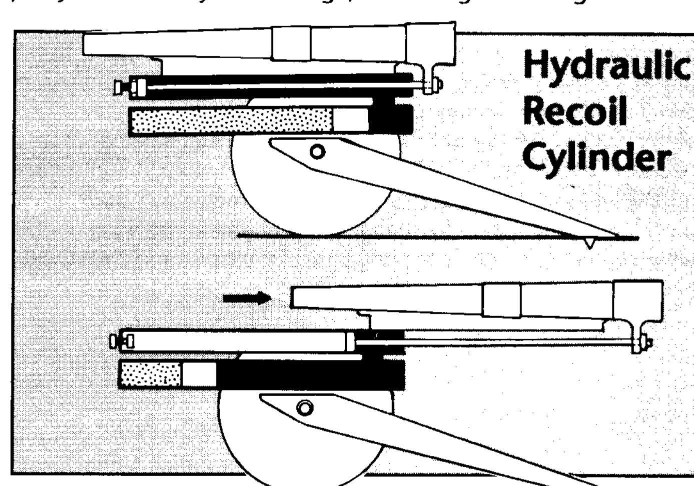
This distance, by the way, is called the gun's "point blank" range, and within that range estimates of distance are considerably less important. Usually you have a good chance of hitting a target by simply pointing at it and firing. Beyond point blank range, however, the story is more complicated. For the round to hit, the gunner has to aim above the target. If the gunner aims too low, the round will hit the ground before it reaches the target; if the gunner aims too high, it will pass over the target. Therefore, knowing the correct angle of elevation depends on knowing, as accurately as possible, the exact range.

The importance of muzzle velocity points to another advantage of subcaliber rounds such as APDS. As these rounds are lighter, the same propellant energy produces a higher muzzle velocity, and thus a more accurate and long-ranged gun. In general, then, the higher the muzzle velocity of a weapon the longer its effective range, but rangefinders and ballistic computers play a major supporting role in determining the actual chance of a hit.

Recoil: Absorbing the recoil energy of a firing gun is the function of its carriage. In the case of armored vehicles, the vehicle itself is the carriage, although some form of recoil absorbers are usually necessary to avoid damaging the vehicle when the gun fires.

The carriage serves to keep the gun in place while it fires. To avoid damaging the carriage from the recoil force, some means of recoil compensation is usually mounted. Truly modern artillery dates from tech level 4 with the introduction of on-carriage recoil absorbers, which allow quicker firing of the gun as well as much more powerful guns and movable carriages.

The recoil absorber is most often a hydraulic compensator; as the gun fires, it recoils on the carriage in a slide cradle, the recoil energy partly being absorbed by the rearward movement of the gun and partly absorbed by the carriage, braced against the ground. The



rearward motion is slowed and the force absorbed by a hydraulic piston in an oil-filled cylinder (or two or three cylinders on larger weapons). This hydraulic recoil compensator is often called a recuperator, since the stored recoil energy in the hydraulic piston is then used to move the gun back forward in its slide cradle on the carriage to its firing position.

Recoil, and the carriage weight necessary to deal with it, is a critical variable in gun design, especially with regard to vehicle-mounted weapons. The heavier the vehicle, the slower it tends to be, as the hardly mobile German Hunting Tiger illustrates. Because of modern ammunition, which gets more penetration out of a particular amount of muzzle energy, the gun of the M1A2 Abrams has almost three times the penetration of the Hunting Tiger's gun while generating only 75% as much muzzle energy. The lower muzzle energy means a less powerful recoil, less massive gun system, and much more mobile vehicle.

When examining the muzzle energies generated by some of the larger guns, it should become clear why they required specially built railway carriages, not only to fire, but also to serve as large recoil slides.

CPR GUN DESIGN SEQUENCE

This design sequence covers "modern" artillery, from tech level 4 on, which fires chemically propelled rounds (CPR). A CPR gun fires a projectile which is propelled by the expansion of gases in a chemical explosion.

A. Specifications

The characteristics of CPR guns are determined by six specifications. In addition, the weapon's muzzle energy is used through the rest of the design sequence and is calculated at this time.

1. Tech Level: Select a tech level appropriate to the world where the gun was built.

2. Bore Size: Bore size, also known as caliber, is the diameter of the gun's bore. The smallest CPR gun has a bore diameter of 2cm. (Anything smaller than this is considered a small arm.) The CPR Gun table lists bore sizes in increments of centimeters, but intermediary sizes may be selected as well, such as 2.4cm or 9.1cm.

3. Barrel Length: Barrel length is usually expressed as a length in calibers. That is, a 2 cm gun with a barrel seventy calibers long would be (2×70=140) 140 centimeters long. Barrels may be of any length desired up to 100 calibers. As a general rule of thumb, howitzers tend to be about 30 calibers long while high velocity guns tend to be about 60-70 calibers long.

The gun is usually identified by its bore size in millimeters (cm × 10) followed by its length in calibers, either separated by a slash or the letter "L," as in "20/70" or "20L70."

4. Fire Control: The type and tech level of fire control equipment must be specified. Fire control equipment is available for direct fire, indirect fire, and point defense. A gun may have more than one type. See Section 14.

5. Mount: A gun is mounted either on a carriage or directly on a vehicle.

6. Options: A gun may have a gun shield if desired, which provides the crew some protection against fragmentation and small arms fire from the front. At tech level 6 and above, a gun may have mechanical assistance for the loaders, which will speed reloading.

7. Muzzle Energy: The CPR Gun table (page 109) lists the muzzle energy, in megajoules (Mj), of each bore size gun assuming a barrel length of 60 calibers. For bore sizes which fall between those listed on the table, use interpolation to find the correct muzzle energy.

For every caliber in length longer than 60, increase the muzzle energy by 1%.

For every caliber less than 60, reduce the muzzle energy by 2%, until the weapon reaches 20 calibers in length. For every caliber in length less than 20 calibers, reduce the muzzle energy by 1%.

When this calculation is completed, multiply the result by the tech level multiplier found on the CPR Gun Tech Level table below.

CPR Gun Tech Level

TL	*ME Tech Mult.*
4	×0.8
5-6	×1
7	×1.2
8	×1.4
9+	×1.6

B. Weight

The complete weapon system weight is equal to the weight of the gun itself, plus its fire control equipment, plus its carriage (unless vehicle-mounted), plus its gun shield (if any), plus its mechanical loader (if any).

1. Gun Weight: Consult the CPR Gun table (page 109) and read the weapon weight (in tonnes). The weight on the table assumes a 60-caliber gun. Increase or decrease the weight by 1% for each caliber change in length up or down. A gun 25 calibers long, for example, is 35 calibers less than 60, and so would weighs (100–35=) 65% of the weight shown on the table.

A 20L70 gun would weigh 110% of the weight shown on the table. Since the listed weight of a 2cm gun is 0.1 tonnes, the gun weighs 0.11 tonnes, or 110 kilograms.

If the bore size falls between two bore sizes on the table, interpolate the correct value.

2. Fire Control: The weights of the various fire control systems are given in the Fire Control chapter (Section 14).

3. Carriage Weight: The carriage weight of a gun, in tonnes, is its muzzle energy in megajoules divided by 2, but is never less than the weight of the gun itself.

Vehicle-mounted guns do not require carriages, but the vehicle itself must weigh at least twice the required carriage weight.

4. Gun Shield: The weight of a gun shield in tonnes is equal to 0.07 times the bore size in centimeters.

5. Mechanical Loading Assistance: The weight of mechanical loading assistance is equal to the gun weight × 0.1.

6. Autoloaders: Autoloaders are available for vehicle-mounted weapons. These have a weight equal to 30 times the weight of a single round for the weapon.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

C. Gun Crew

The number of crewmen required to man a gun depends on its
1 function and how it is mounted. A crew normally consists of a gunner and several loaders. Indirect fire weapons usually include a gun commander as well.

1. Indirect Fire: The crew required to serve a towed (carriage-
2 mounted) indirect fire weapon is equal to its bore size in centimeters. Vehicle-mounted weapons require a crew half this size, rounding fractions up, but never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).

3 **2. Direct Fire:** The crew required to serve a towed (carriage-mounted) direct fire weapon is equal to its bore size in centimeters divided by 3, rounding fractions up. Vehicle-mounted weapons require a crew half this size, rounding fractions up, but
4 never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).

D. Range

5 Weapons have four direct fire ranges: short, medium, long, and extreme. If fitted with indirect fire control equipment, they also have an indirect fire range.

1. Direct Fire Range: Direct fire range is mostly a function of the muzzle velocity of a weapon, which is largely determined by
6 its barrel length. A secondary consideration is the size of the round, as larger rounds lose velocity from drag more slowly than do smaller rounds. A tertiary consideration is the type of ammunition fired, as some ammunition is fired at lower muzzle velocities.

7 Short direct fire range in meters for a CPR gun firing a kinetic penetrator round (AP, HVAP, APDS, etc.) is equal to the 5 times the sum of its bore size in centimeters plus its barrel length in calibers plus 20. [R = 5 (B+L+20)]

8 Hypervelocity smoothbore guns available at TL 7 and higher generate higher muzzle velocities with shorter barrel lengths. To reflect this, multiply range by the following TL modifiers:

	TL	*Modifier*
9	7	1.15
	8	1.3
	9+	1.45

Short direct fire range for all other types of rounds (HE, HEAP,
10 APERS, etc.) is equal to the above range multiplied by 0.75.

Note, however, that the type of direct fire gun sights mounted impose an upper limit on the short range of a direct fire weapon.

2. Indirect Fire Range: To calculate indirect fire range in
11 kilometers, multiply the square root of the weapon's bore (in centimeters) by its barrel length (in calibers) by 0.13. At each tech level above 4 of the gun, add 1 to barrel length for this calculation.

For BB (base bleed) ammunition (see the Munitions chapter,
12 beginning on page 135), multiply the range by 1.2.

For RAP (rocket-assisted projectile) ammunition (also see the Munitions chapter, page 135), multiply the range by 1.5.

13 E. Reloading

The time the weapon requires to reload is a function of its muzzle energy and any mechanical assistance provided. The base number of five-second turns required to load a round is equal to its muzzle
14 energy (in megajoules), rounding fractions to the nearest whole number (but always rounding fractional values less than 1 up to 1).

Mechanical assistance provides a multiplier which has the effect of reducing the muzzle energy for purposes of this calculation, as shown on the Mechanical Loading Assistance table.

Mechanical Loading Assistance

TL	*Multiplier*
6	.9
7	.7
8	.5
9+	.3

Note that autoloaders, if installed, do not increase this rate, but only allow loading crew to be dispensed with.

F. Price

The price of the weapon is equal to the sum of the price of its components. Fire control equipment costs as listed in the Fire Control chapter (Section 14). The prices of other components are determined by their weights and cost multipliers, as shown below.

Component	*Cost Multiplier*
Gun Tube	0.02
Carriage	0.002
Loading Assistance	0.01
Autoloader	0.01
Gun Shield	0.001

Cost Multiplier: Cost of each component in millions of credits is equal to its weight in tonnes (calculated earlier) times the appropriate cost multiplier.

G. Set-Up

All CPR guns must be set up before they can conduct indirect fire, and towed CPR guns must be set up before they can conduct any kind of fire. It takes longer to set up for indirect fire, given the need for precise surveying and positioning, and towed weapons naturally take longer than self-propelled weapons.

The time, in five-second combat turns, needed to set up a towed CPR gun for indirect fire is equal to the gun's bore size in centimeters times 8 (round to the nearest whole number).

The number of turns to set up a self-propelled gun for indirect fire is equal to its bore size in centimeters times 4.

The number of turns to set up a towed gun for direct fire is equal to its bore size in centimeters times 4.

Self-propelled indirect fire guns with land navigation systems of tech level 8 or higher (see the Controls chapter, Section 4) require even less time, equal to the gun's bore size in centimeters times 2.

H. Volume

The volume of CPR gun in cubic meters, for purposes of transportation or mounting in a vehicle, is equal to its mass in tonnes.

SPECIAL CASES

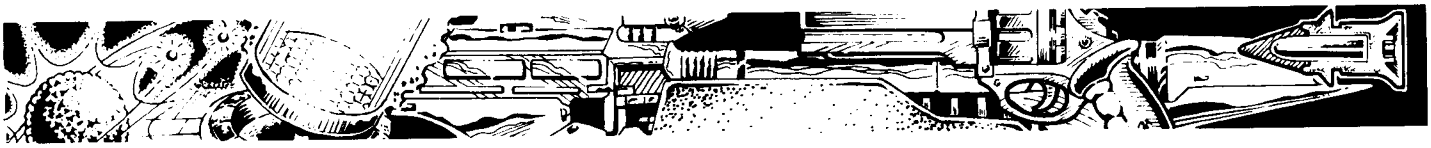
The following weapons are special cases or variants of standard CPR guns.

1. Autocannon

Autocannons are self-loading CPR guns which fire more than one round per combat turn, much like an overgrown machinegun.

A. Specifications: The largest allowed bore size for an autocannon at tech level 4 is 2cm. Add 2cm to the largest allowed bore size for each tech level higher than 4. There are two additional specifications for autocannons:

1. Action: An autocannon may have either a



recoil-operated or an electric-operated action. Electric actions are not available until tech level 7.

2. Number of Barrels: An autocannon may have from one to eight barrels.

B. Weight: The weight of the weapons system includes the additional weight of its action, any additional barrels, and its magazine. A recoil-operated action weighs the same as a single-barrel gun. An electric action weighs 0.3 times the weight of a single-barrel gun. Every additional barrel in excess of one weighs 0.3 times the weight of a single-barrel gun.

The carriage weight of the gun, in tonnes, is its muzzle energy in megajoules multiplied by the gun's rate of fire and then divided by 4, but is never less than the weight of the gun itself.

Vehicle-mounted autocannons do not require carriages, but the vehicle itself must weigh at least twice the required carriage weight.

C. Crew: The crew of an autocannon is usually one, although additional crewmen may be present to assist in changing magazines.

D. Price: Price is calculated the same as for a regular CPR gun. The cost multiplier for a recoil-operated action is 0.003, and the cost multiplier or an electric action is 0.01.

E. ROF: The base rate of fire per barrel is 40 divided by the bore diameter in centimeters. For multiple barrel guns, multiply this by number of barrels and divide by 2.

F. Magazine: The magazine may be any size desired by the player. The weight of the empty magazine is equal to the weight of all the rounds carried multiplied by 0.01. The price of an empty magazine in Cr is equal to its weight in kilograms multiplied by 5. The volume of a magazine in cubic meters is equal to the mass in tonnes of the rounds carried by the magazine + 2.

G. Reload Time: Reload time to change the magazine, in complete five-second turns, is equal to the loaded weight of a magazine, in tonnes, multiplied by 10, rounding fractions up. The number of loaders needed is equal to the mass of a loaded magazine in tonnes multiplied by 10, rounding fractions to the nearest whole number.

2. Mortars

Mortars are a specialized category of CPR guns designed to be lightweight, low velocity, high-angle indirect fire weapons. They have no direct fire ability at all, and are usually drop-fired (that is, a round is dropped down the muzzle and strikes a fixed firing pin at the bottom of the gun tube), eliminating the need for a heavy breach block. They are designed using the CPR gun design sequence with the following exceptions:

A. Specifications: No mortar may be more than 20 calibers in length. Mortars never have gun shields or direct fire control. They may have mechanical loader assistance.

B. Weight: Calculate mortar weight by multiplying bore size (in cm) by barrel length (in cm) by 0.02. This is the tube weight in kg. Multiply tube weight by 1.6 to get man-portable carriage weight (baseplate and bipod only) or by 2 to get wheeled, towable carriage weight.

The tube weight includes a simple indirect fire sight, no additional fire control sight need be installed.

C. Crew: Figure crew as if the mortar were a direct fire weapon.

D. Reloading: Halve the reloading time of the mortar, rounding fractions up.

E. Set-Up: The indirect fire set-up time for the mortar is calculated as if it were its direct fire set-up time. Mortars do not engage in direct fire and so there is no direct fire set-up time. (Note that this means that mortars take half as long to come into action as indirect fire guns of the same bore size).

3. Electrothermal-Chemical Guns

Electrothermal-chemical (ETC) guns are not technically CPR guns because their rounds are not "propelled by the expansion of gases in a 1
chemical explosion." Instead, their rounds are propelled by a rapidly expanding high-temperature plasma. As a result, they are also called combustion-augmented plasma (CAP) guns. However, their design is otherwise so similar as to invite inclusion here as a special case of CPR guns. 2
The only exceptions to the normal CPR design sequence are noted below.

A. Specifications: ETC guns are available from tech level 9 on. They must be specified as ETC guns in the design sequence. Instead of using the muzzle energy tech multiplier on the CPR Gun Tech Level table, 3
multiply muzzle energy by 2.5, regardless of tech level.

B. Electrical Input: ETC guns use an intense pulse of electrical energy to ignite the working fluid into plasma, so a source of pulsed energy must be provided. Multiply the ETC muzzle energy (from A 4
above) by 0.06 to find the amount of energy, in megajoules, required per round fired. The weapon must have a capacitor/homopolar generator installed with this capacity (see Power Production, Section 8). The weight of the HPG becomes part of the total weight of the weapon.

The gun also needs a power supply. Multiply the required energy 5
per round fired in megajoules (this is equal to the capacity of the HPG) by the gun's rate of fire (for autocannons, in rounds per 5-second turn; for slower-firing weapons in fractions of rounds per five-second turn, e.g., one round every three turns equals 0.33 rounds 6
per turn) to get megajoules required per turn. Divide this result by 5. The result is the number of megawatts that must be allocated to the ETC gun from the vehicle's power plant.

C. Weight: For ETC guns, carriage weight is muzzle energy 7
divided by 3.

D. Range: For ETC guns, triple the indirect fire range. BB and RAP rounds may not be fired from electrothermal guns.

CPR Gun Table 8

Bore (cm)	*Gun Weight (tonnes)*	*Gun Muzzle Energy (Mj)*	
2	.10	.06	
3	.12	.15	
4	.16	.35	9
5	.30	.8	
6	.42	1.6	
7	.54	2.4	
8	.60	3.6	10
9	1	4.9	
10	1.2	6	
11	1.5	7.7	
12	2.1	9.3	11
13	2.7	11.7	
14	3.3	15	
15	4	18.6	
16	4.5	23	12
17	6	29	
18	7.5	36	
19	9	41	
20	11	48	
21	13	55	13
22	15	63	
23	17	72	
24	19	83	
25	21	96	14
30	30	150	
35	40	230	
40	50	350	
45	60	500	

CHAPTER 4

1 Mass Drivers

A mass driver is nothing more than the electromagnetic equivalent of artillery. It is a gauss weapon with a bore of 2cm or more. This means that it is mounted on a vehicle or carriage instead of being
2 hand-held, and it means that it is often powered by a separate power plant instead of batteries in a magazine. But these difference notwithstanding, its basic operating principles are identical to those of a gauss rifle.

3 A. Specifications

The characteristics of mass drivers are determined by six specifications. In addition, the weapon's muzzle energy and required power are used
4 through the rest of the design sequence and are calculated at this time.

1. Tech Level: Select a tech level appropriate to the world where the gun was built. Mass drivers may be built from tech level 8 on.

2. Muzzle Velocity: Muzzle velocity at tech level 8 is 3000
5 meters per second, and this increases by 1000 meters per second per tech level until reaching a maximum of 6000 meters per second at TL 11.

3. Projectile: The projectile is defined by its diameter in centimeters. This is also the bore of the weapon.

6 The mass of the projectile is calculated using the following formula:

$$Mp = (\pi r^3) \div 10$$

Mp: Mass of projectile in kilograms
π: 3.1416
7 *r:* Radius of the bore (bore diameter divided by 2) in centimeters

4. Fire Control: The type and tech level of fire control equipment must be specified. Fire control equipment is available for direct fire, indirect fire, and point defense. A gun may have more than
8 one type. See Section 14.

5. Mount: A gun is mounted either on a carriage or directly on a vehicle.

6. Options: A gun may have a gun shield if desired, which
9 provides the crew some protection against fragmentation and small arms fire from the front. If vehicle-mounted, the gun may also have an autoloader.

7. Muzzle Energy: Once the muzzle velocity and the
10 projectile weight are known, the muzzle energy can be calculated using the following formula:

$$Em = 0.0000005MV^2$$

Em: Muzzle energy in megajoules
M: Projectile mass in kilograms
11 *V:* Muzzle velocity in meters per second

8. Required Energy: The energy required to accelerate the projectile to the desired muzzle velocity is a function of the total generated muzzle energy and the efficiency of the weapon in
12 converting electrical power quickly to magnetic force (which is a function of tech level). The required energy (in joules) is equal to the weapon's muzzle energy multiplied by the weapon's tech level efficiency, as shown on the following table.

13

TL	*Efficiency*
8	4.5
9	3.6
10	3
11	2.4
12	2
13	1.8
14	1.6
16+	1.4

14

B. Weight

The complete weapon system weight is equal to the weight of the gun itself, plus its homopolar generator, plus its fire control equipment, plus its carriage (unless vehicle-mounted), plus its gun shield (if any), plus its autoloader (if any).

1. Gun Weight: The weight of the gun is determined by the following formula:

$$Wg = D^2 \div 50$$

Wg: Weight of gun in metric tonnes
D: Bore diameter in centimeters

2. Homopolar Generator Weight: The efficiency by tech level of HPGs is shown in the Power Production chapter (Section 8). The mass driver requires an HPG with a capacity in megajoules equal to the energy requirement of the gun.

3. Fire Control: The weights of the various fire control systems are given in the Fire Control chapter (Section 14).

4. Carriage Weight: The carriage weight of a gun, in tonnes, is its muzzle energy in megajoules divided by 4, but is never less than the weight of the gun itself.

Vehicle-mounted guns do not require carriages, but the vehicle itself must weigh at least twice the required carriage weight.

5. Gun Shield: The weight of a gun shield in tonnes is equal to 0.07 times the bore size in centimeters.

6. Autoloader: The weight of the autoloader is equal to 30 times the weight of a single round.

C. Gun Crew

The number of crewmen required to man a gun depends on its function and how it is mounted. A crew normally consists of a gunner and several loaders. Indirect fire weapons usually include a gun commander as well.

1. Indirect Fire: The crew required to serve a towed (carriage-mounted) indirect fire weapon is equal to its bore size in centimeters divided by 2, rounding fractions up. Vehicle-mounted weapons require a crew half this size, rounding fractions up, but never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).

2. Direct Fire: The crew required to serve a towed (carriage-mounted) direct fire weapon is equal to its bore size divided by 5, rounding fractions up. Vehicle-mounted weapons require a crew half this size, rounding fractions up, but never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).

D. Range

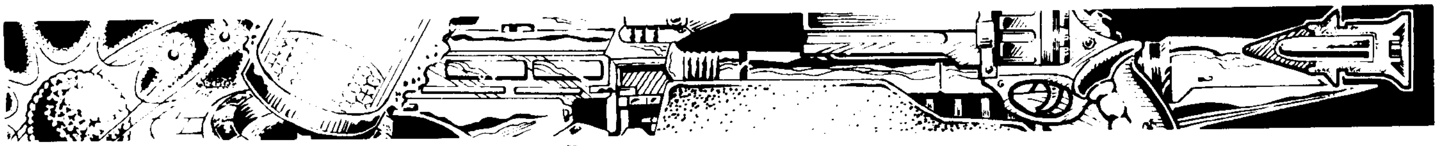
Weapons have four direct fire ranges: short, medium, long, and extreme. If fitted with indirect fire control equipment, they also have an indirect fire range.

1. Direct Fire Range: Direct fire range is mostly a function of the muzzle velocity of a weapon. A secondary consideration is the size of the round, as larger rounds lose velocity from drag more slowly than do smaller rounds. A tertiary consideration is the type of ammunition fired, as some ammunition is fired at lower muzzle velocities.

Short direct fire range in meters for a mass driver gun firing a kinetic penetrator round is equal to the sum of the bore diameter (in centimeters) and the muzzle velocity (in meters per second) all multiplied by .015.

Short direct fire range for all other types of rounds (HE, HEAP, APERS, etc.) is equal to the above range multiplied by 0.75.

However, short range may not exceed the limit imposed by the installed direct fire sights (Fire Control chapter, Section 14).



2. **Indirect Fire Range:** To calculate indirect fire range in kilometers, multiply the square root of the weapon's bore (in centimeters) by its muzzle velocity (in meters per second) by 0.004.

E. Reloading

The time in complete five-second combat turns the weapon requires to reload is a function of its projectile weight and any mechanical assistance provided. The base number of five-second turns required to load a round is equal to its projectile weight (in kilograms) divided by 2, rounding fractions to the nearest whole number. A result of less than 0.5 (which rounds down to 0) indicates that a round can be reloaded in the same combat turn in which the weapon fires, leaving it capable of firing again in the next combat turn.

If an autoloader is available, multiply projectile weight by 0.3 for purposes of this calculation.

F. Power Requirement

The amount of power required to operate a mass driver is based on its required energy, determined in step A, and its reload time, derived in step E immediately above.

The reload time establishes the weapon's rate of fire. Add 1 to the reload time to find the number of turns required for each shot. (For example, a mass driver that requires two turns to reload fires on turn one, spends turns two and three reloading, and then fires again on turn four. Thus it fires once every three turns.) The lowest possible result is one turn. Take the rate of fire in combat turns and multiply by 5 to find the rate of fire in seconds required to fire each round.

Now take the required energy in megajoules (from step A-8) and divide it by the number of seconds required to fire a round. The result is the required power (in megawatts) that must be supplied to the mass driver to allow it to operate.

$$Pr = Er \div S$$

Pr: Required power input (megawatts)
Er: Required energy (megajoules)
S: Number of seconds required for each shot

G. Price

The price of the weapon is equal to the price of its components. Fire control equipment and homopolar generators cost as listed in the Power Production and Fire Control chapters (Sections 8 and 14, respectively). The prices of other components are determined by their weights and cost multipliers, as shown below.

Component	*Cost Multiplier*
Gun Tube	0.05
Carriage	0.002
Autoloader	0.01
Gun Shield	0.001

Cost Multiplier: Cost of a component in millions of credits equals its mass in tonnes times the cost multiplier.

H. Set-Up

All guns must be set up before they can conduct indirect fire, and towed guns must be set up before they can conduct any kind of fire. It takes longer to set up for indirect fire, given the need for precise surveying and positioning, and towed weapons naturally take longer than self-propelled weapons.

The time, in five-second combat turns, needed to set up a towed gun for indirect fire is equal to the gun's bore size in centimeters times 8 (round to the nearest whole number).

The number of turns to set up a self-propelled gun for indirect fire is equal to its bore size in centimeters times 4.

The number of turns to set up a towed gun for direct fire is equal 1
to its bore size in centimeters times 4.

Self-propelled indirect fire guns with land navigation systems of tech level 8 or higher (see the Controls chapter, Section 4) require even less time, equal to the gun's bore size in centimeters times 2. 2

I. Volume

The volume of a mass driver gun in cubic meters, for purposes of transportation or mounting in a vehicle, is equal to its mass in metric 3
tonnes.

Autocannon

The following weapons constitute a special case or variant of 4
standard mass driver guns. Autocannons are mass drivers which fire more than one round per combat turn, much like an overgrown machinegun. Procedures for autocannon design are the same as normal mass driver design, with the modifications below.

A. Bore Size: The largest allowed bore size for an autocan- 5
non at tech level 8 is 10cm. Add 2cm to the largest allowed bore size for each tech level higher than 8.

B. Weight: The weight of the weapon system includes the
normal weight of a weapon of that bore size plus the additional weight 6
of its automatic feed action and its magazine.

The weapon's feed action is the loading mechanism which feeds additional rounds into the breach. Its weight is equal to the weight of a single projectile for the gun multiplied by 50. 7

The carriage weight of the gun, in tonnes, is its muzzle energy in megajoules multiplied by the gun's rate of fire and then divided by 4, but is never less than the weight of the gun itself.

C. Crew: The crew of an autocannon is usually one, 8
although additional crewmen may be present to assist in changing magazines.

D. Price: Price is calculated the same as for a regular mass
driver gun. The cost multiplier for the feed action is 0.01. 9

E. ROF: The base rate of fire per barrel is 50 divided by the bore diameter in centimeters. For single-barrel guns, this is the final ROF. For multiple-barrel guns, multiply this base rate by the number of barrels and divide by 2 to get the final ROF. 10

F. Power Requirement: Take the autocannon's ROF determined immediately above and multiply it by the required energy per shot in megajoules. This yields the total energy required per combat turn.
Divide this by 5 to find its constant power requirement in megawatts. 11

$$Pr = (ROF \times Er) \div 5$$

Pr: Required power input (megawatts)
ROF: Rate of fire per five-second combat turn
Er: Required energy (megajoules) 12

G. Magazine: The magazine may be any size desired by the player. The weight of the empty magazine is equal to the weight of all the rounds carried multiplied by 0.01. The price of an empty
magazine in Cr is equal to its weight in kilograms multiplied by 5. The 13
volume of a magazine in cubic meters is equal to the mass in tonnes of the rounds carried by the magazine ÷ 5.

H. Reload Time: Reload time to change the magazine, in complete five-second turns, is equal to the loaded weight of a
magazine, in metric tonnes, multiplied by 10, rounding fractions up. 14

The number of loaders needed is equal to the mass of a loaded magazine in tonnes multiplied by 10, rounding fractions to the nearest whole number.

CHAPTER 5

1 Particle Accelerator Weapons (PAWs)

The first charged particle accelerators are available at tech level 8, with the more useful neutral particle beam weapons appearing one level later. Particle accelerators use powerful electrical and/or mag- 2 netic fields to accelerate ions or charged subatomic particles to relativistic speeds (close enough to the speed of light that the particles exhibit a measurable increase in mass compared to their rest mass). These same fields are used to focus these particles into 3 concentrated beams that retain their power density over long distances. Because neutral (chargeless) particles cannot be affected by electrical or magnetic fields, these particles must be charged while they are accelerated. However, they do not have to be charged after 4 they leave the barrel of the accelerator. Neutral particles are created by having a device (a screen of foil or gas, or a high-powered laser) that strips the extra electron from a negative ion (thus making a negative hydrogen ion into a neutral atom) as it passes out of the 5 barrel, or adds an electron to a positive ion. (Note that neutral particle beam weapons do not fire neutrons, as there is no way to accelerate a neutron, nor could positive or negative charges be stripped away from neutrons without particle decay.) Charged particle beams are fired by 6 simply allowing the charged particles to fly out toward the target.

This is important, because charged particle accelerator weapons (C-PAWs) propagate fairly well through atmospheres (where the flow of like charges in the same direction behaves like an electrical 7 current and generates a magnetic field around itself that "pinches" the beam together), but effectively disintegrate in vacuum, where the like charges in the beam repel each other, destroying beam focus and integrity. On the other hand, neutral particle accelerator weap- 8 ons (N-PAWs) perform flawlessly in space, as the neutral atoms proceed unperturbed by magnetic or electrical fields. In atmospheres, however, the N-PAW beam breaks up rapidly, as there is no electrical current to provide coherence, and the atmosphere ionizes, 9 absorbs, and otherwise degrades the particle beam. Thus, N-PAWs are the space weapons and C-PAWs are the ground weapons. But because a neutral particle beam weapon can produce charged particle beams simply by disengaging its particle neutralizer, the N- 10 PAW is effectively a dual-purpose weapon, as it can be set to fire beams appropriate to either environment. PAWs intended purely for ground use can forego the needless expense of the particle neutralizer and are therefore single-use weapons.

11 Dual-purpose or not, however, particle accelerators have a problem with planetary bombardment. A ship firing a C-PAW from outside of an atmospheric envelope will find that the beam severely scatters before it enters the atmosphere, often so badly that it does not have enough coherence to create its self-pinching tunnel. Ships 12 with dual-purpose particle weapons must often enter the atmosphere in order to fire C-PAWs at surface targets.

Although particle accelerators can be curved (typical modern particle accelerators used for research are huge rings), for military 13 purposes, curved particle accelerators are inefficient because of the need to keep the particles moving in a circular path (i.e., constantly adding transverse acceleration to keep them in a curving path). Not only does this waste energy that could be spent to increase linear 14 acceleration, but such designs are far more vulnerable to damage than linear designs. While the loss of power to an accelerator coil in a linear design would decrease overall acceleration, loss of an accelerator coil in a ring design would result in particles leaving the circular path. Thus, combat particle accelerators are linear accelerators, built as long tubes.

Because of the need for a long straight run to properly accelerate and aim the pulses of particles, a particle accelerator must be long and straight in order to be most effective.

PARTICLE ACCELERATOR WEAPON SYSTEM DESIGN

1. ACCELERATOR TUNNEL LENGTH

Tunnel length aboard ship is defined by the type of installation and the size of the ship the gun is to be fitted to. Ground mounted PAWs can be built to any length desired, within normal cost, facility, and power constraints.

Spaceship installations are of three types: spinal, parallel, and bay.

1A. Spinal Mounts

As the name implies, a spinal mount gun serves as the central internal-strength member of the entire ship. The gun defines the longitudinal axis of the ship, as well as its axis of mass and thrust. The length of a spinal mount is equal to the length of the ship (in meters) as defined during the spacecraft hull design step. Spacecraft with an open frame hull form may not have a spinal mount.

The spinal mount can be installed to fire either dead ahead (this is the standard configuration) or dead astern (called the "stern chaser" configuration). Its arc of fire is therefore either 1 or 5 (see Spacecraft Design Evaluation, page 16).

Each ship may have only one spinal weapons mount. The one exception to this is the so-called "Janus" mount, in which two spinal guns are installed in the spinal tube butted against each other, one pointing forward and one astern, where each is half the total length of the ship.

1B. Parallel Mounts

Parallel mounts, like spinal mounts, are mounted directly fore and aft, parallel to the ship's spine. Unlike spinal mounts, there can be more than one per ship.

The length of a parallel mount is 0.8 times the length of the ship in meters. They may be installed to fire either directly forward into fire arc 1, or dead astern into fire arc 5.

Ships with a sphere hull form may make a slightly different use of parallel mounts. Rather than being restricted to mounting parallel mounts along the fore-and-aft axis, a sphere's dimension allows the installation of parallel mounts athwartships, firing broadside, or at any other angle off of the centerline. These mounts are designed just as normal parallel mounts, but may be installed to fire into any one arc of fire, not just 1 or 5.

1C. Bay Mounts

PAWs may also be mounted in bays set into the hull surface. There is no limit to the number of bays that can be fitted to a ship, beyond the normal limits of hull surface area, mass, and volume.

A bay may be constructed to any size desired, although the most popular are the 50-ton (700 cubic meters) and 100-ton (1400 cubic meter) bays. A bay's dimensions are calculated as follows:

Each bay has a single long dimension and two shorter dimensions. The long dimension, in meters, is found by taking the bay's volume in cubic meters, extracting the cube root, multiplying by 1.4, and rounding to the nearest whole number.

$$1.4\sqrt[3]{Vol}$$

Divide the bay's total volume in cubic meters by the long dimension, and extract the square root of this result, rounding to the nearest 0.5 meters. This is the approximate length of the bay's short dimensions. Multiply the long dimension by the short dimension to get the surface area of the bay in square meters.

Standard Bays and their Dimensions

Size	Cubic Meters	Long Dim.	Short Dim.	Surface Area
50 ton	700	12 m	7.5 m	91.2 m²
100 ton	1400	16 m	9.5 m	150.4 m²

The length of the accelerator tunnel is the long dimension of the bay.

2. ACCELERATOR TUNNEL CROSS-SECTIONAL AREA

Accelerator performance is also dependent on its cross-sectional area, i.e., the space within which the electromagnetic coils bend and focus the paths of the particles. The cross-sectional area is also called the tunnel's focal area. Like laser beams, particle beams can be more tightly focused by larger focal areas.

Define the diameter of the accelerator tunnel in meters, and find its surface area based on this number, using the formula

Area (square meters) = πr^2

where r (meters) = diameter ÷ 2, and $\pi = 3.1416$

Limits to tunnel diameter include total space available to the PAW (bay-mounted PAWs must fit completely within the volume of the bay), and the length of the tunnel. Tunnel diameter may not be greater than actual tunnel length times 0.125.

3. DISCHARGE ENERGY

Specify the amount of output energy that will be fired in each shot (*discharge energy*, abbreviated DE) in megajoules (Mj). The greater the discharge energy, the greater the damage of each shot, and the greater the final size of the particle accelerator installation.

The maximum discharge energy is limited by the length of the accelerator tunnel. DE in Mj cannot be greater than the square of tunnel length in meters.

4. ACCELERATOR TUNNEL CHARACTERISTICS

Find effective tunnel length, effective focal area, tunnel volume, tunnel mass, and tunnel price based on tunnel length in meters, discharge energy, and the table below. The table shows the tunnel length multiplier, focal area multiplier, and mass multiplier by tech level.

The column for C-PAWs is for single-purpose, charged-particle only weapons; N-PAWs is for dual-purpose, neutral/charged particle beam weapons.

Accelerator Tunnel Characteristics

		FA Multiplier		
TL	Length Multiplier	C-PAW	N-PAW	Mass Multiplier
8	**0.12**	**1**	**—**	**1.2**
9	0.14	1	1	1.0
10	**0.16**	**2**	**1**	**1.0**
11	0.2	3	2	0.75
12	**0.25**	**3**	**3**	**0.75**
13	0.3	4	3	0.75
14	**0.5**	**4**	**4**	**0.75**
15	1.0	5	4	0.75
16	**1.25**	**5**	**5**	**0.6**
17	1.3	5	5	0.5
18	**1.4**	**6**	**5**	**0.4**
19	1.5	6	6	0.4
20	**1.6**	**6**	**6**	**0.3**
21	1.7	6	6	0.3
22	**1.8**	**7**	**6**	**0.2**
23	1.9	7	7	0.2
24	**2.0**	**7**	**7**	**0.1**

4A. Tunnel Effective Length

The effective length (meters) of the accelerator tunnel increases
with tech level and is used in calculating range performance below. 1
Effective Length = actual tunnel length (meters)×length multiplier

4B. Effective Focal Area

The effective area (square meters) of the tunnel focal area (same 2
as its cross-sectional area) increases with tech level and is also used in calculating range performance below.

Effective Focal Area (square meters) = actual cross-sectional area
(in square meters, from Step 2 above) × FA multiplier appropriate to 3
type of PAW.

4C. Tunnel Volume

Tunnel Volume (cubic meters) = actual length (meters) × actual 4
cross-sectional area (square meters) from Step 2.

4D. Tunnel Mass

Tunnel Mass (tonnes) = tunnel volume (cubic meters) × mass 5
multiplier.

4E. Tunnel Price

Tunnel price depends on whether the weapon is an N-PAW (dual-
purpose, neutral/charged beam capable) or single-purpose C-PAW. 6

C-PAW Tunnel Price (MCr) = tunnel volume (cubic meters) × 0.09 at all tech levels.

N-PAW Tunnel Price (MCr) = tunnel volume (cubic meters) × 0.1 7
at all tech levels.

Tunnel price is calculated *after* any increase in size due to high rates of fire (Step 8C, below)

5. PERFORMANCE 8

The effective range (range at which energy delivered on target is equal to discharge energy) in kilometers is equal to the effective tunnel length (meters) × effective focal area × 1000.

Beyond this range, the beam's performance drops due to the 9
gradual expansion of beam width over distance which results in the lowering of beam intensity per unit area of the beam's "footprint."

For space combat range in hexes/range bands, divide this result by
30,000. It is usually best to drop fractions in order to find the range 10
best suited for the weapon's short range. However, these may be rounded up to the higher value if the designer is prepared to accept the potential drop in damage performance due to the higher range
(see Step 7B, below). 11

5A. Atmospheric Performance

All particle beam energy is eventually absorbed by planetary
atmospheres. The effective range defined above is the accelerator's 12
theoretical effective range. For neutral particle beams, this theoretical effective range is achieved in vacuum: in space or on the surface of airless worlds. For charged particle beams, this theoretical effective
range can never be reached; C-PAWs have their effective range 13
modified for fire in vacuum as well as in atmospheres.

When the accelerator is to be used within atmospheres, the following modifications must be made to its effective range, which
controls its damage performance. Although theoretically a PAW 14
might be rated for its performance in all potential atmospheres, in practice it need only be rated for the environment for which it was originally intended, for example the atmosphere of the world on which it was designed, or in vacuum for a starship N-PAW.

Atmospheric Range Modifiers

	Atmosphere (UWP Code)	N-PAW (Firing Neutral Beam)	C-PAW (Any PAW firing Charged Beam)
1	**Vacuum (0)**	**1**	**0.001**
	Trace (1)	1	0.005
2	**Very Thin (2, 3)**	**0.1**	**0.01**
	Thin (4, 5)	0.02	0.05
	Standard (6, 7)	**0.01**	**0.1**
	Dense (8, 9)	0.005	0.1
	Exotic+ (A+)	**0.001**	**0.05**

3

Effective range as adjusted by atmosphere can be used in different ways according to the purposes of the designer. If the accelerator is a C-PAW intended for use in an atmosphere, the atmosphere
4 adjusted effective range should probably be used when choosing a beam pointer (Step 6, immediately following). If it is an N-PAW intended for space combat, its unadjusted effective range should be used to choose the beam pointer.

5 **Planetary Bombardment:** This is a specific application of the atmospheric modifier rules. This is not calculated in advance for each particle weapon, but is calculated separately each time it is done.

First find the range to the world being bombarded, in hexes. Planetary bombardments from the same hex are given a default
6 value of 0.5 hexes. Divide this range by the atmosphere modifier appropriate to the atmosphere type and PAW type from the table above. The result is the equivalent range in hexes to a target on the planetary surface, called the *atmosphere adjusted range*. Use this
7 range to find the proper range band of the PAWs rated range performance. If the range falls between two range bands, use the higher band. This gives the weapon's damage performance. Difficulty of the firing task is still calculated according to the actual range.

8 If the adjusted range falls beyond the PAW's extreme range, use the PAW's effective range along with the procedure defined in Step 7B below to determine if the PAW has any damage performance left at that range.

If the target is an aircraft or spacecraft flying at high altitude, cut this final atmosphere adjusted range in half.

9

5B. Magnetic Fields

Charged particle beams also run into difficulties when fired at, on, and around worlds that possess a magnetic field. All firing tasks are
10 one difficulty level higher.

6. DEFINE SHORT RANGE

Select a beam pointer from the Beam Pointer table (Fire Control
11 chapter, Section 14) based on the PAW's tech level and the range performance desired. Note that range is given in kilometers and 30,000-km hexes/range bands for space combat. The listed range in km/hexes will be the weapon's short range for purposes of combat.

12 Whenever possible, the beam pointer range should be equal to the weapon's effective range to take full advantage of its range-intensity performance. If the beam pointer range is less than the effective range, the PAW will not have the maximum possible hit probability out to its maximum beam intensity (although the absolute upper
13 limit of beam pointer short range is 300,000 km/10 hexes). If the beam pointer range is longer than the effective range, the PAW will not deliver its maximum damage performance at its best hit probability. However, these decisions are up to the designer.

14 When a particle accelerator has its performance adjusted for atmosphere, remember that its atmosphere-adjusted ranges are for purposes of damage calculation only. Its short range (and medium, long, and extreme ranges which are derived from it) based on installed beam pointers are still used for resolving hits.

7. COMBAT RATINGS

7A. Combat Range Bands

All combat ranges are based on the PAW's short range, established in Step 6. For planet-bound C-PAWs, these ranges should be expressed in kilometers; for space-based N-PAWs, these ranges should be expressed in starship combat hexes/range bands in whole numbers.

Medium range = Short range × 2
Long range = Short range × 4
Extreme range = Short range × 8

7B. Damage Value

Define the particle accelerator's damage characteristics at its short, medium, long, and extreme range bands.

Particle accelerators do damage to enemy targets based on their *penetration value* (PV).

$$PV = 5\sqrt{I}$$

where I is the weapon's *intensity* (units for intensity are MJ per square centimeter) at that range. Intensity is derived as follows:

For each of the four range bands, divide that range band's actual range (from 7A, in kilometers or hexes, as appropriate to the type of weapon) by the PAW's effective range (in the same units) from Step 5. Round this result to the nearest 0.01. This figure is used as R in the next formula:

$$I = DE\ (1 + R^2)$$

where
DE is discharge energy from Step 3 above.

8. POWER REQUIREMENTS

8A. Input Energy

Particle accelerators have a 20% energy efficiency, meaning that of the energy put into each shot, 20% is projected toward the enemy in the form of the particle beam. The remaining 80% is spent ionizing, accelerating, and magnetically aiming, and in N-PAWs, neutralizing, the particles.

Find input energy in MJ according to this formula:

Input Energy (IE) = Discharge Energy (DE) + 0.2

8B. Homopolar Generator

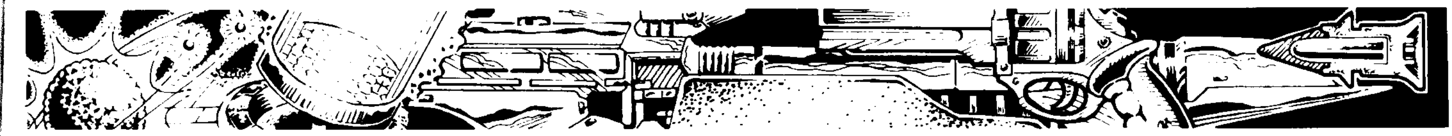
A particle accelerator requires a homopolar generator (HPG) to store the energy required for each shot until that energy is ready to be expended as a pulse. The HPG's volume is calculated by multiplying the accelerator's input energy (IE) in MJ determined above by the value on the HPG table in the Power Production chapter (Section 8).

8C. Rate of Fire

Select the PAW's rate of fire (ROF).

Space Combat: N-PAWs, intended to be used for space combat, must have an ROF of at least 10 shots per 30-minute space combat turn. Higher rates gain reductions in difficulty level according to the table below. Due to the tremendous energies generated by each shot, which must be dissipated during the cooling/purge cycle, the maximum ROF of a standard particle accelerator is 100 shots per 30-minute turn. Rates of fire above this level require that the PAW be "beefed up" to stand up to the higher usage rate. The amount of this beefing up is expressed on the following table as a multiplier to the the PAW's volume. This increase in volume does not change its tunnel cross-sectional area or effective focal area, but does affect its weight and price.

To convert space to planetary ROFs, divide the space combat ROF per 30 minutes by 360. Take the inverse (i.e., divide 1 by that number), and round fractions *up*. The result is the number of five-



second combat turns required for each shot. Express this number as a fraction, i.e., one shot every five turns is 1/5, one shot every 36 turns is 1/36, etc. Because this conversion system results in distortion of total number of shots due to rounding, this converted ROF must never be used when calculating power input. The original space combat ROF must always be used when rating a space combat meson gun.

Diff Mods on the following table apply to space combat only, not ground combat.

Rate of Fire Benefits in Space Combat

Space Combat ROF (Shots per 30-minute turn)	*Benefit (In Diff Mods to Fire Task)*	*Vol Mod*	*Ground Combat ROF (Shots per 5-second turn)*
10	**None**	**×1**	**1/36**
50	–1 Difficulty levels	×1*	1/8
100	**–2 Difficulty levels**	**×1***	**1/4**
200	–3 Difficulty levels	×1.3	1/2
400	**–4 Difficulty levels**	**×1.7**	**1**
800	–5 Difficulty levels	×2.2	2

*There is no penalty for firing a particle accelerator at one of these higher power levels if it is mounted in a vehicle or starship which is designed from the outset to provide sufficient power for the higher ROF (50 or 100 shots). However, PAWs which were not installed with the higher power levels may fire at these levels if sufficient power is made available by diverting it from other systems. However, because of the extra strain this places on power couplings, HPGs, etc., an Engineering task must be rolled each turn this is attempted (roll using crew quality). The difficulty level is Difficult if the ROF is raised one step (from 10 to 50 or from 50 to 100) over the installed power allocation, or Formidable if raised two steps (10 to 100). Failure at this roll indicates a System Reset result (see the **TNE** Space Combat chapter, or **Brilliant Lances: Traveller Starship Combat**), with the additional penalty that the PAW may not fire on the current turn. Catastrophic Failure indicates more severe damage. Roll 1D10: 1-5 indicates a Degraded Performance result in addition to System Reset, 6-10 indicates a Major Hit on the particle accelerator.

PAWs may only fire at the 200+ ROFs if they are designed as such with beefed-up focal arrays.

Planetary Combat: ROF for planetary combat C-PAWs is defined in terms of five-second planetary combat turns. The maximum rate of fire for planetary combat is one shot every fourth turn (expressed as 1/4), due to the need for a cooling cycle following each shot.

8D. Power Input

Power input in megawatts (MW) is calculated differently for space combat and planetary combat purposes. Although they are calculated differently, space and planetary combat power input values are absolute values, as they are both based on MW input per second. However, be careful to make these calculations based on the *true* ROF for the accelerator, based on its primary environment: space or planetary combat. Do not use ROFs converted from one system to the other, as the rounding involved distorts the numbers.

Space Combat (Neutral) PAWs: Multiply ROF per 30 minutes times input energy (IE) from Step 7A. This is the total number of megajoules needed over the course of a 30-minute turn. Divide this result by 1800 to find the MW of power that must be allocated to operate the weapon.

Planetary Combat (Charged) PAWs: Multiply ROF times input energy (IE) from Step 7A. This is the total number of megajoules consumed by the weapon each five-second turn. Divide this result by 5 to find the MW of power that must be allocated to operate the weapon.

9. GUN CREW AND WORKSTATIONS

All particle accelerators must be crewed according to the following formula: 1

Crew = (Tunnel Volume ÷ 100) × CP

CP: Computer multiplier based on tech level of computer installed aboard ship/hooked up to ground-based PAW. See Computers table in the Controls chapter (Section 4).

Round to the nearest whole number, but results of less than 1 must 2 always be rounded up to 1.

Each crewmember must have a gunner's (normal) workstation installed with characteristics obtained from the Controls Chapter (Section 4). 3

10. PARTICLE ACCELERATOR CARRIAGE, MOUNT, ETC.

If the accelerator is a starship- or vehicle-mounted N-PAW, skip this 4 step. If it is a C-PAW intended for use as a towed weapon, calculate the size of its carriage, mount, etc. A towed carriage has the same mass as the C-PAWs mounted on it. The PAW must include its HPG, but may be plugged in to a power source at its destination.

Carriage-mounted PAWs have an all-around armor value of 1. This 5 can be increased by enclosing the PAW and its supporting equipment in a "hull" (cylinder hull form) with a certain thickness of armor according to the vehicle or spacecraft design rules. As this armor increases the mass of the PAW, it will increase the mass of the carriage 6 as well.

The price of the carriage, in MCr, is equal to its mass in tonnes multiplied by 0.002.

7

11. PARTICLE ACCELERATOR PHYSICAL CHARACTERISTICS

Add up or bring down the above components to obtain the following total figures for the gun. 8

11A. Volume

In cubic meters. Add tunnel volume, beam pointer volume, HPG volume, gunner's workstation volume, carriage volume (if any).

9

11B. Mass

In tonnes. Add tunnel mass, beam pointer mass, HPG mass, gunner's workstation mass, carriage mass (if any).

10

11C. Price

In MCr. Add tunnel price, beam pointer price, HPG price, gunner's workstation price, carriage price (if any).

11

11D. Power Requirements

In MW. Carry down from Step 8D above.

11E. Length

Actual tunnel length in meters. Carry down from Step 1 above. 12

11F. Surface Area

Surface area for a spinal mount is equal to the tunnel cross-sectional area times 2. Surface area for a bay-mounted PAW is equal 13 to the bay's surface area.

11G. Combat Performance

Short range, medium range, long range, and extreme range in km 14 and/or space combat hexes, plus damage values at those ranges, along with ROF, listing any –difficulty modifiers as applicable. Carry down from Steps 7 and 8C.

CHAPTER 6

1 Meson Guns

Meson guns are an extremely advanced form of particle accelerator that becomes available at TL 11. Like particle accelerators, the meson gun accelerates charged subatomic particles to
2 very high velocities, but unlike simple particle accelerators, the meson gun does not simply fire these particles at enemy targets. Instead, the high-velocity particles are made to collide, creating in the process another particle, a meson (mesons are the sub-
3 atomic particles that transmit the strong nuclear force within the atomic nucleus). By carefully aiming the colliding particles, the direction and velocity of the resulting mesons can be controlled.

Mesons do not interact with matter, and therefore follow a
4 perfectly straight path, passing through all obstacles. However, the meson has a very short life span, and soon explosively decays, producing radiation and damaging particles. By accelerating a meson to relativistic speeds, its subjective passage of time is
5 slowed, and its decay is delayed. By controlling the precise velocity of a meson, its decay can therefore be timed to take place at a certain distance, ideally inside an enemy ship, whose armor
6 is completely useless.

Because of the need to accelerate the primary particles that produce the meson, and to control their speed and trajectory so that the mesons are emitted in the proper direction and at the
7 correct velocity, a meson gun must be extremely long and straight in order to be most effective.

MESON GUN DESIGN

8 *1. MESON TUNNEL LENGTH*

Tunnel length aboard ship is defined by the type of installation and the size of the ship the gun is to be fitted to. Ground-mounted
9 meson guns can be built to any length desired, within normal cost, facility, and power constraints.

Spaceship installations are of three types: spinal, parallel, and bay.

10 1A. Spinal Mounts

As the name implies, a spinal mount meson gun serves as the central internal-strength member of the entire ship. The gun
11 defines the longitudinal axis of the ship, as well as its axis of mass and thrust. The length of a spinal mount is equal to the length of the ship (in meters) as defined during the spacecraft hull design step. Spacecraft with an open frame hull form may not have a
12 spinal mount.

The spinal mount can be installed to fire either dead ahead (this is the standard configuration) or dead astern (called the "stern chaser" configuration). Its arc of fire is therefore either 1 or 5 (see
13 Spacecraft Design Evaluation, page 16).

Each ship may have only one spinal weapons mount. The one exception to this is the so-called "Janus" mount, in which two spinal guns are installed in the spinal tube butted against each
14 other, one pointing forward and one astern, where each is half the total length of the ship.

1B. Parallel Mounts

Parallel mounts, like spinal mounts, are mounted directly fore and aft, parallel to the ship's spine. Unlike spinal mounts, there can be more than one per ship.

The length of a parallel mount is 0.8 times the length of the ship in meters. They may be installed to fire either directly forward into fire arc 1, or dead astern into fire arc 5.

Ships with a sphere hull form may make a slightly different use of parallel mounts. Rather than being restricted to mounting parallel mounts along the fore-and-aft axis, a sphere's dimension allows the installation of parallel mounts athwartships, firing broadside, or at any other angle off of the centerline. These mounts are designed just as normal parallel mounts, but may be installed to fire into any one arc of fire, not just 1 or 5.

1C. Bay Mounts

Meson guns may also be mounted in bays set into the hull surface. There is no limit to the number of meson gun bays that can be fitted to a ship, beyond the normal limits of hull surface area, mass, and volume.

A bay may be constructed to any size desired, although the most popular are the 50-ton (700 cubic meters) and 100-ton (1400 cubic meter) bays. A bay's dimensions are calculated as follows.

Each bay has a single long dimension and two shorter dimensions. The long dimension, in meters, is found by taking the bay's volume in cubic meters, extracting the cube root, multiplying by 1.4, and rounding to the nearest whole number.

$$1.4\sqrt[3]{Vol}$$

Divide the bay's total volume in cubic meters by the long dimension, and extract the square root of this result, rounding to the nearest 0.5 meters. This is the approximate length of the bay's short dimensions. Multiply the long dimension by the short dimension to get the surface area of the bay in square meters.

Standard Bays and their Dimensions

Size	*Cubic Meters*	*Long Dim.*	*Short Dim.*	*Surface Area*
50 ton	700	12 m	7.5 m	91.2 m²
100 ton	1400	16 m	9.5 m	150.4 m²

The length of the meson gun tunnel is the long dimension of the bay.

2. DISCHARGE ENERGY

Specify the amount of output energy that will be fired in each shot (*discharge energy*, abbreviated DE) in megajoules (Mj). The greater the discharge energy, the greater the damage of each shot, and the greater the final size of the meson gun.

There is no inherent limit to the amount of discharge power, other than power supply requirements, size of ship, etc.

3. MESON TUNNEL CHARACTERISTICS

Find effective tunnel length, tunnel volume, tunnel mass, and tunnel price based on tunnel length in meters, discharge energy, and the table below.

Meson Tunnel Characteristics

TL	*Length Multiplier*	*Vol Multiplier*	*Mass Multiplier*
11	0.8	0.02	1.0
12	1.0	0.01	0.75
14	1.2	0.01	0.6
16	1.4	0.005	0.5
18	1.5	0.005	0.4
20	1.6	0.002	0.3
22	1.8	0.002	0.2
24	2.0	0.001	0.1

3A. Tunnel Effective Length

The effective length (meters) of the tunnel used in calculating range performance below

Effective Length = actual tunnel length (meters) × length multiplier

3B. Tunnel Volume

Tunnel Volume (cubic meters) = actual length (meters) × discharge energy × volume multiplier

3C. Tunnel Cross-Sectional Area

Cross-sectional area in square meters is equal to tunnel volume divided by actual tunnel length.

3D. Tunnel Mass

Tunnel Mass (tonnes) = tunnel volume (cubic meters) × mass multiplier

3E. Tunnel Price

Tunnel Price (MCr) = tunnel volume (cubic meters) × 0.1 at all tech levels

4. PERFORMANCE

The effective range (range at which energy delivered on target is equal to discharge energy) in kilometers is equal to the meson gun's effective tunnel length × 1000. Beyond this range, the beam's power drops due to dissipation of intensity and uncontrolled meson decay.

To find space combat range in hexes/range bands, divide this result by 30,000.

5. DEFINE SHORT RANGE

Select a beam pointer from the Beam Pointer table in the Fire Control chapter (Section 14) based on the gun's tech level and the range performance desired. Note that range is given in kilometers and 30,000-km hexes/range bands for space combat. The listed range in km/hexes will be the gun's short range for purposes of combat. Whenever possible, the beam pointer range should be equal to the gun's effective range to take full advantage of the gun's range-intensity performance.

6. COMBAT RATINGS

6A. Combat Range Bands 1

All combat ranges are based on the gun's short range.

Medium range = Short range × 2

Long range = Short range × 4

Extreme range = Short range × 8 2

Note: Meson guns have a maximum range in thousands of kilometers of 8.5 times their effective tunnel length. If a meson gun's short range is selected in such a way that its extreme range
is in excess of this maximum figure, the gun has no extreme range 3
band, and is unable to fire at any targets beyond its long range.

6B. Damage Value

Define the particle accelerator's damage characteristics at its 4
short, medium, long, and extreme range bands.

Meson guns do damage to enemy targets based on their *damage value* (DV).

5

$$DV = 5\sqrt{I}$$

where I is the weapon's *intensity* at that range. Intensity is 6
derived by the formula

$$I = DE \div (R \div EL)^2$$

where 7

DE is discharge energy from Step 2 above

R is range (short, medium, long, or extreme, as defined in 7A
above) in 1000s of kilometers 8

EL is the effective length of the meson tunnel from Step 3A above

Note that the term $(R \div EL)^2$ should be rounded to the nearest
0.5 (e.g., 1.24 = 1, 1.25 = 1.5) before dividing DE, with a 9
minimum result of 1.

Calculate DV for short, medium, long, and extreme range. The short range in hexes for space combat meson guns will
often fall between two whole number values. Designers should 10
try calculating intensity for both these hexes before selecting the beam pointer, above, because if $(R \div EL)^2$ for the farther hex is between 1 and 1.24, effective range will round up to that hex.
Note that this rounding may result in the loss of the extreme 11
range band. Compare the longer short range in hexes × 8 to (effective length × 8.5) ÷ 30 to see if this is the case.

12

13

14

7. POWER REQUIREMENTS

7A. Input Energy

Meson guns have a 20% energy efficiency, meaning that of the energy put into each shot, 20% is projected toward the enemy in the form of mesons as discharge energy. The remaining 80% is spent creating, accelerating, and magnetically aiming the subatomic particles.

Find input energy in Mj according to this formula:

Input Energy (IE) = Discharge Energy (DE) ÷ 0.2

7B. Homopolar Generator

A meson gun requires a homopolar generator (HPG) to store the energy required for each shot until that energy is ready to be expended as a single pulse. The HPG's volume is calculated by multiplying the gun's input energy (IE) in Mj determined above by the value on the HPG table in the Power Production chapter (Section 8).

7C. Rate of Fire

Select the meson gun's rate of fire (ROF).

Space Combat: Any meson gun intended to be used for space combat must have an ROF of at least 10 shots per 30-minute space combat turn. Higher rates gain the gun reductions in difficulty level according to the table below. Due to the tremendous energies generated by each shot, which must be dissipated during the cooling purge cycle, the maximum ROF of a meson gun is 100 shots per 30-minute turn.

Diff Mods on the following table apply to space combat only, not ground combat.

Rate of Fire Benefits in Space Combat

Space Combat ROF (Shots per 30-minute turn)	*Benefit (In Difficulty Modifiers to Fire Task)*	*Ground Combat ROF (Shots per 5-second turn)*
10	None	1/36
50*	–1 Difficulty levels	1/8
100*	–2 Difficulty levels	1/4

*There is no penalty for firing a meson gun at one of these higher power levels if it is mounted in a vehicle or starship which is designed from the outset to provide sufficient power for the higher ROF (50 or 100 shots). Nonetheless, meson guns which were not installed with the higher power levels may fire at these levels if sufficient power is made available by diverting it from other systems. However, because of the extra strain this places on power couplings, HPGs, etc., an Engineering task must be rolled each turn this is attempted (roll using crew quality). The difficulty level is Difficult if the ROF is raised one step (from 10 to 50 or from 50 to 100) over the installed power allocation, or Formidable if raised two steps (10 to 100). Failure at this roll indicates a System Reset result (see the **TNE** Space Combat chapter, or **Brilliant Lances: Traveller Starship Combat**), with the additional penalty that the meson gun may not fire on the current turn. Catastrophic Failure indicates more severe damage. Roll 1D10: 1-5 indicates a Degraded Performance result in addition to System Reset, 6-10 indicates a Major Hit on the meson gun.

Planetary Combat: To convert space to planetary ROFs, divide the space combat ROF per 30 minutes by 360. Take the inverse (i.e., divide 1 by that number), and round fractions *up*. The result is the number of five-second combat turns required for each shot. Express this number as a fraction, i.e., one shot every five turns is 1/5, one shot every 36 turns is 1/36, etc. Because this conversion system results in distortion of total number of shots due to rounding, this converted ROF must never be used when calculating power input. The original space combat ROF must always be used when rating a space combat meson gun.

ROF for planetary combat is defined in terms of five-second planetary combat turns. The maximum rate of fire for planetary combat is one shot every fourth turn (expressed as 1/4, due to the need for a cooling cycle following each shot.

7D. Power Input

Power input in megawatts (MW) is calculated differently for space combat and planetary combat meson guns. Although they are calculated differently, space and planetary combat power input values are absolute values, as they are both based on MW input per second. However, be careful to make these calculations based on the *true* ROF for each meson gun, based on its primary environment: space or planetary combat. Do not use ROFs converted from one system to the other, as the rounding involved distorts the numbers.

Space Combat Meson Guns: Multiply ROF per 30 minutes times input energy (IE) from Step 7A. This is the total number of megajoules needed over the course of a 30-minute turn. Divide this result by 1800 to find the MW of power that must be allocated to operate the weapon.

Planetary Combat Meson Guns: Multiply ROF times input energy (IE) from Step 7A. This is the total number of megajoules consumed by the weapon each five-second turn. Divide this result by 5 to find the MW of power that must be allocated to operate the weapon.

8. GUN CREW AND WORKSTATIONS

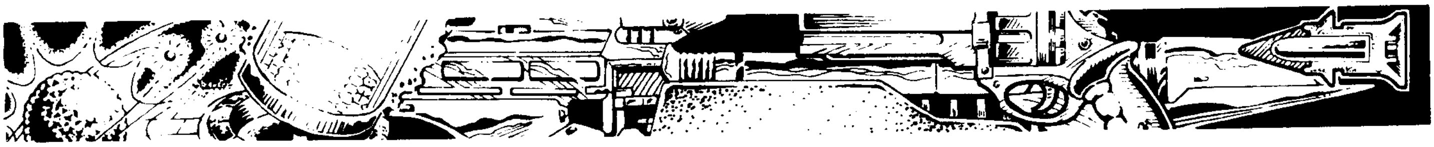
All meson guns must be crewed according to the following formula:

Crew = (Tunnel Volume ÷ 100) × CP

CP: Computer multiplier based on tech level of computer installed aboard ship/linked to ground-based PAW. See Computers table in the Controls chapter (Section 4).

Round to the nearest whole number, but results of less than 1 must always be rounded up to 1.

Each crewmember must have a gunner's (normal) workstation installed with characteristics obtained from the Controls chapter (Section 4).



9. MESON GUN CARRIAGE, MOUNT, ETC.

If the gun is to be mounted in a starship, skip this step. If the gun is intended for use as a towed weapon, calculate the size of its carriage, mount, etc. A towed carriage has the same mass as the meson gun mounted on it.

The gun must include its HPG, but may be plugged in to a power source at its destination. Carriage-mounted meson guns have an all-around armor value of 1. This can be increased by enclosing the gun and its supporting equipment in a "hull" (cylinder hull form) with a certain thickness of armor according to the vehicle or spacecraft design rules. As this armor increases the mass of the gun, it will increase the mass of the carriage as well.

The price of the carriage, in MCr, is equal to its mass in tonnes multiplied by 0.002.

For use in planetary combat, meson guns make excellent indirect fire weapons. Although a meson gun is actually a pure line-of-sight weapon, the fact that it can fire through intervening forests, mountains, even entire planets (if it has sufficient range) means that its fire control solutions are usually of an indirect nature. Meson guns are hardly ever risked in the direct fire role, as they are too valuable.

Ground combat (vehicle- or carriage-mounted) meson guns are usually equipped with indirect fire control systems. Performance details, weight, volume, and price are in the Fire Control chapter (Section 14).

10. MESON GUN PHYSICAL CHARACTERISTICS

Add up or bring down the above components to obtain the following total figures for the gun.

10A. Volume

In cubic meters. Add tunnel volume, beam pointer volume, HPG volume, gunner's workstation volume, carriage volume (if any), indirect fire controls (if any).

10B. Mass

In tonnes. Add tunnel mass, beam pointer mass, HPG mass, gunner's workstation mass, carriage mass (if any), indirect fire controls (if any).

10C. Price

In MCr. Add tunnel price, beam pointer price, HPG price, gunner's workstation price, carriage price (if any), indirect fire controls (if any).

10D. Power Requirements

In MW. Carry down from Step 7D above.

10E. Length

Actual tunnel length in meters. Carry down from Step 1 above.

10F. Surface Area

Surface area for a spinal mount is equal to the tunnel cross-sectional area times 2. Surface area for a bay-mounted gun is equal to the bay's surface area.

10G. Combat Performance

Short range, medium range, long range, and extreme range in
km and/or space combat hexes, plus damage values at those 1
ranges, along with ROF, listing any –difficulty modifiers as applicable. Carry down from Steps 6 and 7C.

11. DEEP SITE MOUNT 2

Because they can freely fire through matter, meson guns buried in "deep sites" far beneath a planetary surface are favored planetary defense weapons. Not only are they immune to fire
except from other meson guns, their location can be difficult to 3
determine. During the Final War, the crews of deep meson gun sites were the last living persons on some worlds.

11A. Volume 4

Volume of the deep site is a sphere calculated from the length of the meson gun.

Divide gun length by 2 to get radius of the sphere in meters.

$^4/_3\pi r^3$ = volume of sphere 5

Mass of this sphere is irrelevant, as it is immobile. Price is equal to tunneling costs per cubic meter, below.

11B. Lift Carriage 6

The gun has infinite traverse within its sphere. This is provided by a lift carriage which negates the various bending stresses on
the tunnel so that it retains its accuracy, and also allows it to be 7
traversed.

Install a CG lifter from the Lifters subsystem chapter (Section 10) based on the volume of the sphere. Volume of the generator
is added to that of the sphere. Mass is irrelevant, and price is 8
calculated normally.

If contra-grav technology is not available, the gun must have a mechanical carriage which costs MCr0.01 per cubic meter of sphere.

11C. Other Support Systems 9

Fire control, crew, and power requirements are determined the same as for any other meson gun. In addition, crew for the power
plant plus life support, staterooms, etc. should be provided. Costs 10
for all of these elements are calculated normally.

Access to the surface is provided by twin high-speed elevators. Volume of this shaft equals the depth of the site beneath the
surface times a cross section of 36 square meters. Cost is 11
MCr0.001 per vertical meter of shaft.

Once all components of the deep site have been calculated, total their volume (including the access shaft) to calculate the cost
of tunneling based on the table below. 12

TL	MCr/cubic meter	
7	0.0005	
8	0.0003	13
9	0.0002	
10	0.00015	
11	0.00015	
12	0.00007	14
13	0.00007	
14	0.00007	
15	0.00007	

CHAPTER 7

1 High-Energy Weapons

High-energy weapons use a laser to heat hydrogen to a plasma state, containing it in a magnetic bottle until it reaches maximum energy, then opening an aperture in the bottle, releasing the plasma
2 in a high-temperature, high-velocity (in excess of 8000 meters per second) jet. Fusion weapons operate on identical principles but contain the plasma slightly longer until a fusion reaction begins.

High-energy weapons use power cartridges identical to those
3 used in explosive power generators as their ammunition. Each high-temperature ceramic cartridge is ignited and serves as the liner for the magnetic bottle that contains the plasma generated inside it. Recoil energy activates a purge cycle, during which liquid nitrogen
4 is used to cool the cartridge before a new one is fed into the chamber from the magazine or autoloader, kicking what's left of the spent one out of the weapon (some of the mass of the cartridge becomes a part of the plasma jet). After the purge/eject cycle, the action locks closed,
5 and the weapon is ready to fire again. The spent cartridge case is still hot enough to inflict burns on unprotected skin, although the purge cycle cools it enough so that it is no longer a source of ignition.

The heat of the ejected cartridges and the incidental heat from the
6 plasma stream require users to wear protective clothing of some sort. The flame-retardant properties of most standard military uniforms provide adequate protection.

Supporting hardware consists of the cooling system and the
7 power pack for the magnetic bottle. In the case of small arms weapons, this supporting hardware is worn as a backpack and the plasma or fusion cartridges are loaded into the weapon in detachable box magazines.

8 *ENERGY WEAPON DESIGN SEQUENCE*

A. Specifications

9 The characteristics of high-energy weapons are determined by five specifications. In addition, the weapon's power cartridge is designed at this time, as it is used through the rest of the design sequence.

1. Tech Level: Determine the tech level of design of the
10 weapon. Plasma weapons can be designed from tech level 10 and up. Fusion weapons can be designed from tech level 14 and up.

2. Pulse Energy: Pulse energy is measured in megajoules (Mj) and is the basic defining parameter of energy weapon perfor-
11 mance. Theoretically, any pulse energy level may be specified, but there are practical limits based on the size of weapon desired.

3. Fire Control: The type of fire control equipment, if any, must be specified. Since energy weapons are direct line-of-sight
12 weapons, they do not require sophisticated rangefinders. A simple optic sight is sufficient for most targets, and this is included in the basic cost of the weapon. Ballistic computers or point-defense computers may be added to give the weapon a better capability
13 against high-speed targets. Enhanced-visibility equipment may be added to enable the gunner to engage targets in limited-visibility conditions. See Fire Control, Section 14.

4. Mount: An energy weapon may be hand-carried or
14 mounted either on a carriage or directly on a vehicle. All guns mounted on vehicles and on towed carriages are collectively called "cradle guns," as opposed to smaller man-portable weapons, which are usually called rifles, or in militarese, PGMPs (plasma gun, man portable) and FGMPs (fusion gun, man portable).

5. Options: A cradle gun may have a gun shield if desired, which provides the crew some protection against fragmentation and small arms fire from the front. If vehicle-mounted the gun may also have an autoloader.

6. Power Cartridge: Ammunition for energy weapons consists of explosive power generation (EPG) cartridges, which provide both power for the system and the fuel mass that forms the plasma stream fired by the weapon. At tech level 10, these are CPCs, at TL 12 they are PPCs, at TL 14 PFCs, and at TL 16 GCFCs, as described in the explosive power generation section of the Power Production chapter (Section 8).

Consult the Power Production chapter and design a cartridge from the correct tech level which has the output necessary to power the weapon.

B. Mass

The complete weapon system weight is equal to the weight of the weapon itself, plus its supporting hardware, plus its fire control equipment, plus its recoil system, plus its gunshield (if any), plus its feed system. The empty weight of a small arm energy weapon is equal to the mass of the firing unit. The loaded mass of a small arm energy weapon is equal to the mass of the firing unit plus the mass of a loaded magazine.

1. Firing Unit: The firing unit consists of what we would call the barrel and receiver of a conventional small arm. The ammunition supply feeds plasma or fusion pulse cartridges into the receiver where the internal ignition lasers of the system heat the fuel in the cartridge to a plasma state. The firing unit also contains the pilot laser that opens the atmospheric tunnel for the passage of the plasma or fusion bolt.

The mass of the firing unit is determined by the following formula:

Mf = TmEp

Mf: Mass of the firing unit in kilograms
Ep: Pulse energy in megajoules
Tm: Tech level multiplier, as shown on the following chart:

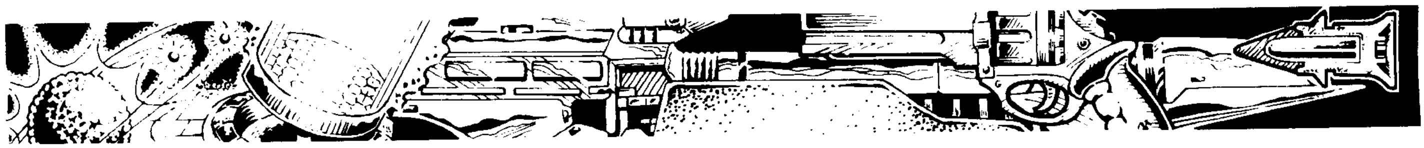
TL	*Tm*
10	8
11	6
12-14	4
15	2
16-17	1
18-19	0.5
20+	0.3

2. Supporting Hardware: The supporting hardware includes the liquid nitrogen (LN) purge cooling system and a power pack to support the magnetic bottle. The power pack includes a small battery and homopolar generator (for the pilot laser) and is thermoelectrically powered by excess heat from the main ammunition ignition system. On man-portable weapons, the supporting hardware is contained in a backpack linked to the weapon by a multiflex cable including data, power, and LN lines.

The mass of the firing unit is determined by the following formula:

Ms = TmEp

Ms: Mass of the supporting hardware in kilograms
Ep: Pulse energy in megajoules
Tm: Tech level multiplier, as shown on the following chart



TL	Tm
10	12
11	10
12	8
13	6
14	4
15	2
16-17	1
18-19	0.5
20	0.3

3. Fire Control: The weights of the various fire control systems are given in the Fire Control chapter (Section 14). Basic optic sights are included in the mass of the firing unit.

4. Recoil System Weight: Man-portable energy weapons do not require a cradle. The mass (and price) of a stock are subsumed in the basic cost of the firing unit.

At tech level 10, gyroscopic recoil compensators become available. This recoil compensator is a gyroscopic unit mounted in a backpack and body harness to which the gun is connected by a flexible articulated arm. The arm becomes rigid when the weapon is fired and helps absorb the recoil.

At tech level 14 and beyond, inertial compensators become available to reduce the recoil of man-portable energy weapons. This is a more sophisticated version of the gyro-compensator.

The mass of both gyroscopic and inertial compensator is determined by the following formula:

$$Mc = TmEp$$

Mc: Mass of the compensator in kilograms.
Ep: Pulse energy in megajoules.
Tm: Tech level multiplier, as shown on the following chart:

TL	Tm
10-11	6
12-13	5
14	4
15	2
16-17	1
18-19	0.5
20	0.3

Cradle guns, whether they are towed or vehicle mounted, require a recoil-absorbing cradle. This is similar in design to the hydraulic recuperators used to absorb recoil on CPR guns.

The mass of the recoil cradle is determined by the following formula:

$$Mr = TmEp$$

Mr: Mass of the recoil cradle in kilograms
Ep: Pulse energy in megajoules
Tm: Tech level multiplier, as shown on the following chart

TL	Tm
10	75
11	50
12	35
13-14	20
15-16	15
17-18	10
19-20	6
21+	4

Towed guns also require a carriage. The carriage weight of a gun, in tonnes, is its pulse energy in megajoules divided by 2.

Vehicle-mounted cradle guns do not require carriages, but the vehicle itself must weigh at least twice the required carriage weight.

5. Gun Shield: The weight of a gun shield in tonnes is equal to 0.1 times the pulse energy in megajoules.

6. Feed System: Specify the number of cartridges in the magazine. On cradle guns or very large man-portable weapons, this will usually be only one, with individual rounds loaded by hand or by autoloader into the weapon each time it fires. For most man-portable weapons, several rounds can be carried in a box magazine attached to the weapon.

The mass of a box magazine is determined by the following formula:

$$Wm = .6(N+4)Wa$$

Wm: Weight (in kilograms) of an empty magazine.
Wa: Weight (in kilograms) of a complete round of ammunition.
N: Number of rounds the magazine is designed to hold.

A loaded magazine weighs this plus the weight of the individual cartridges loaded into it.

Empty magazines cost Cr10 per kilogram, rounding fractions up.

The weight of the auto-loader is equal to the cartridge weight times 30.

C. Gun Crew

The number of crewmen required to man a gun depends on its function and how it is mounted. A crew normally consists of a gunner and several loaders.

The crew required to serve a towed (carriage-mounted) energy weapon is equal to the mass in kilograms of its power cartridge multiplied by 0.03, rounding fractions up. Vehicle-mounted weapons require a crew half this size, rounding fractions up, but never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).

D. Range

Weapons have four direct fire ranges: short, medium, long, and extreme. Medium range is 2 × short, long is 4 × short, and extreme is 8 × short.

Direct fire range is mostly a function of the pulse energy of the weapon. A second consideration is the type of weapon, as fusion guns have a longer range for the same energy than do plasma guns.

Short direct fire range in meters for a plasma gun is its pulse energy in megajoules multiplied by 30.

Short direct fire range in meters for a fusion gun is its pulse energy in megajoules multiplied by 50.

E. Damage Value

The damage value of an energy weapon at short range is calculated using the following formula:

$$D = 11.5(\sqrt{E})$$

D: Damage value
E: Pulse energy in megajoules

F. Penetration

Penetration is expressed in two ways: as *penetration value*, and as *penetration rating*.

Penetration value is a measure of the weapon's absolute ability to penetrate armor, and is the measure most often used in vehicle combat.

Penetration rating describes the relationship between the weapon's damage value and its penetration value. Penetration value = Damage value + Penetration rating. Likewise, Damage value = Penetration value × Penetration rating.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Penetration rating is also equal to the number of points of damage value that are lost for each level of armor value that is penetrated
1 (thus the smaller the penetration rating, the better the penetration performance). This is the measure most often used in personnel combat. Penetration ratings become higher (i.e., penetration performance becomes worse) as range increases. Ratings are given by
2 range: short/medium-long-extreme (penetration rating for medium is the same as for short).

Plasma weapons have a penetration rating of 1-2-10.

Fusion weapons have a penetration rating of ½-1-4.

3 Small arms are usually listed with their damage value and penetration ratings listed separately.

Cradle guns are usually listed with their damage value and penetration ratings combined into their penetration values at the
4 various ranges.

Thus, a small arms fusion gun might be described as having a damage value of 20 with penetration ratings of ½-1-4. That same fusion gun, if it were rated as a cradle gun, would have listed
5 penetration values of 40-20-5 (short/medium-long-extreme).

G. Reloading

The time the weapon requires to reload is a function of its energy. The base number of five-second turns required to load a round is
6 equal to its pulse energy (in megajoules) divided by 3, rounding fractions to the nearest whole number. A result of less than 0.5 (which rounds down to 0) indicates that a round can be reloaded in the same combat turn in which the weapon fires, leaving it capable
7 of firing again in the next combat turn.

If an autoloader is available, multiply pulse energy by 0.3 for purposes of this calculation.

If the weapon is man-portable and fed by a box magazine, the
8 weapon is always semiautomatic with a maximum rate of fire of 1 round per combat turn.

H. Price

9 The price of the weapon is equal to the price of its components. Fire control equipment costs are listed in the Fire Control chapter (Section 14). The prices (in credits) of other components are determined by their mass (in kilograms)and cost multipliers, as
10 shown below. Note that the cost multipliers for certain components of plasma and fusion guns are different.

Price Multiplier

	Component	Plasma	Fusion
11	Firing Unit	2500*	7500*
	Support Hardware	2500*	7500*
	Gyro-Compensator*	1000	1000
12	Inertial Compensator*	2500	2500
	Recoil Cradle	100	100
	Towing Carriage	2	2
	Autoloader	10	10
13	Gun Shield	1	1

* Installing a gyro-compensator or inertial compensator requires that the electronic components of the system be designed more
14 robustly. This has no effect on mass, but doubles the price of the firing unit and support hardware.

Empty magazines cost Cr1 per kilogram, rounding fractions up.

I. Set-Up

A towed energy weapon must be set up before it can fire. The set-up time (in five-second combat turns) for a towed energy weapon is determined by multiplying the total mass of the weapon (in tonnes) by 10.

J. Volume

The volume of an energy weapon in cubic meters, for purposes of transportation or mounting in a vehicle, is equal to the mass of its components in metric tonnes multiplied by 0.5 (for the firing unit and support hardware) or 1 (for all other systems).

K. Recoil

Recoil is only calculated for man-portable weapons, not cradle guns. Recoil is calculated using the following formula:

$$R = \{[(150\sqrt{E})+Ww]+4\}\times Rcm$$

R: Recoil number
E: Pulse energy in megajoules
Ww: Weight, in kilograms, of weapon (loaded)
Rcm: Recoil compensator modifier. The only allowed recoil modifiers are from gyroscopic or inertial compensators. (All plasma and fusion weapons are assumed to have recoil-absorbing stocks as standard equipment. Muzzle brakes are not effective, and in fact are extremely dangerous, on energy weapons.) The recoil modifiers for these vary with tech level and are shown below. Note that these systems, due to the larger recoil forces at work, are not as effective at reducing recoil as similar systems used with small arms.

TL	*Type*	*Rcm*
10	Gyro	.8
14	Inertial	.5
15	Inertial	.4
16	Inertial	.3
18+	Inertial	.2

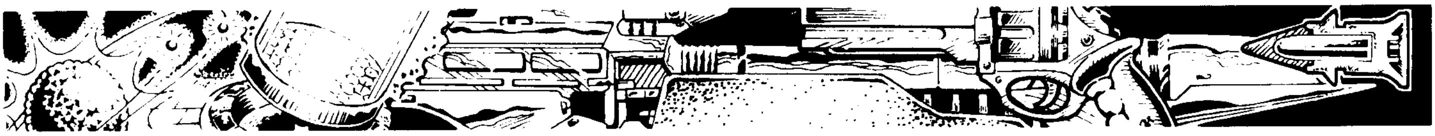
L. Bulk

Bulk is only calculated for man-portable systems, not cradle guns. Bulk is calculated using the following formula. However, results of greater than 5 are treated as 5.

$$B = MfTm$$

B: Bulk
Mf: Unloaded mass (in kilograms) of the firing unit.
Tm: Tech level modifier, as shown below.

TL	*Tm*
10-11	3
12	2
13	1.5
14	1.25
15	1
16+	0.75



CHAPTER 8
Lasers

Laser, as all science-fiction gamers probably know, stands for Light Amplification by the Stimulated Emission of Radition, and is one of the most used—and, it would appear, misused—concepts in science-fiction gaming. (Incidentally, lasers were originally referred to as "optical masers"—maser = Microwave Amplification by the Stimulated Emission of Radiation—although masers could as easily be referred to as "radar lasers.")

Laser Basics

The key concept behind lasers is *stimulated emission*, meaning that an atom or molecule is hit by light of a particular wavelength which then causes that particle to emit light of that same wavelength. The reason that substances can be stimulated to produce specific wavelengths has to do with the way atoms and molecules store and release energy with their electrons. Electrons belonging to an atom are found in "orbits" (they are not really orbits, but in the interest of not going into weird existential Schrödinger's cat-style quantum physics, orbits are a close enough concept) around the atom's nucleus (that's *noo-klee-us*, Mr. Secretary). These electrons move from low-energy orbits close to the nucleus out to high-energy orbits farther from the nucleus as they gain energy by absorbing photons, and move back in toward the nucleus as they give up energy by emitting photons.

These orbits are not set up with an infinite number of fine gradations, they are more like the rungs of a ladder—there are only so many, and they are a fixed distance apart. One can step up or down one, two, three or more rungs at a time, but cannot go up or down a fraction of a rung. Like the difference between electron orbits, the differences between the rungs on a ladder are *quantized*. This means that an electron which absorbs a photon and moves, or *transitions*, to a higher orbit, or *energy level*, can only have absorbed a photon with a certain fixed amount of energy, no more and no less, to move to that energy level. As that same electron transitions back down to the earlier lower energy level, it emits that same amount of energy, the difference between the two energy levels, in the form of a photon which is identical to the photon it absorbed earlier. Thus, based on the number of available energy levels and the combination of transitions (energy level 0-1, 0-2, 0-3, 1-2, 1-3, etc.), an atom can only absorb or emit photons of certain discrete energies.

Photons are described in three ways: by their energy, their frequency, and their wavelength (remember that electromagnetic radiation behaves as simultaneously as particles—photons—and waves, so that particles can be said to have frequency and wavelength). However, these are merely three different descriptions of the same thing—a given wavelength is equivalent to a certain frequency is equivalent to a certain energy. That means that an atom which can only absorb or emit photons of certain energies can only absorb or emit radiation of a certain wavelength.

Molecules also store energy electronically as just described, but they also store energy as vibrational energy, where the component atoms vibrate back and forth with relation to each other, and rotational energy, where the molecule rotates around its center of mass (atomic nuclei cannot store energy like this because their mass is completely symmetrical). However, like electronic energy, vibrational and rotational energy are also quantized—there are only certain allowed levels of these energies, which of course define the energy/wavelength of the photons that these molecules can absorb or emit. (Rotational transitions are the least energetic, with most transitions corresponding to the far infrared portion of the spectrum. Most vibrational transitions are in the near infrared. Electronic transitions are the most energetic, with most of these corresponding 1
to the visible and ultraviolet portion of the spectrum. However, there are notable exceptions to all of these generalizations. Nonetheless, this means that electronic transformations are the most useful for military purposes, as we will see below.) 2

Most photon emission is spontaneous. Energetic atoms or molecules, like those in the filament of a light bulb, shed their energy by spontaneously spewing photons—atoms and molecules tend to be in their lowest energy states, so the chances of spontaneous emission 3
increase with the energy state. What stimulated emission does is to hit an energetic atom or molecule with a photon of a wavelength that corresponds to one of that atom or molecule's transitions (i.e., a wavelength which it can absorb or emit). If the atom or molecule 4
is already at the energy state where it can emit a photon of the wavelength which struck it, the atom or molecule will emit that photon, and in the same direction as the photon which struck it, so that now there are two identical photons travelling in the same direction. So long as this takes place within a population of atoms or 5
molecules which are already at the required energy level, this chain reaction will continue, creating ever more photons of the same wavelength. This is a laser. What? No powerful concentrated beam? Nope. All that is required of a laser is laser gain—the amplification of 6
light radiation by stimulated emission—it need not be unidirectional, or focussed. Mars' upper atmosphere is one such non-unidirectional laser. If this emission takes place between a pair of focusing mirrors, the photons will bounce back and forth, continu- 7
ously stimulating more photons travelling in the same direction, until one of the mirrors is made transparent ("Q-switched"), and the focused beam of photons is released. This is what we normally think of as a laser, although it is more properly a "diffraction limited laser." 8
However, these diffraction limited lasers are what we simply call "lasers" in **Traveller** and in the design sequence below.

The problem is that a population of atoms or molecules will not all be at the proper energy state at the same time. Instead, they will 9
naturally be at thermodynamic equilibrium, which means that the number of atoms or molecules at a given energy state varies inversely with the amount of energy in that energy state, with the result that each energy state is outnumbered by the lower energy state 10
immediately beneath it (i.e., the energy state which will immediately absorb photons released by the upper energy states). What this means is that this population would rather absorb the photons coming by than be stimulated to emit any. The stimulated emission 11
chain reaction is dead before it begins.

In order to get stimulated emission to work, there must be a *population inversion*. A population inversion means that the target energy state (that which produces the photon wavelength desired) 12
is more common than the energy states beneath it. This allows the target energy state population to stimulate each other's emission without these photons being immediately absorbed. This inversion cannot be created simply by heating the population, as this would 13
merely create thermodynamic equilibrium at a higher set of energy states, which would be just as disastrous to the chain reaction. The way to selectively populate an upper energy level is via electrical current, intense light, or chemical reaction.

There are three main types of lasers to discuss in relation to 14
Traveller. They are presented in the order of their technological advancement on modern Earth.

First is what we will call a static laser. A static laser uses a single

population of atoms or molecules which are energized by electrical or light input, emit their photons and fall to a lower energy state, and
1 are then re-energized to emit again, over and over and over. They are called static because they use the same population time after time. They are distinguished by the need for significant electrical input in order to function. Static lasers include modern ruby lasers, gas lasers,
2 and excimer lasers. These are represented in **Traveller** by the direct electrical input lasers at the lower tech levels of roughly 7-9, with rubies and gas lasers from TL 7-8, and excimers from 8-9.

Second are chemical lasers. These lasers do not use the same
3 population over and over, but continuously create a new energized population which emits its photons and is discarded. These atoms or molecules are not energized *per se*, but are created in an energized state as the products of an energetic chemical reaction. By keeping
4 a continous reaction going and venting away the spent material, a population inversion can be maintained without the need for outside power input, as the energy comes purely from combusting chemicals. These are most commonly used in **Traveller** as small arms lasers.

5 Third are free-electron lasers, or FELs. This laser passes an electron beam through a series of magnets which bend the paths of the electrons. As the electrons' paths are bent, they are made to emit or absorb photons. By placing mirrors at both ends of the electron beam, the photons are gathered coherently to form a beam in the
6 usual fashion. Because these electrons are free, and not bound to an atom, they are not locked into quantized energy states, and therefore can absorb or emit photons of any wavelength, depending upon how they are manipulated by the magnets. In this way, the FEL
7 can actually be tuned to emit different wavelengths. In **Traveller**, FELs are represented by the great tunable direct electrical input lasers, the mainstay of **Traveller** space combat from TLs 10-15. For simplicity in the design sequence, however, these overlap with the
8 static lasers above.

The non-tunable X-ray lasers that appear from TLs 13 to 19 are also FELs, but are very specialized to produce X rays and have therefore given up their tunability. X-ray stimulated emission is very hard to
9 induce because the chance of inducing stimulated rather than spontaneous emission of a photon varies with its wavelength cubed. By the very short X-ray wavelengths, this probability has dropped off sharply from that of the more amenable, longer wavelengths.

10 An additional specialized type of laser should be mentioned. It is an odd subset of static laser, called the nuclear-pumped X-ray laser.

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12

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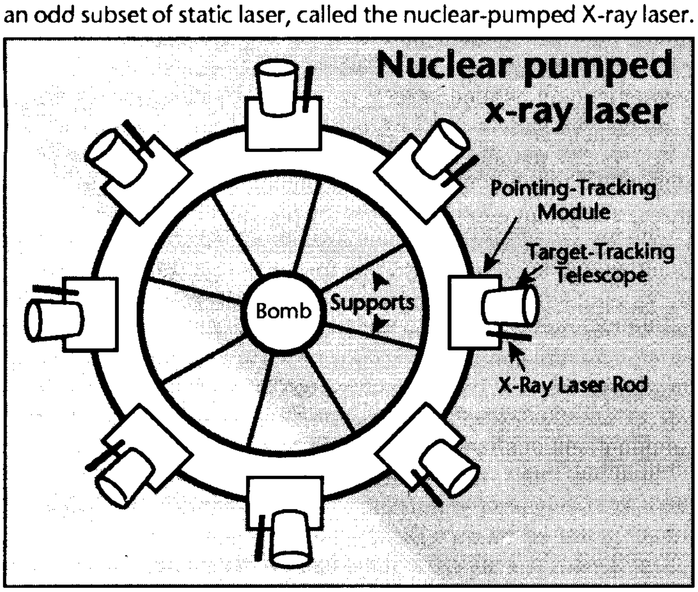


To create the necessary population inversion for X-ray emission requires a great deal of power, because the transition that produces an X ray is an extremely powerful one. The radiation from a nuclear explosion provides sufficient power, but also vaporizes the laser-producing population after one shot. Another troublesome characteristic of short wavelength stimulated emission is the incredibly short life time of their excited state before spontaneously emitting. In the case of the 10Å photon that would be emitted by a nuclear-pumped laser, this lifetime is only about 10^{-13} seconds (one-tenth of a trillionth of a second), which is probably just as well, under the circumstances.

The X rays are generated by a population shaped in the form of very thin rods, about a millionth of a meter in diameter. There are no mirrors or sophisticated focusing arrays on these expendable beam-generating rods. It is the shape of the rods themselves that create the beam by directing the path of the stimulated emission chain reaction along their lengths.

Laser Functions

All of the rules on laser performance and design are defined by the following formula which describes the physics of focusing light, based on its wavelength and its focusing elements.

$$\mathbf{I = (P \div [\{L \div F\}^2]) \div R^2}$$

Where:

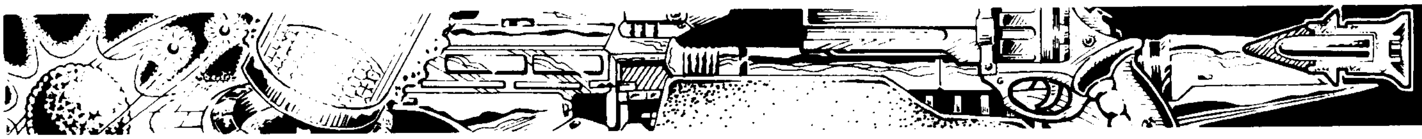
- **I** = Delivered energy intensity (watts/cm^2)
- **P** = Discharge energy (watts)
- **L** = Wavelength (centimeters)
- **F** = Focal value (centimeters)
- **R** = Range (centimeters)
- **L÷F** = Divergence angle (radians)

The calculations in the design sequence below do not require designers to use this formula, but all of the formulas and concepts are derived from it. One of the most important facts derived from this formula is that the shorter the wavelength of the laser, the better its range performance will be. The longer its wavelength, the worse it will be. Lasers start with rather long wavelengths (in the infrared band of the electromagnetic spectrum) at low tech levels, but are able to achieve shorter wavelengths at higher tech levels. The other important fact is that lasers, no matter how we might fervently wish it, do not have the range performance we have been led to expect by a steady diet of movies, television, and soft science fiction. Space combat ranges are simply too great.

All light disperses over distance, even diffraction-limited laser light. The variables are wavelength, diameter of the focusing elements, and range. We've already mentioned that short wavelengths are desired to get good range performance, and we know that the bigger the focal elements, the tighter the focus.

The problem is that dispersion increases with the *square* of the range. Once any variable becomes squared, it quickly overwhelms the other variables, particularly when the squared variable is big to begin with. In space, the range variable is very, very big. Very, very big squared is almost insurmountable.

To get an idea of how almost insurmountable real physics is, let's try a rough laser design using the formula above. How big does our focal array need to be? Let's try 10 meters in diameter, much larger than anything ever visualized for **Traveller**, or any other science-fiction game, movie, or TV show. And let's set its wavelength in the ultraviolet (UV) range, better than we can handle today, but not as good as X rays (which, as with earlier editions of **Traveller**, show up at TL 13), and we'll set its output at 1000 megajoules.



How does the beam hold together? At only 30,000 km (one space combat hex), its spot size is almost 70 meters in diameter, diluting the 1000 megajoules down to only 0.3 megajoules per square centimeter. Since a laser needs about 2 megajoules per square centimeter to punch through a centimeter of steel, our laser is off by a factor of almost 100 to punch a civilian starship hull, and that's at only one hex.

What do we need to get a 10-hex range with tight enough focus to punch a starship? We need a divergence angle of around 0.3 picoradians (10^{-12} radians), which we can get by using shorter wavelength light or a larger focal dish. But since we've already decided that UV is as short as we can go before TL 13, we're left with a dish diameter of *6000 meters*.

In order to deal with this cruel reality, **Traveller: The New Era** incorporates a rule for gravitic focusing to allow lasers to continue to have the long-range space performance we've all grown used to. This gravitic focusing of the laser beam appears at the same time as contra-gravity technology, and creates the effect of a larger diameter dish by creating an intense point source of gravity within the focusing area to bend the light with gravity. However, because this bending of light is such a departure, we present it as an optional technology, instead of just fudging the rules to cover up the reality gap. By doing this, we allow referees to design campaigns that use real physics, to discover what space combat of the future might actually be like, starting with SDI. Although we call it an optional technology, gravitic laser focusing is an official and important part of the Imperial Space campaign, and will be used in all **Traveller: The New Era** background material intended for that campaign.

LASER DESIGN

1. TECH LEVEL

The tech level at which a laser is built has obvious impact on its effectiveness. Tech level affects the mass and volume of the laser itself, its power supply, the wavelength of light that can be used, and the fire control systems that are used to guide it. Tech levels of 13 or greater also affect the type of laser that can be built. If the tech level is 13 or more, at this time the designer must designate if the laser will be a *tunable* laser or an *X-ray* laser.

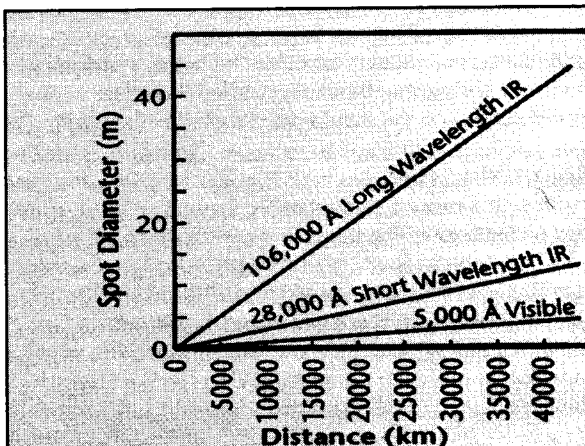
Tunable lasers have a shortest allowable wavelength defined by their tech level. At most tech levels, this shortest wavelength is longer than X-ray wavelengths, and therefore cannot be focused as tightly and so has less range. However, a tunable laser can be tuned to fire a pulse of any wavelength equal to or longer than its shortest allowable wavelength, which is advantageous when firing into or through atmospheres. Ultraviolet and X-ray radiation are absorbed quite well by atmospheres, making these wavelengths quite useless for use in ground vehicles or for planetary bombardment from space. Even though visible and infrared wavelengths have poorer focusing and range performance than X rays, they are the only wavelengths useful for attacking targets within an atmosphere. Thus a tunable laser with a shortest allowable wavelength in the ultraviolet or soft X-ray bands could use these wavelengths for maximum range performance in space, but still be tuned to visible bands when conducting planetary bombardment.

X-ray lasers, on the other hand, are built for the maximum possible range performance in vacuum. But because of the specialized nature of equipment necessary to focus X rays, these X-ray lasers cannot be "de-tuned" to fire longer wavelength pulses. (Note, however, that at high tech levels, tunable lasers become capable of ever shorter wavelengths, so that tunable lasers and X-ray lasers eventually merge.)

2. GRAVITIC FOCUSING (OPTIONAL TECHNOLOGY FIELD)

Gravitic focusing allows lasers to be be focused at lethal intensities over the ranges at which **Traveller** space combat takes place. This is an official part of the standard Imperial Space campaign, but need not be used by players who are creating their own "universe" or campaign background.

Gravitic focusing does not require any additional equipment to be installed in the design sequence, but it does affect laser energy efficiency (Step 4), and adds another step to improve the performance of the laser in the performance rating step (Step 5).



Why Gravitic Focusing?

This graph shows the focussing performance of several current or hypothetical lasers using real-world physics. The graph shows the spot size at various ranges of a laser beam fired from a focal mirror 30 meters in diameter. Note that a range of 30,000 km is only one hex in Traveller space combat. Bearing in mind that intensities of at least one megajoule per square centimeter must be obtained to get meaningful combat performance, think of how hard that must be when a laser spot is over five meters across (50,000 square centimeters) at a range of only one hex.

This is why we have chosen in Traveller: The New Era to postulate gravitic focusing as an optional (though passionately recommended) technology field.

3. FOCAL ARRAY

Select the diameter of the laser *focal array* (abbreviated FA Diameter). At low tech levels, this is a pair of simple concave mirror at opposite ends of the laser-generating cavity. At higher tech levels, it is an array of smaller reflective surfaces which are focused mechanically or electro-hydraulically, using electricity or sound passed through a fluid focal medium to focus and traverse the beam. The larger the diameter of the focal array, the greater the range at which the laser beam can be focused to lethal intensities.

During the design sequence itself, the focal array diameter must be specified in meters, although small arms lasers are usually described in centimeters once their designs are completed. Many of the equations that follow require units in meters in order to give proper results.

In general, focal arrays may be built to any dimensions desired. However, certain standardized weapons installations are used on starships which require certain parameters to be observed.

3A. Standard Socket-Mounted Lasers

Most starships are fitted with one or more of two standard-sized
1 *sockets*. These sockets will accept standard-sized lasers, missile launchers,
and nuclear dampers. These sockets come in two sizes, referred to by
tradition as turrets and barbettes. Turret sockets are 3 displacement tons
(42 cubic meters), and barbette sockets are 6 displacement tons (84 cubic
2 meters). Both sockets are cylinders, with the following dimensions:

	Type	*Displacement*	*Volume*	*Diameter*	*Height*	*Surface Area*
3	Turret	3 tons	42 m^3	3.6 m	4.2 m	10 m^2
	Barbette	6 tons	84 m^3	4.5 m	5.25 m	16 m^2

A designer may always build a laser "turret" or "barbette" that does not
4 fit these parameters, and these may be readily installed aboard starships—
however, they will not fit into the standardized sockets.

3B. Bay-Mounted Lasers

For lasers which are mounted in starship bays, the focal array
5 diameter is dependent upon the size and dimensions of the bay.

A bay may be constructed to any size desired, although the most
popular are the 50-ton (700 cubic meters) and 100-ton (1400 cubic
6 meter) bays. A bay's dimensions are calculated as follows.

Each bay has a single long dimension and two shorter dimensions.
The long dimension in meters is found by taking the bay's volume
in cubic meters, extracting the cube root, multiplying by 1.4, and
7 rounding to the nearest whole number.

$$1.4\,(\sqrt[3]{Vol})$$

Divide the bay's total volume in cubic meters by the long
dimension, and extract the square root of this result, rounding to the
nearest 0.5 meters. This is the approximate length of the bay's short
8 dimensions. Multiply the long dimension by the short dimension to
get the surface area of the bay in square meters.

Standard Bays and their Dimensions

	Size	*Cubic Meters*	*Long Dim.*	*Short Dim.*	*Surface Area*
9					
	50 ton	700	12 m	7.5 m	91.2 m^2
	100 ton	1400	16 m	9.5 m	150.4 m^2

10 The diameter of the focal array is equal to the short dimension of
the bay.

Characteristics of the focal array are specified after selecting the
laser's maximum pulse energy in Step 4.

11

4. DISCHARGE ENERGY

Specify the amount of output energy that will be fired in each laser
pulse (*discharge energy*, abbreviated DE) in megajoules (Mj). (In the
12 weapons ratings, this is usually referred to as the "pulse".) Naturally,
the greater the discharge energy, the more damaging the laser, and
the more equipment is required to allow the laser to function.

Focal arrays fall into one of two performance brackets: *heavy* and
13 *light*. A heavy focal array is any array, regardless of power output,
which is intended for permanent installation in a vehicle, spacecraft,
or static ground installation. A light focal array is one which is
intended for use in a small arm or heavy weapon, and is generally
14 man-portable. Light focal arrays (which can be more massive than
a heavy focal array of the same power output) are therefore not
subsumed under the various support systems (power, environmental protection, and cooling, etc.) of, say, a ship-mounted system, and require some additional expense as well as support components to be added separately (which will be detailed below).

A heavy focal array must be further defined as a trainable or fixed array. A trainable array is one which will be mounted so it can be traversed and pointed at its target, as in a turret or similar mount (this also includes barbettes, bays, and vehicle turrets). A fixed mount is one which will be mounted to have no flexibility, and must be aimed by pointing the vehicle in which it is mounted. This is typical of lasers mounted in the noses of fighters, fixed to fire directly ahead. When mounted in spacecraft in this way, these are referred to as laser "lances."

Now calculate the characteristics of the focal array. The volume of the focal array (in cubic meters) is its surface area (in square meters) times its maximum discharge energy (in Mj) times the tech level modifier from the table below.

Surface area is calculated by first dividing the FA diameter in meters by 2 to get its radius, r, in meters.

Surface area = πr^2, where $\pi = 3.1416$

Focal Array Volume Modifiers

TL	*TL Modifier* — *Heavy Focal Array*	*Light Focal Array*
7-8	1	10
9	0.1	1
10-11	0.01	1
12-15	0.001	0.5
16-19	0.0005	0.1
20+	0.0001	0.05

Mass: Mass in tonnes of the focal array is equal to its volume in cubic meters ×1

Price: Price in megacredits (MCr) of a trainable heavy focal array is equal to its volume in cubic meters × 0.2; of a fixed heavy array in MCr is cubic meters × 0.1, and of a light array in MCr is $m^3 \times 0.5$.

Energy Efficiency and Input Energy: All lasers have a required amount of energy input, defined as input energy (IE) for each shot.

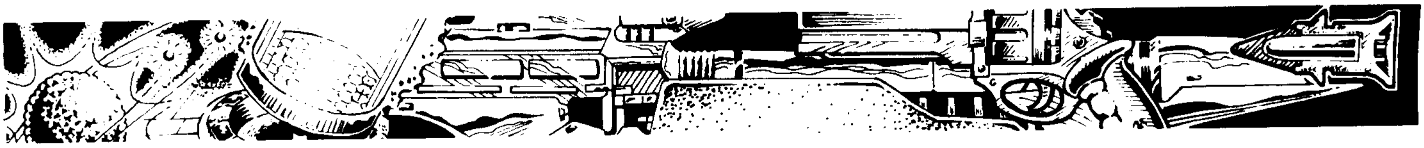
Non-Gravitic Focusing: Lasers designed without the gravitic focusing optional technology field derive their input energy from their energy efficiency based on tech level.

TL	*Efficiency*
7	0.20
8	0.25
9	0.30
10	0.35
11	0.45
12	0.55
13	0.65
14	0.75
15	0.85
16+	0.95

To find the input energy needed for each shot, divide DE in Mj by the efficiency value on the table according to tech level.

Gravitic Focusing: All lasers using gravitic focusing have a 20% energy efficiency. In other words, the discharge energy chosen above is only 20% of the total energy expended for each pulse; the remaining 80% is spent in generating the beam, generating the gravitic focusing elements, or lost as waste heat. To find the actual energy in Mj needed to fire each laser shot, use the equation

DE + 0.2 = input energy (IE) required per shot



5. LASER PERFORMANCE RATING

To find a laser's performance, multiply its *focal value* (F) by the range factor used at the laser's tech level. The result is the laser's *effective range* in kilometers. Effective range is the range at which the laser's full pulse energy is focused into an area on the target of 1 square centimeter. Within this range, a laser's full pulse energy is used to inflict damage on its target. Beyond this range, the beam's intensity per unit area diffuses, and the damage becomes lower. Effective range is not used in combat, but it is used in the steps below to derive the laser's combat performance at short, medium, long, and extreme range, which are used in combat.

5A. Non-Gravitic Focused

If the laser will not be using gravitic focusing, F is equal to the FA diameter in meters, and the range factor is selected according to tech level. Ignore the two columns (for X-ray lasers, single column) under the Gravitic Focusing heading.

5B. Using Gravitic Focusing

F must be calculated based on the gravitic focusing focal modifier. Based on the tech level and class of the focal array (heavy or light), choose the correct focal modifier. To apply this modifier:

1. Take the FA diameter (in meters) and convert it to decimeters (1 dm = 0.1 m) by multiplying by 10.
2. Apply the focal modifier to the diameter D in decimeters.
3. Divide the result by 10.
4. The result is the laser's focal value F. Multiply F by the proper range factor for the tech level to get the laser's effective range in km.

Note that for each focal modifier there is a lower limit of focal array size that can be gravitically focused. Because of the exponential function, beneath these levels the focal array effectiveness actually decreases. At $F = D^2$, for example, the lower limit is 0.1 meter.

TUNABLE LASERS

TL	*Gravitic Focusing Focal Modifier (Heavy)*	*Focal Modifier (Light)*	*Range Factor (Wavelength of Light)*
7	$F = D$	$F = D$	3 (30,000 Å, Infrared: IR)
8	$F = D$	$F = D$	20 (5000 Å, Visible light: VL)
9	$F = D^2$	$F = D$	33 (3000 Å, Near Ultraviolet: NUV)
10	$F = (3D)^2$	$F = D^2$	50 (2000 Å, Ultraviolet: UV)
11	$F = (4D)^2$	$F = (3D)^2$	100 (1000 Å, Far Ultraviolet: FUV)
12	$F = (5D)^2$	$F = (4D)^2$	100 (1000 Å, Far Ultraviolet: FUV)
13	$F = (6D)^2$	$F = (5D)^2$	100 (1000 Å, Far Ultraviolet: FUV)
14	$F = (6D)^2$	$F = (6D)^2$	100 (1000 Å, Far Ultraviolet: FUV)
15	$F = (6D)^2$	$F = (6D)^2$	1000 (100 Å, Soft X-ray/Extreme UV: EUV)
16	$F = (6D)^2$	$F = (6D)^2$	2000 (50 Å, X-ray: XR)
17	$F = (6D)^2$	$F = (6D)^2$	5000 (20 Å, X-ray: XR)
18	$F = (6D)^2$	$F = (6D)^2$	10,000 (10 Å, X-ray: XR)
19	$F = (6D)^2$	$F = (6D)^2$	50,000 (2 Å, Far X-ray: FXR)
20	$F = (6D)^2$	$F = (6D)^2$	100,000 (1 Å, Extreme X-ray: EXR)
21	$F = (6D)^2$	$F = (6D)^2$	200,000 (0.5 Å, Near Gamma ray: NGR)
22	$F = (6D)^2$	$F = (6D)^2$	500,000 (0.2 Å, Gamma ray: GR)
23	$F = (6D)^2$	$F = (6D)^2$	1,000,000 (0.1 Å, Gamma ray: GR)

Notes:

At TL14+, the distinction between heavy and light focal arrays no longer affects focusing performance.

At TL 20+, the distinction between tunable and X-ray lasers becomes irrelevant, as lasers are now tunable down to X-ray wavelengths.

X-Ray Lasers

For heavy focal arrays only. Light focal arrays must use tunable table above. 1

TL	*Heavy Focal Modifier*	*Range Factor (Wavelength of Light)*
13	$F = (4D)^2$	100,000 (1 Å, Extreme X-ray: EXR)
14	$F = (5D)^2$	100,000 (1 Å, Extreme X-ray: EXR) 2
15-19	$F = (6D)^2$	100,000 (1 Å, Extreme X-ray: EXR)
20+	See Tunable Lasers, above	

If the laser is being designed for space combat use, divide the resulting effective range (kilometers) by 30,000 to get effective range in space combat hexes or range bands. Round to the nearest 0.01. 3

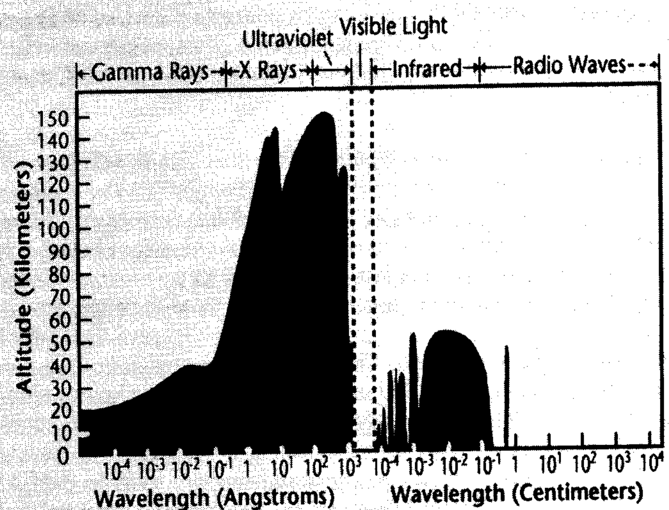
4

5C. Tunable Lasers

Note that tunable lasers must have their effective ranges calculated separately for the different wavelengths that they are capable of firing. This is done with the procedures above by using the correct focal modifier by tech level, but multiplying the resulting focal value F by the various wavelength range factors that are available to the weapon. Tunable lasers of a given tech level have available to them all wavelengths above them (i.e., at lower tech levels) on the table above. 5 6

Atmospheric Absorption

7



8 9 10 11

This graph illustrates the problems of atmospheric absorption of laser energy by showing how far electromagnetic radiation can penetrate through the Earth's atmosphere from space. The graph shows radiation entering our atmosphere from space; the curve shows how far into the atmosphere the radiation gets before half of it is absorbed. In Traveller, denser atmospheres would have greater shaded area beneath the curves, while thin atmospheres would have less. Worlds with tainted atmospheres would have many more "spikes" where particular atmospheric components would absorb specific wavelengths. Studying this graph explains why our eyes see in the wavelengths that they do, as well as why radio works so well for us. Bear in mind that even where the graph seems to show complete transparency, such as in the visible bands, our atmosphere is not really transparent. Think of clouds, rainstorms, mist, haze, snow, and fog, which all increase the average absorption of our atmosphere. 12 13 14

5D. Atmospheric Performance

All laser energy is absorbed by planetary atmospheres to some extent, but this is especially the case with laser wavelengths shorter than visible light, i.e., ultraviolet and X-ray lasers. The effective range defined above is the laser's effective range in vacuum: in space or on the surface of airless worlds.

When the laser is to be used within atmospheres, the following modifications must be made to effective range. Although theoretically a laser might be rated for its performance in all potential atmospheres, in practice a laser need only be rated for the environment for which it is primarily intended, for example the atmosphere of the world on which it was designed, or in vacuum for a starship laser.

Atmospheric Range Modifiers

Atmosphere (UWP Code)	*Visible and Infrared* (Range Factors 3 and 20)*	*Ultraviolet, X Rays, and Beyond (Range Factors 33 and above)*
Vacuum (0)	**1.0**	**1.0**
Trace (1)	1.0	0.9
Very Thin (2, 3)	**0.5**	**0.1**
Thin (4, 5)	0.2	0.02
Standard (6, 7)	**0.1**	**0.01**
Dense (8, 9)	0.05	0.005
Exotic+ (A+)	**0.01**	**0.001**

*Although most infrared radiation is readily absorbed by atmospheres, atmospheres contain many "windows" in the infrared range in which specific IR wavelengths are only absorbed at about the same rate as visible light. Thus it is assumed that the infrared lasers in use are those which are designed to take advantage of these windows.

Effective range as adjusted by atmosphere can be used in different ways according to the purposes of the designer. If the laser is intended primarily for use in an atmosphere, the atmosphere adjusted effective range should probably be used when choosing a beam pointer (Step 6). If the laser is intended for space combat, its unadjusted effective range should be used to choose the beam pointer.

Planetary Bombardment: This is a specific application of the atmospheric modifier rules. This is not calculated in advance for each laser, but is calculated separately each time it is done.

First find the range to the world being bombarded, in hexes. Planetary bombardments from the same hex are given a default value of 0.5 hexes. Divide this range by the atmosphere modifier appropriate to the atmosphere type and laser wavelength from the table above. The result is the equivalent range in hexes to a target on the planetary surface, called the *atmosphere adjusted range*. Use this range to find the proper range band of the laser's rated range performance. If the range falls between two range bands, use the higher band. This gives the laser's damage performance. Difficulty of the firing task is still calculated according to the actual range.

If the adjusted range falls beyond the laser's extreme range, use its effective range along with the procedure defined in Step 7B below to determine if it has any damage performance left at that range.

If the target is an aircraft or spacecraft flying through the atmosphere at high altitude, cut this final atmosphere adjusted range in half.

6. DEFINE SHORT RANGE

6A. Large (Non-Hand-Held) Lasers

The beam pointer represents the integral fire control capabilities installed on the laser mount.

Select a beam pointer from the Fire Control chapter (Section 14). Note that range is given in kilometers and 30,000-km hexes/range bands for space combat. The listed range in km/hexes of the selected beam pointer will be the laser's short range for purposes of combat. Whenever possible, the beam pointer range should be equal to the laser's effective range to take full advantage of the laser's range-intensity performance.

When a laser has its performance adjusted for atmosphere, remember that its atmosphere-adjusted ranges are for purposes of damage calculation only. Its short range (and medium, long, and extreme ranges which are derived from it) based on installed beam pointer are still used for resolving hits.

6B. Small Arms (Hand-Held) Lasers

Small arms lasers include laser rifles, carbines, and pistols, as well as larger lasers used as man-portable infantry heavy weapons.

For small arms lasers, which are not fitted with beam pointers, short range is based on human aiming limits. These are calculated as follows.

Short Range (meters) = 200 × Configuration Multiplier

Configuration	*Cm*
One-Handed*	**0.4**
Two-Handed*	1.3
Optic Sights (TL 7)**	**1.05**
Optic Sights (TL 8)**	1.1
Optic Sights (TL 9+)**	**1.15**

*One-handed refers to pistols, fitted with only a pistol grip. Two-handed refers to weapons specifically designed to be fired with two hands, and thus include a stock instead of simply a pistol grip.

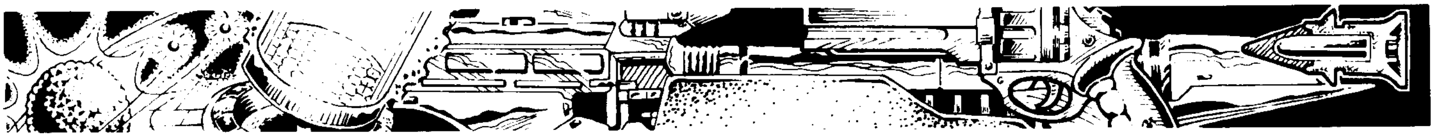
Some weapons are intended to be used exclusively from a tripod or vehicle pintle mount, and are only fitted with pistol grips. However, these weapons are considered to be two-handed for determining range.

**Mass and weight for these items is recorded in Step 10.

Final short range should be rounded to the nearest 10 meters if greater than 20. Short ranges less than 20 meters are retained unrounded. (Iron sight ranges are also retained without rounding.)

If two configuration descriptions apply to the same weapon, use both. Even if an optic sight is fitted to a two-handed weapon, the basic (iron sight) range should be calculated as well. This is necessary because an advanced sight (see the Small Arms Design chapter, page 97) might be installed later, and the advanced sight enhancement is applied to the basic range, not the optic sight range. The maximum short range for any small arm, after all modifications for optic or advanced sights, bipod and tripod effects, is always 300 meters.

Compare the short range derived above to the small arms laser's effective range, and use the shorter of the two for the laser's short range.



7. LASER COMBAT RATINGS

A laser's combat performance is rated in three areas: range performance, damage at those ranges, and penetration ratings at those ranges.

7A. Combat Range Bands

All combat ranges are based on the laser's short range, established in Step 6. For lasers intended for planetary combat, these ranges should be expressed in kilometers; for spacecraft lasers, these ranges should be expressed in starship combat hexes/range bands in whole numbers.

Medium range = Short range × 2
Long range = Short range × 4
Extreme range = Short range × 8

7B. Damage Value

Define the laser's damage characteristics at its short, medium, long, and extreme range bands.

Lasers do damage to enemy nonpersonnel targets (i.e., vehicles, structures, spacecraft) based on their *damage value* (DV). Damage value is calculated as follows (round to nearest whole number):

$$DV = 2.5\sqrt{I}$$

where I is the weapon's *intensity* (units for intensity are Mj per square centimeter) at that range. Intensity is derived as follows.

For each of the four range bands, divide that range band's actual range (from 7A, in kilometers or hexes, as appropriate to the type of weapon) by the laser's effective range (in the same units) from Step 5. Round this result to the nearest 0.01, but *always* treat results of less than 1 as 1. This figure is used as R in the next formula:

$$I = DE\ (1+R^2)$$

where
DE is discharge energy from Step 4 above.

7C. Penetration Rating

Lasers penetrate enemy armor based on their *penetration value.* Penetration value is not derived separately, but is calculated from the laser's DV by using the laser's *penetration rating* (PR). DV÷PR = penetration value; penetration value × PR = DV. Penetration rating is calculated as follows.

Take the intensity (I) as calculated in 7B above, and apply the formula

$$(\sqrt{I}) \times 0.8 = IPR$$

IPR is the *inverse penetration rating.* Round IPR decimals as follows: 0.5 and above rounds up to the next whole number; less than 0.5 rounds down. Now take the inverse of the IPR by dividing 1 by it. This is the laser's penetration rating, PR. Leave this number expressed as the fraction, $^1/_{IPR}$. For example, an IPR of 3.49 rounds to IPR of 3 and the PR is expressed as $^1/_3$. Intensities that yield IPRs of less than 0.5 (an intensity of 0.390625 Mj per cm^2 yields an IPR of 0.5, which rounds up to 1) have a final penetration rating of *Nil,* meaning that they have no penetrative capability. This is because a laser's damage value and penetration capacity both decrease at the same rate, and that at less than 0.39 Mj there is not sufficient damage value in the shot to allow penetration (i.e., 1 point of damage value required by a penetration rating of 1 to penetrate an armor value of 1).

Note: For purposes of target penetration, lasers are only affected by personal armor of a rigid nature. Rigid armor is defined in the Personal Armor section (Section 2), and consists of metallic and hard 1 ceramic armor. Non-rigid, or flexible personal armor (leather, ballistic cloth, and ballistic weave) is always treated as no armor by laser hits. Metal chain mail, because of its porous nature, is also treated as no armor. Metallic or ceramic insert plates added to flexible armor 2 are treated as rigid armor.

"Natural" armor on animals, such as tough skin or bony plates, is also treated as no armor by lasers. However, natural cover used by personnel, such as trees, fences, stone walls, dirt berms, etc., are not 3 ignored by lasers, but must be penetrated before personnel sheltering behind them may be hit.

7D. Personnel Damage Dice

The damage that a laser does to a personnel target (which includes 4 animals) is calculated differently from the damage value calculated in 7B above. Damage done to personnel is based on damage dice, which is also based on the laser's intensity at the range in question according to the formula 5

$$50\sqrt{I}$$

For small arms lasers, particularly those with penetration ratings of 6 Nil, the number of damage dice can be calculated in advance. However, because damage capacity lost when penetrating armor is calculated in terms of *damage value* and not *damage dice,* it is best to calculate damage dice versus a personnel target after penetration 7 has occurred. Multiply the remaining damage value by 20, and the result is the number of damage dice done to the target (DV × 20 = damage dice).

8

8. POWER SOURCE AND RATE OF FIRE

Most lasers are powered by electrical energy supplied by a vehicle power plant and stored in a form of capacitor until the weapon is 9 fired. However, at TL 11 and above, lasers can also be supplied by stored chemical energy. Stored chemical energy is popular for use with small arms lasers because the chemical laser cartridges (CLCs) are easier to use than cumbersome rechargeable power packs. 10

There is a drawback with CLCs, however, which makes them less desirable for use in spacecraft, which is the fact that the chemicals contained in the cartridges and produced in the firing process are highly corrosive, flammable, and poisonous. This presents a great 11 threat to any craft which must dispose of these byproducts or which sustains an ammunition hit. Because spacecraft or vehicles intended for use in vacuum or hostile atmospheres cannot flush and replenish their atmospheres from outside sources of oxygen, CLCs are generally not chosen for their lasers. 12

8A. Direct Electrical Power

Direct electrical power requires the installation of a homopolar 13 generator (HPG), which is a type of capacitor in the form of an electro-mechanical flywheel. The HPG must be of sufficient size to store the laser's one-shot input energy (IE) as defined in Step 4. Calculate the volume of HPG needed by multiplying the laser's input energy in Mj by 14 the value on the HPG table in the Power Production chapter (Section 8).

In large vehicle- and ship-mounted lasers, the HPG is added into the total mass and volume of the entire laser. For small arms lasers, the HPG is carried separately in a backpack or beltpack.

Rate of Fire: Define the laser's rate of fire (ROF). This rate will be expressed differently depending upon whether the laser is intended
1 for space combat or ground combat, as space combat turns are 30 minutes in length, while ground combat turns are five seconds. Rate of fire will define the amount of power input that the weapon needs, and may require an increase in the volume, mass, and price of the
2 focal array.

Rate of fire for a direct electrical input (HPG) laser is limited by available input power, and structural qualities of the laser's focal array. The HPG itself does not limit the ROF, regardless of tech level.
3 The size of the HPG is the same regardless of the laser's rate of fire, as it must only store enough energy for one shot at a time, regardless of how often those shots are fired.

Space Combat ROF: All space combat lasers must have a rate of fire
4 of at least 10 shots per 30-minute turn, or one shot every three minutes. This is equivalent to a ground combat ROF of $^1/_{36}$, one shot every 36 turns. When converting space combat ROFs to ground combat, divide the ROF per 30 minutes by 360. If this number is
5 greater than 1, round any fractions *down*. This is the number of shots per five-second combat turn.

If it is less than 1, take the inverse (i.e., divide 1 by that number), and round fractions *up*. The result is the number of five-second combat turns required for each shot. Express this number as a
6 fraction, i.e., one shot every 5 turns is $^1/_5$, one shot every 36 turns is $^1/_{36}$, etc.

For purposes of space combat, lasers gain to-hit benefits for higher ROFs as shown in the table below.

7 Lasers process a tremendous amount of energy each time they fire, and this energy creates thermal effects throughout the focal array. These thermal effects result in minute deformations of the focal array itself, which affect the accuracy of later shots. Enough of a thermal
8 effect will actually damage the laser. At space combat ROFs of 200 and higher, the focal array of a direct electrical input laser must be increased in size to allow for active and passive measures of heat dispersion as shown on the Rate of Fire Benefits in Space Combat
9 table. This focal array multiplier is applied to the FA volume, from which mass and price are then derived.

Rate of Fire Benefits in Space Combat

	Space Combat ROF (Shots per 30-minute turn)	Equivalent Benefit (In Diff Mods to Fire Task)	Ground Combat ROF (Shots per 5-second turn)	FA Mult
10				
11	10	None	$^1/_{36}$	1
	50	–1 difficulty levels	$^1/_8$	1*
	100	**–2 difficulty levels**	$^1/_4$	1*
	200	–3 difficulty levels	$^1/_2$	2
12	400	**–4 difficulty levels**	1	4
	800	–5 difficulty levels	2	8

*There is no penalty for firing a laser at one of these higher power
13 levels if the laser is mounted in a vehicle or starship which is designed from the outset to provide sufficient power for the higher ROF (50 or 100 shots). However, lasers which were not installed with the higher power levels may fire at these levels if sufficient power is made
14 available by diverting it from other systems. Unfortunately, because of the extra strain this places on power couplings, HPGs, etc., a Ship's Engineering task must be rolled each turn this is attempted. The difficulty level is Difficult if the ROF is raised one step (from 10 to 50 or from 50 to 100) over the installed power allocation, or Formidable if raised two steps (10 to 100). Failure at this roll indicates a System Reset result (see the **TNE** Space Combat chapter, or **Brilliant Lances: Traveller Starship Combat**), with the additional penalty that the laser may not fire on the current turn. Catastrophic Failure indicates more severe damage. Roll 1D10: 1-5 indicates a Degraded Performance result in addition to System Reset; 6-10 indicates a major hit on the laser.

Lasers may only fire at the 200+ ROFs if they are designed as such with beefed-up focal arrays.

Ground Combat ROF: To be really useful, ground combat lasers should have an ROF of at least one shot per turn. Rate of fire for a direct electrical input (HPG) laser is limited by available input power, and structural qualities of the laser's focal array. The HPG itself does not limit the ROF, regardless of tech level.

Like space lasers, ground combat direct electrical lasers need to have their focal arrays beefed up in order to fire at high ROFs.

Rate of Fire Benefits in Ground Combat

Ground Combat ROF (Shots per 5-second turn)	FA Multiplier
$^1/_2$	2
1	4
2	**8**
3	12
4	**16**
5	20
15 (Automatic: 3-round bursts)	**60**
25 (Automatic: 5-round bursts)	100
50 (Automatic: 10-round bursts)	**200**
250 (Automatic: 50-round bursts)	1000

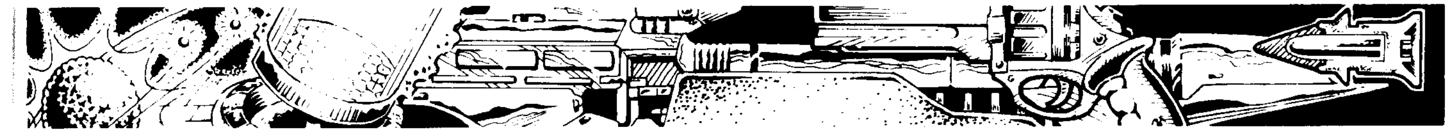
Note: Lasers with an ROF of 15+ count as automatic weapons for purposes of firing at aircraft

Power Input: Power input in megawatts (MW) is calculated differently for space combat and planetary combat lasers. Although they are calculated differently, space and planetary combat power input values are absolute values, as they are both based on MW input per second.

Space Combat Lasers: Multiply ROF times the laser's input energy (IE) as determined in Step 4. This is the total number of megajoules needed over the course of a 30-minute turn. Divide this result by 1800 to find the MW of power that must be allocated to operate the weapon.

Planetary Combat Lasers: Multiply ROF times the laser's input energy (IE) as determined in Step 4. This is the total number of megajoules consumed by the weapon each five-second turn. Divide this result by 5 to find the MW of power that must be allocated to operate the weapon.

Direct electrical power input requirements are usually met by power plants in vehicles and spacecraft, but are typically met by battery packs or fuel cells in the case of small arms lasers. These battery packs or fuel cells are carried in the same backpack as the homopolar generator.



8B. Chemical Laser Cartridge

Powering a laser by chemical laser cartridge (CLC) allows the laser to function in the fashion of a conventional firearm or artillery piece, in that each shot consumes an ammunition cartridge, whose empty casing is then ejected allowing the laser to be reloaded and fired again.

A chemical laser cartridge is quite different from the similarly named cartridges used by the explosive power generators (EPGs) in the Power Production chapter (Section 8). The chemical reactions generated by CLCs are not efficient for producing electrical energy. Rather, they produce a population inversion of energized atoms and/or molecules which can be manipulated to release photons of a particular wavelength which are focused into a laser beam.

Each CLC contains the full input energy required for the shot as calculated in Step 4 above. The chart below shows the amount of Mj per kilogram that can be chemically stored for release as laser energy, based on tech level. To calculate the mass of chemicals needed, divide the IE (in Mj) from Step 4 by the number on the chart, and the result is the required amount of chemicals in kilograms.

TL	*Mj per kg*
11-12	1
13-15	2
16-19	3
20+	4

Once the required mass of chemicals is known, the chemical cartridge itself must be designed. The simplest way to do this is to design a cylindrical cartridge three times as long as its diameter. CLC chemicals have a volume of 0.1 liters per kilogram (10 kg per liter; other units may be more convenient for very large or very small lasers; CLC chemicals also have a volume of 0.1 cubic meters per tonne [10 tonnes per cubic meter] or 0.1 cubic centimeters per gram [10 grams per cc]—note also that one cubic meter = 1000 liters and 1 liter = 1000 cubic centimeters). Cartridge price is Cr30 per Mj of input energy.

To find the dimensions of the 3xD cartridge, use the equation:

$$0.376 \times \sqrt[3]{\text{Volume}} = \text{radius of cartridge}$$

(where volume is in cubic meters or cubic centimeters)

Cartridge diameter is 2 x radius, and cartridge length is 6 x radius. Designers will frequently prefer to change the diameter into a round number and recalculate the cartridge length to make up for the difference, using the formula:

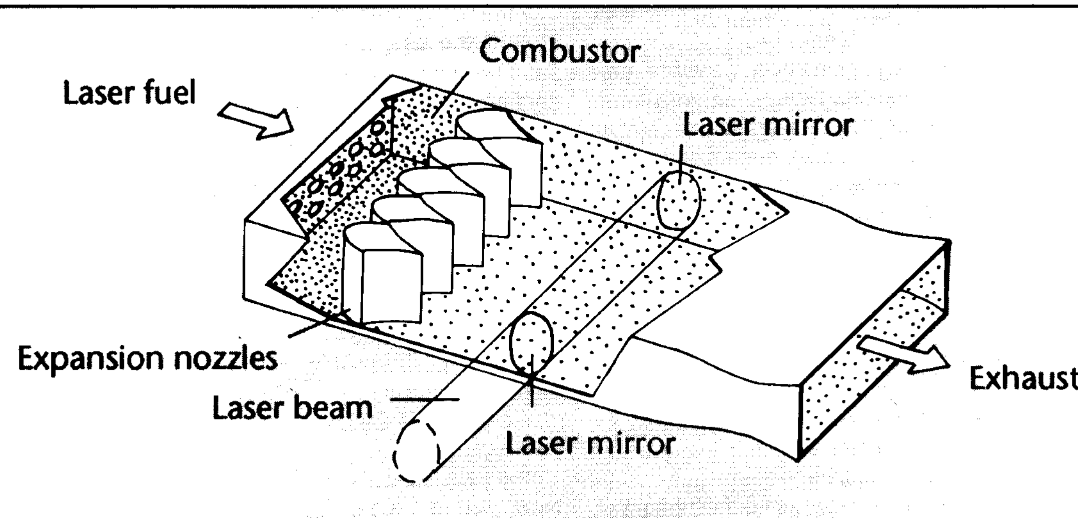
$$\pi r^2 \times \text{length} = \text{cartridge volume, where } \pi = 3.1416$$

Rate of Fire: Rate of fire is defined as above for direct electrical input lasers.

Rate of fire with CLCs is limited by the weapon's purge cycle, the rate at which it burns and disposes of the CLC chemicals. CLC lasers create energy by releasing the chemical energy stored in the cartridges. These chemicals are combined in a controlled fashion in the laser's *combustor.* It is in the combustor, filled with energetic atoms and/or molecules, that the laser beam is generated. As the energy is withdrawn from these molecules in the form of energetic photons, the used chemical fuel is removed by the *evacuator* to prepare for the next shot. Depending upon the environment, this highly caustic, highly poisonous spent fuel is either stored in a cannister or expelled out of the laser. This evacuation cycle is combined with the cooling cycle for greater efficiency.

Unlike direct electrical lasers, ROFs above a certain level do not require the increase in size of the focal array. Instead, the volume of the combustor/evacuator system yields the maximum rate of fire.

All CLCs have a base combustor/evacuator volume of 0.055 cubic meters (55 liters) per Mj of input energy (IE, defined in Step 4) per



High-Power Chemical Laser

Chemical fuel extracted from the cartridge is burned in the combustor at left, and its pressure causes it to pass through the expansion nozzles into the laser-generation cavity. By firing a tiny starting pulse of photons, energy from the hot gas is extracted in the form of photons of the same wavelength, which are then bounced back and forth between the mirrors, stimulating more photon emission from the gas. The pressure of the hot gas causes a continuous flow from the combustor to the exhaust. But because the pressure in the combustor is often less than 1 atmosphere, a vacuum evacuator must be installed at the exhaust unless the laser is being vented directly into space. The laser is fired to the lower left.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

CLC cartridge. This yields an ROF of one shot per second (five shots per combat turn). Volumes greater or less than this amount yield
1 correspondingly higher or lower rates of fire.

Divide the actual volume of the combustor/evacuator by the base volume (0.055 m³/55 liters × IE), and multiply the result by 5. This is the number of shots per combat turn that can be fired. Combustor/
2 evacuators mass 1 tonne per cubic meter (1 kg per liter) and cost Cr0.5 per cubic meter (Cr500 per liter). This includes weight and volume for a closed-cycle cooling system. The cooling system requires overhaul and recharging of fluids after the equivalent of
3 1000 turns of maximum ROF fire. This recharging costs Cr100 times the cooling system's displacement in liters.

CLC Laser Ammunition Feed: CLC lasers require an ammunition feed system. For small arms lasers (light focal arrays), this is a receiver-
4 magazine assembly similar to those used by normal slug-firing small arms. For non-man-portable lasers (heavy focal arrays), the feed system is an electrical action with attached autoloader. Some heavy weapons may fall between this range; although they are equipped
5 with light focal arrays, it is more convenient to equip them with heavy autoloaders.

The maximum CLC cartridge feed rate is five cartridges per five-second turn (but this may be limited by combustor size). This is sufficient for full semiautomatic fire. In order to achieve automatic
6 ROF levels, multiple laser pulses are extracted from a single CLC cartridge. Burst size can be 3, 5, 10, or 50 depending upon the amount of energy stored in the cartridge. Simply design cartridges with sufficient input energy for the full number of shots in the burst. Be
7 sure to note in the weapon's listing that only one cartridge is fired per automatic *burst*, rather than the usual one cartridge per automatic *shot*.

Small Arms with Magazines: Each weapon requires a receiver, which extracts the CLC from the magazine, holds the cartridge while its contents
8 are explosively combined in the combustor, and then ejects the spent round to make space for a new one. The receiver's volume is equal to 80 times the volume of the CLC cartridge, weighs 1 kilogram per liter (1 gram per cubic centimeter), and has a cost in credits equal to its volume in liters
9 multiplied by 2000 (Cr = 2000 × volume in liters).

Magazine types used with these weapons are grip magazine, box magazine, and cassette. Their characteristics are identical with those described for CPR small arms on pages 96-97. The CLC receiver as
10 described above is fully compatible with the listed magazine descriptions, and CLCs are not necked cartridges.

Large Lasers with Autoloaders: The volume of the action and autoloader is equal to 35 times the volume of a single CLC round for
11 the laser. The assembly weighs 1 tonne per cubic meter and costs MCr0.01 per cubic meter.

The magazine may be any size desired by the designer. The weight of the empty magazine is equal to the weight of all of the rounds
12 carried multiplied by 0.01. The price of an empty magazine (sometimes called a hopper) in Cr is equal to its weight in kilograms times 5. The volume of a magazine in cubic meters is equal to the mass (in tonnes) of the rounds carried by the magazine + 5.

13 Reload time, in five-second turns, is equal to the loaded weight of a magazine in tonnes multiplied by 10, rounding fractions up.

Wavelength Tuning of CLC Lasers: CLC lasers may have tunable wavelengths as discussed above in Steps 1 and 5. However, because
14 the wavelength of a CLC's beam is controlled by the specific chemical reaction taking place in its combustor, it must have a combustor which is modified to allow for various chemical reactions, and the laser must also be supplied with a variety of ammunition which will generate a variety of wavelengths. A tunable combustor/evacuator assembly merely costs twice the normal price (Cr1 per cubic meter/Cr1000 per liter) listed above. CLC ammunition for specific wavelengths has no difference in price, but any players or military force must take steps to ensure that they are supplied with the correct ammunition for their needs. In addition, referees may stipulate that some worlds have specific compounds in their atmospheres that absorb common laser wavelengths that are otherwise normally effective in that atmosphere type (this should especially be the case in tainted atmospheres). As with all tunable lasers, tunable CLCs must have their effective ranges calculated separately for the different wavelengths that it fires.

9. CREW

Any vehicle- or spacecraft-mounted weapon must be designated as crewed or uncrewed. A laser can only be left uncrewed if the vehicle in which it is installed is equipped with one or more master fire directors (MFDs) which will be used to control it remotely. In the event of the destruction of all of a vehicle's MFDs, an uncrewed laser may not be fired. A crewed laser may also be fired remotely by an MFD, but can also be fired under "local control" by the gunner if the MFD cannot be used to fire the laser.

Small arms or heavy weapons lasers do not need workstations, but ground turret and carriage-mounted lasers do, unless they are wired into a ground-based MFD. If it is to be crewed, the weapon must have a gunner's workstation installed with the characteristics of a normal workstation as presented in the Controls chapter (Section 4).

Heavy weapons lasers require a crew of one, although additional crew may be required to help carry the weapon and its mount, and (in the case of CLC lasers) to assist with ammunition. On average, troops can carry 72 kg each at the burdened rate, but this must also include all of their other equipment.

10. LASER FURNISHINGS AND SUPPORTING HARDWARE

If the laser is to be mounted aboard a starship or vehicle, skip this step. If the laser is intended for use as a towed weapon, heavy weapon, or small arm, calculate the size of its carriage, mount, cooling system, stock, etc.

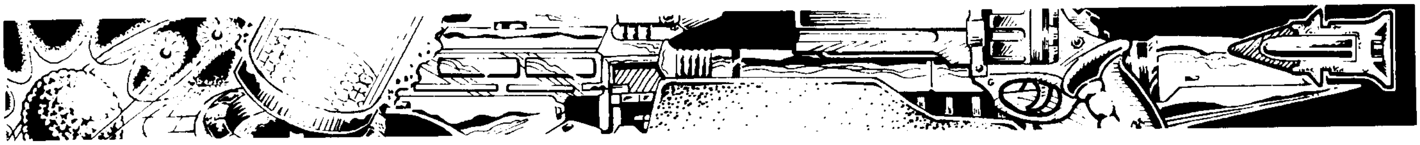
10A. Carriage

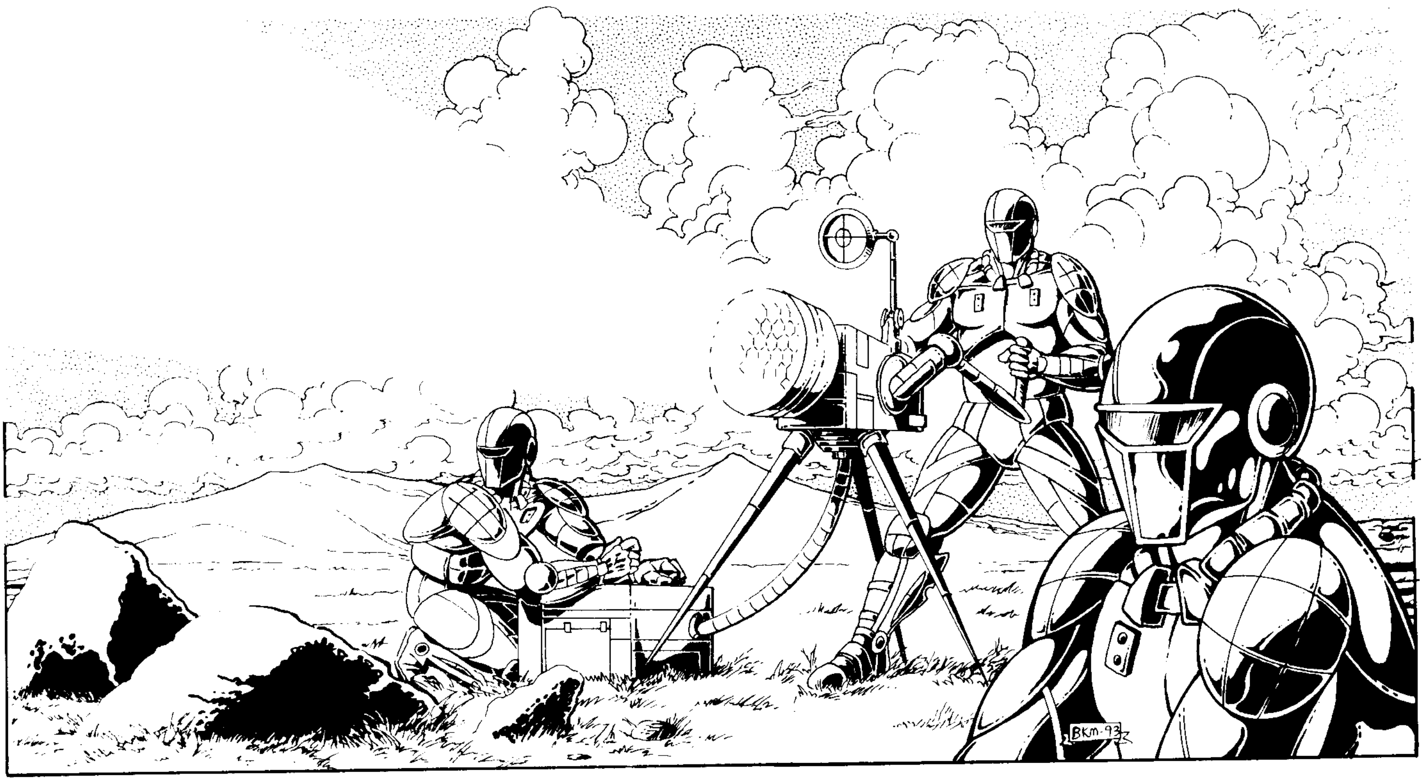
A heavy focal array laser can be mounted as a towed or otherwise movable weapon by placing it on a carriage. A towed carriage has the same mass as the laser mounted on it. The laser must include an HPG if it is direct electrical-powered, but may be plugged in to a power source at its destination. Carriage-mounted lasers have an all-around armor value of 1. This can be increased by enclosing the laser and its supporting equipment in a "hull" with a certain thickness of armor according to the vehicle- or spacecraft-design rules. As this armor increases the mass of the laser, it will increase the mass of the carriage as well.

The price of the carriage in MCr is equal to its mass in tonnes multiplied by 0.002.

10B. Mounts

Very large or even normal-sized small arms lasers (light focal arrays) may be provided with tripods or bipods for use as heavy weapons. When fired from a bipod, short range is increased by 30% (multiply by 1.3); when fired from a tripod, short range is doubled (multiply by 2). However, short range may never be modified to greater than 300 meters.





Bipods weigh 0.1 times the loaded weight of the laser; their price in credits is 50 plus the bipod's weight in kilograms times 10 (50 + [10 × weight]). The weight of a bipod is included in the final weight of a laser, but does not count against its volume.

The weight of a tripod is equal to the fully loaded weight of the laser times 0.5; the price in credits is 100 plus the tripod's weight in kilograms times 10 (100 + [10 × weight]). The weight of a tripod is not included in the final weight of a laser.

10C. Small Arms Cooling Systems

CLC-powered lasers have their cooling systems integral to their combustor/evacuator assemblies. Only light focal array lasers powered by direct electrical input need to undergo this step.

Take the per-shot input energy (IE) calculated in Step 4 and multiply it by 10 (IE x 10). The result is the volume of the closed-cycle cooling system in liters. At least 50% of this system must be placed in the weapon itself, and at least 20% must go into the backpack. The remaining 30% may be placed in either the weapon or backpack.

The cooling system masses 2 kilograms per liter (2 grams per cubic centimeter) and costs 1700 credits per liter.

The cooling system requires overhaul and recharging of fluids after the equivalent of 1000 turns of maximum ROF fire. This recharging costs Cr100 times the cooling system's displacement in liters.

10D. Small Arms Body and Stocks

Add together the volume of the components that will be fitted into the weapon itself, separate from its backpack. For direct electrical weapons, this is focal array and cooling system; for CLC lasers, this is focal array, combustor/evacuator, and receiver (magazines are not part of the "empty" volume).

Weapon Body: Multiply this volume (in liters or cubic centimeters, whichever unit the designer is using) by 0.05. This is the volume of the weapon's structural body, which encloses and protects the weapon's components. Because lasers are finely calibrated and relatively fragile weapons, they must be "ruggedized" if they are to be fitted with additional items such as attached grenade launchers or rifle grenade adapters. Double the structural body above for ruggedization (to 0.1 × volume).

These weapons are still too fragile to function in combat as melee weapons, and will not function after being used as clubs. If a designer wishes for a laser to be fitted with a bayonet lug for use as a melee weapon, the body volume must be doubled again (four times the basic volume or 0.2 × volume).

Mass of the body is 1 kilogram per liter (1 gram per cubic centimeter), and price is 100 credits per liter (0.1 credits per cubic centimeter).

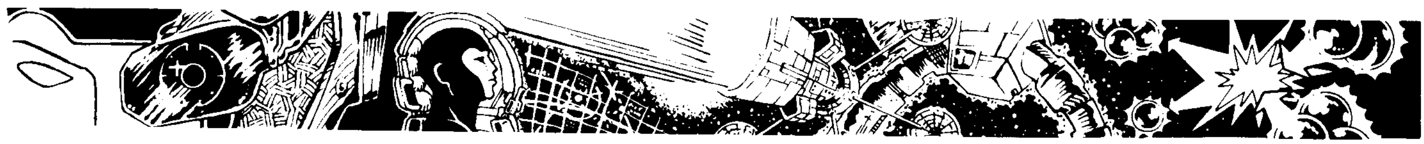
Weapon Length: To find the length of the weapon, take its total volume including its body, and convert into cubic centimeters. (For those not already working in cubic centimeters, 1 liter = 1000 cubic centimeters, 1 cubic meter = 1,000,000 cubic centimeters.)

Take the cube root of the volume, and multiply the result by the configuration multiplier. Direct electrical input and CLC lasers have different configurations, with CLCs being shorter, bulkier, and more robust looking, and direct electrical lasers being lighter, longer, and finer-lined.

Type	*Length Multiplier*
Direct Electrical Input	4.3
Chemical Laser	3.4

The result is the weapon's basic length in centimeters before stocks and optional items below are added.

Additional features may be added to the weapon, and may increase its length.



Bayonet Lugs: Bayonet lugs are simple standardized brackets at the end of the weapon barrel. A bayonet lug costs nothing, has
1 negligible mass, and adds no length to the weapon.

To be most effective, a bayonet must be mounted on a well-balanced weapon with sufficient length to allow it to be used as a spear point. As a result, only weapons with a bulk (see 11F below) of
2 4 or more may profitably benefit from a bayonet lug. Shorter weapons may have them but the mounted bayonet counts as a short range (instead of long range) melee weapon and suffers a +1 Difficulty modifier for its chance to hit in armed melee combat. The laser's structural body
3 must be ruggedized to the 4 × level for a bayonet lug.

Grenade Adapter: For obvious reasons, lasers may not fire standard shot trap rifle grenades. They may, however, fire RAM (Rocket Assisted Multipurpose) rifle grenades (RAMRiGs). A grenade
4 adapter allows the firing of RAMRiGs, adds 5 cm to the length of the weapon and costs Cr50. The laser's structural body must be ruggedized to the 2 × level for a grenade adapter.

Attached Grenade Launcher: Lasers may have attached
5 (underslung) grenade launchers added to them. See the Launchers chapter for details on their design. The launcher may not be greater than one half the length of the laser. The laser's structural body must be ruggedized to the 2 × level for an attached grenade launcher.

Stocks: If the weapon's length (exclusive of RAM grenade adapt-
6 ers) is greater than 40 centimeters, it is presumed to already be configured as a two-handed weapon, and need only be fitted with a bullpup stock from the table below. If shorter, it must be fitted with
7 a stock to function as a two-handed weapon to gain the range benefits in Step 6B above. If left as a one-handed weapon, it must be fitted with a pistol grip.

The weapon's final length is its base length derived above plus the length of any stocks fitted, plus the length added by a rifle grenade
8 adapter (if any).

	TL	Type	Length (cm)	Mass (kg)	Credits
	4	**Wood pistol grip**	**0**	**0.2**	**5**
9	4	Wooden stock	25	1	25
	4	**Carbine stock**	**25**	**0.7**	**20**
	5	Hollow pistol grip	0	0.1	25
	6	**Folding stock**	**5/25**	**0.5**	**50**
10	7	Plastic stock	25	0.5	30
	7	**Bullpup**	**5**	**0.1**	**10**

10E. Sights

Because light focal arrays may not be fitted with beam pointers,
11 they must be fitted with either small arms sights, or sometimes direct fire controls for heavy weapons. For direct fire controls, see the Fire Control chapter (Section 14).

If optic sights were specified in Step 6B above, their price, volume,
12 and mass must be added to the laser. These are mounted outside of the laser's structural body, so are specified at this point, and their volume is added to the already calculated volume. Volume of all sights listed below is one liter per kilogram.

13

Optic Sights

	TL	Range	Mass (kg)	Price (Cr)
	7	x1.05	0.1	150
14	8	x1.1	0.1	150
	9	x1.15	0.1	150

For advanced sights (laser, telescopic, and electronic—*note*: all DEI lasers automatically incorporate laser sights) see pages 97-98.

10F. Small Arms Backpacks

Small arms laser backpacks are only needed by direct electrical input lasers. They contain the full volume and mass of the HPG and power supply, plus power supply fuel if necessary, and 20-50% of the cooling system.

Total the volume of the included components, and convert the results into liters. Multiply the volume in liters by 0.3 to get the mass, in kilograms, of the backpack casing. The volume of the backpack is equal to the volume of its contents, calculated above. The casing provides an armor value of 1 to the contents, and costs 3 credits per liter of volume. Armor protection may be increased by increasing these values (doubling the casing mass and price double the armor value, and so on).

The weight and cost of the cable connecting the backpack to the weapon is subsumed in the weights and costs of those items.

11. PHYSICAL CHARACTERISTICS

Add up or bring down the above components to obtain the following total figures for the gun.

11A. Volume

In cubic meters. Add focal array volume (as adjusted by ROF), beam pointer volume, HPG or combustor/evacuator volume, CLC feed system (if any), gunner's workstation volume, carriage volume (if any), and any small arms systems.

11B. Mass

In tonnes. Add focal array mass (as adjusted by ROF), beam pointer mass, HPG or combustor/evacuator mass, CLC feed system mass (if any), gunner's workstation mass, carriage mass (if any), and any small arms systems.

11C. Price

In MCr. Add focal array price (as adjusted by ROF), beam pointer price, HPG or combustor/evacuator price, CLC feed system price (if any), gunner's workstation price, carriage price (if any), and any small arms systems.

11D. Power Requirements

In MW, if direct-electrical type. Carry down from Step 8A above. If CLC, power requirement is limited to description of the size of its ammunition and magazines from step 8B.

11E. Surface Area

Surface area of a laser for purposes of installation on a starship or vehicle only is equal to its focal area surface area as calculated in Step 4, or its bay surface area as calculated in Step 3.

11F. Bulk

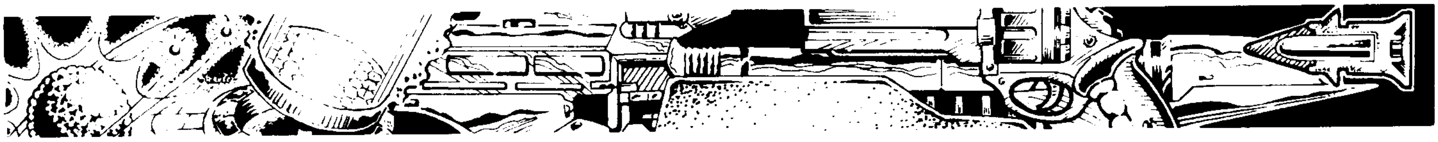
For small arms lasers only, calculate the bulk by taking the length of the weapon in centimeters and dividing by 15. Drop fractions. The result is its bulk.

11G. Recoil

Lasers have no recoil.

11H. Combat Performance

Short range, medium range, long range, and extreme range in km and/or space combat hexes, plus damage values at those ranges, along with ROF, listing any –difficulty modifiers as applicable. Carry down from Steps 7 and 8C.



CHAPTER 9
Munitions

This chapter covers the variety of projectiles fired by weapons, excluding small arms projectiles. These projectiles have various functions. This chapter's design sequence will be broken into three general parts: warheads, propellant, and guidance. Warheads are dealt with first, since even the simplest projectile has a warhead, even if it is only a solid metal shot. Mass driver projectiles and gravity bombs usually consist solely of a warhead.

CPR gun projectiles have a propellant charge which is consumed in the gun itself. CPR gun projectiles which also have a small rocket for additional range are called RAP (rocket-assisted projectile) ammunition. If a solid-fuel rocket motor is attached to a warhead, the warhead becomes a free-flight (FF) rocket.

If a guidance package is attached to an unpowered warhead, it becomes either a cannon-launched guided projectile (CLGP) or a guided bomb. If a guidance package is attached to a rocket-propelled warhead, it becomes a guided missile.

WARHEADS

Warheads are the business end of any munition. Designing warheads proceeds in the following order.

A. Specify Warhead Type: A number of different warhead types are available, each with its own specialized function.

1. High Explosive (HE): High explosive is probably the most common warhead in use. The warhead is hollow and filled with an explosive bursting charge and fused to detonate under a variety of conditions (impact, altitude, proximity, delay, etc.) The metallic warhead casing is often scored internally or lined with scored wire to produce the maximum number of lethal fragments.

2. Kinetic Energy Armor Piercing (KEAP): The earliest gunpowder artillery was used in siege work to batter down the enemy's walls, and so penetration of armor (stone armor in this case) has been an issue of gun design from the very beginning. The ability of a gun to penetrate metallic armor has been addressed urgently and scientifically ever since the appearance of the first ironclad warships in the mid-19th century.

In general terms, a gun's projectile penetrates armor by means of kinetic energy, and so the greater the muzzle energy, the greater the penetration of the gun, all other things being equal. All other things are seldom equal, however. A round with a smaller frontal area will penetrate more armor than a round with identical muzzle energy and a larger frontal area, as the energy of the round is concentrated on a smaller part of the armor, giving more energy per square centimeter.

This is part of the reason discarding sabot rounds have greater penetration than normal rounds. The penetrator is a subcaliber rod encased in a lightweight sabot (pronounced SAY-bow) which fills the space around the penetrator in the gun barrel. Once the round leaves the gun, the sabot falls away (hence the term *discarding* sabot) leaving the penetrator to fly on alone to the target. When it strikes, the full energy of the round is concentrated on the smaller frontal area of the penetrator.

The above discussion should not leave the impression, however, that penetration is a simple matter of joules per square centimeter of armor contacted; it is not. Overall muzzle energy is a far more powerful predictor of penetration than energy per square centimeter contacted, since certain minimum energies are required to disrupt the integrity of armor of a given thickness and hardness.

For example, the German World War II 50L60 antitank gun, found on field carriages and in the turret of Panzer IIIs, could penetrate about six centimeters of armor (**Traveller** armor value of 12) at 1
medium range (1000 meters). It had a muzzle energy of 1.63 Mj. Given a projectile diameter of 50mm, this gives it a frontal area of about 20 square centimeters, or an energy density over its front of roughly 80 kilojoules. 2

By contrast, the German 88L71 gun, found on field carriages and as the turret gun of the massive Tiger II, could penetrate about 19 centimeters of armor (**Traveller** armor value of 38). It had a muzzle energy of about 4.5 Mj, a front cross-sectional area of 60 square 3
centimeters, and an energy density over its front of roughly 75 kilojoules.

Notice that the 88L71's round penetrates almost three times as much armor but has about the same (actually slightly lower) energy 4
density across the front than does the 50L60. Notice also that in both cases, the rounds penetrate about four centimeters of armor (8 levels of **Traveller** hard steel armor) per megajoule, illustrating the overwhelming importance of gross muzzle energy. 5

There are some limits to the penetration ability of a solid shot, however, and those limits center around the ability of the shot to withstand the impact with the armor. Beyond a certain velocity, solid steel shot will simply shatter against an armored plate. Early naval designers noticed this effect, and found it particularly prevalent 6
against face-hardened armored plates. To deal with the problem, hard steel caps were fitted over the nose of the shot, and this type of ammunition (APC, for Armor Piercing Capped) is the type most often found at tech level 5. Since the best penetrating caps were rounded 7
or blunt, a second pointed cap, to improve the ballistics of the shot, was often fitted as well, producing APCBC (Armor Piercing Capped, Ballistic Capped) ammunition. These are not treated as separate ammunition types in these rules, as they are really just minor 8
improvements on the same basic round—a solid steel full-caliber penetrator.

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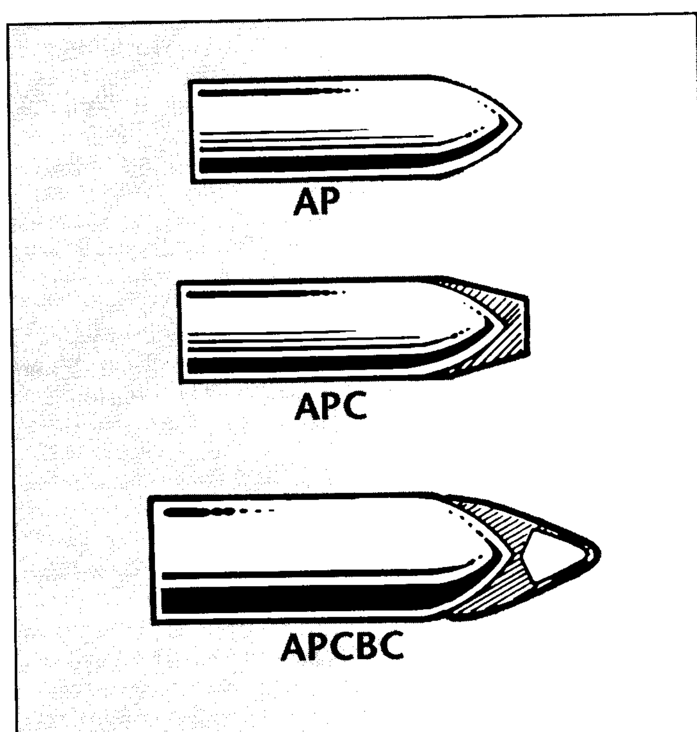

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The next step forward was to concentrate the muzzle energy of the round over a smaller surface. This was accomplished by embedding
1 a subcaliber penetrator in a lightweight outer shell. The lower weight of the round usually meant that it had higher muzzle velocity (gaining back its original muzzle energy as it traded mass for velocity) and so these rounds are usually called HVAP (for High Velocity Armor
2 Piercing). A conventional steel penetrator would not stand up to this greater energy density, and so tougher materials had to be used, usually tungsten at tech level 5, where this ammunition appears. Difficulties in machining tungsten at that tech level make the round
3 difficult to mass-produce, and so it was usually issued in limited numbers as a back-up round in case the weapon encountered a particularly well-armored opponent. The disadvantage of this round, aside from that mentioned above, was that its full-caliber ballistic
4 cross-section gave it a high drag relative to its mass, and so it tended to decelerate more quickly than did a conventional round. Thus its penetration, while higher at first, declined quickly.

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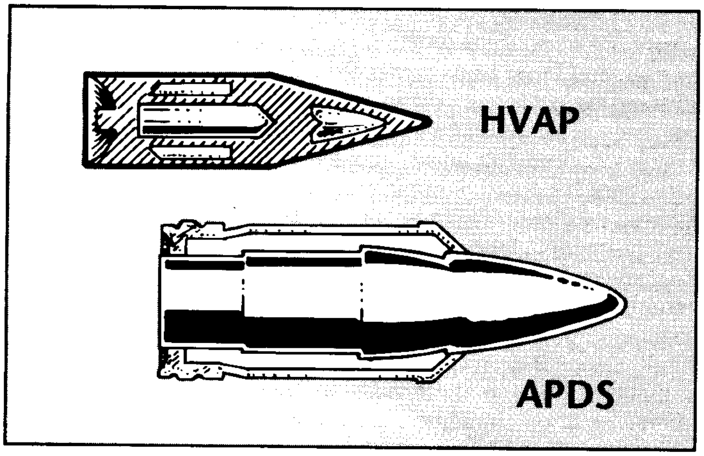
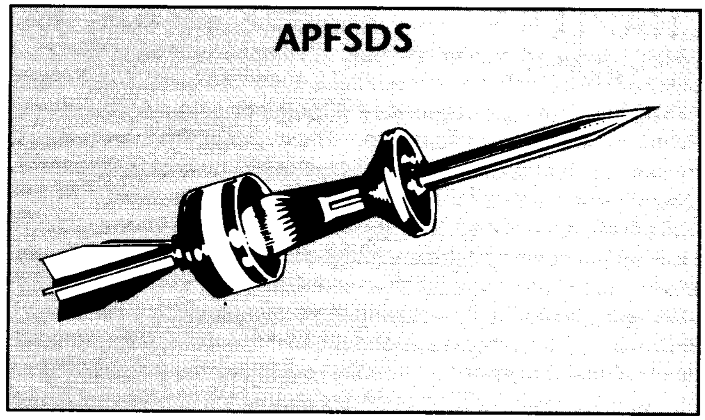


At almost the same time, gun designers began experimenting
9 with the discarding sabot mentioned earlier. The advantage of this approach was that when the lightweight sabot was discarded, the round no longer suffered drag from it and so did not suffer the sharp fall-off in velocity. The disadvantage was that early APDS rounds
10 tended to be unstable in flight and inaccurate, effectively negating the advantage of the round. For this reason, we ignore sabot rounds until tech level 6, where the technology was sufficiently perfected to allow accurate long-range fire. As with the HVAP round, the penetrator
11 of a sabot round had to be made of a very tough metal, such as tungsten, or it would break up on impact with enemy armor.

As propellant and metallurgy allow higher pressure levels in the gun tube, it becomes possible to force a round out of the gun at
12 higher velocities. Some of this energy is used, however, in forcing the round through the rifling grooves (called lands) in the barrel. These grooves impart spin to stabilize the round, but limit the speed of the round. Forcing a round out the barrel too fast will simply strip the
13 outer band from the round and push it out the barrel with no spin at all, in which case it will tumble end-over-end and quickly veer off course and decelerate. This is a function not only of velocity but also of the resistance the round has to spinning, based usually on its mass.

14 The solution is to dispense with rifling altogether and use fins to stabilize the round, hence the APFSDS (Armor Piercing Fin Stabilized Discarding Sabot) ammunition of tech level 7. Some early rounds at this tech level, in order to use existing rifled guns, used an ingenious hybrid system where the penetrator itself did not spin but the sabot,



mounted on a free-spinning race around the penetrator, did. Since only the lightweight sabot spun, little energy was used forcing it to do so, and its low resistance to spin meant that rounds could be forced out of the tube at very high velocities.

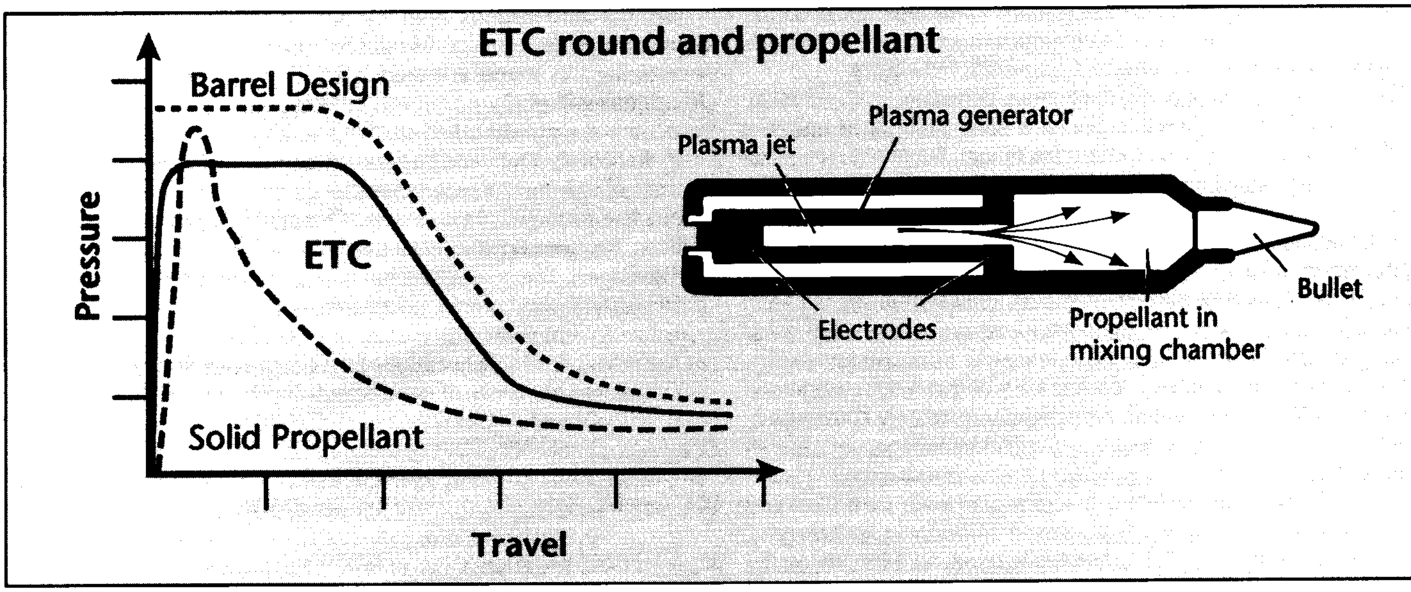
Smoothbore guns are so efficient that they enabled gunners to approach the practical limit on muzzle velocities of an explosively propelled gun, that being the velocity at which the gas expands from the explosion of the propellant. Obviously, a round cannot be pushed faster than the rate of gas expansion in the explosion, no matter how powerful the explosion, and the effective upper limit on velocity from this sort of propellant is 2000 meters per second. Contemporary smoothbore tank guns all throw their APFSDS rounds at about 1700 meters per second. (By contrast, hardly any World War II guns exceeded 1000 meters per second in muzzle velocity.)

The next step was to make the penetrator more massive, but hopefully without increasing its frontal area. This was accomplished by using not only tougher metals, but heavier ones, the first being depleted uranium, producing the APFSDSDU (Armor Piercing Fin Stabilized Discarding Sabot Depleted Uranium) ammunition of tech level 8. The ammunition of the 120mm gun of the M1A1 is a good illustration of the performance possible with this approach. The depleted-uranium penetrator has a mass of a little over 6 kilograms (as opposed to the 4.5-kilogram tungsten penetrator of the Soviet 125mm gun). Its muzzle velocity of 1675 meters per second gives it a muzzle energy of slightly more than 9 megajoules. By comparison, the German 128L55 gun mounted on the Hunting Tiger of World War II threw a 28-kilogram penetrator at 930 meters per second for a whopping 12 megajoules of muzzle energy. But while the German full-caliber capped steel round would penetrate 24 centimeters of armor (2 centimeters, or 4 armor levels, per megajoule), the M1A1's round will penetrate 65 centimeters (7 centimeters, or 14 armor levels, per megajoule).

Notice that even as early as World War II (tech level 5), it was possible to mount a gun on a mobile chassis capable of generating over 10 megajoules of muzzle energy.

Having reached the ballistic limits of this type of weapon, remaining improvements come from tougher and more massive subcaliber penetrators, made from crystaliron (tech level 10), superdense (tech level 12), bonded superdense (tech level 14), and bonded coherent superdense (tech level 17).

But while the limits of explosively driven projectiles had been reached, there was still an additional step available to wring the last ounce (or gram) of performance from conventional guns, that being electrothermal propulsion or, in its most effective form, electrothermal-chemical (ETC).



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An ETC round consists of a projectile exactly like that fired by a conventional powder charge and a casing behind it. This casing consists of two parts, a fuel supply and a combustion chamber. The fuel can consist of any fluid, even water, although chemically energetic working fluids work best (the difference between basic electrothermal—ET—weapons and ETC is that ETC harnesses and enhances the chemical energy of the working fluid, rather than using an inert working fluid). A powerful electric current converts the fuel in the combustion chamber to a plasma state, which escapes out the front of the casing and propels the projectile down the barrel. How is this different from a conventional round and what makes it more efficient?

Conventional barrels are designed to withstand the high pressures created by firing the explosive that propels the round out of the gun. However, a conventional explosive propellant produces a dramatic pressure spike at the breach end of the barrel, which falls off dramatically as the projectile moves down the barrel (as the volume of space behind it in the barrel increases). This means that even though most guns have reinforced breaches and thinner barrels near the muzzles, they are still capable of withstanding much more pressure toward the end of the barrel than they are called on to withstand.

In the case of ETC, however, the fuel is not converted to plasma all at once. The initial conversion creates pressure behind the projectile similar to that found in a conventional weapon, but as the projectile moves down the barrel, the casing continues to convert fuel to plasma, maintaining the same pressure in the barrel. Electrothermal-chemical propulsion techniques allow effective doubling of muzzle energy without any increase in weight of a gun (although some additional recoil compensation is necessary). ETC ammunition is being test-fired as this is written, with some extraordinary results, and will be widely available at tech level 9.

Beyond ETC and certain dense, tough metals for penetrators, the next major step forward will be electromagnetic propulsion. But as that constitutes an entirely different class of weapon, it is discussed separately.

3. High Explosive Armor Piercing (HEAP): The disadvantage of a high-velocity solid penetrator is that it relies almost exclusively on muzzle energy to pierce armor, and high muzzle energies require massive gun systems, much more massive than can be carried by an infantryman (who usually has his hands full with his personal weapon). One answer was found in the shaped charge round, also called a hollow charge round, which relies on the energy generated by an exploding shell rather than the muzzle energy of the projectile. 6

A shaped charge shell has an explosive charge with a hollow cavity recessed into the front of it (hence the "hollow charge" name). The hollow cavity is shaped like an inverted cone (hence the "shaped charge" name) and lined with metal. When the round hits its target, 7
the charge detonates and turns the metal conical liner of the charge into a stream of molten metal. The shape of the charge tends to focus the molten metal into a narrow high-speed jet directly forward. This jet of gas and molten metal is what actually penetrates the armor. 8

For years it was widely thought that the molten jet burned through the armor, and so these shaped charges were also often called "thermal" penetrators. Actually, the temperatures generated by the explosion, while very high, are not high enough to melt through the 9
armor as quickly as the jet actually penetrates it. Instead, the jet penetrates by kinetic energy, the same way that a solid penetrator does. That is, if you calculate the mass of the molten metal jet and its velocity, you can determine its impact energy in the same way that 10
we calculated muzzle energy above and determine its armor penetration. (The mechanism used to calculate its game penetration is somewhat easier than that, however.)

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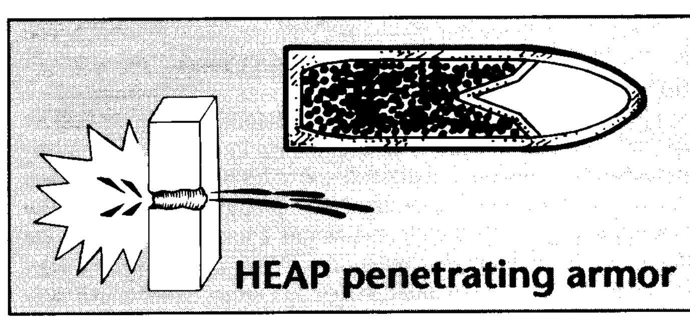

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4. Self-Forging Penetrator (SEFOP): A SEFOP round is a cross between a KEAP and HEAP round. Like the HEAP round, the 14
warhead gains its penetrating energy from the force of an explosion. The penetrator created by the shaped charge explosion, however, is a much more massive stream of metal, and the charge fires a farther

distance away from the target. The stream of molten metal becomes dart-shaped and hardens due to atmospheric resistance as it travels to the target (hence the term "self-forging")

SEFOP rounds are less effective than comparably sized HEAP rounds, but have the advantages of a solid penetrator and not requiring the round itself to contact the target. The solid penetrator means that armor systems treat SEFOP as a KEAP round (reducing the effect of electrostatic armor and making explosive reactive armor completely ineffective against it).

The fact that the round itself does not have to contact the target makes it useful as a remote-area munition. SEFOP warheads with sensors (IR sensors, video sensors, etc) and suspended from parachutes can be dropped near the enemy. As the warhead swings around under the parachute, it scans for a target. When it is aimed at a target and within its effective range (approximately 100 meters), it simply fires and does not require any additional maneuver capability to hit the target.

5. Chemical (CHEM): Chemical warheads are hollow and filled with a chemical agent. This agent may be toxic (poison gas), or it may be a smoke-generating compound. In both cases the characteristics of the warhead itself are identical—only the effect of the agent differs.

Most chemical rounds are base-ejection rounds. This means that the agent is released through the base of the round, either after it hits or while it is still in flight, depending on which is the most effective means of delivering the agent.

6. White Phosphorus/Incendiary Smoke (WP/IS): White phosphorus burns at very high temperatures and produces large quantities of thick, white smoke. As a result, these rounds are sometimes called WP (White Phosphorus), or "Willy Pete," and sometimes called IS (Incendiary Smoke). The round is excellent for building a quick smoke screen. The heat of the round also makes it difficult for thermal or infra-red vision devices to see past the impact point of the shell. Finally, white phosphorus also has considerable anti-personnel capabilities.

White phosphorus rounds are difficult for many vehicles to use, as ammunition is usually stored horizontally in vehicles. (It is easier for a human loader to remove rounds stored horizontally than vertically.) White phosphorus rounds must be stored vertically, however. If the round is stored horizontally, the white phosphorus filler will settle to one side of the warhead and throw it out of balance, ruining its accuracy.

7. Illumination (ILLUM): Illumination rounds contain a brightly burning flare, usually made in part from magnesium powder, suspended from a parachute, balloon, or other lift agent. The round burns brightly after it bursts over the target, providing bright daylight illumination of the battlefield.

8. Submunition (SM): Submunition warheads are hollow shells containing a number of smaller warheads. These smaller warheads are usually the size of hand grenades or slightly larger. The submunition warhead bursts over the target and scatters the submunitions (grenades) over the target area. Submunitions are particularly effective against personnel in the open. Variant warheads with HEAP warheads also can damage armored vehicles if their overhead armor is fairly thin. Submunitions are seldom effective against troops in hardened shelters with good overhead protection. Incendiary warheads allow a large area to be ignited quickly and are often used in aerial attacks on cities.

Submunition rounds fired by artillery are usually called ICM (Improved Conventional Munitions). If the grenades have HEAP warheads, the round is called ICM-DP (Improved Conventional Munitions—Dual Purpose). When dropped from aircraft, these warheads are usually called cluster bombs.

9. Remotely Delivered Mine (RDM): RDM Ammunition is a variant of submunitions ammunition, but instead of impact warheads the round contains mines. The mines become active upon striking the ground and create a surface minefield. Although not camouflaged, the mines can be difficult to detect from a vehicle, particularly if they are in tall grass. This type of warhead is not effective against areas with particularly tall vegetation (such as trees) as the mines tend to get caught in the branches overhead.

There are two types of remotely delivered mines: RDAAM (Remotely Delivered Antiarmor Mines) and RDADM (Remotely Delivered Area Denial Mines). RDAAM mines use HEAP warheads and will only detonate if crossed by a vehicle. RDADM mines use HE warheads and are intended mainly to attack personnel.

10. Flechette: Also called APERS (antipersonnel), this warhead is filled with thousands of very small arrowhead-shaped darts (flechettes). The round also has a timing fuse and a bursting charge. When fired at the enemy, the round travels part of the distance to the target and then explodes, releasing the flechettes to continue along the ballistic path of the round. The round is murderous against unprotected or lightly protected personnel, but has little penetration against armor.

11. Chaff: A chaff warhead is filled with lightweight strips of radar-reflective material designed to reduce the effectiveness of enemy radar and active EMS sensors.

B. Warhead Tech Level

The tech level of the warhead influences its performance in a variety of ways shown in later steps of the design process. In addition, certain warheads are not available until higher tech levels.

TL	*Warhead*
4	Most warheads
5	HEAP
5	WP
6	Flechette
6	Chaff
7	Submunition
7	RDM
8	SEFOP

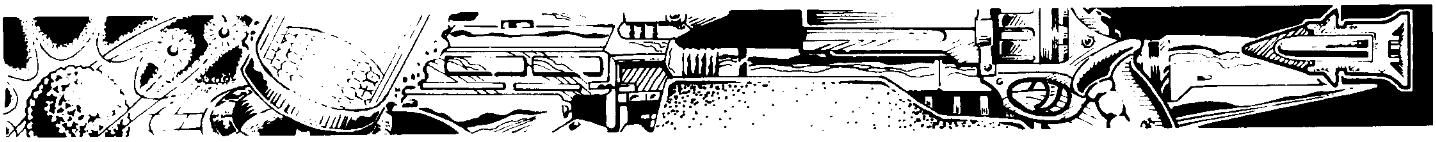
C. Warhead Diameter

The warhead diameter is the bore of the gun (in centimeters) from which the round is fired, if it is a round of artillery ammunition. Bomb, rocket, and missile warheads may be of any diameter desired.

HE, KEAP, and HEAP warheads may be any size from 2cm up. Submunition and RDM warheads must be at least 10cm in diameter. All other warheads must be at least 4cm in diameter.

Submunitions are additionally categorized as light, medium, or heavy, depending on their warhead diameter. Light submunition warheads are less than 15cm in diameter. Medium submunition warheads are less than 20cm in diameter. Heavy submunition warheads are 20cm or more in diameter.

Aerial bombs are usually designated by mass rather than diameter, but since the rest of the design sequence relies on warhead diameter, select a warhead size that corresponds to the desired mass.



D. Damage Value

Damage value is a measure of the force generated at the point of impact by the warhead. Usually this is a measure of the explosive force of the round, and is called its concussion rating. Non-exploding rounds do damage by energy of impact. Damage is calculated differently for various types of warheads.

1. High Explosive: HE rounds do damage by the concussion of the explosion of their bursting charges. The concussion value of the charge is calculated using the following formula:

$$C = Tm \times D^2$$

(Concussion equals tech modifier times diameter squared)

C: Concussion value
D: Warhead diameter in centimeters
Tm: Tech level modifier, as shown on the following chart:

TL	*Tm*
4	.075
5	.1
6	.125
7	.15
8	.175
9	.2
10+	.25

2. KEAP: Kinetic energy warheads have a damage value equal to their diameter in centimeters multiplied by 2.2. This is a constant value for use only for direct hits on personnel. It is never used vs. vehicle targets.

3. HEAP: HEAP warheads use the same formula and table as for an HE round of the same diameter, but multiply the final result by 0.66.

4. SEFOP: SEFOP warheads use the same formula and table as for an HE round of the same diameter, but multiply the final result by 0.5.

5. CHEM: All chemical warheads less than 10cm in diameter have a concussion value of 2, while all warheads 10cm or more in diameter have a concussion value of 3.

6. WP: All white phosphorus warheads less than 10cm in diameter have a concussion value of 2, while all warheads 10cm or more in diameter have a concussion value of 3.

7. Flechette: Each flechette does personnel damage equal to fragments by burst area (2D6 within primary radius, 1D6 in secondary).

8. Others: Other warhead types have no damage value.

E. Burst

Burst radius defines the area covered by the primary effects of a bursting warhead. This can be the area covered by potentially lethal fragments, chemical agents, illumination, and so on, depending on warhead type.

The formulas below give exact burst radii. To convert to the standard **Traveller** burst area figures resolved to the 10-meter grid (see page 284, basic rules), round to the nearest 10-meter increment. For example, 7 meters rounds to 5, 12 rounds to 15, 30 to 35.

1. High Explosive: The burst radius of an HE warhead is the primary burst area covered by fragments. The burst radius in meters is the square root of the warhead's concussion value multiplied by the munition multiplier, as shown below.

Munition	*Multiplier*
Gun, Grenade	7
Mortar, Rocket, Aerial Bomb	10

2. KEAP: Kinetic energy penetrators do not explode and so have no burst radius.

3. HEAP: The burst radius of a HEAP warhead is calculated with the formula for HE warheads, but using the HEAP concussion calculated above.

4. SEFOP: The burst radius in meters of a SEFOP warhead is calculated using the same formula as for an HE warhead.

5. CHEM: The burst radius in meters of a chemical warhead is equal to the warhead diameter squared and divided by 8.

6. White Phosphorus: The burst radius in meters of a white-phosphorus warhead smaller than 10cm in diameter is equal to the warhead diameter multiplied by 2. The burst radius in meters of a warhead 10cm or greater in diameter is equal to the warhead diameter multiplied by 3.

7. ILLUM: The burst radius in meters of an ILLUM warhead is equal to the warhead diameter in centimeters multiplied by a tech level modifier and the result squared.

$$B = (D \times Tm)^2$$

D: Warhead diameter in centimeters
Tm: Tech level modifier, as shown below.

TL	*Tm*
4-5	2.5
6-7	3
8-9	3.5
10+	4

8. Submunition: The burst radius in meters of a submunition warhead is equal to the warhead diameter in centimeters squared and divided by 4.

At tech level 9 and above, it is possible to reduce the number of submunitions and add homing systems to the individual bomblets. Submunition rounds with homing bomblets have only half the burst radius of a regular submunition round. (Burst radius in meters is equal to the warhead diameter squared and divided by 8). However, the designer specifies whether the homing sensors are set for vehicles or personnel. Add 2 to the chances of a direct hit against that target type from a homing submunition. (Personnel would be hit on a roll of 1-3 instead of just 1. Vehicles would be hit on a roll of 1-7 instead of 1-5.)

9. RDM: The burst radius in meters of a remotely delivered mine warhead is equal to the warhead diameter squared and divided by 2.

10. Flechette: Unlike other rounds, flechette rounds have an elongated burst area, since the flechettes keep moving along the ballistic path of the round after it explodes. The primary burst area is the area immediately after the point at which the round explodes, while the secondary burst area is the area after that.

Because the flechettes retain the original velocity of the carrier round after it explodes, the burst area (also called danger space) of the flechettes is based on the velocity of the warhead. The calculated burst area is the length of the burst area. The width of the burst area is one-quarter of its length.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

Flechette burst radius for artillery shells is calculated using the following formula:

1 $$B = .2R$$

B: Burst radius in meters
R: Short range in meters

Flechette burst area for rocket and missile warheads is calculated
2 using the following formula:

$$B = .05V$$

B: Burst radius in meters
V: Average velocity in kilometers per hour

3

11. Chaff: The burst radius in meters of a chaff warhead is equal to the warhead diameter multiplied by a tech level modifier and the result squared.

4 $$B = (D \times Tm)^2$$

D: Warhead diameter in centimeters
Tm: Tech level modifier, as shown below:

TL	*Tm*
4-5	2.5
6-7	3
8-9	3.5
10+	4

5

6 Any enemy radar attempting to detect a target through a chaff cloud does so at one level of difficulty higher. For each tech level the chaff warhead is above the sensor, add one more to difficulty.

Chaff from a chaff round remains airborne in effective quantities
7 for 1D6 combat turns.

F. Penetration

Penetration represents the ability of a warhead to punch through
8 armor and cause damage to the systems protected by that armor. The specific penetration capability of the weapon depends on the type of ammunition being fired.

Penetration capabilities in **Traveller** are quantified in two ways:
9 *penetration value* and *penetration rating.*

Penetration value is the total penetrative capability of a weapon or munition. It is most often used in vehicle combat, and in rating large weapons.

10 Penetration rating describes the relationship between the weapon's damage value and its penetration value. Penetration value = Damage value + Penetration rating. Likewise, Damage value = Penetration value × Penetration rating.

11 **1. High Explosive:** HE (High Explosive) rounds are the standard ammunition of most field guns from tech level 4 on. As they explode on contact and are designed to spread fragments in every direction, they are not effective armor penetrators, but can do some damage.

Penetration of HE rounds is a function of bore size. Multiply the bore size (in centimeters) by 1.5 and subtract 7 to determine the penetration value of the round. All HE rounds have a constant penetration value and so should have the letter "C" written after the value. Rounds with a penetration value of less than 0 are shown as "Nil." Rounds with a penetration value of 0 have that listed as their penetration value (meaning that the final penetration is the base 2D6 roll without any addition).

2. KEAP: KEAP (Kinetic Energy Armor Piercing) includes all solid penetrators which rely on muzzle energy to pierce hostile armor. Penetration value is a function of range, muzzle energy, and the type of ammunition fired.

The base penetration value of solid shot (tech level 4) ammunition at medium range is based solely on muzzle energy (in megajoules) of the gun, as shown below:

If Mj = 12+, then PV = Mj×4
If Mj < 12, then PV = Mj×5 (but never higher than 48)
If Mj < 9, then PV = Mj×6 (but never higher than 45)
If Mj < 7, then PV = Mj×7 (but never higher than 43)
If Mj < 5, then PV = Mj×8 (but P never higher than 35)
If Mj <1.5, then PV = Mj×10 (but P never higher than 12)
If Mj < 1, then PV = Mj×12 (but P never higher than 10)
If Mj < 0.5, then PV = Mj×16 (but never higher than 6)
If Mj < 0.3, then PV = Mj×22 (but never higher than 5)

For example, a gun has a muzzle energy of 4.6 Mj. Since this is less than 5 but not less than 1.5 Mj, the gun has a penetration value equal to Mj×8, or 36.8, rounded up to 37, but then reduced to 35 (the maximum PV for weapons with a muzzle energy less than 5 Mj).

At higher tech levels, specialized ammunition allows increased penetration. Multiply the penetration of the round as calculated above by the ammunition multiplier, as shown below:

Special Ammunition

TL	*Ammo*	*Multiplier*
5	HVAP	1.3
6	APDS	1.7
7	APFSDS	2.4
8	APFSDSDU	3
10	APFSDSCI	4.5
12	APFSDSSD	5
14	APFSDSBSD	6
17	APFSDSBCS	7

HVAP: High Velocity Armor Piercing
APDS: Armor Piercing Discarding Sabot
APFSDS: Armor Piercing Fin Stabilized Discarding Sabot
DU: Depleted Uranium
CI: Crystaliron
SD: Superdense
BSD: Bonded Superdense
BCS: Bonded Coherent Superdense

Once the medium-range penetration is known, penetration values at the other range bands can be calculated.

At short range, add 15% of the penetration value or a flat value of 10, whichever is less.

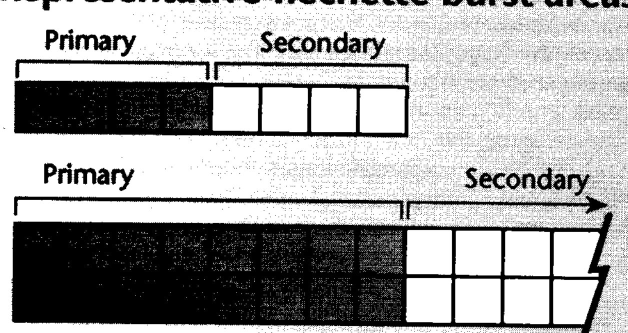
At long range, subtract 15% of the penetration value, or a flat value of 10, whichever is less.

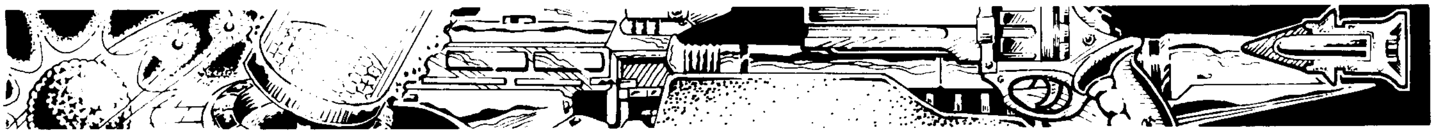
At extreme range, subtract 45% of penetration, or a flat value of 30, whichever is less.

12 **Representative flechette burst areas**

13

14





3. HEAP: HEAP rounds are available at TL 5 and higher. Penetration of HEAP rounds is a function of bore size and tech level. Multiply the bore size (in centimeters) by the tech level multiplier shown below and subtract 7 from the result to determine the penetration value of the round. All HEAP rounds have a constant penetration and so should have the letter "C" written after the value. Rounds with a penetration value of less than 0 are shown as "Nil." Rounds with a penetration of 0 have that as penetration (meaning that the final penetration is the base 2D6 roll without any addition).

TL	*Multiplier*
5	**4**
6	6
7	**8**
8	10
9+	**12**

4. SEFOP: Self-forging penetrator warheads are available at tech level 8 and above. Penetration is calculated the same as for HEAP warheads, and using the same table of tech level multipliers.

5. Submunition: Penetration of grenades.

6. Flechette: The flechettes contained in the warhead have the same penetration as normal fragments (1 in the primary radius, Nil in the secondary), but the flechette round itself, should it hit an armored surface, has a penetration of Nil.

7. Other: All other warheads have a penetration of Nil.

G. Mass

The table below lists the mass of most warheads. Values between those shown on the table can be obtained by interpolation.

Diameter (cm)	*Mass (kg)*
2	**.2**
3	.4
4	**.8**
5	1.5
6	**3**
7	6
8	**12**
9	17
10	**21**
11	25
12	**30**
13	35
14	**43**
15	50
16	**60**
17	72
18	**85**
19	100
20	**115**
21	140
22	**160**
23	185
24	**215**
25	250
30	**500**
35	1000
40	**2500**
45	5000
50	**10,000**

1. KEAP: Regular KEAP warheads (solid shot) are twice the mass shown on the table above. HVAP rounds are 1.5 times the mass shown on the table above. All other KEAP rounds (APDS, APFSDS, etc.) have the mass shown on the table.

2. Special Rounds: The above values are for aerial bombs and artillery shells. Alternative munitions have the following masses.

Type	*Mass*
Hand and Low-Velocity Propelled Grenade*	**×0.3**
Medium-Velocity Propelled Grenade*	×0.4
Rocket, Missile, Light Recoilless Rifle*	**×0.4**
Rifle and High-Velocity Propelled Grenade*	×0.5
RAM Grenade*	**×0.6**
Heavy Recoilless Rifle*	×0.7
Mortar*	**×0.8**

*Note that in the case of propelled grenades, mortar rounds, and recoilless rifle rounds, the above masses are for the entire round including propellant.

H. Volume

The volume of a warhead in cubic meters for purposes of storage is equal to the mass of the warhead in tonnes ÷ 5.

I. Price

The base price for ammunition in credits is equal to its mass multiplied by its ammunition type modifier, as shown below.

Type	*Modifier*
HE	**10**
KEAP (AP)	5
HVAP	**15**
APDS	15
APFSDS	**15**
APFSDSDU	30
APFSDSCI	**35**
APFSDSSD	40
APFSDSBSD	**45**
APFSDSBCS	50
HEAP	**15**
SEFOP	20
CHEM	**10**
WP/IS	20
ILLUM	**10**
SM	60
SM (Homing)	**100**
RDM	100
Flechette	**50**
Chaff	20

RAM (rocket-assisted multipurpose) grenades cost 10 times the normal warhead price.

Recoilless rifle ammunition costs 1.5 times the normal warhead price.

Note that in the case of propelled grenades, mortar rounds, and recoilless rifle rounds, the above prices are for the entire round including propellant.

SPECIAL WARHEADS

Most munitions consist of standard warheads used in a variety of
1 roles, either fired, propelled, or dropped. The following warheads are more specialized with limited uses or limited acceptable delivery means.

1. Hand Grenades: Hand grenades are thrown weapons, with the
2 distance thrown being determined by the mass of the grenade. (See the thrown weapon rules on page 282 of the basic game for an explanation of this procedure.)

Hand grenades can use HE, HEAP, CHEM, WP, or ILLUM warheads.
3 They consist exclusively of a warhead and a detonator (either a timer or a contact fuse), but the mass and cost of the detonator are subsumed in the values or the warhead itself. Most hand grenades use a warhead of about 4.5cm diameter, which results in a grenade
4 massing 0.35 kilograms, costing Cr3.5, and with, at tech level 7, damage values of C:3, B:15 (round 12 to 15) assuming HE.

Two special types of warheads are available for grenades: concussion and thermite.

5 *Concussion:* These grenades have more explosive filler than HE grenades and are enclosed in a pressed paper or plastic container designed to be completely consumed by the explosion. The result is a more powerful blast but no lethal fragments.

To calculate the concussion value of concussion grenade, multiply
6 the normal HE concussion value of a grenade of that size by 1.6. Concussion grenades have no burst radius and have the same mass and cost of HE grenades.

Thermite: These grenades are extremely hot incendiary
7 grenades useful for destroying large machinery. (Dropped down the barrel of cannon, the thermite grenade will burn through the breach block.) Thermite grenades have the same concussion as a WP grenade, but only one-third of the burst radius. Thermite grenades
8 produce no significant mount of smoke. Thermite grenades cost half as much as WP grenades of the same size, but are otherwise identical.

2. Rifle Grenades: Rifle grenades are designed to be fired from standard military slug-firing rifles. The grenade itself has no propel-
9 lant and is instead projected by the force of the bullet fired from the rifle. As a result, rifle grenades tend to be fairly light, and they are very inaccurate.

Range: Rifle grenades may only be fired in indirect fire. The indirect
10 fire range of a rifle grenade is determined using the following formula:

$$R = (D+M)Tm$$

11

R = Indirect fire range in meters
D = Damage value of the rifle or carbine firing the grenade
M = Mass in kilograms of the grenade
12 Tm = Tech level modifier, as shown below:

TL	Tm
5-6	35
7-8	65
9+	95

13

14

3. RAM Grenades: Rocket-assisted multipurpose (RAM) grenades are available at tech level 8 and above as rifle grenades. These grenades may be fired in either direct or indirect fire. Since these are rocket-propelled grenades, their range does not vary with damage value of the bullet fired from the rifle. Masses and prices are given in the design sequence above. Range is shown below:

TL	Short Range	Indirect Fire Range
8	30	500
9	40	550
10	50	1500
11	60	2000

4. Mines: Mines are simply emplaced warheads. Any warhead type may be used as a mine. The mine consists of the warhead and a fuse. Fuses have negligible volume and mass, and cost as shown on the following table:

TL	Fuse	Cr
4	Contact	10
6	Radio	20
8	Proximity	100

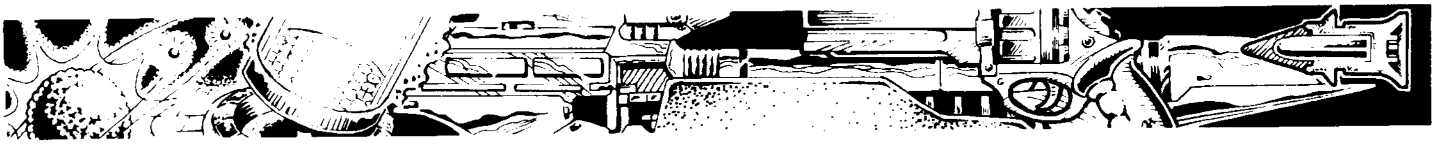
Mines mass half as much as a standard warhead of the chosen diameter and use the same cost multipliers as for a conventional warhead. Nonmetallic mines cost twice as much for the warhead and 10 times as much for the trigger.

5. Napalm: Napalm is a mixture of hydrocarbon distillates, thickeners, and other components designed to aid combustion (such as powdered aluminum, charcoal, white phosphorus, etc.).

Napalm is available at tech level 5 and up. Because it is most effective when spread over a wide area, it is not generally used in artillery or rocket warheads or streamlined gravity bombs designed to impact the ground at a steep angle. Instead, it is used in unstreamlined cannisters designed to tumble when released by aircraft at low altitude. These cannisters break open when they hit the ground and scatter burning fuel along the flight path of the aircraft.

Aerial napalm cannisters are relatively inaccurate weapons and are effective against personnel in the open and soft vehicles. Their effect is increased greatly by the presence of dry foliage, and reduced almost to nil by wet weather or ground conditions.

Napalm cannisters mass 350 kilograms each. They have no concussion value and a burst area 20 meters wide and 100 meters long. (There is no secondary burst area.) If hit by fragments, consult the burn damage rules (TNE, page 286).



6. Nuclear Warheads: Because of the tremendous damage already caused by the Final War, nuclear warheads are looked upon with a particularly intense revulsion. That does not keep occasionally irresponsible leaders from using, or threatening to use, these weapons of indiscriminate mass destruction.

Yield	*Crater*	*Induced*	*Destruction*	*Primary*	*Secondary*	*Size*
.1	25	30	30/50	100/150	200/300	17
.5	25	35	30/60	150/180	330/360	18
1	40	40	30/60	210/240	420/420	19
2	50	60	60/90	300/300	540/540	20
5	50	80	150/120	480/420	660/600	21
10	60	90	180/120	540/480	720/660	22
20	60	100	300/240	540/480	900/720	23
50	70	120	420/300	750/600	1200/900	24
100	100	140	480/420	750/600	1260/1080	25

Yield: Warhead size in kilotons.

Crater: Diameter of crater in meters. Only ground strikes produce craters. Ground units may not enter the crater of a nuclear blast until it has been decontaminated.

Induced: Radius of induced radiation in meters. For 30 minutes after the detonation of the the warhead, the radius of induced radiation is equal to the secondary blast radius. After that, it shrinks to the listed induced radiation radius listed above. Everything inside this radius is contaminated with radiation. Unprotected personnel must leave the induced radiation area within 15 minutes or begin suffering progressively greater health effects. Personnel in sealed environment suits, sealed armor, or vehicles with hostile environment capability ignore induced radiation.

Destruction: The destruction radius in meters. The first number is the destruction radius from a ground strike, the second is the area from an air burst.

All targets in the destruction radius are destroyed, and any flammable material ignites and burns.

Primary: The primary blast radius in meters. The first number is the blast area from a ground strike, the second is the area from an air burst.

All targets in the primary blast radius are treated as if within the primary blast radius of a conventional explosion and suffer fragmentation attacks accordingly. All targets are also attacked with a concussion value of 10. (Note that this does not affect enclosed vehicles.) All trees and frame buildings in the primary blast radius are blown down.

Secondary: The secondary blast radius in meters. The first number is the blast radius from a ground strike, the second is the radius from an air burst.

All targets in the secondary blast radius are treated as if within the secondary blast radius of a conventional explosion and suffer fragmentation attacks accordingly.

Size: Minimum warhead diameter in centimeters for this yield. Nuclear warheads are first available at tech level 6. At later tech levels, the minimum warhead size is reduced as shown on the following chart:

TL	*Size*
7	–2 cm
8	–4 cm
9	–6 cm
11	–7 cm
13	–8 cm
15	–9 cm
17	–10 cm
19	–11 cm

Price: The price of the warhead in millions of credits is equal to its yield multiplied by 0.01.

Storage: A nuclear warhead must be stored in a shielded container or a damper box. A shielded container takes up four times the volume of the warhead, masses three times the mass of the warhead, and costs MCr0.01 per cubic meter of volume.

7. Collapsing Nuclear Warheads: Collapsing warheads are much smaller than standard nuclear warheads. This is made possible by using very unstable fissionable materials, such as californium, and by omitting the reliable but bulky detonation system found in standard rounds. Instead, these warheads rely on impact with vehicle or structural armor to collapse the hollow round quickly into a critical mass, resulting in unreliable performance.

Collapsing rounds may only be fired from CPR or mass driver guns with a short range of 400 meters or more. They may only be fired at hard targets, such as concrete buildings, armored vehicles, starships, etc.

If a collapsing round hits, it successfully detonates only on a die roll of 7 or less (on a D20). On any other roll, the round was a dud.

The information on collapsing rounds is noted in the following table. It is read exactly the same as the main nuclear warhead table above, except as noted specifically below.

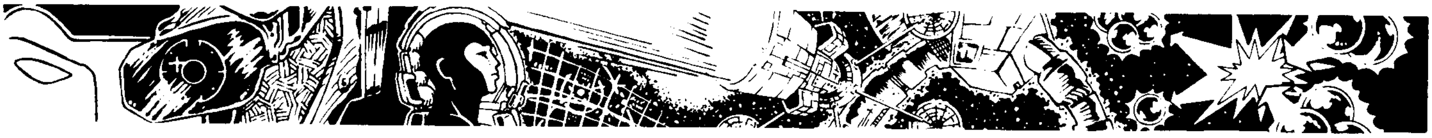
Yield	*Crater*	*Induced*	*Destruction*	*Primary*	*Secondary*	*Size*
.001	10	5	20/30	25/60	50/120	2
.002	10	10	20/35	30/70	60/140	3
.005	15	10	20/35	40/75	80/150	3.5
.010	15	15	25/40	50/95	100/190	4
.050	20	20	25/45	75/120	150/240	6
.100	25	30	30/50	100/150	200/300	7

TL: Collapsing nuclear rounds are available at tech level 14 and higher.

Size: Minimum warhead diameter in centimeters for this yield.

Price: The price of the warhead in millions of credits is equal to its yield multiplied by 1.

Storage: Because of their short useful half-life, collapsing rounds *must* be carried in damper boxes.



8. Nuclear-Pumped X-Ray Lasers: The one area where nuclear warheads are used fairly regularly is on space-based X-ray laser
1 missiles. Each of these warheads consists of a nuclear device, an array of X-ray lasing rods, a short-range tracker, a receiver for a 300,000-km laser communicator, and a small battery power pack. The missile operator maneuvers the warhead into range of the target (using
2 whatever maneuver package the designer has chosen to include in the weapons system). The on-board tracker makes the final precision target corrections and the operator fires the warhead. The explosion of the warhead destroys the lasing rods, but not before pumping a tremendous
3 burst of energy through them and toward the target.

All components of the nuclear X-ray laser warhead are included in a single package as shown on the following chart.

All nuclear X-ray pumped warheads roll 1D6 for hits on target
4 when they detonate; each of these hits does damage equal to that listed in the "Dmg" column.

Range for space combat (in increments of 30,000 km) is given on the bottom line. By increasing size and price, longer range (to the
5 right of the slash) may be acheived. Note that this is only possible in a campaign using the optional laser focusing technology field.

				Volume at Tech Level					
	Yield	MCr	Dmg	8	9-10	11-12	13-14	15-16	17+
6	**10**	**.6**	**1/8-25**	**.29**	**.195**	**.16**	**.132**	**.103**	**.08**
	20	.7	1/11-35	.32	.215	.18	.148	.113	.09
	50	**.8**	**1/14-43**	**.35**	**.235**	**.2**	**.168**	**.127**	**.10**
	100	.9	1/18-56	.39	.265	.22	.188	.147	.11
7	**200**	**1.1**	**1/21-66**	**.51**	**.355**	**.28**	**.248**	**.167**	**.13**
	500	1.2	1/25-79	.71	.505	.4	.358	.247	.17
	Range	—	—	**0/0**	**0/0**	**0/0**	**0/1**	**0/1**	**0/2**

8 **Yield:** Warhead yield in kilotons.

MCr: Price in millions of credits for the warhead package.

Dmg: Damage expressed in terms of laser penetration rating-damage value.

9 **Volume:** The listed values are the volumes in cubic meters of the complete warhead packages at each tech level.

Mass: Each warhead masses 1 tonne per cubic meter.

Range: Range in starship combat hexes/range bands. Range to
10 the left of the slash is normal range, to the right is range available by doubling volume and multiplying price by 10. Range of 0 means fires into same hex only.

11 *GUIDANCE*

Warheads, whether they are powered or unpowered, may have guidance systems installed.

Maneuver: In order to have a guidance system installed, a
12 warhead must be able to maneuver. In most cases, this will mean that it is powered by an engine of some kind. Unpowered warheads can have guidance packages installed however, which allow them to vary their projected target point by as much as 10% of the distance between
13 the target and the launch point (or firing point). An unpowered warhead must have fins that enable it to maneuver, however. These fins are extremely light and do not add significantly to warhead mass. They do add Cr1 to the warhead price per kilogram of warhead mass.

14 **Guidance:** Guidance systems include command guidance, target designation, homing, and smart.

1. Command Guided: In this guidance system, the operator must pilot the warhead to the target. These guidance systems are distinguished by their operating system and their command link.

Operating system is a measure of how sophisticated the tracking software of the guidance system is. Manual operation means that the warhead must be maneuvered toward the target by the operator by observing both the target and warhead and mentally computing the necessary course changes. Semiautomatic guidance still requires the operator to track both the target and the missile, but flight controls are vastly improved and the warhead has superior flight characteristics, enabling it to fly at higher speeds and still be controlled. Automatic guidance means that the operator is only required to track the target, while the guidance system itself computes the corrections necessary to fly the warhead to it. Teleguidance allows the operator to "see" directly out the front of the warhead and thus eliminates the need for a continuous line of sight between the operator and the target. Instead, the operator simply flies toward the target until impact.

The characteristics of the various operating systems are shown on the table below.

TL	*Type*	*Mass*	*Cr*	*Speed (kph)*	*AGL*
5	**Manual**	**1**	**40**	**300**	**–2**
6	Semiauto	2	80	600	–1
7	**Automatic**	**2**	**100**	**900**	**—**
8	Teleguidance	2	100	1200	—

TL: Tech level of first availability.

Type: Operating system used.

Mass: Mass in kilograms of the controller in the warhead.

Cr: Price in credits of the controller in the warhead.

Speed: The highest allowed average speed. This value is used when calculating missile propellant and performance later.

AGL: Modification to the missile's final Agility rating (if mounted on a missile).

Volume: All operating systems have a volume of 1 liter per kilogram.

In addition to an operating system, a command guidance package must have a communication link between the operator's control unit and the controller in the warhead itself. For wire-guided missiles, there is no additional equipment to be installed as this equipment is subsumed under the other areas of the design, but radio and laser guidance does. The type of communication link also limits the maximum range of the missile. The table below summarizes the characteristics of various communication links.

TL	*Type*	*Mass*	*Cr*	*Range (km)*
5	**Wire**	**—**	**—**	**2**
6	Wire	—	—	4
7	**Wire**	**—**	**—**	**6**
5	Radio	2	40	*
6	**Radio**	**1**	**40**	*****
7	Laser	1	70	10
8+	**Laser**	**1**	**50**	*****

TL: Tech level of first availability.

Type: Comm link used.

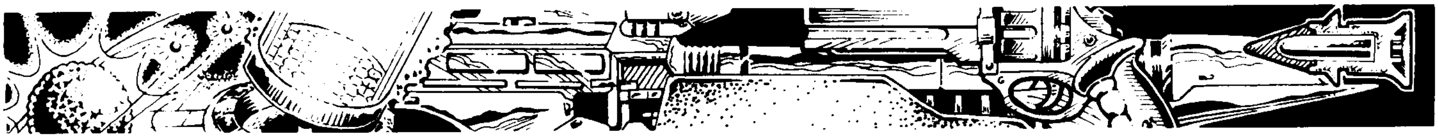
Mass: Mass in kilograms of the comm link in the warhead.

Cr: Price in credits of the comm link in the warhead.

Range: The longest allowed range using the listed communication link.

* The range of radio-guided warheads and tech level 8+ laser-guided warheads is equal to the long range of the communicator installed in the control unit. Consult the Launchers chapter (page 147) for a discussion of the launcher control unit.

Volume: All comm links have a volume of 1 liter per kilogram.



2. Target Designated: This guidance system employs a seeker head in the warhead which enables it to home in on the reflected radiation of a designator, either a laser or a radar. The prices and masses of the seeker heads are shown on the table below.

TL	*Type*	*Mass*	*Cr*
6	**Radar**	**2**	**1000**
7	Radar	2	1000
8+	**Radar**	**1**	**1000**
7	Laser	1	500
8	**Laser**	**1**	**500**
10+	Laser	1	500

3. Homing: These guidance systems lock onto and home on certain well-defined levels of emissions of radiation. Infrared missiles home on high heat signatures. Anti-radiation missiles (ARM) home on radar or radio emissions. In both cases, improved versions have more sophisticated sensors capable of tracking at greater distances and at more difficult engagement angles.

TL	*Type*	*Mass*	*Cr*	*Range*	*AGL*
6	**IR**	**1**	**500**	**10**	**−2**
7	Improved IR	1	1000	15	−1
8	**Advanced IR**	**1**	**1500**	**20**	**—**
7	ARM	1	1000	12	−2
8	**Improved ARM**	**1**	**2000**	**24**	**−1**

TL: Tech level of first availability.
Type: IR = Infrared homing. ARM = Anti-radiation missile.
Mass: Mass in kilograms of the guidance system in the warhead. There is no control unit.
Cr: Price in credits of the guidance system in the warhead.
AGL: Modification to the missile's final Agility rating (if mounted on a missile).
Volume: All homing guidance systems have a volume of 1 liter per kilogram.

4. Smart Warheads: Smart warheads encompass two methods of guidance: target memory and target seeker. Both are true "fire-and-forget" weapons, but they are distinguished by what the operator is required to do prior to firing.

Target memory warheads have sensor units capable of distinguishing between unique target shapes. While still carried by the launch vehicle, the image generated by the sensor is projected onto the operator's video screen. When the sensor in the warhead acquires a target the operator considers suitable, the warhead is launched and the sensor, remembering the specific target acquired, will move to intercept it.

Seeker warheads have a pre-programmed set of target images that the sensor will recognize, and are simply launched into the general area of likely targets, after which they will seek out an appropriate target and attack it.

The characteristic of smart guidance systems are shown below:

TL	*Type*	*Mass*	*Cr*	*AGL*
7	**Memory**	**3**	**10000**	**−1**
8	Memory	2	5000	—
8-10	**Seeker**	**1**	**1000**	**−2**
11-13	Seeker	1	1000	—
14+	**Seeker**	**1**	**1000**	**+2**

TL: Tech level of first availability.
Type: Target memory or seeker.
Mass: Mass in kilograms of the guidance controller in the warhead.
Cr: Price in credits of the guidance controller in the warhead.
AGL: Modification to the missile's final Agility rating (if mounted 1
on a missile).
Volume: All operating systems have a volume of 1 liter per kilogram.

2
In addition to a guidance system, a smart warhead must have a sensor which it uses to gather target information. The type of sensor used has no effect on the chance of the missile hitting, but does effect the conditions under which it can operate at all. 3

Visual sensors allow clear-weather daylight operation. IR sensors allow night operations along with some low-visibility operations (chemical smoke, fog, light rain, etc.). Imaging radar sensors allow operation in all light and atmospheric conditions (but is subject to 4
jamming like all radars).

The characteristics of sensors are summarized on the table below.

TL	*Type*	*Mass*	*Cr*	
7	**Visual**	**1**	**200**	
7	IR	1	2000	5
8	**Imaging Radar**	**1**	**10,000**	

TL: Tech level of first availability.
Type: Type of installed sensor. 6
Mass: Mass of the sensor added to the warhead.
Cr: Additional price to add the sensor to the warhead.
Vol: The volume of a sensor is 1 liter per kilogram. 7

5. Top Attack: Top attack may be added as an option to any guidance package from tech level 8 on, provided the warhead is either HEAP or SEFOP. Top attack means that the weapon's warhead is angled to fire perpendicular to the flight path of the 8
munition, thus firing into the top of a vehicle as it passes over it. Top attack options are of no real use against aircraft, only vehicles which generally have weaker overhead armor than front armor.

Adding the top attack option doubles the warhead price, but has 9
no other effect on the munition.

PROPELLANT

Virtually all warheads are propelled in one manner or another 10
(with the notable exception of mines).

A. CPR Ammunition: CPR projectiles are propelled by the explosion of a propellant charge in the gun tube. This propellant charge is purchased separately from the warhead (although its mass is 11
usually added to that of the warhead to make a complete round of ammunition).

Mass: The propellant required for CPR guns varies with the mass of the warhead and the length of the barrel. Propellant mass for 12
CPR gun ammunition is calculated using the following formula:

$$Mp = .007MwBl$$

Mp: Mass (in kilograms) of propellant for the round.
Mw: Mass (in kilograms) of the warhead 13
Bl: Barrel length (in calibers) of the gun.

Propellants for mortars, propelled grenades, and recoilless rifles are included in the base mass of the warhead.

Rocket-assisted projectiles (RAP) are available from tech level 5 on. 14
RAP projectiles require additional propellant mass equal to the warhead mass (regardless of barrel length). This is in addition to the normal propellant requirement of these weapons.

Base bleed (BB) propellant is available for CPR guns at tech level 7+. Base bleed charges do not add to the mass of propellant, but cost more.
1 Note: In both the RAP and BB rounds, the specialized "propellant" (in the RAP, rocket fuel, in the base bleed round, a combustible chemical which is burned in a generator at the base of the round—the resulting gas creates an overpressure and smooths the airflow
2 around the round, thus increasing its range) is actually part of the warhead, but is calculated here for simplicity.

2. Price: The price of artillery propellant in credits is the mass of the propellant multiplied by 5. This price is doubled when
3 calculating the price of base bleed and RAP propellant.

B. Atmospheric Rockets and Missiles: Rockets and missiles are powered by rocket engines which, unlike artillery shells, continue to propel the projectile after it has left the launcher. For purposes of
4 propellant design, there is no difference between a rocket and a missile. The terms are usually used to distinguish between unguided (rocket) and guided (missile) rocket-propelled warheads.

Rockets and missiles generally use rockets, most commonly solid fuel rockets, but may use any form of thrust desired. Designing the
5 propellant package of the weapon follows these steps:

1. Tech Level: Determine the tech level of manufacture of the weapon.

2. Thruster: Select a thruster from those available at the
6 tech level of manufacture. Consult the Sublight (Maneuver) Drive chapter (Section 9) for a list of available thrusters.

3. Average Velocity: Set the average velocity of the weapon. Note that missiles with certain command guidance pack-
7 ages have maximum allowed average velocities. Multiply average velocity in kph by 1.39 to determine speed in meters per combat turn.

4. Propellant Mass: Set the total propellant mass in the weapon.

8 **5. Average Mass:** The missile will burn fuel throughout its flight and its mass will change accordingly. The average mass is determined by adding the warhead mass, guidance mass, engine mass (if that is separate from the fuel), and half of the fuel mass. The result is the average mass.

9 **6. Required Thrust:** The required thrust is determined using the following formula. Note that since thrusters other than solid-fuel rockets require more engine mass to produce more thrust, the result of this calculation may require tinkering with the design
10 until thrust, speed, and average mass are all compatible.

$$T = V^2MTm$$

T: Thrust in kilograms
V: Average velocity in kilometers per hour
11 *M:* Average mass in kilograms
Tm: Tech level modifier, as shown on the table below:

	TL	*Tm*
	4-6	.0000015
12	7-9	.0000009
	10+	.0000006

7. Fuel Consumption: The Self-Contained Thrusters table
13 in the Sublight Drive chapter (Section 9) shows the fuel consumption of various thrusters in terms of tonnes of fuel burned per hour per tonne of thrust. This is also the number of kilograms of fuel burned per hour per kilogram of thrust. To determine the number of
14 kilograms of fuel burned per second per kilogram of thrust, divide the fuel consumption number on the chart by 3600. To determine how many kilograms of fuel the weapon consumes per second, multiply the fuel consumption per second per kilogram just derived by the actual thrust in kilograms of the weapon (Step 6 above).

Size Efficiency: Solid-fuel rockets with less than 500 kg of propellant (fuel) mass begin to suffer from inefficient fuel combustion. To determine the fuel consumption inefficiency of a solid-fuel rocket, divide 500 by the fuel mass (in kilograms). The result is the fuel use multiplier. Multiply the calculated fuel consumption of the engine by this number. However, any multiplier less than 1 is treated as 1 and any multiplier greater than 10 is treated as 10.

8. Fuel Endurance: The fuel endurance of the missile in seconds is its propellant mass in kilograms (Step 4) divided by its fuel consumption per second (Step 7).

9. Range: The range of the missile in kilometers is its average velocity in kilometers per hour multiplied by its fuel endurance in seconds divided by 3600. For homing missiles, short range is this maximum range divided by 8.

10. Agility: The weapon's Agility is determined by consulting the Agility table below:

Average Velocity (kph)	*Agility*
86-171	1
172-343	2
344-687	3
688-1375	4
1376-2751	5
2752-5503	6
5504-11,007	7
11,008-22015	8
22016+	9

Add +1 to the computed agility for all missiles of TL 10+.

C. Space Missiles: Missiles used in ship-to-ship combat in vacuum have a simpler design sequence that atmospheric missiles, and in many respects they function as small spacecraft. Once the warhead is selected, the following procedure is followed.

1. Tech Level: Identify the tech level at which the missile is built.

2. Install Thruster: Select a thruster from those available in the Sublight Drive chapter (Section 9). Most space missiles use EAPLAC solid-fuel thrusters. Determine the total thrust of the rocket in tonnes. This is set by the designer based on the missile's mission requirements.

3. Install Fuel: Determine the total fuel volume of the rocket. SRF fuel has a volume of 1 cubic meter per tonne.

4. Determine Average Mass: The average mass of the missile is its warhead mass plus its engine mass (unless it uses a solid-fuel rocket, in which case engine mass is 0) plus half of its fuel mass.

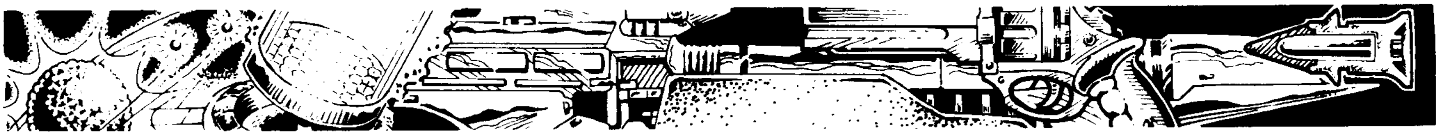
5. Determine G Rating: Divide the missile's thrust in tonnes by its average mass. The result is the missile's G rating.

6. Determine Fuel Consumption: Multiply the fuel consumption rate of the thruster as listed on the Self-Contained Thrusters table in the Sublight Drive chapter (Section 9) by the thrust of the engine in tonnes to determine fuel consumption of the engine in cubic meters per hour. Divide the result by 2 to determine the fuel consumption in cubic meters per space combat turn.

7. Determine Fuel Endurance: Divide the fuel supply in cubic meters by the fuel consumption in cubic meters per turn to determine the number of turns of fuel the missile has. (This may be a value less than 1.)

8. Determine the Missile's G-Turns: Multiply the G rating of the missile by the fuel endurance in turns to determine the total G-turns of acceleration available to the missile.

9. Determine Max Gs per Turn: Enter either the total missile G-turns of acceleration or the missile's G rating, whichever is less.



CHAPTER 10
Launchers

This chapter covers a variety of launchers for rockets, missiles, and related ordnance.

GRENADE LAUNCHERS

Grenade launchers fall between small arms and artillery in that they fire rounds larger than small arms ammunition but do so at extremely low velocities, thus making most of them man-portable.

A. Specifications: Grenade launchers are defined by the following characteristics:

1. Ammunition: Grenade launchers fire propelled grenades. Propelled grenades are designed using the Munitions chapter design rules. A variety of ammunition types are possible. For purposes of designing the launcher itself, however, the key variables are grenade diameter (in centimeters) and grenade velocity (low, medium, high, or RAM—rocket assisted multipurpose).

2. Configuration: Grenade launchers are available in three configurations: attached, shoulder-fired, and mounted.

Attached launchers are never fired separately, but instead are attached to another shoulder-fired rifle or energy weapon.

Shoulder-fired grenade launchers have stocks like rifles, and may be equipped either with a fixed stock or a folding stock.

Mounted grenade launchers usually have only a pistol grip and are designed for fire from vehicles or a tripod mount. Most mounted grenade launchers are either semiautomatic or fully automatic.

3. Action: The grenade launcher may be either single-shot, pump, semiautomatic, or automatic. If automatic, its rate of fire is always 5.

4. Feed System: Pump-action launchers have integral magazines. These are usually tubular magazines mounted either over or under the barrel. Semiautomatic launchers have box magazines. Automatic grenade launchers are belt-fed. If a magazine is used, specify the capacity in number of rounds carried.

5. Barrel: Specify the barrel length in calibers. The shortest allowed barrel is 2 calibers and the longest allowed barrel is 10 calibers.

B. Ratings: Using the data provided above, the weapon's physical characteristics and performance can be determined.

1. Direct Fire Range: Direct fire range for grenade launchers is determined using the following formula:

$$R = 3.75(D+Bl+Vm)$$

R: Short range in meters
D: Grenade diameter in centimeters
Bl: Barrel length in calibers
Vm: Velocity modifier, as shown below:

Velocity	*Modifier*
Low	15
Medium	25
High	40
RAM	50

2. Indirect Fire Range: Maximum indirect fire range (which is also an upper ceiling on direct fire range for low-velocity grenades) is determined using the following formula:

$$Rm = RsVm$$

Rm: Maximum range in meters
Rs: Short range in meters
Vm: Velocity modifier, as shown below:

Velocity	*Modifier*
Low	4
Medium	6
High	10
RAM	15

3. Length: The length of the weapon is calculated using the following formula:

$$L = D(Bl+Rl)+S$$

L: Length in centimeters
D: Grenade diameter in centimeters
Bl: Barrel length in calibers
Rl: Receiver length in calibers, as shown below:

Type	*Rl*
Single Shot	2.5
Pump	5
LV Semiautomatic	5
MV Semiautomatic	8
HV Semiautomatic	10
LV Automatic	8
MV Automatic	12
HV Automatic	14

S: Stock length in centimeters. Shoulder-fired weapons have a stock length of 25cm. If a folding stock is selected, it has a stock length of 25cm when extended and 5cm when restricted. Calculate total weapon length based on both positions. Mounted weapons have a stock (grip) length of 5cm. Attached weapons have no stock length.

Pump-action weapons with an integral magazine must also calculate magazine length in calibers. The magazine length in calibers is the number of rounds in the magazine multiplied by 2.5. If the magazine length in calibers is longer than the combined barrel and receiver length in calibers, then the magazine length is substituted in the equation above for (Bl + Rl).

The length of an attached grenade launcher must be less than or equal to the barrel length of the small arm to which it will be attached.

4. Bulk: Once the final length of the weapon has been determined, the bulk can be calculated. Bulk is equal to the weapon length (in centimeters) divided by 15, rounding all fractions down

5. Recoil Reduction Options: There are two types of devices used to reduce grenade launcher recoil: shock-absorbing stocks and recoil compensators. The inertial recoil compensator is worn as a harness and the gun is attached to it by a flexible arm. The arm becomes rigid when the weapon is fired, and the recoil compensator in the harness pack absorbs much of the force of the recoil. Unlike most other options, the mass of the inertial compensator is not added to the mass of the weapon (Mw) for purposes of determining recoil below.

No more than one of each type may be added to the weapon. Only weapons with stocks may have shock-absorbing stocks added. Recoil devices are summarized on the following page:

	TL	Type	Rcm
	5	SA Stock	.95
1	7	SA Stock	.9
	9	Folding SA Stock	.9
	9	SA Stock	.85
	10	Gyroscopic Compensator	.5
2	14	Inertial Compensator	.3

TL: Tech level
Rcm: Recoil compensator modifier
3 *SA:* Shock-absorbing
If a weapon has more than one Rcm, multiply them all together to get a single combined value.
If a weapon has no recoil modifiers, its Rcm is 1.

4 **6. Empty Mass:** The mass of the weapon is calculated using the following formula:

$$M = (DBlVmCm)+S$$

M: Mass in kilograms
5 *D:* Grenade diameter in centimeters
Bl: Barrel length in calibers
Vm: Velocity modifier, as shown below:

	Velocity	Vm
6	Low	1
	Medium	1.5
	High	2
	RAM	1.5

7 *Cm:* Configuration modifier as shown below:

	Configuration	Cm
	Single-shot	0.05
	Pump	0.15
8	Semiauto	0.1
	Automatic	0.15

S: Mass of the stock, as shown below:

	Stock	Mass
9	Pistol Grip	0.2
	Stock	0.5
	Folding Stock	0.5
	SA Stock (TL 5)	0.6
10	SA Stock (TL 7,9)	0.7
	Folding SA Stock	0.7

Gyroscopic compensators have a mass of 0.5 kilograms. Inertial
11 compensators have a mass of 1 kilogram. Unlike other components of the weapon, inertial compensators are counted separately and are worn as harnesses to which the weapon is attached.

7. Loaded Mass: The loaded mass of the weapon is equal
12 to its empty mass plus the mass of all rounds carried in its magazine (one round if single-shot) plus the mass of an empty magazine.

Integral tubular magazines are already included in the mass of the weapon. The mass of box magazines is calculated as follows:

$$M = 0.1CA$$

13 *M:* Mass of the empty magazine in kilograms
C: Capacity of the magazine in rounds of ammunition
A: Mass or a single round of ammunition in kilograms.

14

8. Muzzle Energy: The muzzle energy of the weapon is a function of its warhead mass and its velocity. Muzzle energy is calculated using the following formula:

$$E = (0.5M)V^2$$

E: Muzzle energy in joules
M: Warhead mass in kilograms
V: Muzzle velocity in meters per second, as shown below:

Vel.	V	V^2
Low	75	5625
Medium	125	15,625
High	250	62,500
RAM	75	5625

9. Recoil: The weapon's recoil when firing a single shot can be calculated.

$$R = \{[(0.15\sqrt{E})+Mw] + Em\} \times Rcm$$

R: Recoil number
E: Muzzle energy
Mw: Mass, in kilograms, of weapon (use empty mass for belt- and cassette-fed weapons, loaded mass for all others)
Rcm: Recoil compensator modifier.
Em: Modifier for high muzzle energy. If the weapon has high muzzle energy, add to the final recoil as shown on the chart below.

E	Em	E	Em
1001+	1	10,001+	4
2501+	2	20,001+	5
5001+	3	50,001+	6

When calculating the recoil energy of a burst of shots, the following formula is used:

$$R = (\{[(Bn+2)(0.15\sqrt{E})]+Mw\} + \{[Bn+2]Em\}) \times Rcm$$

Bn = number of shots in the burst.

10. Price: The price of the weapon is calculated using the following formula:

$$P = (Mw–Ms)Am+Ps+Pc$$

P: Total price of the weapon in credits
Mw: Mass of the weapon in kilograms
Ms: Mass of the weapon stock in kilograms
Am: Action modifier: Single shot = 250, Pump = 100, Semiautomatic =200, Automatic = 100
Ps: Price in credits of the stock, as shown below:

TL	Stock Type	Price
4	Pistol Grip	5
4	Fixed Stock	25
5	SA Stock	50
6	Folding Stock	50
7	SA Stock	75
9	Folding SA Stock	150
9	SA Stock	75

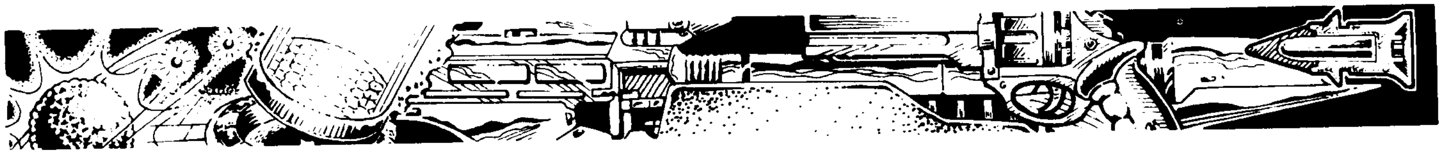
Pc = Price of the recoil compensator, if one is added. Gyrocompensators cost Cr300. Inertial compensators cost Cr1000.

10. Mount: A mounted weapon may be mounted on a vehicle or it may have a field mount. A field mount may be of any mass desired, so long as its mass in kilograms is equal to or greater than the highest base recoil number of the weapon (usually attained when firing a burst).

The price of a field mount is determined by the following formula:

$$Cr = 100 + (10M)$$

Cr: Price in credits
M: Mass of field mount



TAC MISSILE LAUNCHERS

A tac (tactical) missile is one designed for use in planetary combat. Tac missile launchers consist of two elements: the launch system itself and the control unit.

A. Launch Unit: Launch units hold the missile prior to firing and ensure a clean launch once it is fired. There are several different ways of designing a launch unit.

1. Launch Rail: A launch rail is usually mounted on a vehicle or an aircraft and it consists of a simple guide rail on which the missile is mounted by means of brackets. A launch rail has the same mass as a missile, negligible volume (beyond the volume of the missile itself), and costs Cr50 per kilogram of mass.

2. Package Launcher: Package launchers consist of a container holding the missile and a clip-on guidance system. Once launched, the guidance system is detached and the package discarded. The package has half the mass of the missile contained in it and twice its volume. (The missile is carried inside the package, however, so add its mass and ignore its volume when calculating the final values.) The package costs Cr10 per kilogram of package (not missile).

3. Tube Launcher: These are reloadable launch tubes either mounted on field mounts or on vehicles. The tube has four times the mass of the missile it is designed to carry and costs Cr100 per kilogram. If on a field mount (which for lighter launchers can be as simple as a tripod), the mount masses the same as the launcher and costs Cr10 per kilogram. See magazine launcher below for characteristics of the field mount.

4. Magazine Launcher: This is a more sophisticated version of the tube launcher, consisting of a standard tube launcher and a fixed magazine of tac missiles. The magazine will automatically reload a missile each time one is fired, eliminating the necessity for the gunner or loader to do so manually. (Manual reloading often requires that the gunner or loader expose themselves in a hostile environment.) Magazines are not usually detachable from magazine launchers. Instead, missiles are loaded directly into the magazine when reloading is convenient.

The empty magazine for a magazine launcher masses half the mass of the total number of missiles carried in it and costs Cr100 per kilogram. If mounted on a field mount, the mount must have mass equal to the tube launcher used and a loaded magazine (empty magazine mass plus the mass of the loaded missiles). The field mount costs Cr10 per kilogram of mass.

5. Gun Tube: A CPR or mass driver gun of the correct size can be modified to serve as a missile launcher by the addition of a control unit. Gun tubes may not be modified to launch wire-guided missiles, as there is no safe and efficient way to allow the control wire to unspool through the breach while simultaneously sealing the breach and keeping rocket exhaust from injuring the crew.

B. Control Units: The various guidance systems are explained in detail in the Munitions chapter. Most of these guidance systems require supporting hardware as part of the launcher.

1. Command Guided: In this guidance system, the operator must pilot the warhead to the target. These guidance systems are distinguished by their operating system and their command link.

The characteristics of the various operating systems are shown on the table below.

TL	*Type*	*Mass*	*Cr*
5	Manual	10	400
6	Semiauto	15	800
7	Automatic	15	1200
8	Teleguidance	15	1500

TL: Tech level of first availability

Type: Operating system used

Mass: Mass in kilograms of the control unit used by the weapon operator.

Cr: Price in credits of the control unit used by the weapon operator.

Volume: All control units have a volume of 1 liter per kilogram.

In addition to an operating system, a command-guidance package must have a communication link between the operator's control unit and the controller in the warhead itself. The table below summarizes the characteristics of various communication links.

TL	*Type*	*Mass*	*Cr*	*Range (km)*
5	Wire	—	—	2
6	Wire	—	—	4
7	Wire	—	—	6
5	Radio	5	200*	**
6	Radio	5	200*	**
7	Laser	5	1000	10
8+	Laser	5	500*	**

TL: Tech level of first availability

Type: Comm link used

Mass: Mass in kilograms of the comm link in control unit used by the weapon operator.

Cr: Price in credits of the comm link in the control unit used by the weapon operator.

* Radio-controlled guidance and tech level 8 laser-controlled guidance also requires a radio communicator or a laser communicator as part of the operator's control unit. These are purchased separately from the communicators available in the Electronics chapter (Section 5). Note that the tech level 7 laser control unit already includes a laser comm link.

Range: The longest allowed range using the listed communication link.

** The range of radio-guided warheads and tech level 8+ laser-guided warheads is equal to the long range of the communicator installed in the control unit.

Volume: All comm links have a volume of 1 liter per kilogram.

2. Target Designated: This guidance system employs a
seeker head in the warhead which enables it to home in on the
1 reflected radiation of a designator, either a laser or a radar. Target-
designated missiles also require a radar transmitter or a laser desig-
nator to illuminate the target. Standard radars or laser communica-
tors may be used to designate a target for a missile provided they are
2 modified to do so. Target-designation modifications do not affect
the volume, mass, or power requirements of the equipment, but
multiply its price by 1.5. The effective range of the missile from the
designator is equal to the equipment's normal medium range (twice
3 short range).
At tech level 7 (before laser communicators are routinely avail-
able), purpose-built laser designators may be purchased. These have
a useful range of 6 kilometers (i.e., a short range of 3 kilometers), a
4 mass of 16 kilograms, a volume of 8 liters, and a price of Cr12,000.
They are powered by internal batteries good for several hours of use
before replacement or recharging are required.
3. Homing: These guidance systems lock onto and home
5 on certain well-defined levels of emissions of radiation. The control
unit in this case is simply a small data repeater the tells the operator
when the missile has locked onto a target. Its mass is 0.5 kilograms,
and its price is Cr500.
4. Smart Warheads: Smart warheads encompass two methods of
6 guidance: target memory and target seeker. Both are true "fire-and-
forget" weapons, but they are distinguished by what the operator is
required to do prior to firing.
The characteristic of smart guidance systems are shown below:

7

TL	*Type*	*Mass*	*Cr*	*AGL*
7	Memory	10	1000	–1
8	Memory	10	1000	—
8-10	Seeker	5	500	–2
11-13	Seeker	5	500	—
14+	Seeker	5	500	+2

8

TL: Tech level of first availability.
9 **Type:** Target memory or seeker.
Mass: Mass in kilograms of the control unit used by the weapon
operator.
Cr: Price in credits of the control unit used by the weapon
10 operator.
AGL: Modification to the missile's final Agility rating (if mounted
on a missile).
Volume: All control units have a volume of 1 liter per kilogram.

11

DIRECT FIRE ROCKET LAUNCHERS

Unguided rockets designed using the rules in the Munitions
chapter must have launchers in order to fire. In general, these
12 launchers are extremely simple and consist either of a launch rail or
tube. Rocket pods with multiple rockets are also possible, as are
single-shot disposable rocket launchers which double as carrying
containers for the rocket.
13 **A. Empty Mass:** The mass of a reloadable rocket launcher is
determined using the following formula:

$$M = DTCm$$

M: Mass in kilograms
14 *D:* Diameter of the rocket warhead in centimeters
T: Number of tubes in the launcher
Cm: Configuration modifier, as shown below:

Config	*Cm*
Single-Shot Reloadable	1
Multi-Shot Reloadable	.5
Single-Shot Disposable	.4
Multi-Shot Disposable	.2

B. Loaded Mass: The loaded mass of the launcher is its empty mass plus the mass of its rockets. Any weapon with a loaded mass of 45 kilograms or less can be shoulder-fired. Heavier weapons require a field mount (tripod or carriage). Field mounts must be of equal or greater mass than the loaded weapon.

C. Fire Control: Any shoulder-fired weapon includes optic sights in the basic weapon package and no additional mass or price is required. Heavier weapons on a field mount require direct fire controls. Consult the Fire Control chapter (Section 14) for masses and prices. (However, disregard the short range limit.)

D. Price: The price of the launcher in credits is equal to its mass in kilograms multiplied by 35. The price of a field mount is determined by the following formula:

$$Cr = 100 + (10M)$$

Cr: Price in credits
M: Mass of field mount.

E. Range: The short range of a reloadable rocket launcher is the maximum design range of the rocket fired by the launcher divided by 8, but may not exceed 200. The range of a disposable rocket launcher is its the normal short range of the rocket multiplied by 0.75.

F. Bulk: Calculate as for energy weapons (page 122), but treat results greater than 12 as 12.

ARTILLERY ROCKET LAUNCHERS (ARLS)

Artillery rockets are used for indirect instead of direct fire. In general, these launchers are extremely simple and consist either of a launch rail or tube. Most artillery rocket launchers are multiple launchers.

A. Empty Mass: The mass of the launcher in tonnes is equal to the diameter of the rocket warhead (in centimeters) squared, multiplied by the number of launch tubes, multiplied by .002. If an autoloader is incorporated into the launcher, its mass is equal to the empty launcher mass times 0.1. Autoloaders may only be incorporated on vehicle-mounted ARLs.

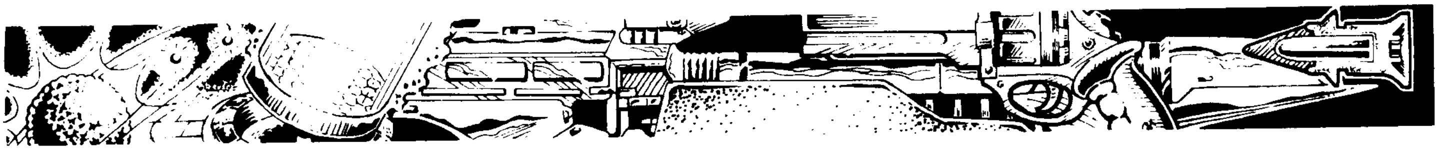
B. Fire Control: Artillery rocket launchers must have indirect fire control fitted. See the Fire Control chapter (Section 14) for details.

C. Loaded Mass: The loaded mass of the launcher is equal to the empty mass of the launcher plus the mass of the fire control equipment plus the mass of the rockets.

D. Carriage Mass: Towed weapons require a carriage of equal or greater mass than the loaded mass of the launcher. Self-propelled launchers are carried as part of a vehicle and have a volume equal in cubic meters equal to their loaded mass in tonnes.

E. Rate of Fire: An artillery rocket launcher may salvo all of its tubes in a single combat turn. It takes 10 minutes (120 combat turns) to reload a launcher by hand. It takes five minutes (60 combat turns) to reload it using an autoloader.

F. Crew: The crew required to serve a towed (carriage-mounted) indirect fire artillery rocket launcher is equal to its bore size in centimeters multiplied by the number of launch tubes and divided by 10 (but never less than two). Vehicle-mounted weapons require a crew half this size, rounding fractions up, but never less than two. Vehicle-mounted weapons equipped with autoloaders require a crew of only one (the gunner).



If the weapon is designed to be fired only once (as with a remote disposable launcher), loaders are not required and so crew size is reduced to one.

G. Range: Artillery rockets have an indirect fire range in kilometers equal to five times the maximum design range of the rocket.

H. Price: The price of the weapon is equal to the sum of the prices of its components. Fire control equipment costs are listed in the Fire Control chapter (Section 14). The prices of the other components (in millions of credits) are determined by multiplying their mass (in tonnes) by the component multipliers listed below:

Component	*Multiplier*
Launcher	0.01
Loader	0.01
Carriage	0.002

I. Set-Up: A launcher must be set up before it can fire. The set-up time for an ARL (regardless of how many launch tubes it has) in combat turns is equal to the diameter of its missile warhead in centimeters multiplied by 8. If self-propelled, the set-up time is its warhead diameter multiplied by 4. If self-propelled and equipped with a TL 8 or higher landnav system, set-up time is warhead diameter multiplied by 2.

RECOILLESS RIFLES

Recoilless rifles are direct fire weapons designed to deliver a large warhead from a light weapon. This is accomplished by reducing the recoil of the weapon virtually to nil. The recoilless rifle counters the normal recoil associated with firing a projectile by venting an equal amount of energy to the rear in the form of exhaust gas. This makes the weapon similar to a rocket, in that it has a pronounced exhaust when fired and virtually no recoil, but also similar to a CPR gun in that the propellant charge burns all at once and thrusts the separate projectile out the muzzle of the gun tube.

A. Types of Recoilless Rifles: There are two general configurations of recoilless rifles: light and heavy. Light recoilless rifles are designed to be man-portable and fired from the shoulder of an infantry soldier. Heavy recoilless rifles are mounted on carriages and generally have heavier actions and longer barrels to achieve greater range.

B. Tech Level: Recoilless rifles may be built at tech level 5 and above. Tech level advances make recoilless rifles more efficient, particularly with regard to mass.

C. Empty Mass: The empty mass of a light recoilless rifle is equal to its bore diameter squared and multiplied by a tech level mass multiplier as shown below:

TL	*Mass Multiplier*
5	0.6
6	0.4
7	0.3
8+	0.2

Heavy recoilless rifles mass twice this amount. In addition, a heavy recoilless rifle requires a field carriage with a mass equal to or greater than the empty mass of the weapon. Light recoilless rifles do not require a carriage.

D. Fire Control: Any shoulder-fired weapon includes optic sights in the basic weapon package and no additional mass or price is required. Heavier weapons on a field mount require direct fire controls. Consult the Fire Control chapter (Section 14) for masses and prices.

E. Loaded Mass: The loaded mass of the recoilless rifle is equal to its weapon mass, fire control mass (if any), carriage mass (if any), and the mass of one round of ammunition.

Light recoilless rifles may not have a loaded mass of greater than 1
45 kilograms.

F. Range: Light recoilless rifles have a short range in meters equal
to their bore diameter in centimeters multiplied by 20. Heavy
recoilless rifles have a short range equal to their bore diameter 2
multiplied by 30.

H. Price: The price of the weapon is equal to the sum of the prices
of its components. Fire control equipment costs are listed in the Fire
Control chapter (Section 14). The prices of the other components (in 3
millions of credits) are determined by multiplying their mass (in
tonnes) by the component multipliers listed below.

Component	*Multiplier*	
Weapon	0.01	4
Carriage	0.002	

I. Bulk: Calculate as for energy weapons (page 122), but treat
results greater than 12 as 12. 5

SPACE MISSILE LAUNCHERS

Launch facilities for missiles from spacecraft are comparatively
simple. Each launch facility consists of a standard crew workstation,
a 300,000-kilometer-range laser communicator, and one or more 6
launchers. Missile launchers may have their own active or passive
sensors and master fire directors installed, but are not required to do
so, as they are able to use target locks obtained by sensors mounted
elsewhere on the ship, and hand off control of their missiles to MFDs 7
elsewhere on the ship. A launch facility may (but need not) also
contain a mechanical reloader and one or more reload cradles.

The laser communicator may not be from a higher tech level than
the installed workstation, but missiles of any tech level may be fired 8
from the launchers. Volumes, masses, and prices of communicators
and workstations are found in the Electronics and Control Systems
chapters (Sections 5 and 4) respectively.

Each launcher has a volume equal to twice that of the missile it is 9
designed to launch. Its mass in tonnes is equal to its volume in cubic
meters multiplied by 0.5, and its price in millions of credits is equal
to its volume in cubic meters multiplied by .0007.

Normally, an hour is required to reload a missile launcher, but this 10
time can be cut to effectively nothing (five to 10 minutes—less than
one space combat turn) by the addition of a mechanical reloader. A
mechanical reloader has the same volume, mass, and price as a
missile launcher. Each actual launcher in a launch facility must have 11
its own mechanical reloader if it is to be reloaded mechanically.

Mechanical reloaders use spare missiles carried in the launch
facility in reload cradles. The volume of each reload cradle is equal
to the volume of the missile carried multiplied by 1.5 and its price 12
in millions of credits is equal to its volume in cubic meters
multiplied by .0001.

Note that missiles carried in launchers and reload cradles do not
count against the volume of the launch facility, as the launchers and 13
reload cradle volumes include the vacant spaces for the missiles.

Missile launch facilities may be of any volume desired. Facilities
designed to fit in standard turret hardpoint sockets may not displace
more than 3 tons (42 cubic meters), and launch facilities designed 14
to fit in standard barbette hardpoint sockets may not displace more
than 6 tons (84 cubic meters). Bays are usually designed in increments of 50 or 100 displacement tons, but there is no specific
requirement that all launch facilities conform to those dimensions.

CHAPTER 11

1 ## Airborne Weapons Mounts

The following information is provided for airborne weapons mounts. What distinguishes these mounts from conventional mounts is that drag is a consideration.

2

Gun Mounts

	TL	Type	Drag	Mass	Capacity	Price
	4	Fixed Mount	0	0	RE = 0.2 per tonne of acft	0
3	4	Flexible Mount	1	0.005	RE = 0.05	.0001
	5	Fixed Mount	0	0	RE = 0.5 per tonne of acft	0
	5	Turret	1	.4	RE = 0.1	.005
	5	Heavy Turret	2	.5	RE = 0.2	.05
4	6	Remote Turret	1	.5	RE = 0.3	.05
	6	Heavy Turret	2	.5	RE = 0.5	.05

TL: Tech level of first availability.
5 **Type:** Description of weapon mount.
Drag: Drag points.
Mass: Mass, in metric tonnes, of the mount, exclusive of ordnance.
Capacity: All gun mount capacities are given in terms of the recoil
6 energy (RE) of the weapon placed in the mount. Recoil energy, for purposes of this rule, is defined as the required carriage weight, in tonnes, of the weapon. (The carriage itself is not mounted in the aircraft, as the gun mount takes its place.)

7 An aircraft may have fixed forward-firing weapons mounted with recoil energy equal to the loaded weight of the aircraft (in tonnes) times 0.2 at tech level 4 and equal to the loaded weight times 0.5 at tech level 5 and above.

Each small arm machinegun (less than 2cm in bore) counts as a recoil energy of 0.05 for purposes of gun mount capacity.

Price: Price, in millions of credits, of the mount, exclusive of weapons.

Ordnance Pods

Almost any weapon or piece of electronic equipment can be mounted in a streamlined pod and hung from a hardpoint. Weapons must include an ammunition supply while electronic equipment must include a power supply or have power needs modest enough to be supplied by the aircraft carrying the pod. Pods may be fitted with power-generating ram-air turbines to supply their own power needs. MW of power per pod is based on airframe type. Ram-air turbines do not function well in supersonic airflows.

Airframe	MW
Simple	0
Fast Subsonic	0.5
Transonic	1
Supersonic	0.5
Hypersonic	0

All pods add 10% to the mass, volume, and price of the components contained in the pod. Pods with ram-air turbines add 20%.

Fuel may also be carried in streamlined pods hung from hardpoints. These are called drop tanks and may only be carried on plumbed hardpoints. The mass and volume of the tank is equal to the mass and volume of the fuel carried multiplied by 1.1 and cost Cr1 per kilogram of mass.

8

Ordnance Racks, Launch Rails, and Hardpoints

	TL	Type	Drag	Mass	Capacity	Price
9	4	FHP (dry)	(1)	0.02	2000 kg*	.002
	4	IWHP (dry)	(1)	0.02	1500 kg**	.002
	4	OWHP (dry)	(1)	0.02	500 kg***	.002
	5	Wingtip Launch Rail	(1)	0.01	1x100-kg missile/rocket	.0001
10	5	FHP (plumbed)	(1)	0.03	2000 kg/liters*	.0025
	5	IWHP (plumbed)	(1)	0.03	1500 kg**	.0025
	5	Internal Bomb Bay	0	1.00	1 tonne bombs*****	.015
	6	Triple Bomb/missile rack****	(2)	0.05	3 bombs/missiles (within hardpoint capacity)	.004
11	6	Multiple Bomb/missile rack****	(4)	0.1	6 bombs/missiles (within hardpoint capacity)	.008
	7	Retractable Missile Bay	0	1.00	1 tonne missiles*****	.030

TL: Tech level of first availability.
12 **Type:** Description of weapon mount.
Drag: Drag points. Values in parentheses are only in effect when the rack, rail, or harpoint is loaded.
Mass: Mass, in tonnes, of the mount, exclusive of ordnance.
Capacity: Ordnance which can be carried by the mount.

13 * FHPs (Fuselage Hardpoints) may carry 2000 kg of ordnance (2000 liters of fuel if plumbed) *or* 10% of the aircraft's loaded weight, whichever is more.

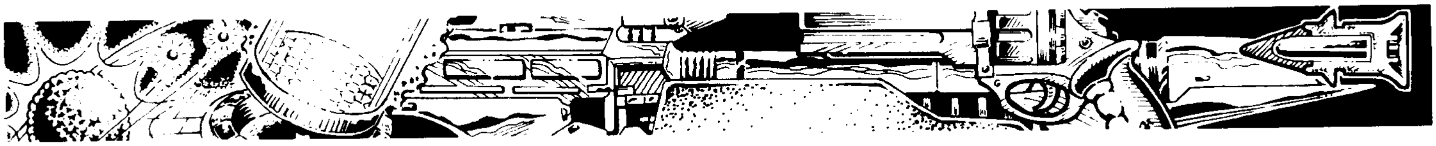
** IWHPs (Inboard Wing Hardpoints) may carry 1500 kg of ordnance (1500 liters of fuel if plumbed) *or* 7.5% of the aircraft's loaded weight, whichever is more.

14 *** OWHPs (Outboard Wing Hardpoints) may carry 500 kg of ordnance *or* 2.5% of the aircraft's loaded weight, whichever is more.

****Racks are fitted to hardpoints to allow carriage of multiple weapons.

*****Capacity based on mass. Volume is assumed to be sufficient for indicated mass of ordnance.

Price: Price, in millions of credits, of the mount, exclusive of ordnance.



APPENDIX 1
Standard Socket-Sized Weapons and Defenses for Installation Aboard Spacecraft

1

Sandcasters for Standard Turret Sockets

TL	Price	Cannisters Carried	Beam Reduction
8	**0.6**	**16**	**1D6×6**
9	0.65	18	1D6×5
10	**0.7**	**20**	**1D10×5**
11	0.75	24	1D10×5
12	**0.8**	**30**	**1D10×5**
13	0.85	35	2D6×5
14	**0.9**	**40**	**2D6×5**
15	1	50	2D10×5

Price: Price of turret in millions of credits; **Cannisters Carried:** Number of sand cannisters carried in turret; **Beam Reduction:** Beam reduction made per successful beam interception

2

Turret and Barbette Socket Missile Launchers

Type	TL	Missiles	Volume	Weight	Power	Price
Turret	**8**	**2**	**42**	**28.4**	**0.15**	**0.08**
Barbette	8	5	84	70.4	0.15	0.11

3

Volume: In kiloliters; **Weight:** In tonnes; **Power:** In megawatts; **Price:** In millions of credits (without missiles)

4

Nuclear Dampers for Standard Turret and Barbette Sockets

TL	Description	Mass	Price	Power
12	**Damper Barbette**	**75.2**	**1.95**	**15**
13	Damper Barbette	72.2	2.7	9
14	**Damper Barbette**	**60.2**	**4**	**6**
15	Damper Turret	33.2	4.5	3

5

Mass: In tonnes; **Price:** In millions of credits; **Power:** In megawatts

6

Sample Space Missiles for Socket Missile Launchers

TL	Guidance	Yield	Mass	MCr	G-Turns	Hits	Damage	Range	Comm	Sensor	Signatures
8	**Controlled**	**50**	**7**	**0.85**	**10/10**	**1D6**	**1/14-43**	**0**	**10L**	**—**	**+2/+2/+2/+2/+1**
9	Controlled	50	7	0.85	12/12	1D6	1/14-43	0	10L	—	+2/+2/+2/+2/+1
11	**Controlled**	**100**	**7**	**0.95**	**12/12**	**1D6**	**1/18-56**	**0**	**10L**	**—**	**+2/+2/+2/+2/+1**
12	Semi-Ind.	500	7	2.0	8/8	1D6	1/25-79	0	10L	1P	+4/+3/+4/+3/+1
13	**Controlled**	**200**	**7**	**1.15**	**12/12**	**1D6**	**1/21-66**	**0**	**10L**	**—**	**+2/+2/+2/+2/+1**
14	Semi-Ind.	500	7	2.7	8/8	1D6	1/25-79	0	10L	3P	+4/+3/+4/+3/+1
15	**Controlled**	**500**	**7**	**1.25**	**12/12**	**1D6**	**1/25-79**	**0**	**10L**	**—**	**+2/+2/+2/+2/+1**

7

8

Yield: Warhead yield; **Mass:** In tonnes; **MCr:** Price in millions of credits; **G-Turns:** Number of G-turns of fuel carried (followed by maximum number of G-turns which can be used in a single turn); **Hits:** Die roll for number of hits from the laser; **Damage:** Damage value of each laser hit; **Range:** Absolute range in hexes (0 = same hex only); **Comm:** Type of communicator (L = laser, M = maser, R = radio); **Sensor:** Sensor range (in hexes) and type (R = radar, T = high-resolution thermal, L = ladar, A = active EMS, P = passive EMS); **Signatures:** Missile's signature vs. radar, active EMS, HRT, passive EMS, and fire. **Standard missiles have a volume of 7 cubic meters (1/2 displacement ton).** 9

10

Sample Standard Turret and Barbette Socket Lasers

TL	Description	MW	MCr	Mass	Short	Medium	Long	Extreme
10	**60-Mj laser turret**	**1.7**	**1.56**	**55**	**1:1/6-19**	**2:1/6-19**	**4:1/3-9**	**8:1/2-5**
11	80-Mj laser turret	2.2	2.08	59	2:1/7-22	4:1/7-22	8:1/6-19	16:1/3-10
11	**150-Mj laser barbette**	**4.2**	**6.56**	**119**	**10:1/10-31**	**20:1/5-17**	**40:1/3-8**	**80:1-4**
12	120-Mj laser turret	3.3	0.94	65	4:1/9-27	8:1/9-27	16:1/6-19	32:1/3-9
13	**150-Mj laser turret**	**4.2**	**0.72**	**68**	**1:1/10-31**	**2:1/10-31**	**4:1/10-31**	**8:1/10-31**
13	106-Mj laser turret	2.9	1.45	59	10:1/8-26	20:1/6-20	40:1/3-10	80:1/2-5
14	**150-Mj laser turret**	**4.2**	**0.72**	**63**	**2:1/10-31**	**4:1/10-31**	**8:1/10-31**	**16:1/10-31**
14	300-Mj laser barbette	8.3	2.16	131	10:1/14-43	20:1/14-43	40:1/8-26	80:1/4-13
15	**150-Mj laser turret**	**4.2**	**0.86**	**57**	**10:1/10-31**	**20:1/10-31**	**40:1/10-31**	**80:1/10-31**

11

12

13

MW: Required power input in megawatts; **MCr:** Price in millions of credits; **Mass:** In tonnes; **Short, Medium, Long, Extreme:** Combat performance at these ranges: range in hexes: penetration rating-damage value.

Note: These weapons are the same as those published, with slightly different details, in **Brilliant Lances and first printing** TNE. The differences are due to slightly different rounding conventions from an earlier version of the design sequence. These have been changed in order to give the designer greater control over details of the design. These figures are calculated using the sequences in this book, are official changes, and will be incorporated into future printings of these products. However, players may continue to use the **earlier** values, as the number of different designs and weapons manufacturers in charted space will result in reasonable variation in performance details. 14

APPENDIX II

1 ## Using Alternate Technologies

To make alternate technologies easy to integrate in your **Traveller** game, we have provided a suggested baseline tech level of introduction and, where appropriate, indicated the tech levels where addi-
2 tional improvements become available. This constitutes a pre-set "slope" for technological innovation which referees may use as a starting point or alter as they see fit.

To vary the technological underpinnings of your campaign, three
3 methods are available.

1. Alternate Technology: Method number one alters the physical universe by using one or more of the alternate technologies presented in the book, either in addition to or as a substitute for some
4 technology already included in **Traveller**. This method can be as simple as just deleting a piece of projected technology from the mix (such as contra-gravity, jump drive, EAPlaC, HEPlaR, laser focusing, or meson screens) and relying on remaining baseline technologies
5 to fill the gap created.

2. Altered Initial Availability: The tech level at which projected technology becomes available can be moved forward or back. Teleportation is an excellent example of this. Matter transmission is set at such a high tech level of initial vailability that it will effectively play no part in any **Traveller** Imperial Space campaign. By moving its availability to tech level 8, the technological basis of the universe (and its adventuring elements) is changed greatly.

3. Altered Slope: Slope is the rate at which technological change is accomplished. (See page 7 for an explanation of slope.) Raising or lowering the slope has a profound effect on the nature of the gaming universe, and referees building their own universe will almost certainly want to tinker here. A cyber-heavy universe, for example, would probably have a steeper slope on cybernetics than is presented in the chapter as it currently stands, with much more of the equipment available at earlier tech levels. A universe where starship combat is difficult, or limited mostly to large line-of-battle ships, might have a much more shallow slope on laser focussing, as well as other directed energy weapon designs.

You will find that by using these three tools and the design sequences provided in this book, virtually any science-fiction universe can be tailored.

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6 # APPENDIX III Design Examples

7 ## Design Example: 7mm TL-10 ACR (ETC)

This will proceeed pretty much in the same order as the design sequence itself. I experimented with several different values for Lcc, E, and Bl until I got numbers for damage and range that I liked (these
8 experimental calculations are not shown here to conserve space). Refer to the design sequence for the meaning of the abbreviations used in the various formulae.

9 ## PART I: Ammunition Design

Tech Level: 10
Bullet: 7mm
Cartridge Case Length: 30mm
10 **Cartridge Case Type:** Necked ETC

Ammunition Evaluation

Length: 44mm
11 Lan = Lcc+2xd = 30+2×7 = 44
Weight: 12 grams
Wa = AwcLccπr² = 0.01×30×3.1416×3.5×3.5 = 11.5454, rounds to 12
12 **Average Muzzle Energy:** 4803 joules
Ea = TmCmLccπr² = 1.3×3.2×30×3.1416×3.5×3.5 = 4802.8781, rounds to 4803
Price: Cr0.24
13 Cr = WTm = 12×0.02 = 0.24

Special Ammunition

HE: TL-6+. Price for HE rounds is multiplied by 2: 0.24×2 = 0.48
14 **DS:** Tech level 8+. Price for DS rounds is multiplied by 2: 0.24×2 = 0.48
HEAP: Tech level 9+. Price for HEAP rounds is multiplied by 3: 0.24×3 = 0.72
Tranq: Tech level 6+. Price for Tranq rounds is multiplied by 2: 0.24×2 = 0.48

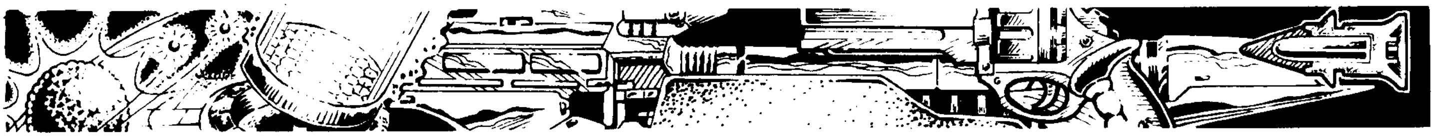
PART II: Weapon Design

1. BARREL

Average Barrel Length: 49 cm
Bla = (Ea+d²)Rm = (4803+7×7)×0.5 = 49.01021 rounds to 49
Actual Barrel Length: 49 cm (10 to 113)
Type of Barrel: Light barrel
Barrel Weight: 0.98 kg
Wbl = 0.02Lb = 0.02×49 = 0.98
Barrel Price: Cr392
Cr = WbxBtm = 0.98×400 = 392.00
Actual Muzzle Energy: Ball, HE, HEAP, & DS: 4803, Tranq: 2882
E = Ea{1+[0.5(Blp-1)]} = 4803×{1+[0.5×(1-1)]} = 4803
Damage: Ball, HE, HEAP, & DS: 5, Tranq: –1*
Ball & DS: D = √E+15 = 69.303679+15 = 4.620245 = 5
HE/HEAP: 7+10 = 17, 17-7 = 10, 10³ = 1000, 1000+4803 = 5803. √5803 = 76.177, 76.177+15 = 5.079 = 5
Tranq: All Tranq round damage = –1 (1D6–1), plus the effects noted in the rules.
Penetration: Ball: 2-3-Nil, DS: 1-2-3, HEAP: 2-2-2, HE & Tranq: Nil.

2. RECEIVER

Receiver Type: Light, self-loading, electrothermal receiver, with selective fire option.
Rate of Fire: 5
Receiver Length: 31 cm
Lr = Tc√Ea = 0.45×69.303679 = 31.186656 = 31
Receiver Weight: 2.702 kg
WrlET = 0.0005Ea+0.3 = 0.0005×4803+0.3 = 2.7015
Receiver Price: Cr875.5
CrEt = (WrAm)+200 = (2.702×250)+200 = 875.5



3. STOCKS

Bullpup stock

Range: Ball: 81, DS: 97, HE/HEAP: 61, Tranq: 30.

SR = $\sqrt{E}$CmBlm = 69.303679×1.17×1 = 81.085305 = 81

DS: 81×1.2 = 97.2 = 97

HE/HEAP: 81×0.75 = 60.75 = 61

Tranq: SR = $\sqrt{E}$CmBlm = 53.68426×1.2×1= 64.42111×0.6 = 38.652668 = 30 (upper limit)

Blm: Modification to short range for barrel length = 1

Blm = 1+[(Blp-1)C] = 1+[(1-1)×0.75] = 1

Cm: 0.9×1.3 = 1.17

4. FEED SYSTEM

Box Magazine: A 20-round detachable box magazine standard issue. This weapon's cartridge is 44mm long, which means that the receiver must be at least 194mm or 19.4 cm to use a box magazine.

Magazine Weight: 0.553 kg

Wm = 0.0006(N+4)Wa = 0.0006×(20+4)×12 = 0.1728, plus 0.019×20 = 0.5528 rounds to 0.553

Magazine Price: 10×0.2592 = 2.592, rounds to Cr3, plus 20×5 = Cr103

5. OPTIONS

Sights: Electronic and laser sights fitted as standard equipment.

Recoil Reduction: Muzzle brake, gyroscopic compensator, and electrothermal action.

Bayonet Lugs: Standard equipment.

Grenade Adapter: RAM shoot-through grenade adaptor fitted as standard equipment.

Flash Suppressor

Length: 1cm per 300 joules of muzzle energy 4803÷300 = 16.01 = 16 cm

Weight: .01 kg per cm of length 16×0.01 = 0.16 kg

Price: Cr1 per cm of length = Cr16

6. TINKERING THE DESIGN

None needed.

EVALUATION

Total the various components:

	Length	*Weight*	*Price (Cr)*
Barrel	49	0.98	392
Receiver	31	2.702	875.5
Bullpup Stock	5	0.1	10
Electronic sights		0.2	2000
Laser sights		0.5	300
Gyros. Comp.		0.5	300
Flash Supressor	16	0.16	16
Muzzle Brake (4 cm)		0.2	50
Grenade Adaptor	5	—	50
Bayonet Lug		—	—
Magazine		0.553	103
Weapon, Empty	106 cm	5.895	4096.5
20 rounds 7×46mm		0.24	4.8
Weapon, Loaded	106 cm	6.135	4101

Determine bulk:

Bulk: 106÷15 = 7.06 = 7

and proceed to determining recoil

Recoil:

Single shot:

R = {[(0.15$\sqrt{E}$)+Ww]+Em}Rcm

Ball, HE, HEAP, & DS: R = {[(0.15×69.303679)+6.135]+2}×0.23 = 0.849 = 1

Tranq: R = {[(0.15$\sqrt{E}$)+Ww]+Em}Rcm={[(0.15×53.684262) + 6.135]+2}×0.23 = 0.762 = 1

R: Recoil number

E: Muzzle energy (in joules) = Ball, HE, HEAP, & DS: 4803, Tranq: 2882

$\sqrt{E}$ = Ball & DS: 69.303679, Tranq: 53.684262

Ww: Weight, in kilograms, of weapon (loaded) = 6.135

Rcm: Recoil compensator modifier = 0.6×0.5×0.75 = 0.23

Em: Modifier for high muzzle energy. 2501-5000 joules = 2

Bn: Number of shots in the burst.

Burst:

R = ({[(Bn+2)(0.15$\sqrt{E}$)]+Ww}+{[Bn+2]Em})×Rcm

Ball, HE, HEAP, & DS: R = ({[(5.0+2)×(0.15×69.303679)] + 6.135}+{[5+2]×2})×0.23 = 2.124 = 2

Tranq: R=({[(5.0+2)×(0.15×53.684262)] + 6.135}+ {[5+2]×2})×0.23 = 1.904 = 2

Finally, we note the weapon's statistics in usable form

7×46mm ETC TL-10 ACR

TL: 10
Ammo: 7×46mm ETC (TL-10)
Weapon Weight: 6.135 kg loaded, 5.895 empty
Magazine Weight: 0.793 kg loaded, 0.553 kg empty
Magazine Price: Cr3
Damage: Ball, HE, HEAP, & DS: 5, Tranq: –1*
Penetration: Ball: 2-3-Nil, DS: 1-2-3, HEAP: 2-2-2, HE & Tranq: Nil.
Range: Ball: 81, DS: 97, HE/HEAP: 61, Tranq: 30.

Round	ROF	Dam	Pen	Blk	Mag	— Recoil — SS	Brst	Rng
7×46mm Ball	**5**	**5**	**2-3-Nil**	**67**	**20**	**1**	**2**	**(81) 101**
7×46mm DS	5	5	1-2-3	7	20	1	2	(97) 117
7×46mm HE	**5**	**5**	**Nil**	**7**	**20**	**1**	**2**	**(61) 81**
7×46mm HEAP	5	5	2-2-2	7	20	1	2	(61) 81
7×46mm Tranq	**5**	**–1***	**Nil**	**7**	**20**	**1**	**2**	**(30) 30**

* See **Traveller** rules, page 350.
Range in parentheses is iron sight range, other range is with electronic sight.

7×46mm ETC, per round

Caliber:	TL	Length (mm)	Weight (grams)	AME (Joules)	Price (Cr)
7×46mm Ball-9	**10**	**44**	**12**	**4803**	**0.24**
7×46mm DS-9	10	44	12	4803	0.48
7×46mm HE-9	**10**	**44**	**12**	**4803**	**0.48**
7×46mm HEAP-9	10	44	12	4803	0.72
7×46mm Tranq-9	**10**	**44**	**12**	**2882**	**0.48**

Design Example: TL-13 Plasma Cradle Gun (Vehicle-Mounted)

SPECIFICATIONS

TL: 13
Pulse Energy: 12 Mj
Fire Control: Comes with basic optic sights. TL 12 ballistic computer added. (Mass = 0.04 tonnes. Price = MCr0.1. Fire Control rating = –4 Diff Mods)
Mount: Cradle (for vehicle mounting)
Cartridge: Tech level 12 Plasma Pulse Cartridge, 12 Mj
Volume: (12x.0003=) .0036 cubic meters
Price: (12x.000025=) MCr.0003 (Cr300)
Mass: (.0036x8=) .0288 tonnes (29 kg)
Radius: .058 meters (58mm)
Dimensions: 116x348mm

WEAPON DESIGN

MASS
Firing Unit: (12x4=) 48 kg
Support Hardware: (12x6=) 72 kg
Fire Control (from above): 40 kg
Recoil Cradle: (12x20=) 240 kg
Autoloader: (30x29=) 870 kg
TOTAL: 1270 kg

GUN CREW
1 (since it is vehicle-mounted with an autoloader)

RANGE
Short Range: (12x30=) 360
Medium Range: (360x2=) 720
Long Range: (360x4=) 1440
Extreme Range: (360x8=) 2880

DAMAGE VALUE
Damage: (11.5x3.46=) 39.79 (40)

PENETRATION
Rating: 1-2-10
Value: 40-20-4

RELOADING
Reload Time: (.3x12+3=) 1.2 (1)
Rate of Fire: 1/2 (once every two turns)

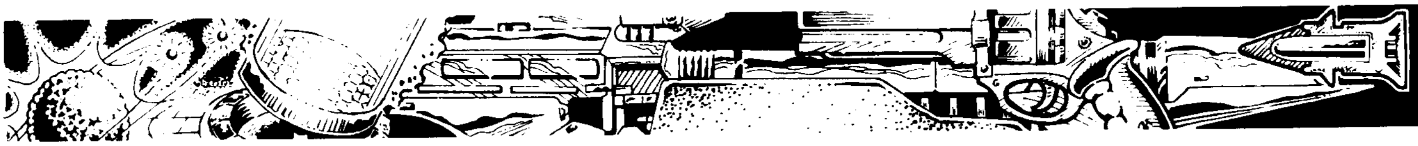
PRICE
Firing Unit: (48x2500=) Cr120,000
Support Hardware: (72x2500=) Cr180,000
Fire Control (from above): Cr100,000
Recoil Cradle: (240x100=) Cr24,000
Autoloader: (870x10=) Cr8700
TOTAL: Cr432,000

SET-UP
None (vehicle-mounted)

VOLUME
Firing Unit: (.048x0.5=) .024
Support Hardware: (.072x0.5=) .036
Fire Control: (.040x1=) .040
Recoil: (.240x1=) .240
Autoloader: (.870x1=) .870
TOTAL: 1.210 cubic meters

RECOIL
None (cradle-mounted)

BULK
None (cradle-mounted)



Design Example: TL-13 Grav Tank

Step 1—Chassis: A 7-ton (98 kiloliter) chassis is selected in a fast subsonic configuration. It uses superdense armor and has an overall level of protection of 4 (0.3cm of armor). This is thickened to 0.39 (AV 5.4) on the sides, 0.6 (AV 8) on the top, and 2.15cm (AV 30) on the front. The sides are given a moderate slope (AV = 5.4×1.5, or 8) and the front is given a radical slope (AV = 30×2, or 60).

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*
Chassis 7	(98)	—	—	—	—
Fast Subs. config.	4.9	—	—	(140)	—
Armor: 0.3cm SD (AV 4)	0.6	9	—	—	8568
Top: + 0.3cm (AV 8)	0.15	2.25	—	—	2142
Side: + 0.09cm (AV 5.4)	0.054	0.81	—	—	771.12
Front: + 1.85cm (AV 30)	0.37	5.55	—	—	5283.6
Front rad. slope (AV 60)	19.6	—	—	—	—
Side, mod slope (AV 8)	19.6	—	—	—	—

Step 2– Suspension: High-efficiency CG lifters are used.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*
High-Efficiency CG	2.1	1.4	0.7	—	210,000

Step 3– Control Systems: The vehicle uses tech level 13 holographically linked controls and has both flight avionics and terrain-following avionics. It also has two flight computers (main and backup).

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*
TL-13 Holo-linked controls	0.098	0.0098	0.007	—	14,000
TL-10 Flight Avionics	0.001	0.001	0.1	—	250,000
TL-13 Terrain-Follow. Avn.	0.1	0.02	0.02	—	15,000
Model 13 Flight computer	0.9	0.18	0.045	—	4000
Backup computer	0.9	0.18	0.045	—	4000

Step 4– Life Support: The vehicle is pressurized to allow operations in hostile environments.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*
Basic Life Support	0.49	0.49	0.0098	—	29,400

Step 5–Electronics: The vehicle has a 300-kilometer radio for broadcast communications and a 30-km laser communicator for secure tacnet communication. For sensors, it mounts a 3-km active EMS array and a jammer of equivalent performance and a 30-km passive EMS sensor.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*
300-km radio (TL 12)	0.0001	0.0002	0.01	0.1	500
30-km laser comm (TL 12)	0.004	0.008	0.01	1	5000
3-km active EMS (TL 12)	0.1	0.2	0.5	0.2	200,000
3-km active EMS jammer	0.1	0.2	1.0	0.2	400,000
30-km passive EMS (TL12)					
Processor	0.04	0.08	0.004	—	80,000
Antenna (TL 13)	0.0005	0.0005	—	0.01	500

Step 6–Weaponry: The tank mounts a 12-Mj plasma cradle gun in the turret and both a 7.5mm machinegun and 8cm laser coaxial with it (and operated from a single gunner's station). The plasma gun is that designed in the example provided earlier in this appendix; the laser and machinegun were designed using the sequences elsewhere in this book. All volumes are doubled because of placement in the turret. (At tech level 7, volumes would be tripled; at tech level 6, they would be quadrupled). Note that the mass and volume of the plasma gun includes a ballistic computer and autoloader. The weapon mount is stabilized. 400 PPC for the plasma gun and 3000 rounds of 1
ammunition for the machinegun are carried as well.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*	
12-Mj Plasma Cradle Gun	2.42	1.27	—	—	432,000	
7.5mm machinegun	0.032	0.016	—	—	4500	2
8cm coaxial laser rifle	0.01	0.005	—	—	2855	
Stabilized turret mount	0.2	0.1	—	—	50,000	
400 × PPC	2.88	11.52	—	—	(120,000)	
3000 rounds 7.5mm	0.132	0.066	—	—	(1320)	3

Step 7–Power Plant: The vehicle has a 3.3 MW fusion power plant and a HEPlaR chamber to convert 0.8 MW of power to thrust. Fuel tankage for one year of reactor operation and 20 hours of thrust are 4
included as well.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*	
TL 13 3.3 MW fusion reactor	1.1	3.3	(3.3)	—	220,000	
0.8-MW HEPlaR Thruster (16tt)	0.08	0.08	0.8	—	800	5
Reactor fuel	0.33	0.0231	—	—	—	
Reaction mass	4	0.28	—	—	—	

Step 8–Crew: The vehicle has a driver (in the hull), a commander 6
(turret), and gunner (turret). There is also a passenger seat (adequate) installed in the hull. Note that workstation volumes in the turret are doubled.

7

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*	
2 turret workstations	14	0.4	—	—	4000	
1 hull workstation	3.5	0.2	—	—	2000	
1 passenger seat	3.5	0.2	—	—	100	8

Step 9–Cargo: Most remaining volume is devoted to cargo space.

Component	*Vol*	*Mass*	*Power*	*Area*	*Price*	
Cargo	15.7	3.925	—	—	—	9

EVALUATION

DESIGN FEATURES 10

See above.

Fuel consumption is 0.11 kl of fuel per year for the reactor and 0.2 kl of fuel per hour as thruster reaction mass. On-board reaction mass is sufficient for 20 hours of movement; the reactor requires refueling 11
once per year.

MOVEMENT

Thrust: 0.8 MW = 16 tonnes

Gs: 16÷70 = 0.2286 Gs 12

Max Speed: 0.2286×3500 = 800.1 kph (limited to 800 by airframe type)

Heavy turret is 10% of volume (5.617 ÷ 58.8 kl after sloping), reducing speed by 10% to 720 kph

Cruising Speed: 720×0.75 = 540 kph 13

NOE Speed: 720×0.25 = 180 kph (limited to 170 kph by TL-13 avionics)

Combat Move: 24 (NOE), 100 (high mode) 14

Travel Move: 1020 (NOE), 2160 (high mode)

MAINTENANCE POINTS

41.7659÷6 = 6.96 (rounded to 7)

DESIGN RECAPITULATION

	Component	Vol	Mass	Power	Area	Price
1	**Chassis 7**	(98)	—	—	—	—
	Fast Subsonic configuration	4.9	—	—	(140)	—
	Armor: 0.3cm superdense (AV 4)	0.6	9	—	—	8,568
	Top: + 0.3cm (AV 8)	0.15	2.25	—	—	2142
	Side: + 0.09cm (AV 5.4)	0.054	0.81	—	—	771.12
2	Front: + 1.85cm (AV 30)	0.37	5.55	—	—	5283.6
	Front armor rad. slope (AV 60)	19.6	—	—	—	—
	Side armor mod slope (AV 8)	19.6	—	—	—	—
	High-Efficiency CC	2.1	1.4	0.7	—	210,000
	Holo-linked control system	0.098	0.0098	0.007	—	14,000
	TL-10 Flight Avionics	0.001	0.001	0.1	—	250,000
3	TL-13 Terrain–Following Avionics	0.1	0.02	0.02	—	15,000
	Model 13 Flight computer	0.9	0.18	0.045	—	4000
	Backup computer	0.9	0.18	0.045	—	4000
	Basic life support	0.49	0.49	0.0098	—	29,400
4	300-km radio (TL 12)	0.0001	0.0002	0.01	0.1	500
	30-km laser comm (TL 12)	0.004	0.008	0.01	1	5000
	3-km active EMS (TL 12)	0.1	0.2	0.5	0.2	200,000
	3-km active EMS jammer	0.1	0.2	1.0	0.2	400,000
	30-km passive EMS (TL12) Processor	0.04	0.08	0.004	—	80,000
5	Antenna (TL 13)	0.0005	0.0005	—	0.01	500
	12-MJ Plasma Cradle Gun	2.42	1.27	—	—	432,000
	7.5mm machinegun	0.032	0.016	—	—	4500
	3cm coaxial laser rifle	0.01	0.005	0.02	—	2855
	Stabilized turret mount	0.2	0.1	—	—	50,000
6	**TL-13 3.3 MW fusion reactor**	1.1	3.3	(3.3)	—	220,000
	0.8-MW HEPlaR Thruster (16tt)	0.08	0.08	0.8	—	800
	2 turret workstations	14	0.4 (+.2)	—	—	4000
	1 hull workstation	3.5	0.2 (+.1)	—	—	2000
	1 passenger seat	3.5	0.2 (+.1)	—	—	100
7	Reactor fuel	0.33	0.0231	—	—	—
	Reaction mass	4	0.28	—	—	—
	400×PPC	2.88	11.52	—	—	(120,000)
	3000 rounds 7mm	0.132	0.066	—	—	(1320)
	Cargo	15.7	3.925	—	—	—
8	**TOTAL**	97.9916	25.9736 42.1646 (loaded)	3.2708	1.51	1,945,419.7 +121,320 ammo

9 **Sample Design: Tech Level 14 Socket Barbette Turret**

The following example explains the design of the standard TL-14 socket laser barbette as seen in Appendix 1, and mounted on the famous *Gazelle*-class close escorts.

10 **1. Tech Level**

Laser is TL 14, and will be tunable. This will allow the laser to have the greatest possible utility as it will be installed in standard sockets aboard a wide variety of vessels.

11 **2. Gravitic Focusing**

The laser is for the Imperial Space campaign, so uses gravitic focusing.

12 **3. Focal Array**

In order to attain maximum range at all of the tunable wavelengths, the laser's focal array will use the full diameter of the standard barbette socket.

13 **3A. Standard Socket Mounted Lasers**

From the table, the diameter used for the focal array is 4.5 meters.

3B. Bay-Mounted Lasers

Does not apply.

14 **4. Discharge Energy**

Discharge energy (DE) will be 300 megajoules.

Because the turret is intended for installation on a starship, it is built with a heavy focal array.

The focal array has a diameter of 4.5 meters, which gives a radius of 2.25 meters. Surface area is therefore:

$3.1416 \times (2.25)^2 = 15.9$, rounded to 16.

Focal array volume multiplies the surface area by the discharge energy (300) and by the tech level volume multiplier, which for a TL-14 heavy focal array is 0.001.

$16 \times 300 \times 0.001 = 4.8$ cubic meters.

Mass is 4.8 tonnes, and price for a heavy focal array is volume times 0.2 or ($4.8 \times 0.2 =$) 0.96 MCr.

Because gravitic focusing was chosen in Step 2 above, the laser's efficiency is automatically 20%. Input energy is calculated from the discharge energy (300) as follows:

$300 + 0.2 = 1500$ megajoules.

5. Laser Performance Rating

5A. Non-Gravitic Focused

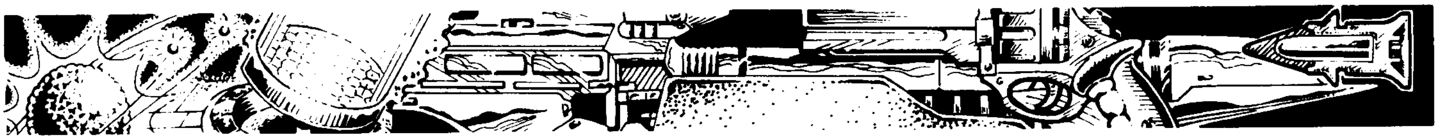
Does not apply.

5B. Using Gravitic Focusing

The FA diameter established above is 4.5 meters.

1. 4.5 meters × 10 = 45 decimeters
2. The focal modifier for a TL-14 heavy focal array is $F = (6D)^2$

$(6 \times 45)^2 = 72{,}900$



3. 72,900 ÷ 10 = 7290, which is the laser's adjusted focal value F.

4. We will calculate two effective ranges here for our tunable laser: its best range, by tech level, which is far ultraviolet (FUV: wavelength of 1000Å), and also its range in the visible band (VL: 5000Å), which is usually the best wavelength for planetary bombardment.

These equations both use the formula F × range factor = effective range, where the FUV range factor from the Tunable Lasers table is 100, and the VL range factor is 20.

Effective range in FUV is 7290 × 100 = 729,000 kilometers, or (729,000 ÷ 30,000 =) 24.3 space combat hexes/range bands.

Effective range in VL is 7290 × 20 = 145,800 kilometers, or (93,300 ÷ 30,000 =) 4.86 space combat hexes/range bands.

5C. Tunable Lasers

We have already calculated one of our available tunable wavelengths immediately above.

5D. Atmospheric Performance

We will now calculate ranges in a standard atmosphere at FUV and VL wavelengths.

For FUV, we multiply the range of 729,000 by 0.01 to get an atmospheric effective range of 7290 km.

For VL, we multiply the range of 145,800 by 0.1 to get an atmospheric effective range of 14,580 km.

The selection of visible tuning was significant, as it has twice the atmospheric range as far ultraviolet.

Planetary Bombardment: To see this effect, we will examine the example of this laser conducting planetary bombardment from a range of 2 hexes.

In FUV, 2 ÷ 0.01 = an atmosphere adjusted range of 200 hexes, far beyond the laser's effective range.

In VL, 2 ÷ 0.1 = an atmospheric adjusted range of 20 hexes, within the laser's effective range. We will find the laser's damage and penetration performance at these ranges below.

6. Define Short Range

6A. Large (Non-Hand-Held) Lasers

Because this is a large (heavy focal array) laser, it will be fitted with a beam pointer. Since its effective range (24.3 hexes) is well in excess of any beam pointer, we will select the best available beam pointer from Section 14, the 300,000 km/10 hex model. At TL 14, it has a volume of 6 cubic meters, a mass of 6 tonnes, and a price of (6 × 0.1 =) 0.6 million credits.

Our laser's short range is therefore 300,000 km or 10 hexes.

6B. Small Arms (Hand-Held) Lasers

Does not apply.

7. Laser Combat Ratings

7A. Combat Range Bands

Because our laser is designed for spacecraft mounting, we will calculate ranges in space combat hexes/range bands.

Our laser has a medium range of 10 × 2 = 20 hexes.

Our laser has a long range of 10 × 4 = 40 hexes.

Our laser has an extreme range of 10 × 8 = 80 hexes.

7B. Damage Value

In order to calculate damage values, we must first calculate the laser's intensity at its four combat ranges using $I = DE \div (1 + R^2)$.

Value for R at short range is (10 ÷ 24.3 =) 0.412 which becomes 1.

Value for R at medium range is (20 ÷ 24.3 =) 0.823 which becomes 1.

The value for R at medium range is (40 ÷ 24.3 =) 1.64609 which is rounded to 1.65 (nearest 0.01).

The value for R at extreme range is (80 ÷ 24.3 =) 3.29218 which is rounded to 3.29.

At short range, the laser has an intensity of $300 \times (1 + [1]^2) = 300$

At medium range, the laser has an intensity of $300 \times (1 + [1]^2) = 300$

At long range, the laser has an intensity of $300 \times (1 + [1.65]^2) = 110.2$

At extreme range, the laser's intensity is $300 \times (1 + [3.29]^2) = 27.72$

With the four range intensities, we can now calculate damage values.

Damage value at short range is $2.5 \times \sqrt{300} = 43$

Damage value at medium range is $2.5 \times \sqrt{300} = 43$

Damage value at long range is $2.5 \times \sqrt{110.2} = 26$ 1

Damage value at extreme range is $2.5 \times \sqrt{27.72} = 13$

7C. Penetration Rating

These calculations are made using the same intensity values derived in 7B above. 2

Inverse penetration rating at short range is $0.8 \times \sqrt{300} = 13.85$ rounded to 14, inversed = $^1/_{14}$

Inverse penetration rating at medium range is $0.8 \times \sqrt{300} = 13.85$ 3 rounded to 14, inversed = $^1/_{14}$

Inverse penetration rating at long range is $0.8 \times \sqrt{110.2} = 8.4$ rounded to 8, inversed = $^1/_8$

Inverse penetration rating at short range is $0.8 \times \sqrt{27.72} = 4.21$ rounded to 4, inversed = $^1/_4$ 4

7D. Personnel Damage Dice

Because this is a space combat weapon, and would only hit personnel after penetrating a starship hull, personnel damage dice should only be 5 calculated on a case-by-case basis on remaining damage value.

8. Power Source and Rate of Fire

8A. Direct Electrical Power

This laser will be powered by direct electrical power, and will require 6 a homopolar generator of 1500 × 0.04 = 60 cubic meters. The HPG masses (60 × 2 =) 120 tonnes, and costs (60 × 0.01 =) 0.6 million credits.

Rate of Fire: The laser will be powered to a rate of fire of 10 shots per 30-minute space combat turn. This rate of fire does not require an 7 increase in focal array volume.

Power Input: (10 × 1500) ÷ 1800 = 8.33 megawatts.

8B. Chemical Laser Cartridge

Does not apply. 8

9. Crew

The barbette will be crewed to allow local control and therefore requires a normal workstation. The Controls chapter (Section 4) shows that a normal workstation has a volume of 7 cubic meters and a mass of 9 0.2 tonnes, and at TL-14 costs 0.002 million credits.

10. Laser Furnishings and Supporting Hardware

Does not apply. 10

11. Physical Characteristics

11A. Volume

Focal array plus beam pointer plus homopolar generator plus workstation total (4.8 + 6 + 60 + 7 =) 77.8 cubic meters, well within the 84 11 cubic meter restriction for standard barbette sockets.

11B. Mass

Focal array plus beam pointer plus homopolar generator plus workstation total (4.8 + 6 + 120 + 0.2 =) 131 tonnes.

11C. Price 12

Focal array plus beam pointer plus homopolar generator plus workstation total (0.96 + 0.6 + 0.6 + 0.002 =) 2.162 million credits (MCr).

11D. Power Requirements

From Step 8A: 8.33 megawatts (MW). 13

11E. Surface Area

From standard barbette socket table and Step 4, 16 square meters.

11F. Bulk

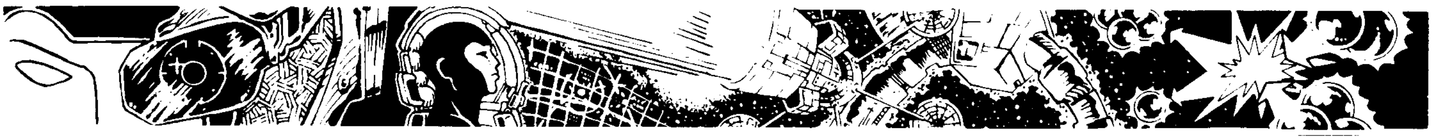
Does not apply.

11G. Recoil 14

None.

11H. Combat Performance

See final listing of the weapon in Appendix 1 on page 153.



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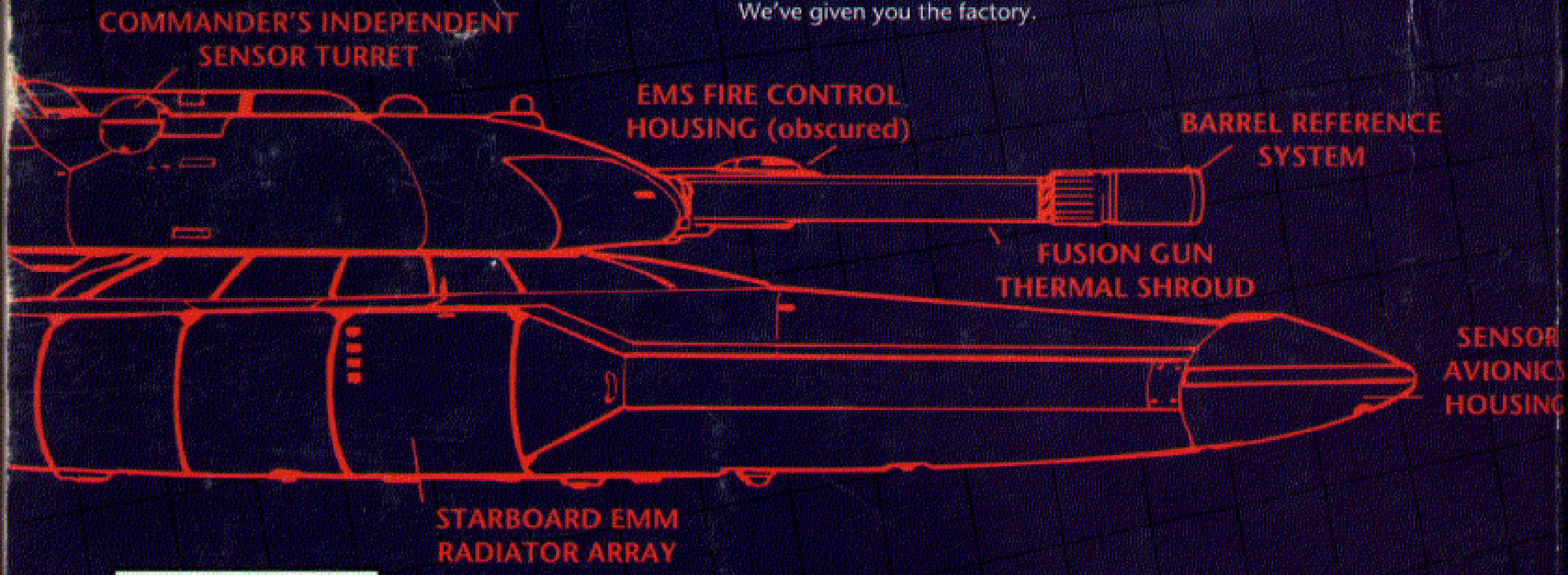

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