Vanguard Spaceships

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Vanguard Spaceships was created by Matthew DeBell and Mark Kalina.
This is Version Alpha 000711a. Revisions will me made, and we will be delighted to receive user feedback. Please email authors@vanguardrpg.com

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Introduction

Vanguard Spaceships is a set of rules for spaceship design and spaceship combat intended both to serve as a stand-alone tactical spaceship combat game and to serve as a supplement to the Vanguard science-fiction roleplaying game. As a game of hard science fiction, it includes speculative but plausible technology. Spaceships are propelled with reaction drives, not inertialess drives. If crews need simulated gravity then they spin the ship or accelerate hard; they don't have artificial gravity. To destroy an enemy, they fire lasers, missiles, or kinetic-energy projectiles. To survive combat, they usually must avoid being hit, since there are no shields. This is not a prediction of what the future will hold, but it is a representation of something that is a remote possibility.

Action Resolution

Vanguard Spaceships uses the general action resolution system from its parent roleplaying game, Vanguard. You can read those rules to learn the action resolution system, but they are summarized here in case you don't have the full rules handy.

There are four simple concepts you'll learn to resolve game events: ability, action, success, and difficulty modifier.

First we need to explain the concept of an *ability*. This term refers to people's skills and attributes and to the abilities of computers or other equipment to perform tasks on their own. Abilities are rated on a scale from 1 to 10 where the average 3 or 4. We can rate an engineer's skill at repairing fusion drives this way, as well as a gunnery computer's ability to target and fire a laser at an enemy ship. Abilities are used to perform *actions*, which are described in terms of a goal (such as repairing a damaged spaceship drive) and the difficulty of achieving that goal (which, in the case of the spaceship drive, would depend on how badly it was damaged).

Action results are described in terms of *successes*; this result is a number usually in the range of about 1 to 20. To find the number of successes achieved for any action, you simply add the relevant ability level, the results of a roll of two six-sided dice (abbreviated 2d6), and a modifier for the action's difficulty. Ability levels are rated on a scale from 1 to 10 where average is 3 to 4. As will be explained below, action *difficulty* is a positive or negative modifier, usually in the range of –2 to +2, though sometimes with much larger values. You simply add the ability level, the modifier, and 2d6 to find the number of successes. Thus:

success = ability level + difficulty modifier + 2d6

What Successes Mean: The Action Result Chart

For any action, you usually want one of three kinds of descriptions of the results: quality, time, or hits. That is, you either want a general description of how well you did, or you want to know how long the task took, or, if you're shooting at a target, you want to know how many times you hit. More successes mean that you've done better, worked faster, or hit more often. To make these descriptions more specific, look at the Action Result Chart (ARC) after you find the number of successes for an action. Each number of successes corresponds to a specific quality, time, or fire combat result, as indicated below.

Action Result Chart

Success: 2d6 + ability + modifiers	*Qualitative Result*	*Fire Combat Result*	*Timed Result*
16 and up	divine	all shots hit	.25
15	excellent	¾ (ss hit)	.5
14	excellent	2/3 (ss hit)	.5
13	very good	½	.75
12	good	¼	.75
11	high average	1/8	1
10	low average (succeeded)	1/16	1
9	marginal (barely failed)	1/32	1.5
8	poor	1/64	1.5
7	poor	1/128	2
6	poor	1/250	3
5	terrible	1/500	4
4	terrible	1/1000	5
3 or less	disaster	miss	10

In the leftmost column is the number of successes: 2d6 + ability + modifiers. Just add them up, and that's the number of successes achieved. The columns to the right describe success results in practical, game-world terms. The second (Qualitative Result) column describes the quality of the result in terms like "excellent" or "good" or "terrible." When you need a simple "succeeded or failed" result, most of the time you can draw the line at 10; nine or fewer is failure and 10 or more is success. The next column, headed "Fire Combat Result," applies to tasks that involve shooting guns at targets. The numbers in this column describe the fraction of bullets fired that hit the target. For instance, on the 10 successes row the fraction is "1/16," which means that one shot out of every 16 hit the target. If you fired fewer than 16 shots, then you missed. The Combat rules will flesh this out in detail. The last column (Timed Result) tells you how long an action took as a fraction of the amount of time one would ordinarily expect the action to take. This "ordinary" time is called the *base time*. For instance, on the row for seven successes the Timed Result number is 2, indicating that the action takes twice as long as the base time.

Almost all actions in Vanguard are resolved using the ARC, and you have just seen how it is used: to resolve an action with the ARC, first add the character's ability level, the action's difficulty modifier, and 2d6 to find the number of successes the character achieved. Then look on the ARC to find the description for the kind of action being performed. That's all there is to it. But you don't yet know much about "difficulty modifiers," so read on.

Modifiers and Action Difficulty

Obviously not all actions are of the same difficulty. It is easier to fly an airplane on a clear day than in a storm, and the action system addresses this sort of issue by adding or subtracting “modifiers” (a.k.a. action difficulty ratings) from the number of successes indicated on the ARC.

An action difficulty is a rating of how hard an action is to perform relative to other actions of the same general type. For example, recalling the accomplishments of a famous person like George Washington is much easier than recalling the accomplishments of a person of relative obscurity, like Franklin Pierce (who was President of the US from 1852 to 1856). Recalling information about Washington might be a very easy action, while recalling comparable information about Pierce would likely be pretty hard.

An action difficulty rating directly modifies the number of successes rolled on the ARC. Action difficulty modifiers are as follows:

Difficulty	*Modifier*
Very easy	+2
Easy	+1
Moderate (Average)	+0
Hard	-1
Very hard	-2

Thus, when a character attempts an Easy (+1) task, the GM adds 1 to the sum of 2d6 and the character’s relevant ability level to find the total number of successes. For a very hard (-2) task, the GM subtracts two.

In addition to these action difficulties, some actions may be deemed Extraordinary, and have a special modifier greater than +2 or less than –2, specified in the action description.

How Spaceships Work

Functions

There are three basic kinds of spacecraft: transports, warships, and research vessels. Transports are the most common spacecraft. They ship cargo and people across interstellar or interplanetary space. Combat vessels are used to project physical power in space. They serve to protect or attack other ships and the planets they visit. Research vessels are used to study astronomical phenomena. They prospect for FTL jump points, they observe the heavens, they collect samples of interplanetary flotsam, and they study planets to determine their suitability for colonization.

Crews

Spacecraft require dedicated crews to operate them. The members of these crews handle cargo, maintain and repair crucial systems such as life support, fusion drives, and FTL drive, and attend to passengers, if there are any aboard. Spaceships need crew members with a range of skills including aerospace engineering, FTL drive technician, fusion drive technician, electrical/electronics technician, and life-support technician. The Spaceship Design rules provide details about crew requirements for ships of various configurations; see page 20.

Fusion Propulsion

The primary propulsion system for spacecraft are large, powerful fusion drives. These drives cause the nuclear fusion of the two elements of their fuel, usually Deuterium (an isotope of hydrogen with two neutrons) and Helium–3 (an isotope of Helium). When fused, these two elements produce ordinary helium, protons, and an enormous amount of heat. The heat causes the fusion products (helium and protons) to expand in all directions at extremely high velocities. The fusion drive contains this reaction in a magnetic bottle open at one end with a nozzle to direct the exhaust. The fusion products fly out this nozzle at a velocity of thousands of kilometers per second, pushing the spacecraft in the opposite direction just as a bullet pushes back against the gun that fires it, only much harder.

Fusion drives generate a tremendous amount of waste heat, so ships require large fins for radiative cooling.

The exhaust from these fusion drives is concentrated in a cone only a few degrees wide, so it is dangerous for hundreds of kilometers behind the ship. Thus, spacecraft captains must be sure not to point their exhaust stream at anything nearby.

Life-Support

The first task of any spacecraft, prior to conveying its users and material from one place to another, is to protect passengers and cargo from the hazards of radiation, vacuum, and micrometeors which will be encountered in space. These functions are accomplished by a combination of a thick metal and carbon composite hull and a shielding magnetic field around the ship. Additionally, temperature regulation is a prime concern. While the space outside is very cold, the main temperature problem aboard ship is excess heat. A ship in vacuum can only lose heat by radiating it, and ships in space radiate heat slowly, so heat buildup can become a problem. In order to keep the ship's temperature at a level suitable for human habitation and mechanical function, spacecraft have skins with adaptable absorptance/emittance characteristics and advanced thermal control systems to transfer heat away from vital components to the ship's radiator fins. These fins act as heat sinks to dump heat into space. Without such apparatus, the heat generated by a fusion drive would literally melt the ship. When the ship's tremendously hot fusion drive is on, the large radiating vanes will glow brightly as they draw heat away from the rest of the hull and radiate it into space.

In addition to providing a temperature and pressure that will keep the crew comfortable, life support must provide appropriate levels of oxygen and carbon dioxide in the air and in many cases assure that the ship's hydroponic greenhouse is healthy and yielding enough food to feed the crew.

Air and temperature aboard ship will be livable so long as there is a power supply and minimal maintenance is performed. Ships with self-sustaining environments in the form of a CELSS also provide the crew with food and can continue to do so for several years without external replenishment. Crews on ships without self-sustaining environments rely upon food storage which will eventually run out; usually sufficient food reserves are carried to keep the crew alive for three or four months, in case an accident occurs and the wait for rescue is long.

Simulated Gravity

There is no way to create an artificial gravity field aboard a starship, so the norm aboard ship is weightlessness. However, the effects of gravity can be simulated in two ways. One is by accelerating the ship using its main drive system. Transport and research vessels usually travel with their drives generating acceleration equivalent to a fraction of the normal gravity experienced on Earth (called a *g*), so passengers will feel very light. In exceptional cases, fast ships that are in a great hurry may accelerate at a *g* or even more. Military ships sometimes make very high accelerations during combat maneuvers, but they too usually accelerate at less than one *g* during ordinary maneuvers.

The second way to simulate gravity is to use a spin habitat. In a spin habitat, "centrifugal force" (technically centripetal force) hurls objects away from the axis of the habitat, creating an apparent floor along the habitat's circumference when it is spinning. Ships on long missions and large ships carrying passengers frequently have a spin habitat to provide passengers and crew with the comforts and health benefits of simulated gravity.

Want To Get Technical?

If you're trying to do some math for starships, this may help you. Otherwise it's okay to just ignore this box!

First, basic physics:
Force equals mass times acceleration:
$F = ma$.
Kinetic energy equals half mass times velocity squared: $KE = \frac{1}{2} mv^2$
Velocity equals acceleration times time:
$v = at$
Distance traveled equals one half acceleration times time squared:
$d = \frac{1}{2} at2$

Now for rocket stuff:

- The rocket equation: a rocket's change in velocity equals the exhaust velocity times the natural log of the mass ratio. $\Delta V = V_e \ln R$
- Exhaust velocity (in km/s) times fuel flow rate (in kg/s) = thrust (in thousands of Newtons). E.g. an exhaust of 7500km/s at 1kg/sec produces thrust of 7.5 million N. Plugging in the general equation F=ma, this accelerates a 1000 ton ship at roughly 7.5 meters per second, or about .75 Earth gravities.
- Thrust power in Terawatts equals ship mass (in 10,000 ton units) times acceleration (in Earth gravities). E.g. a 10,000 ton ship accelerating at 1*g* requires thrust power of 1 TW.

FTL

FTL, or faster-than-light travel, makes interplanetary travel practical. Even with the fastest fusion drives, travel between star systems at sublight speeds would take years at best. FTL technology, combined with astrophysical phenomena known as wormholes, allow ships to jump the great distances between stars instantaneously.

FTL travel remains a puzzle to scientists. It was discovered largely by accident, and the only theories of FTL/wormhole physics are demonstrably faulty. Nevertheless, FTL does work and is used routinely.

FTL drives can only be engaged at jump points, which are regions of space where instantaneous interstellar jumps through wormholes are possible. FTL drives are of no use at all outside these regions. Typically these regions of space are a few thousand kilometers in diameter and are located at distances of 10 to 20 AU from their primary star. They follow erratic orbits around these stars, not the relatively smooth elliptical orbits of planets. They also fluctuate in size, occasionally winking out altogether, as when the FTL jump point at Sol disappeared for several months in 2081, a period known in history as the Interruption. Physicists theorize that their paths are determined by complex interactions with nearby planets and stars, but no satisfactory theory has been devised. In the meantime, predicting the motion of a wormhole access point is a matter of statistics, where trends in past movement are projected to predict future movement.

Kinds of Space Vessels

This is an alphabetical list of the kinds of vessels used in space, with brief descriptions.

Barge. A vessel without power, intended to be docked to a propulsion unit, or to drift to its destination. STL. Any size.

Canner. A fuel mining ship that takes in fuel directly to tanks rather than having a large towed scooping array. Usually a large, expensive ship in the range of 20,000 to 200,000 tons.

Cargo ship. A ship that primarily carries cargo.

Carrier. A warship that carries reusable, crewless fighter craft.

Combination. A ship that combines the functions of a cargo ship and a liner.

Corvette. The smallest warship, with light armament, not intended for prolonged autonomous deployment. Usually STL. 500-1500 tons. Similar to a cutter but usually more heavily armed and without boarders.

Cruiser: A large, very dangerous warship. Usually FTL. Light cruisers are in the range of 6000-10,000 tons. Standard cruisers are in the range of 10,000-20,000 tons. Heavy cruisers are 20,000-30,000 tons or more.

Cutter. A small, lightly armed vessel, usually STL, used for patrol, salvage, customs inspections, etc. Intended to deliver boarders to other vessels. 500-1000 tons.

Destroyer: A medium-sized warship. 3000-6000 tons.

Dueter. A fuel tanker. The fuel is usually deuterium, hence the name. However, these days they often carry helium-3 as well. Also known as a “tanker.”

Frigate. The smallest warship used on lengthy missions. Approximately 1500-3000 tons.

Jumper. An FTL tug.

Launch. Usually a small craft carried by a larger one, but also a small craft aboard a station used for short-range hops to ships or other stations. STL. From about one ton to a few hundred tons. Sometimes called a “boat.”

Liner. Primarily a passenger vessel.

Mosquito. An asteroid mining ship that attaches to an asteroid with several legs and inserts a mining proboscis into the asteroid to extract ore.

Packet. A ship that follows a regular route delivering cargo or passengers; may be a liner, tanker, or other type of vessel. Any size.

Pinnace. A very small vessel that could serve as a large boat or could operate on its own. About 500 tons.

Scull. A very small vessel with a single propulsion nozzle that pivots to allow maneuvers, rather than using dedicated maneuvering thrusters. Sculls are usually boats or unmanned probes. A few tons.

Seiner. A fuel trawler that lowers a line into the atmosphere of a gas giant to draw in desired molecules. Usually in the range of 20,000 to 200,000 tons.

Tanker. A ship that carries fuel.

Tender. A ship that provides supplies and fuel to other ships, often war vessels.

Trawler. A fuel mining ship. Also called a fuel trawler. Usually 20,000 to 200,000 tons.

Tug. A ship that serves as a propulsion unit for a barge or a vessel that is damaged or out of fuel.

Yacht. A vessel for pleasure cruising or private transportation; not a commercial vessel or a warship. Usually under 1000 tons.

Spaceship Combat Tactics and Hardware

The potency of spacecraft weapons combined with the relative fragility of ships results in spacecraft combat engagements where one or both sides may be destroyed in short order. Attacks are usually anticipated by both sides days in advance because stealth is practically impossible in space, and with such advance warning battles are frequently preceded by attempts at diplomacy or psychological warfare.

Six Dicta of Spaceship Combat

1. *Everyone Can See You*
Space is vast, but it's also mostly empty, which means that spaceships are easy to see, even from spectacular distances. A drifting ship can't help but emit some waste heat or reflect some sunlight, and relatively inexpensive infrared sensors will detect drifting ships hundreds of millions of kilometers away. With a fusion drive running, ships are beacons, promptly noticeable from across the solar system. For the most part, stealth in space is hopeless.

Two circumstances in which stealth is possible are when ships can hide behind objects such as planets, planetary rings, or asteroids, and when ships employing state of the art stealth technology approach ships with stunningly abominable sensors. No military ships have sensors poor enough that they may be snuck up upon, but some civilian vessels have poor enough sensors to make a drifting, close approach possible before detection occurs.

2. *The Side With the Greater Delta-V Capacity Chooses When, or If, to Fight*
After ships detect each other at ranges of many AU, an engagement will occur if the ship with the greater delta-V presses one. A ship without the fuel to escape must surrender or face combat.

3. *Slow Passes and Meeting Engagements Are Very Deadly*
Anti-ship weapons are very powerful, and if they are brought to bear on targets for a significant length of time then destruction of the target is almost assured. Battles are largely decided by the volume of fire that one ship can bring to bear against another. A secondary factor is maneuverability; a ship that is very maneuverable can avoid laser weapons at extreme ranges. The best way to survive an engagement is usually to make that engagement very brief by passing the enemy at very high velocity so that one is in the enemy's weapons range for as little time as possible.

4. *Coordinated Fire is Most Effective*
Except for X-ray lasers and small UV laser batteries, ship-based weapons do not simply aim directly at their targets and fire. Weapon flight times can be several seconds, leaving a target ship enough time to move out of the way of incoming projectiles. Even with lasers, at extreme range the lightspeed delay can be enough for a ship to move out of the way before the beam arrives. Thus, gunnery computers don't aim where ships are; they aim where ships are likely to be when the beam or projectile arrives downrange.

The longer the range to target, the longer the flight time, and the longer the time the target has to maneuver to avoid getting hit. It could be anywhere within an increasingly large "maneuver circle" around its position when the weapon was fired. A single weapon battery is unlikely to be able to saturate this entire circle. However, several batteries working in concert can saturate increasingly large circles of space, allowing hits at longer ranges.

5. *Laser-Armed Ships Like Meeting Engagements*
If armed with heavy lasers, a ship will want an acceleration advantage to hold at maximum range, hopefully out of range of the enemy's weapons, and fry him.

6. *Gun-Armed Ships Need to Get Very Close or Make a Fast Pass*
Ships armed with guns, especially spinal coil guns, need to get in very close to their targets. Usually they need to do this in a great hurry so they are not destroyed by the enemy's longer-ranged weapons on their approach. However, if a close approach is achieved, the coil guns do devastating damage. When facing an opponent armed with heavy lasers, the gun-equipped ship will want to make a fast pass, because guns are more likely to kill with one hit than lasers. Also, the fast pass will prevent the laser ship from holding beyond gun range in a static engagement and lasing the gun ship to death.

Overview of Spacecraft Weapons

The weapons most commonly used in spaceship combat are X-ray lasers, UV lasers, hypervelocity coil guns, scatterguns, and missiles.

X-ray lasers are warheads mounted on missiles. They cannot be mounted directly on ships because the laser is pumped by a nuclear explosion that would destroy the firing ship. These have effective ranges of only about 2000km but do a great deal of damage. When the nuclear warheads detonate they fire a batch of simultaneous pulses to saturate an area of space for an instant.

UV lasers are long-ranged, ship-mounted weapons. They fire a series of pulses or a continuous beam of laser energy with constant adjustment of aim. Rather than doing all their damage at once, they fire at their targets for minutes at a time. Heavy laser batteries can have effective ranges of up to 100,000km, though more common lasers have half this range. In addition to a normal attack mode, lasers can take on an ECM function, dazzling an enemy's sensors to degrade his or her effectiveness in weapons targeting.

Hypervelocity coil guns are large, spinally (longitudinally) mounted weapons that project a mist of fluid metal at velocities of about 1000km/s. (The metal is turned to fluid by the enormous acceleration it undergoes to reach a velocity of 1000km/s in less than the length of the ship.) At this velocity, contact with miniscule projectile droplets can cause severe damage. Effective range is a few thousand kilometers.

Scatterguns are short-ranged point-defense weapons that fire a hail of tiny projectiles against incoming missiles or other targets at very close range. The effective range of scattergun batteries is about 2000km. While hypervelocity coil guns are effective because the projectiles travel so fast that the target has little time to maneuver out of the way, scatterguns are effective because they saturate such a large volume of space with projectiles that even if a target is able to maneuver a hundred meters before the projectiles arrive, it may still be within the cone of fire.

Missiles come in several varieties. They can mount fusion or conventional propulsion systems and can carry x-ray laser warheads or scattergun warheads. Fusion missiles are large, expensive beasts that are launched in small numbers but are dangerous because of their large payloads and high delta-v. Conventional missiles are much smaller and slower, but are cheaper and can be carried in much larger numbers.

Spaceship Sensor Rules

Detecting spaceships at long range is a time-based task. Base time is 10 hours. The task is based on the Vskill of the sensor array (4 for ordinary sensors or 7 for enhanced sensors; see the design rules), with modifiers for range, stealth, and whether or not the target ship's drive is activated.

Modifiers to the detection task are as follows:

Ship detection modifiers

- range modifier: 10-AU/2.
- standard drive activated: +40
- stealth drive activated: +10
- stealth fittings on ship: as specified for target ship
- sensor clutter: -1 or more (see text below)

For instance, detecting a ship at 12AU, with no stealth, with its drive turned off, would involve a +4 modifier. This makes prompt detection likely. Detecting a ship at 80AU with its standard drive activated would be a task with a +10 modifier, so detection is immediate.

As you can see, it's hard to hide in space. One exception applies when "*sensor clutter*" is present. This means that the target for detection is in close proximity to another object such as a comet, asteroid, or planet, that will return a confusing signal to the detecting ship. Use the following guidelines: in low orbit over a planet with an atmosphere, or hiding in a comet's tail, -2. In low orbit over a cold, airless rockball, or attached to an asteroid or inert comet, or in a dense planetary ring system (like Saturn's), -1.

Spaceship Combat Rules

The first step in starship combat is to determine the kind of engagement ships will experience. Based on the ships' courses through space and their velocities, the GM and players must figure out the combined closing velocity at which two ships will meet. Depending on this velocity, we treat the combat as either a meeting engagement, a slow pass, a fast pass, or a very fast pass. These pass speeds affect the chances of scoring hits, as indicated in the Hit Modifier column in the table below.

Closing Velocity	*Engagement Type*	*Hit Modifier*
under 30km/second	meeting engagement	+2
30-300km/s	slow pass	0
300-3000km/s	fast pass	-1
over 3000km/s	very fast pass	-3

Fire combat between spacecraft is resolved with the ARC. Just like regular tasks, it is based on a skill (in this case Targeting), and applicable modifiers are applied to the result. These modifiers are the hit modifier based on the *closing velocity* (or speed of the pass), the *target's evasion* modifier, and the *target's ECM* modifier (including both ship's ECM and extra bonuses derived from using weapons to boost ECM).

To resolve general attacks, roll 2d6 on the ARC for the attack and add the attacker's Targeting value, modified by the type of pass (meeting, slow pass, etc.). Subtract the ECM value of the target ship, and subtract the extra ECM protection the target enjoys because the firer is the target of an ECM attack from ECM weapons. Finally, subtract the target ship's evasion rating. This gives the number of successes.

As with regular fire combat, spacecraft weapons have a Rate of Fire. The Fire Combat column on the ARC says how many hits are scored for a given number of successes, depending on the number of shots fired.

Passing Engagements

The passing engagements (slow, fast, and very fast) are played in the abstract, and don't require any mapping. They are pretty simple to resolve. Just follow these steps:

1. Determine pass range. The ship with the acceleration advantage chooses how close to make the pass. A missile-armed ship may want to get only close enough to make a missile attack, staying out of range of lasers and guns. A laser armed ship may choose to pass close enough for lasers but not close enough for guns. Gun armed ships with an acceleration advantage will want to get close enough to use their guns effectively.

2. If waves of missiles are involved, resolve them. The target ship attacks the missiles with point defense (PDF) weapons before the missiles make their attack. PDF and missiles both use the hit modifiers in the table above depending on the speed of the pass, plus applicable modifiers for ECM and evasion.

3. Resolve damage from missile attack.

4. Resolve ship weapon attacks, again using the applicable modifiers. Attacks are simultaneous, so all ships get to attack before damage is resolved.

5. Resolve damage.

Attack example: The Brazen and Intrepid make a fast pass. The Brazen is armed with three medium laser batteries, each with a rate of fire of 3 and an ECM value of –2. The Brazen has an evasion rating of 1, a Targeting rating of 5, and ECM value of 2. The Intrepid is armed with a spinal coil gun and a small laser battery. The gun has a rate of fire of 2. The laser has a rate of fire of 2 and an ECM value of 1. Intrepid's Evasion, Targeting, and ECM values are 1, 5, and 2, just like Brazen. Intrepid has the acceleration advantage, so she makes a close pass in order to let her coil gun do its work.

Before the pass, Intrepid allocates her laser to ECM. Brazen allocates two of her lasers to ECM and uses the third to attack Brazen.

To resolve Intrepid's attack, we roll 2d6 and get 6. Add 5 for targeting. Subtract two for Brazen's Evasion and 2 more for the ship's ECM. Subtract another 4 for the ECM from Brazen's two ECM lasers, leaving 3. Subtract 1 for the fast pass, leaving 2 successes. The attack is a total failure.

Brazen attacks Intrepid with one laser battery, having used two for ECM. The 2d6 roll is 8. Add 5 for Targeting. Subtract 2 for Intrepid's evasion and 2 more for the ship's ECM. Subtract 1 more for the Intrepid's ECM laser, leaving 8 successes. Subtract 3 for the fast pass, leaving 5 successes. You can see from the ARC that with five successes an attacker needs to have fired 500 times to get a hit. The Brazen's laser battery has a RoF considerably less than 500, so it missed.

Meeting Engagements

Meeting engagements may involve maneuvers and formations, so they are played using hexagonal grid maps. These maps are available at hobby stores. (Use cardboard counters, or get a map you can write on with a dry-erase or water-soluble marker.) Of course, these maps are flat, while space is three dimensional. A two-dimensional surface is a fine map so long as there are three or fewer ships involved in combat, because three objects in space describe a plane, just like the map. If there are more than three ships in combat, you may need to do some careful note taking to keep track of each ship's vertical displacement and velocity in the third dimension with respect to the map.

On the grid map, each hex is 2500km in diameter. Combat is played on this scale in turns that last 10 minutes. When ships draw close enough to each other to map on this scale, the tactical engagement begins.

Start by positioning each ship toward the edges of the map, at least as far apart as the longest-ranged weapon carried by any ship on the map. The ship with the acceleration advantage can choose to start the tactical encounter at a greater distance than this, but usually 40 hexes—the maximum range of the longest-ranged lasers—is a good starting point. If missiles were fired before the ships met, their approach should be plotted too.

Before combat begins, plot each ship's expected position at the beginning of the next turn, barring changes in velocity, and place an "expected position marker" at this location. The ship with the acceleration advantage can choose the relative velocities of the two ships. If any missiles were deployed before the engagement, plot their expected positions as well.

Now play the 10 minute combat turns, acting in the following phases:

Phase 1: ECM attacks. ECM-capable weapons (i.e. lasers and particle beams) can attack a ship in an ECM attack that will degrade the subject's Targeting ability. The target of an ECM attack suffers no damage, but the attacker's weapon's ECM value is subtracted from all of the target's attacks that turn. If weapons are to be used for an ECM attack, allocate them to this function now. They may not be used for anything else until the next turn.

Phase 2: Missile maneuver, movement, and attack. Missiles may attack their targets. Targets may use any point-defense-capable weapons to attack missiles that are in range. Damage from missile hits is not resolved until phase 4. For now, just see how many hits there are.

Phase 3: Weapons firing. Resolve any laser or gun attacks. Weapons used for PDF (point defense fire) in the last phase cannot be used to attack ships. Each weapon attacks simultaneously, and all ships are allowed an attack (assuming they are in range).

Phase 4: Damage application. Resolve damage effects resulting from above attacks.

Phase 5: Ship maneuver plotting. Ships may operate their drives to change course. When changing course, move the expected position marker, not the ship, as far as the ship's acceleration allows.

Phase 6: Ship movement. Note the distance and direction from the ship to the expected position marker. Move the ship to the expected position marker and move the expected position marker to its new position, which should be located along an imaginary line extending from the ship's original position through the new position, extending as far from the new position as the old position was from the new position.

Phase 7: Missile deployment. Place missile counters on the map on top of the ship for all missiles that are fired. (You can use one counter for several missiles of the same type, so long as you note how many missiles the counter represents.) They start with velocity equal to the firing ship's, so until they maneuver they will drift with the ship's current velocity. Place an expected position counter for the missiles on top of the firing ship's expected position counter.

Spaceship Damage

When ships take damage, compare the number of damage points caused by a weapon's attack to the ship's Damage Index. The higher the number of damage points relative to the Damage Index, the worse the result for the ship, as indicated in the list below.

- If damage ≤ DI, then the result is a Minor hit: roll once on the Surface table.
- If damage ≤ 2DI, the result is a Moderate hit: roll twice on Surface table and once on Internal table.
- If damage ≤ 4DI, the result is a Severe hit: roll twice each on Surface and Internal tables.
- If damage ≤ 6DI, the result is a Grave hit: roll three times each on Surface and Internal tables.

- If damage > 6DI, the result is a Catastrophic hit: roll four times each on the Surface and Internal tables.

Surface Spacecraft Hit Location Table

d100	*location*	*Remarks*
1-5	Hardpoint attachment destroyed	Attached materials drift away from one hardpoint
6-12	Hardpoint payload hit	Apply damage to hardpoint payload
13-14	Lifeboat complement reduced by 25%	
15-16	One docking ring/airlock fused shut	
17-33	Stealth reduced by 1	
34-36	Hangar doors inoperable	Hangar contents unharmed
37-43	One sensor suite lost	
44-48	One communications suite lost	
49-53	Defensive ECM reduced by 1	
54-60	Targeting reduced by 1	
61-67	One weapon damaged: ROF reduced 50%	Choose a weapon at random
68-74	Armor reduced by 20%	Adjust Damage Index accordingly
75-95	Fusion drive performance reduced 10%	Reduce Evasion accordingly
96-100	Fusion drive performance reduced 20%	Reduce Evasion accordingly

Note: reroll results that do not apply to the ship being hit.

Internal Spacecraft Hit Location Table

d100	*location*	*Remarks*
1-3	FTL drive damaged	Inoperable
4-23	fuel reduced by 25% of original capacity	
24-33	hull: *g* tolerance reduced by 25%	Reduce Evasion and DI accordingly
34-38	25% of passenger accommodations destroyed	Occupants (if any) are killed
39-40	medical facilities destroyed	Occupants (if any) are killed
41-43	spin habitat won't spin	
44-48	hangar contents hit for ½ attack's damage	
49-63	cargo hit for ½ attack's damage	Choose a cargo component at random
64-65	automated "crew" reduced by 25%	
66-75	25% of crew killed	
76-80	fusion drive performance reduced by 25%	Reduce Evasion accordingly
81-90	fusion drive performance reduced by 50%	Reduce Evasion accordingly
91-100	weapon destroyed	Choose a weapon at random

Note: percentage reductions are additive; e.g. after two 50% reductions to drive performance, the drive is inoperable, not at 25%. Four 25% reductions to the crew eliminate it entirely.

Repairing Damage

Components that are inoperable or have had performance reduced are repaired at difficulty of d10-5. Components that have been "destroyed" or had performance reduced by 100% are repaired at (negative d10) difficulty.

Spaceship Design

This system allows you to design custom starships for Vanguard. You'll get consistent relationships among acceleration, cargo capacity, weapons potency, price, reliability, and other salient features of starship operation—things you'll want to know about your ship if your adventure is centered around it. Once you get the hang of it, designing a new starship should take about 30 minutes. This system works for ships of 500 tons or more. As you proceed from step to step, use the spaceship design sheet to keep a running tally of the total mass you have allocated to various ship components, including fuel and cargo capacity. You may also want to keep track of the money you've spent.

1. Gross ship mass.
   Begin by choosing an approximate target for the total mass of your ship. You can get an idea of the total mass required by considering two things: the amount of mass of payload (cargo, passengers, weapons, etc.) the ship will carry and the proportion of the total mass that will be fuel. Most of the mass of very fast ships is devoted to fuel; very little of the mass of very economical and slow ships is devoted to fuel. Very small ships mass around 1000 tons, the most common ships mass between 2000 and 20,000 tons, and the largest ships can mass over 100,000 tons. In combination, fuel and payload will typically mass 65% to 85% of the total ship mass. The remainder is devoted to hull, drives, armor, etc.

2. FTL drive.
   If the ship is to have an FTL drive, it will mass 75 tons plus (total tonnage, including all cargo to be carried/30). FTL drive equipment costs $2,000/ton. An FTL drive for a 5000 ton ship would mass 242 tons and cost $484,000. Note that an FTL jump requires FTL tonnage capacity at least equal to the gross mass of the entire ship including all cargo, fuel, and attachments on hardpoints.

3. Fusion drive type selection.
   Choose the ship's drive type. The drives available are:

High-performance binary plasma drive. This is the fastest propulsion system available, and also the most expensive to operate. The system fuses deuterium and helilum3 (the two fuel components that make this a "binary" drive) at extraordinarily high temperatures and yields enormous amounts of energy. The fusion products are released directly from the reaction chamber through a nozzle, yielding high efficiency and great thrust. These drives are state of the art and are usually found only on military vessels. Exhaust velocity of this drive is 7,500km/s. Minimum mass 200 tons. Each ton of drive mass delivers 5 tons of thrust, costs $300,000 and consumes fuel at a rate of 24 kg per hour. For instance, a 200 ton drive (the smallest available) would cost $60 million, deliver 1000 tons of thrust (enough to propel a 1000 ton ship at 1 *g*, because one ton of thrust accelerates one ton of ship at one *g*, or $9.8ms^{-2}$), and consume fuel at a rate of 4.8 tons per hour. If half of a ship's gross mass is devoted to fuel, a high performance binary plasma drive can give the ship a cruising speed of almost 1.5 AU per day. (A twin-fuel version of this drive can accommodate either pure deuterium fusion or deuterium-helium3 fusion. The twin-fuel version has twice the mass of the binary-fuel-only version. When using deuterium alone the exhaust velocity is 1000km/s.)

Standard binary plasma drive. Fuses deuterium and helium3. This drive system has been around for a while but is more economical and more reliable than the high-performance system above. Exhaust velocity is 3000 km/sec. (A twin-fuel version of this drive can accommodate either pure deuterium fusion or deuterium-helium3 fusion. The twin-fuel version has twice the mass of the binary-fuel-only version. When using deuterium alone the exhaust velocity is 1000km/s.) Minimum mass 100 tons. Each ton of drive mass delivers 4 tons of thrust, costs $200,000, and consumes fuel at a rate of 48 kg per hour. If half of a ship's mass is devoted to fuel, this drive can give the ship a cruising speed of almost 0.6 AU per day.

Deuterium plasma drive. This drive fuses deuterium (with no helium3). Though it is increasingly viewed as obsolete, this drive is more economical (in terms of fuel costs) than the binary plasma drives because deuterium alone is much cheaper than the binary fuel used by the drives above. However, the deuterium-deuterium reaction produces much more dangerous radioactivity than the deuterium-helium3 reaction, and requires more radiation shielding. It also produces less energy than the binary fuel; exhaust velocity is 1000km/s. Minimum mass 700 tons. Each ton of drive mass delivers 2 tons of thrust, costs $100,000, and consumes fuel at a rate of 72 kg per hour. If half of a ship's mass is devoted to fuel, this drive can give the ship a cruising speed of almost 0.2 AU per day.

Standard thermal fusion rocket. This drive uses a fusion reactor to generate power to expel a reaction mass (usually hydrogen, but almost anything will do) out a rocket nozzle. Unlike a plasma drive, the thermal fusion rocket does not generate thrust by expelling fusion reactants from the rocket nozzle. These drive designs are mechanically much less demanding than the plasma drives, but they also generate much less thrust for a given fuel expenditure. Exhaust velocity is 100km/sec. Minimum mass 50 tons. Each ton of drive mass delivers 2 tons of thrust, costs $150,000, and consumes fuel at a rate of 720 kg per hour. If half of a ship's mass is devoted to fuel, this drive can give the ship a cruising speed of almost 0.02 AU per day.

Stealth fittings for thermal fusion rocket. Stealth fittings minimize drive signature, reducing the probability of detection. Exhaust velocity for the thermal fusion rocket is reduced to 10km/sec when operating in stealth mode. Stealth fittings double the mass and cost of the drive. When operating in stealth mode, each ton of drive delivers 0.5 tons of thrust and consumes fuel at a rate of 1.8 tons per hour. If half of a ship's mass is devoted to fuel, a thermal fusion rocket operating in stealth mode can give the ship a cruising speed of almost 0.002 AU per day (about 3.4 km per second).

High-thrust fittings for thermal fusion rocket. When equipped for high-thrust operation and operating in high-thrust mode, a thermal fusion rocket has an exhaust velocity of

50km/sec, and each ton of drive delivers 20 tons of thrust and consumes fuel at a rate of 14.4 tons per hour. High-thrust fittings add 20% to the total mass of the fusion rocket installed and cost $75,000 per ton. The benefit of high-thrust mode is an acceleration capacity that is 10 times greater than the acceleration capacity of the normal thermal fusion rocket. However, in high thrust mode the rocket can only accelerate the ship to a cruising speed of 0.01 AU per day (about 17 km per second) when half the ship mass is fuel.

4. Acceleration and drive mass & cost.

Decide the rate of acceleration you want your ship to be able to achieve with a full load of fuel and cargo by consulting the table below. Look on the row appropriate for the kind of drive and fuel you selected in step 3 above to find the proportion of your total ship mass that must be allocated to drive to achieve this rate of acceleration. (Note that these accelerations are the maximums when the ship is fully loaded. Maximum acceleration goes up as fuel is burned and gross mass declines.) Figure the cost of this drive using the price figures from step 3, above.

	.001g	*0.01g*	*0.1g*	*0.25g*	*0.5g*	*0.75g*	*1.0g*	*1.5g*	*2.0g*	*3.0g*
High-performance binary plasma	.02%	0.2%	2%	5%	10%	15%	20%	30%	40%	60%
Standard binary plasma	.025%	0.25%	2.5%	6.3%	12.5%	18.75 %	25%	37.5%	50%	75%
Deuterium plasma	0.05%	0.5%	5%	12.5%	25%	37.5%	50%	75%	n/a	n/a
Thermal rocket	0.05%	0.5%	5%	12.5%	25%	37.5%	50%	75%	n/a	n/a
High-thrust thermal	0.005%	0.05%	0.5%	1.25%	2.5%	3.75%	5%	7.5%	10%	15%
Stealth thermal rocket	0.2%	2%	20%	50%	n/a	n/a	n/a	n/a	n/a	n/a

The figures in the table above are calculated as follows: drive mass ratio = (acceleration in *g*)/(thrust ratio), where drive mass ratio is the mass of the drive divided by the gross mass of the ship, including the drive, and thrust ratio is the number of tons of thrust a drive can deliver for each ton of drive.

Note on velocity change per day at selected rates of acceleration: When acceleration is measured in g and velocity is measured in AU/day, each day of acceleration changes a ship's velocity by about half the rate of acceleration. E.g. accelerating at 1*g* for one day imparts a velocity change of about 0.5 AU per day; accelerating at 0.6*g* changes velocity by 0.3 AU/day.

5. Fuel capacity and maximum speed.

The speed a ship can attain (or its delta-v) is limited by the amount of fuel it carries. The formula for the maximum cruise speed for any given fuel-mass ratio is $\Delta V_{rt} = (V_e \ln R)/2$, where ΔV_{rt} is maximum velocity attainable while still leaving enough fuel to stop at the destination, Ve is the drive's exhaust velocity, ln R tells you to take the natural log of R, and R is the ratio of maximum gross ship mass to dry (fuel-less) mass. For convenience, several cruise speeds are calculated in the table below for each of the drive types. Note that these speeds leave no fuel reserve at all; realistic cruising speeds will be perhaps 5% lower.

	high-perf. binary fusion	*standard binary fusion*	*deuterium-only fusion*	*thermal fusion rocket*	*high thrust thermal*	*stealthed thermal*
1%	37.7km/s 0.0217 AU/day	15.1 km/s 0.0087 AU/day	5.03 km/s 0.0029 AU/day	0.503 km/s 0.00029 AU/day	0.251km/s 0.000145 AU/day	0.0503 km/s 0.000029 AU/day
5%	192.3 km/s 0.111 AU/day	76.9 km/s 0.0443 AU/day	25.65 km/s 0.0148 AU/day	2.565 km/s 0.00148 AU/day	1.283 km/s 0.00074 AU/day	0.2565 km/s 0.000148 AU/day
25%	1078.8 km/s 0.62 AU/day	431.5 km/s 0.2486 AU/d	143.8 km/s 0.0828 AU/day	14.38 km/s 0.00828 AU/day	7.19 km/s 0.00414 AU/day	1.4384 km/s 0.000828 AU/day
50%	2599.3 km/s 1.5 AU/day	1039.7 km/s 0.6 AU/day	346.6 km/s 0.2 AU/day	34.66 km/s 0.02 AU/day	17.33 km/s 0.01 AU/day	3.466 km/s 0.002 AU/day
75%	5198.6 km/s 3.0 AU/day	2259.4 km/s 1.3 AU/day	693.1 km/s 0.4 AU/day	69.31 km/s 0.04 AU/day	34.66 km/s 0.02 AU/day	6.931 km/s 0.004 AU/day
90%	8634.7 km/s 4.98 AU/day	3453.9 km/s 1.99 AU/day	1151.3 km/s 0.66 AU/day	115.13 km/s 0.066 AU/day	57.56 km/s 0.033 AU/day	11.513 km/s 0.0066 AU/d

Once you have chosen the percentage of your ship mass to devote to fuel, add tonnage equal to 8% of the fuel mass to account for fuel tanks, pumps, and cryogenic storage equipment. For instance, if you have a 10,000 ton ship and have allocated 40% of that mass to fuel, you are carrying 4,000 tons of fuel and will require 320 tons (4000 x 0.08) for tanks and associated machinery. Fuel tanks and associated equipment cost $500 per ton.

6. Hull structure.

For ships with a gross mass under 50,000 tons, required mass for the hull and ship's structure equals (desired *g* tolerance for ship, i.e. maximum acceleration) (0.07) (gross ship mass). Minimum *g* tolerance is 0.25. Costs $10,000 per ton allocated to structure. For ships over 50,000 tons, add to the structure requirement a mass equal to 20% of (gross mass minus 50,000). Note that the hull should tolerate the maximum acceleration the drive is capable of delivering, and that acceleration is achieved just before the ship runs out of fuel, not when it has a full load.

7. Communications equipment.

Basic comm suite includes radio transceiver and antennae allowing broadcast and reception over ranges of about 150AU. Mass is negligible; cost is $10,000. Advanced comm suite includes receiver equipment to pick up weak signals and a communications laser to allow secure communications to ranges of several AU. (Security declines with range.) This equipment adds $50,000. Communication redundancy: Ships that will engage in combat should be fitted with back-up communication suites in case one is destroyed. Each back-up costs the same as the main suite ($10,000 for basic, or $50,000 for advanced). For every 10 communication suites, add one ton of mass, but otherwise treat mass as negligible.

8. Optional scientific equipment.

FTL jump point prospecting equipment costs $15,000,000, adds 1000 tons. Astronomy gear varies. Planetary survey gear varies. A basic planetary survey suite includes mapping equipment, observation sensors, magnetic and radiation field detectors, etc. Mass 10 tons, cost $200,000.

9. Sensors.

Ordinary sensor equipment (required), for astrogation and close-range object detection; costs $50,000 and adds negligible mass. Enhanced sensor equipment: For long-range automatic detection and tracking capacity of thrusting ships. Includes multi-spectrum telescopes. $100,000 and one ton. As with communications gear, ships that anticipate combat should mount redundant sensor suites.

10. Weapons targeting.

Costs for fire control equipment, which confers a virtual skill in *targeting*, are indicated in the table below. The quality of this equipment is very important in determining the fighting effectiveness of warships.

Targeting VSkill	*Mass (tons)*	*Cost ($)*
1	2	$1 million
2	4	$4 million
3	8	$16 million
4	16	$64 million
5	32	$256 million
6	64	$1 billion
7	125	$4 billion
8	250	$16 billion
9	500	$64 billion
10	1000	$256 billion

11. Weapons.

The mass and cost of various weapons is listed below. General descriptions of each weapon type are presented in the Overview of Spacecraft Weapons (page 13). Note that a military sensor suite and fire control system (i.e. Targeting) are required to use weapons.

Weapon	*Range*	*Damage*	*RoF*	*ECM*	*Mass*	*Cost*
Laser – Small Aperture	2	6	8	1	50	2 million
Laser – Medium Aperture	10	20	8	2	100	20 million
Laser – Large Aperture	20	20	6	3	400	115 million
Laser – Very Large Aperture	40	30	4	3	1600	600 million
Scattergun*	1	30	20	0	300	6 million
Spinal Coilgun	0	90	8	0	3000	200 million
X-Ray Warhead	1	200	2	0	5	2 million
Plasma fusion drive	0	3	16	2	na	na
Small Missile Launch Tube	na	na	1	na	3	$20,000
Medium Missile Launch Tube	na	na	1	na	6	$30,000
Large Missile Launch Tube	na	na	1	na	10	$50,000

*Scatterguns fired at targets on perfectly predictable courses have a range of 20 hexes.

Missiles:

Small conventional missile (long obsolete). 50 tons. Delta V = 12km/s; max acceleration is 5 g. 3 hexes per turn. Warhead: 1 x-ray laser. Cost: $200,000 + $1 million for warhead.

Small fusion missile. 50 tons. No throttle control. Moves 3 hexes the first turn and 6 hexes per turn thereafter. Payload holds one x-ray laser warhead. Cost: $12 million plus $1 million for warhead.

Medium fusion missile. 100 tons. Delta V = 42km/s; max. acceleration is 5 g. Once activated, this drive runs at full power until it dies; it can't be turned off or throttled down. Moves 5 hexes the first turn and 10 hexes per turn thereafter. 5 ton payload holds one x-ray laser warhead. Cost: $15 million + $1 million for warhead.

Heavy missile. 200 tons. Delta V = 170km/s; max acceleration is 2 g. 40 hexes per turn. 25 ton payload holds 5 x-ray laser warheads or 1 scattergun shot. Cost: $25 million + warhead(s); $2 million for scattershot warhead or $5 million for five x-ray laser warheads.

Fighter (unmanned). 350 tons. Armed with one medium-aperture laser. Delta V = 18 hexes per turn. Acceleration 2 g. May be re-fueled with deuterium and re-used. Destroyed by any damage. Cost: $150 million. Targeting value: 4. Requires a hangar.

12. Evasion and Maneuverability

Being able to maneuver erratically, quickly, helps a ship evade fire. The effectiveness of evasive maneuvers depends on the ship's maximum acceleration capacity. See the table below to find the Evasion rating of your ship, based on its maximum acceleration capacity.

Acceleration	*.001g*	*0.01g*	*0.1g*	*0.25g*	*0.5g*	*0.75g*	*1.0g*	*1.5g*	*2.0g*	*3.0g*
Evasion	*+3*	*+2*	*+1*	*+1*	*0*	*-1*	*-2*	*-3*	*-3*	*-4*

13. Defensive ECM.

Electronic Countermeasures to enemy targeting. See the table below for costs.

ECM modifier to enemy's attack	*Mass*	*Cost ($)*
None	None	None
-1	200 tons	30 million
-2	500	90 million
-3	1500	270 million
-4	4500	810 million
-5	13,000	2,430 million

14. Passengers.

Passenger accommodations, per person. These figures include common areas, passages, and life support. (Crew determined separately.)

Accommodations	*Mass*	*Cost ($)*	*Remarks*
Hibernation storage	1 ton	10,000	Cold-storage hibernation chamber
3rd class	3 tons	10,000	Enclosed bunk and shared bathroom facilities
2nd class	6 tons	25,000	Small stateroom and private bath
1st class	10 tons	50,000	Comfortable stateroom and private bath

15. Preliminary estimate of crew size.

An approximation of the crew requirement will be at least 3, with 1 for every 30 passengers on board and 1 for every 5000 tons of gross ship mass, plus between 10 and 40 for military ships. You can use this crew size estimate to help guide your choices of various pieces of equipment for the ship, such as spin habitats, medical facilities, life boats, and air locks.

16. Medical facilities.

Minimal infirmary: 5 tons, $15,000 for patient capacity of one plus 2 tons and $2,000 for each extra patient. Regular infirmary: 7 tons, $25,000, plus 2 tons and $3,000 per extra patient. Minimal sick bay: 10 tons, 75,000 plus 2 tons and $5,000 per extra patient. Regular sick bay: 15 tons and $250,000 for patient capacity of one plus 3 tons and $10,000 per additional patient. Hospital facilities: 20 tons and $1,000,000 plus $20,000 and 5 tons per additional patient. Advanced hospital facilities: 25 tons and $5,000,000 plus $50,000 and 8 tons per additional patient.

17. Docking rings and airlocks.

At least one docking ring and airlock combination is required. Small air lock (holds two people comfortably, four if they squeeze): one ton, $10,000. Medium air lock (4-8 people): 2 tons, $25,000. Large air lock (8-16 people): 4 tons, $30,000. Each air lock includes a docking ring. Note: docked ships cannot maneuver unless hardpoints (see Hardpoints below) are also used to attach the ships.

18. Simulated gravity.

For long trips it is often desirable to have a spin-habitat to simulate gravity. Putting all passenger accommodations in a spin-habitat adds 15% to the required passenger accommodation mass and adds 10% to the required cost, with minimums of 20 tons and $150,000. A small spin-habitat, with about 300 square meters of floor area, costs 20 tons and $150,000. 22 second class staterooms could be installed in a habitat this size. (You must buy and account for the mass of the staterooms separately.) Note that smaller spin habitats are impractical because Coriolis effects will nauseate and disorient the users.

19. Lifeboats.

Basic four-person lifeboats (including their deployment equipment) mass 500kg and cost $5000. Basic ten-person lifeboats mass a ton and cost $10,000. Advanced four person lifeboats mass 3 tons and cost $50,000. Advanced ten person lifeboats mass 5 tons and cost $100,000. Also may use life support bubbles; see equipment list.

20. Hardpoints.

A hardpoint is a fitting to which something (such as a cargo container or fuel tank) can be attached to the exterior of a ship's hull. Hardpoint capacity requires mass of 2% of desired external cargo or fuel capacity and costs $500 per ton of hardpoint. Cargo attached to hardpoints must usually be put in containers. Fuel or other ships may also be attached to hardpoints. When ships are connected via hardpoints, both ships must dedicate a hardpoint to the connection and both ships must dedicate docking rings and airlocks if people are to be able to pass between the ships.

21. Hangars.

Hangar accommodations cost 15% of the mass of the craft to be carried. This provides a launch or recovery rate of one craft per turn. To boost this rate, add 2% to the hangar mass for each additional launch/recovery/turn capacity, up to 50% of the mass of carried ships. For example a rate of two ships per turn requires 12% of the mass of all carried craft, and a three ship rate requires 14%, while all ships carried can be launched or recovered in one turn with hangar equipment of mass equal to half the mass of the carried ships. Dollar cost is $5,000 per ton of hangar. (Note: An alternative method of carrying ships is to use a hardpoint and a docking ring with airlock for each embarked ship. This allows an unlimited launch/recovery rate, however this does not allow the carried ships to enjoy the armor protection of the carrier and it makes repairs of the embarked ships more difficult.)

22. Cargo hold.

Specify capacity in tons. Cargo mounting and handling equipment adds 3% of cargo capacity mass to the ship's empty mass, and costs $100 per ton. Cargo mass contributes to the gross ship mass, but of course it does not contribute to the empty mass.

23. Stealth.

Stealth fittings make the ship more difficult to detect when the drive is off. They are of no use when a drive is activated. Each –1 applied to stealth requires 5% of the ship's maximum gross mass, up to 25% of the total ship mass (so maximum stealth modifier is –5). Stealth fittings cost $200,000 per ton. For example, a 5000 ton ship with a –3 stealth rating would require 750 tons of stealth equipment (i.e. 15% of 5000 tons), which would cost $150 million.

24. Repair and maintenance demands (RMD factor).

A ship's reliability affects the amount of labor it requires for maintenance and repair. For a new ship, repair and maintenance demands (RMD factor) is a function of the quality of initial construction. (The reliability of older ships will decline as they age, and the rate of decline will be increased by slipshod maintenance.) RMD simply describes the amount of repair a ship requires in proportion to "normal" reliability. The normal RMD factor is 1; if a ship requires only 90% as much repair work as a normal ship, then its RMD factor is .9; if a ship requires twice the repair work of a normal ship, then its RMD factor is 2. Price goes up from 1 as the cube of the decline in RMD; conversely, price goes down at half the rate that RMD goes up. If that sounds complicated, just look at the table below.

RMD (smaller is better)	*Effect on total ship price*
0.5	x 8
0.75	x 2.37
1	no effect
1.5	reduced 16.6%
2	reduced 25%

25. Automation and final crew requirements.

Consult the table below to determine the minimum crew requirements for your ship. The number of hours of labor required by each ship system is listed. (These requirements assume an RMD factor of 1. Multiply by the listed labor time requirement by the RMD factor to find the actual labor time requirement for any ship.) You may extrapolate the necessary number of crew members from these labor requirements, keeping in mind the "typical" work week of 35-40 hours. For instance, if a ship needs 100 hours of a certain kind of labor each week, then at least two crew members, and preferably three, should be embarked to do this work.

Automation allows the number of required crew members to be reduced by substituting robots and self-maintaining systems for some (generally up to half) of the repair work. For instance, a ship with 80 people on board would require enough life-support technicians to perform 80 hours of labor per week, but this number could be reduced to 40 hours per week at a cost of $300,000.

Ship feature	*Labor time requirement*	*Skill requirement(s)*	*Automation?*
Any ship's minimum required crew	Varies	At least one person is required to command, operate the nav/helm console, sensors, and communications equipment, perform FTL astrogation (on FTL-capable ships), etc. On small ships these functions are often performed by one commander/pilot.	No.
Optional crew	Varies	It is typical for a large ship to have people aboard to perform cooking, medical care, and clerical/yeoman functions.	Cooking: yes. Medical: no. Clerical: no.
Any combat vessel	Varies	Combat vessels require a crew member with space combat tactics skill, or the computer can fight automatically.	Yes.
Ship tonnage	One hour per week per 200 tons of empty mass.	Aerospace engineer	No.
Passengers and crew carried	One hour each week for every person on board.	Spaceship life support technician	50%; $150,000 for 20 crew-hours per week.
Military communications, military sensors, ECM, fire control, and weapons	Cube root of dollars spent on this equipment equals hours of work per week.	Computer technician (20%) and electrical/electronics technician (80%)	50%; $300,000 for 20 crew-hours per week.
High performance binary fusion drive	Three hours per week per 50 tons of drives.	Spaceship drive technician	50%; $150,000 for 20 crew-hours per week.
Standard binary fusion drive	One hour per week per 50 tons of drives.	Spaceship drive technician	As above.
Deuterium fusion	One hour per week per 50 tons of drives.	Spaceship drive technician	As above.
Thermal fusion	One hour per week per 100 tons of drives.	Spaceship drive technician	As above.

FTL drive	Ten hours per jump per 100 tons of FTL drive.	FTL drive technician	50%; $150,000 for 20 crew-hours per week.
Combat damage control ability	One person per 500 tons empty mass.	Any of the technician skills above, or any engineer skill except biomedical.	50%; $500,000 for 20 crew-hours per week.
Automated repair equipment	One person for every 10 crew members replaced by automated repair equipment.	Computer technician (20%), electrical/electronics technician (40%), and aerospace engineer (40%).	No.

26. Crew accommodations.
Refer to the passenger accommodation rules (part 14) and provide quarters for your crew. It is prudent to provide accommodations for more crew than the absolute minimum, since ships tend to get less reliable and require more crew as they age.

27. Armor.
Armor increases a ship's ability to survive attack. (Structure also affects survivability; see Structure rules at part 6 above.) Armor comes in three varieties.

Plate armor. Protection value per ton is 0.5, cost $500 per ton.
Ordinary armor. Protection value per ton 1, cost $1000 per ton.
Advanced armor. Protection value per ton 1.5, cost $2000 per ton.

Record the ship's armor value = tons of armor times protection value per ton.

28. Final Empty Hull Mass.
Compute the mass of the empty hull without fuel, cargo, or embarked missiles or boats, by adding the mass of items 1 through 27.

29. Damage Index.
Damage Index equals the cube root of (empty hull mass in tons times *g* tolerance plus armor value), rounded to the nearest whole number.

30. Construction time.
Building a ship takes a number of days equal to the square root of the empty tonnage, or six days, whichever is more. The effective tonnage may be reduced (for build-speed calculation purposes only!) up to half the actual tonnage for a cost of $10,000 per ton reduced from the effective tonnage.

31. Final Cost
Add the cost in dollars of every item on the ship to find its final cost.

Spaceship Design Example

Here is an example of the starship creation process, with a description of what is done at each step.

1. For our first ship, we choose to design a good-sized vessel outfitted for duty as a privateer. It will have a gross mass of 15,000 tons. Let's call her *Queen Anne's Revenge*.
2. *Queen Anne's Revenge* needs an FTL drive. This will mass 75 tons plus (15,000 tons / 30) = 75 + 500 = 575 tons. FTL drives cost $2000 per ton, so hers will cost $1,150,000.
3. We opt for a standard binary plasma drive, which gives good performance without being wildly expensive.
4. We want a moderately fast ship, so a peak acceleration of 0.75*g* would be good. We see from the table that this requires 18.75% of the ship's gross mass be devoted to drive. 18.75% of 15,000 tons is 2813 tons. At $200,000 per ton, our fusion plasma drive costs $562.5 million. (Gross mass accounted for so far: 3388 tons.)
5. Since Queen Anne's Revenge will work as a privateer, she needs to be able to achieve high speeds to intercept other ships. This means she needs to devote a large percentage of her gross mass to fuel. Looking at the table in part 5 of the design rules, we see that if we devote half of the gross mass to fuel, the ship will be able to achieve a maximum velocity of about 0.6AU per day. This means we will haul 7500 tons of fuel. For this, we'll need 7500 x 0.08 = 600 tons for fuel tanks. Fuel tanks cost $500 per ton, so our tanks will cost $300,000. (Gross mass accounted for: 11488 tons.)
6. Our ship has a peak acceleration capacity of 0.75*g* when fully loaded at 15000 tons gross mass. Half the mass is fuel, so just before her tanks run dry she has a mass of only 7500 tons. With half the mass, her acceleration will be doubled, at 1.5*g*. Also, if she unloads any cargo or equipment her mass could be below 7500 tons, so the maximum acceleration her drives can give her could be closer to 2*g*. Let's opt for a hull structure that tolerates 2*g*. Using the formula from step 6 we see that 2100 tons are required for structure; this adds $21 million to the ship's price. (Gross mass accounted for: 13588 tons; we have only 1412 tons left.)
7. We opt for an advanced communications suite with one extra communications laser at a total cost of $70,000. (Gross mass accounted for: 13589 tons.)
8. *Queen Anne's Revenge* doesn't need any scientific equipment.
9. Enhanced sensors mass one ton and cost $100,000.
10. We choose a weapons Targeting Vskill of +5, which requires equipment with a mass of 32 tons, costing $256 million. (Gross mass accounted for so far: 13621 tons.)
11. Since *QAR* is a privateer, she needs at least a modest armament. We give her two heavy laser arrays. Total mass is 300 tons; total cost is $40 million. (Gross mass accounted for: 13921 tons.)
12. Consulting the table at step 12, we note that QAR's Evasion rating when fully loaded is –1.
13. We opt for a –1 ECM rating, costing 200 tons and $30 million. (Gross mass accounted for: 14121 tons.)
14. Queen Anne's Revenge will embark 15 cold storage hibernation chambers. 15 tons, $150,000. (Gross mass accounted for: 14136 tons.)
15. We make a preliminary estimate of crew size at 30. This would require something in the range of 100-200 tons for crew accommodations. We don't actually budget those

accommodations in the design yet, but we know to keep some gross mass free for later allocation to crew quarters.

16. We opt for a regular sick bay with a capacity for three patients. This costs 24 tons and $280,000. (Gross mass accounted for: 14150 tons.)
17. Two large and two small airlocks. 10 tons, $80,000. (Gross mass accounted for: 14160 tons.)
18. We add a small spin habitat; costs 20 tons and $150,000. (Gross mass accounted for: 14180 tons.)
19. Six basic ten-person lifeboats are fitted. Six tons, $60,000. (Gross mass accounted for: 14186 tons.)
20. *Queen Anne's Revenge* will carry two hardpoints, each with the capacity to attach a 2000 ton payload. The pair of hardpoints will mass 80 tons and cost $40,000. [Hardpoint capacity does not necessarily detract from gross mass; we note that these hardpoints are only to be used when fuel is not fully loaded, or the ship will exceed its rated gross mass.] (Gross mass accounted for: 14266 tons.)
21. *QAR* is not fitted with a hangar.
22. A cargo hold of some sort is a necessity for any ship, although QAR will have room for only a small one. If we leave 250 tons of gross mass for crew accommodations to be fitted at the end, we have 484 tons remaining of the ship's 15,000 ton gross mass. Step 22 of the ship design rules note that three percent of cargo hold capacity is allocated to cargo mountings and associated equipment. Thus, we can have a cargo hold with a 470 ton capacity and allocate 14 tons for cargo mounts. This costs $1500. (Gross mass accounted for: 14750 tons.)
23. *QAR* has no stealth fittings.
24. We choose an RMD factor of one.
25. We need to know the ship's empty mass. Empty mass is the mass of the ship minus the mass of its fuel and cargo capacities, which total 7970 tons. Empty mass is 7030 tons. Looking over the requirements for labor, it looks like QAR will need somewhere in the neighborhood of 900 hours of maintenance work per week. If each member of the crew works a 35 hour week, this means the ship needs a crew of 26.
26. We choose to provide accommodations for 37 people on board (in addition to the cold-storage capsules added at step 14.) There will be 10 3rd class bunks, 25 2nd class rooms, and 7 1st class rooms. These will mass 250 tons and cost $1,075,000.
27. No armor is fitted.
28. The mass of the empty hull is still 7030 tons.
29. Damage Index is 24.
30. The ship will take 84 days to build, unless extra money were spent to accelerate the process.
31. The ship's final cost is a little over $900 million, about 90% of which is accounted for by the large binary plasma drive and the +5 weapons targeting system for the lasers.

The next page shows an example of what a completed spaceship design sheet looks like for another ship the same size as *Queen Anne's Revenge*.

Vanguard Spaceship Design Sheet

Design Phase	*Options Selected*	*Empty Tonnage*		*Gross Tonnage*		*Dollar Cost, in millions*	
		added this phase	*Total*	*added this phase*	*Total*	*added this phase*	*Total*
1. Gross mass	15000 tons planned	0	0	0	0	0	0
2. FTL drive	FTL drive is included	575	575	575	575	1.15	1.15
3. Fusion drive type	Deuterium plasma selected	0	0	0	0	0	0
4. Acceleration and drive mass & cost	Loaded max. accel. 0.25*g*, requiring 12.5% of gross mass as drive.	1875	2450	1875	2450	187.5	188.65
5. Fuel capacity & max. speed	25%: 3750 tons fuel capacity.	300	2750	4050	6500	.15	188.8
6. Hull structure	Hull tolerance of 0.5*g*.	525	3275	525	7025	5.25	194.05
7. Communications	Ordinary	nil		nil		.01	194.06
8. Scientific equip.	none						
9. Sensors	ordinary	nil		nil		.05	194.11
10. Targeting	none						
11. Weapons	none						
12. Evasion rating	+1 [which is poor]						
13. ECM	0						
14. Passengers	10 second class cabins	60	3335	60	7085	.25	194.36
15. Prelim. crew	guess 3 crew required; remember to save at least 30 tons at the end for crew accommodations						
16. Medical	Regular infirmary, capacity for one patient	7	3342	7	7092	.025	194.61
17. Docking	Two large & two small airlocks	10	3352	10	8002	.08	194.69
18. Spin Hab.	Small spin habitat	20	3372	20	8022	.15	194.84
19. Lifeboats	4 advanced 4-person lifeboats	12	3385	12	8035	.2	194.86
20. Hardpoints	4 hardpoints, 1000 ton capacity ea.	80	3465	80	8115	.04	194.9
21. Hangars	none						
22. Cargo	cargo capacity 6636 tons	199	3664	6835	14950	.099	195
23. Stealth	none						
24. Repair/RMD	RMD factor 1						
25. Automation	none; three crew required						
26. Crew	first class accommodations for 5 crew.	50	3714	50	15000	.25	195.25
27. Armor	none						
28. Empty Mass	3714 tons						
29. Damage Ind'x	15						
30. Construction	Construction takes 61 days						
31. Final Price	$195.25 million						

Vanguard Spaceship Design Sheet

Design Phase	*Options Selected*	*Empty Tonnage*		*Gross Tonnage*		*Dollar Cost, in millions*	
		added this phase	*Total*	*added this phase*	*Total*	*added this phase*	*Total*
1. Gross mass							
2. FTL drive							
3. Fusion drive type							
4. Acceleration and drive mass & cost							
5. Fuel capacity & max. speed							
6. Hull structure							
7. Communications							
8. Scientific equip.							
9. Sensors							
10. Targeting							
11. Weapons							
12. Evasion rating							
13. ECM							
14. Passengers							
15. Prelim. crew							
16. Medical							
17. Docking							
18. Spin Hab.							
19. Lifeboats							
20. Hardpoints							
21. Hangars							
22. Cargo							
23. Stealth							
24. Repair/RMD							
25. Automation							
26. Crew							
27. Armor							
28. Empty Mass							
29. Damage Ind'x							
30. Construction							
31. Final Price							