GURPS Metric

These are some modifications to the rules found in GURPS Vehicles. As well as using the metric system, they are optimised for a science fiction campaign, specifically one of TL 10 - 12.

Technical Levels

The types of technology possible at each Tech level has been changed in these rule modifications. The following guidelines assume a somewhat 'harder' brand of SF than given in standard GURPS. For the sake of play balance though, the rates of advancement given here are way too slow.

TL	Start Year	Technology available
7	1950	
8	2000	
9	2050	
10	2150	
11	2300	
12	2400	
13	2250	
14	2300	
15	2350	
16	2400	

2 Vehicle Body and Armour

This is the structural frame of the body. First, choose a volume (in cubic metres), then the body strength. This represents both the HT of the vehicle and how much weight it can carry. Note that weight is *not* mass. A big space freighter carrying massive cargo can get away with a lighter body as long as it has a low thrust, and doesn't land.

Each vehicle is given a *body strength*, which is some value normally between 0.5 and 2.0, with the average being 1.0. This corresponds to the extra-light, light etc body strengths of standard GURPS rules, but the introduction of ultra-tech materials means much lighter frames are possible.

Equivalent to…		***Body Strength***
Extra-light	(XL)	0.3
Light	(LT)	0.7
Medium	(MD)	1.0
Heavy	(HV)	1.5
Extra-heavy	(XH)	2.0

The *maximum load* of the vehicle is found by the following formulae:

Maximum load = 250kg × SQR(material strength) × body strength × volume.

The material strength depends on the exact material used for the body of the vehicle, examples of which are given in the following section. The volume is in cubic metres. The body mass (in kg) of the vehicle is found as follows:

Body mass = SQR(material density) × body strength × volume × 10.

At this stage, it is probably also a good idea to work out the *armour factor* of the vehicle. This is equivalent to the surface area of the vehicle, and also gives its HT.

armour factor = $volume^{2/3} \times 65$.

ie, the square of the cube root of the volume, times 65. Round off to the nearest 5. The chart in GURPS Vehicles may also be used if the volume is converted to cubic feet (×37 the metric volume), but this method is more accurate. Body HT is equal to

body HT = armour factor × SQR(material strength) × body strength.

Ultra-Tech Materials

This is a combined body and armour table. Values approximate to those in GURPS Vehicles, though above about tech level 9, figures given here assume material technology gets a lot better than that suggested by standard GURPS.

Information given is the name of the material used, its strength (this is based on the number of MJ per cm^2 needed to penetrate 1cm of material thickness), its specific density (tonnes/m^3) and its mass. Mass is used to calculate body mass according to the volume of the vehicle, and also the mass of any armour if that is used. Body material and armour material do not have to be the same.

Mass is derived from strength and density, by dividing density by the strength, and then by 90.

				Cost by Tech Level				
Tech level 7	***Mass***	***Strength***	***Density***	***7***	***8***	***9***	***10***	***11+***
Iron	.0593	1.5	8	.02	.01	—	—	—
Soft steel	.0523	1.7	8	.03	.02	.01	—	—
Hard steel	.0444	2	8	.05	.03	.02	.01	—
Light alloy	.0392	1.7	6	.10	.05	.03	—	—
Fibreglass	.0444	0.25	1	.03	.03	.02	—	—
Titanium alloy	.0296	3	8	.20	.10	.05	—	—
Light composite **L**	.0194	4	7	.40	.20	.10	.05	—

				Cost by Tech Level				
Tech level 8	***Mass***	***Strength***	***Density***	***8***	***9***	***10***	***11***	***12+***
Durasteel alloy **L**	.0139	8	10	.25	.15	.10	—	—
Durasteel composite **L**	.0093	12	10	.30	.20	.10	.05	—
Monoplate **L**	.0044	10	4	.40	.20	—	—	—
Monofibre composite	.0222	0.5	1	.05	.04	.02	.02	—

				Cost by Tech Level				
Tech level 9	***Mass***	***Strength***	***Density***	***9***	***10***	***11***	***12***	***13+***
Biphase carbide (BPC) **L**	.0033	27	8	.30	.20	.10	.05	.05
Light BPC **L**	.0040	14	5	.20	.15	.10	.05	.05
Nano-crystal **R**	.0333	2	6	.50	.25	—	—	—

				Cost by Tech Level				
Tech level 10	***Mass***	***Strength***	***Density***	***10***	***11***	***12***	***13***	***14+***
Atomic lattice **L**	.0014	56	7	.40	.15	.10	.05	—
Bio-plastic **R**	.0130	6	7	.30	.20	.10	.05	—
TSC alloy **S**	.0056	30	15	.50	.40	.30	.20	.10
BPC fibre	.0062	2.5	1.4	.10	.05	.03	.02	.01

				Cost by Tech Level				
Tech level 11	***Mass***	***Strength***	***Density***	***11***	***12***	***13***	***14***	***15+***
Inert **NL**	.0025	110	25	.50	.25	—	—	—
Superdense Atomic **L**	.0007	590	35	.30	.15	.10	.05	.03
TSC Atomic **SL**	.0017	52	8	.20	.15	.10	.05	.03

				Cost by Tech Level				
Tech level 12	***Mass***	***Strength***	***Density***	***12***	***13***	***14***	***15***	***16+***
Quantum lattice **L**	.0003	206	6	.40	.20	.10	.05	.05
Inert lattice **NL**	.0013	150	18	.30	.20	.15	.10	.05
Improved Bio-plastic **R**	.0028	32	8	.25	.10	.05	—	—
TSC Superdense atomic **SL**	.0008	590	40	.20	.15	.10	.05	—

				Cost by Tech Level			
Tech level 13	***Mass***	***Strength***	***Density***	***13***	***14***	***15***	***16+***
Living metal **RL**	.0022	62	12	.30	.20	.15	—
Light Living metal **RL**	.0022	25	5	.50	.30	.15	.10
TSC Quantum lattice **SL**	.0007	95	6	.25	.15	.10	.05

				Cost by Tech Level		
Tech level 14	***Mass***	***Strength***	***Density***	***14***	***15***	***16+***
Fake matter **NRLS**	.0001	60	.5	.20	.05	.01

				Cost by Tech Level	
Tech level 15	***Mass***	***Strength***	***Density***	***15***	***16+***
Hyper-exotic **NL**	.0001	7500	85	.30	.20
Hyper-exotic TSC **NLS**	.0001	7500	90	.40	.20

L means this armour can be laminated. +50% to cost, and double DR versus shaped charges.
R means regenerating material.
N means neutral matter – this material does not react with anti-matter or normal matter.
S means material is a superconductor of heat.

The cost of the main body is equal to the cost of the material, times the body strength, times the body volume times 1000.

Durasteel: An alloy produced in micro gravity conditions to produce a high quality metal structure free of defects. Used principally during the early 21st century, but quickly superseded by monoplate.

Monofibre composite: Mono-molecular threads of carbon, produced under zero gravity conditions are woven together and used to reinforce a hard plastic, but in the same way as fibreglass. Though not overly strong, it is cheap and lightweight, making it useful for many civilian vehicles.

Monoplate: Thousands of layers of monofibre are woven together into rigid plates, tougher and steel but far lighter. By the end of TL8, monoplate has replaced durasteel as the material of choice, except in situations were cost is paramount.

Bi-phase Carbide (BPC): Basically a highly improved version of monoplate, much denser and considerably stronger. Since the technology is an extensive of earlier TL8 technology, it is reasonably cheap, and becomes common quite quickly. A lighter version, though not as strong, is also available for less cost.

Atomic lattice: The theory of using the strong nuclear force to bind atoms in a much tighter lattice had been around for a while, but it isn't until TL10 that the theory becomes practise. Atomic lattice is a dull grey material, very strong but not particularly dense. Late TL10 technology allows the colour to be changed, even making it transparent. By TL11, chameleon properties are available to allow this to be done 'on the fly', rather than merely at the time of construction.

Thermal Super-Conducting Alloy (TSC): An "above room temperature" superconductor of heat, such a material has uses against direct energy weapons. Any heat energy directed at a point on the armour is immediately conducted across the entire hull, heating up the entire craft instead of one single point. Since the total gain in heat is the same, but distributed over a much larger area, any damage is reduced. TSC alloy gains heat energy whenever it gains damage. From a pure energy attack, such as a laser, all of the damage is converted into heat, at a rate of 10kW-H per point of damage received. Particle beams convert 90% of their damage to heat, and plasma and fusion weapons 99%. Projectile weapons, such as railguns and mass drivers, are not affected by TSC alloy. TSC alloy has a total heat capacity of 100 KW-H per kg of mass. When this capacity is exceeded, the thermal superconducting properties of the material break down, and the armour is destroyed, causing damage equal to that stored to the vehicle. Divide the total damage amongst each facing of the vehicle equally.

Aerodynamic Streamlining

Any body can be streamlined to give better aerodynamic performance.

		Cost as percentage of body cost by TL											
Streamlining	***Volume***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***	***16***
Unstreamlined	0%	0	0	0	0	0	0	0	0	0	0	0	0
Fair	10%	100	75	50	25	25	20	20	15	15	10	10	5
Good	15%	—	400	200	100	75	50	25	25	20	20	15	15
Very good	20%	—	—	1000	700	400	200	100	75	50	25	25	20
Superior	20%	—	—	2500	1000	700	400	200	100	75	50	25	25
Excellent	25%	—	—	5000	2500	1000	700	400	200	100	75	50	25
Radical	25%	—	—	10000	7500	5000	2500	1000	700	400	200	100	75

Volume is percentage of vehicle volume used up.

Superstructures

A superstructure is a structure mounted on top of the vehicle's body. They are most useful on seaborne vessels were some extra height is required. On a spacecraft, a superstructure can be located anywhere on the body of the vehicle. The maximum size of a superstructure is 80% of the body volume, or just 10% if the vehicle has *partial* or better streamlining, or an *albacore* hull.

A superstructure is designed in the same way that the main vehicle body is – choose the material, body strength and armour. It is only necessary to give armour to five sides, since the underside of the structure will be connected to the main body of the vehicle.

Motive systems, flight systems and propulsion systems cannot be based in the superstructure. If the vehicle is *stealthed* or similarly designed, the superstructure must also be equally protected in order to gain any benefits.

The superstructure and anything in it counts against the vehicle's maximum load.

Turrets

Turrets are rotating superstructures, often used to house weapons to provide a greater arc of fire. Since equipment is needed to rotate the turret, a turret takes up some of the volume of the main body. This is equal to 20% of the volume of the turret for a *limited-traverse turret* (180° rotation), or 30% of turret volume for a *full-traverse turret* (360° rotation). Mass, HT and armour of the turret is figured in the same way as for vehicle body, except that body mass is doubled for a limited traverse turret, and tripled for a full traverse turret. Maximum size of a turret is 40% of body volume, or 10% of body volume if the vehicle has partial or better streamlining, or an albacore hull. The turret and anything in it counts against the vehicle's maximum load.

Turrets require 30KW of power per m^3 of turret size for rotation. All turrets $1m^3$ or smaller can be assumed to rotate at 90° a turn. Turrets up to $3m^3$ can rotate at 60° a turn. Turrets up to $15m^3$ can rotate at 30° a turn. Larger turrets rotate at 15° a turn. Double rotation speed at TL8+, at TL11+ and at TL14+.

Pop-up Turrets

Such turrets can be retracted into the body. They take up volume inside the body equal to their own volume when retracted. Volume and mass of the turret are increased by 50%.

Turrets on Turrets

The upper turret cannot be larger than 40% of the volume of the lower turret. Volume for the mechanism is taken from the lower turret, not the main vehicle body. Turrets can also be fitted onto a superstructure.

Mini-turret

A mini-turret cannot be larger than $0.75m^3$, and not more than 10% of body volume. It has only one armour location, and has armour equal to the side of the vehicle it is attached to (ie, it doesn't require its own armour).

Sloped Turrets

Turret sides may be sloped in the same way a vehicle body can be. A turret (except a mini-turret, which cannot be sloped) does not gain the slope benefits of the side of the vehicle it is attached to.

The Human Element

Any vehicle which is designed to carry occupants needs seats or quarters. Mass of these do not include the occupants themselves, though the volume does.

Seats

Internal seat: A seat inside the vehicle. May be *cramped* ($100, 25kg, $0.5m^3$), *normal* ($100, 25kg, $0.75m^3$) or *roomy* ($100, 25kg, $1m^3$).

Open seat: Half the volume of an internal seat of the same type, since it includes no overhead protection from attacks or weather. Same cost and mass.

Light seats: Any seat can be made lighter, which halves cost and mass, but such seats aren't as comfortable.

At TL6+, any seat can be assumed to be provided with seat belts etc at no extra cost.

Quarters

Quarters are designed for use 24 hours a day, providing seating, working, sleeping, cooking and living space. Quarters also includes corridor space etc.

Cramped quarters: \$250, 200kg, 5m³. The very minimum required.

Standard quarters: \$1,000, 400kg, 10m³. Assume two people share the same cabin.

Roomy quarters: \$4,000, 800kg, 20m³. First class passenger or officer's cabins.

If the quarters are to be used in a spacecraft or similar vehicle in a zero gravity environment, volume and mass can be reduced by 30%. Note that any spacecraft which is going to have an acceleration about 0.05g cannot take advantage of this.

Cryogenic Freezers (TL8+)

On very long journeys, it can be useful to freeze people, reducing their need for nutrients, air and space. Normally, such techniques are only used on space vessels, especially when travel times are long. The technology comes into use at TL8, though it is somewhat imperfect. At higher TLs, the reliability of the systems improve.

A single freeze cube costs \$20,000, masses 400kg, and takes up 2m³. At TL9, cost, mass and volume are halved, and again at TL10. At TL11, only cost is halved, and again at TL12. At TL8, a HT roll at -4 must be made whenever someone is put into freeze, and taken out. Failure means death. Each TL over TL8, a +4 bonus is gained to the HT roll (so at HT at TL9, HT+4 at TL10 etc).

Consumables

People need to eat. To supply enough consumables for eating, washing etc for one person for one day, you need 30kg of supplies, which take up 0.03m³. Add 10% to mass and volume if refrigeration is also required. The latter also requires a power source, of negligible power.

Crew and Passengers

The mass of crew and passengers (volume is included in seating and quarters) depends on their own mass, plus any luggage they have with them. Without luggage, figure 80kg for an average person, this wil include clothes and basic effects. For longer duration travel, assume 120kg. If crew need heavy weapons and armour, this is going to have to be calculated separately.

Vehicle Size and Other Things

Every vehicle has a *size*, which is a modifier to how easy it is to detect visually. Related to this, is also a radar signature and heat signature. All of these can be modified using various stealth systems. The rules in GURPS Vehicles have been replaced by the following:

$$\textit{Vehicle size} = 2 \times lg(5 \times volume) \div lg(8).$$

This approximates to the size table in GURPS Vehicles (actually, the table approximates to this). Round to the nearest integer. This value is used when trying to detect the vehicle by sight, or when trying to hit it. Volume is in cubic metres, as always.

Range

The equation for the range modifier is also given here, since we want it in metres, and equations are so much nicer than the big cumbersome chart in the main rule book.

$$\text{Range modifier} = -((2 \times lg(distance) \div lg2) + 16).$$

Distance is in kilometres. A range of 1 km has a modifier of -16 (remember, this is character scale, so 1km is quite a way, hence a large penalty. Big weapons have a high accuracy which offsets this).

3 Motive Systems

Ground Motive Systems (Powered)

Since all options for ground motive system are in % of body size, this remains the same.

Flight Systems

Wings

Stall speeds for winged vehicles, according to type of streamlining, are as follows:

Unstreamlined	30 kmh
Fair	45 kmh
Good	60 kmh
Very good	85 kmh
Superior	90 kmh
Excellent	105 kmh
Radical	120 kmh

Wings cost 500% of the vehicle's aerodynamic streamlining's cost; if the vehicle has no aerodynamic streamlining, the wings cost 400% of the body cost. Wings mass 125% of body mass, and use up 5% of body volume. *Each* wing has its own HT score, equal to body HT/2.

Rotary Wings

All stats remain the same, except autogyros have a stall speed of 10 kmh. A rotary wing costs 300% of body cost, masses 50% of body mass, and requires 5% of body volume. The rotary wing's HT is equal to body HT/4.

Vertol Lift

Vertol systems consist of the flight controls and thrust vectoring system. At TL7, it costs $20,000 per cubic metre of body size, masses 15kg per cubic metre of body size and takes up 2% of the bodies volume. At TL8+, it is $4,000 and 8kg per cubic metre of body, volume remaining the same. At TL10+ is is $2000 and 5kg. At TL12+ volume drops to 1%.

A vertol lift system requires a reaction engine of some kind to provide the necessary thrust.

Space Flight

Options for propulsion in space are limited, since the only way to move forward is to chuck something out the rear. The most common method is a pure reaction drive, spitting out superheated plasma at hundreds of kilometres per second.

Basic Reaction Thrusters

Consists of exhaust nozzles pointing in the direction opposite to the one along which acceleration is required. Size, mass and cost of the thrusters depends on the power of the reaction engine being used to power them (see next section). A single thruster which allows the full power of the reaction engine to be channelled through it has cost, mass and volume equal to 5% of the reaction engine.

A smaller manoeuvre thruster has cost, mass and volume equal to 1% of the reaction engine, but only allows 10% of the power of the engine to be channelled. Manoeuvre thrusters are often mounted on the front of the spacecraft, to allow breaking without the necessity of having to turn the craft around and use the main thrusters (very useful when docking). A common configuration is to mount four manoeuvre thrusters on pylons near the rear of the craft, pointing forward, each at 90° to each other. This allows the ship to turn, while providing up to 40% backward thrust.

The total thrust from all thrusters at any one time cannot exceed the output from the reaction engine, though they can share it in any combination.

Orion Star Drive

This has to get a mention, since its so much *fun*. Basically, the Orion drive consists of a big plate at the rear of the craft, with the main body of the spacecraft connected via powerful suspension system. Then you drop a nuclear bomb out the back and set it off. The explosion pushes against the plate, and forces the craft forward.

To design the ‘plate’, consider it a hull in its own right, separate from the main body of the vehicle. It must be given a DR of at least 100 per tonne of explosive force of the bombs.

Light Sail

The light sail (also known as a solar sail) consists of a (very) large ‘sail’ which is used to catch the solar wind. The sun though isn’t the only possible source of thrust for a light sail – a massive ground based or orbital laser does just as nicely, and can generate a much more powerful thrust as well (though this requires that you happen to have a nice big laser handy).

Gyroscopic Manoeuvring System

By use of massive gyroscopes, a spacecraft can turn itself without needing to resort to reaction thrusters. By turning the gyroscopes in one direction, the spacecraft is forced to turn in the opposite direction. The gyroscopes are normally made of some massive material, in order to reduce the required size. Mass is measured in tonnes, and volume is 1m³ per tonne of mass of the gyroscope.

Hyperspace

Any craft wishing to travel through hyperspace requires two items of equipment. First, a ‘twister’ is needed to allow the craft to enter and leave hyperspace. In practise, it is possible to do away with a twister, and rely on *shunt freighters* which carry craft into and out of hyperspace. Such freighters are rare though, and never found around except around the most advanced of worlds.

The second item is the ‘mover’, which allows movement through hyperspace. Unlike realspace, the chaotic nature of hyperspace causes friction.

Twister (TL11+)

The most expensive and massive part of the hyperdrive system, which is why shunt freighters can be so useful. A twister cannot be used within a steep gravitational incline – ie close to a star or planet. The *safe limit* is defined by the acceleration due to gravity acting on the spacecraft, in m/s/s. If the acceleration is greater than the safe limit, then a jump to hyperspace can be fatal. Where a craft is being influenced by two or more bodies, add the accelerations together. This will generally be the case when the craft is in orbit close to a planet, since it will be affected by both the planets gravity, and the gravity of the star (in theory it will also be affected by *all* the planets in the system, but the influence of even a Jupiter sized planet outside its moon system is generally negligible compared to the influence of the star at that point).

Of course, at some point, a craft may be forced into entering or leaving hyperspace too far inside a gravity well. When this happens, the craft risks being ripped apart. For each multiple of the *safe limit* the strength of the gravity field is at, roll 3d6. If any of them come up a 6, the craft is utterly destroyed, and all aboard are killed. If any come up a five, it is crippled, and everyone on board must make a HT roll at -2 for each 5 rolled or die. Success merely means they have been seriously injured (GM's discretion here), and suffer 1d6×100 rads of radiation. If any 4's are rolled, the twister is destroyed, and everyone suffers 1d6×50 rads of radiation.

Tech	***Safe***	***Basic Start-up***		***Per m³ of volume***	
Level	***Limit***	***Cost***	***Volume***	***Cost***	***Mass***
11	0.0001	$2M	25%	$5000	1,000
12	0.0005	$1M	15%	$2000	500
13	0.0025	$500K	10%	$1500	300
14	0.01	$200K	5%	$1000	200
15	0.05	$100K	2%	$750	150
16	0.25	$50K	1%	$500	100

The *safe limit* of a twister is the acceleration due to gravity in metres per second per second. Volume is percentage of body volume. Mass is in kg, and is based on the volume of the twister, not of the whole vehicle.

Cheap: A cheap twister, which is half cost, has a safe limit of half the normal level for the TL.

Expensive: An expensive twister is double total cost, but is either half the mass, or has double the safe limit. Volume cannot be changed.

Advanced: An advanced twister is quintuple normal cost, but is both half mass and has its safe limit doubled. Volume cannot be changed.

Mover (TL11+)

The *mover* is what allows a vehicle to move in hyperspace. Hyperspace is a shifting, chaotic realm totally unlike the vacuum of space. There is friction in hyperspace, and hence vehicles have a maximum speed – the point at which the thrust of the vehicles equals the drag of the hyper-medium. The same effects which cause friction also give the vehicle something to push against to move. A *mover* acts much like a propeller on an aircraft, pulling the craft through hyperspace without needing to use propellant.

The velocity of a craft in hyperspace is equal to:

$$velocity = SQR(energy \div mass).$$

Energy is in watts, mass is in kg and velocity is in c (where c equals the speed of light). There is no speed of light limit in hyperspace, and even relatively slow craft can manage several tens of times the speed of light. Note that though there is friction in hyperspace, it is not physical in nature, and the shape of the craft does not allow streamlining.

Tech	*Basic start-up*			*Per MW of thrust*		
Level	***Cost***	***Mass***	***Volume***	***Cost***	***Mass***	***Volume***
11	$1M	50,000	10	$500	50	.0005
12	$200K	10,000	5	$200	10	.0002
13	$40K	5,000	2	$100	2	.0001
14	$8K	3,000	1	$50	0.5	.00005
15	$2K	2,000	1	$25	0.2	.00002
16	$500	1,000	.5	$15	0.1	.00001

Mass is in kg, and volume is in m^3.

The mover also includes the equipment necessary to provide protection to the interior of the vehicle against the ravages of hyperspace. It requires a minimum energy expenditure equal to 1KW per cubic metre of the vehicle to be protected. Generally, the mover is set up to protect the entire ship, though it is only necessary to protect the crew quarters.

Expensive mover: An expensive mover is quintuple normal cost, but has the advantage of being at half mass and volume (both start-up and per MW of thrust).

4 Propulsion Systems

A propulsion system is the heart of the vehicles means of travel. It will often require a power source to power the engine, as well as a motive system to provide the movement. For example, a reaction engine needs a large source of power to heat the reaction mass, and exhaust nozzles through which the heated mass is ejected.

The Physics of Space Travel

The thrust from a reaction drive, where *E* is the energy of the drive, in watts, and *v* is the exhaust velocity (in m/s, *not* km/s), is equal to:

$$thrust = 2 \times E \div v$$

The rate at which reaction mass is used up, in kg per second, is equal to:

$$mass = 2 \times E \div v^2$$

A lower exhaust velocity will actually give a greater amount of thrust for the same energy expenditure, but at the cost of far lower efficiency (double the thrust, you quadruple the rate at which the reaction mass is used up, so you halve your final velocity).

To find the maximum *delta vee* (change in velocity, ie the maximum velocity that the ship can obtain in a straight run. Since you also have to stop though, a ship will generally use about half its delta vee to accelerate initially, and the other half to brake at the destination. Smaller fractions will be needed for in course manoeuvres) the following formula can be used:

$$delta\ vee = exhaust\ velocity \times \log(full\ mass \div dry\ mass).$$

This equation is needed since the mass of the ship changes as propellant is used up, so towards the end of the journey, when the total mass of the ship is lower, the acceleration will be greater. It also means that the final attainable *delta vee* doesn't worry about the actual mass of the ship, just the proportion of the original mass which is propellant. For instance, a 100t ship with 500t of propellant would have the same *delta vee* as a 500t ship with 2500t of propellant. Of course, the more massive ship will take longer to accelerate up to full velocity (assuming the thrust is the same).

There is a major difference between spacecraft design and aircraft design. Aircraft don't need to carry their propellant with them – jet engines suck in air, heat it, and then expel it at high velocity to produce thrust. A spacecraft has no similar surrounding medium. The propellant has to be carried with them, which adds to the mass of the spacecraft. Typically, the full mass of an interplanetary spacecraft will consist of 50% to 90% propellant, depending on their drives, and how fast they want to travel.

Helicopter Powertrains

A helicopter powertrain may be installed on any vehicle with a rotary wing. A helicopter requires a minimum motive power of 1 KW per 5kg of maximum load (1 KW per 6kg if vehicle uses dual top rotors). Cost, mass and volume are based on motive power, type of rotor assembly, and TL, and are per KW of helicopter motive power.

TL	*Rotor assembly*	*Cost*	*Mass*	*Volume*
TL6	Top and tail rotors	$50	.5	.0005
TL6	Dual top rotors	$75	.75	.0008
TL7	Top and tail rotors	$50	.25	.00025
TL7	Dual top rotors	$75	.04	.0004
TL7	NOTAR	$100	.25	.00025
TL8	Top and tail rotors	$50	.15	.00015
TL8	Dual top rotors	$75	.25	.00025
TL8	NOTAR	$90	.15	.00015
TL9+	Top and tail rotors	$50	.1	.0001
TL9+	Dual top rotors	$75	.15	.00015
TL9+	NOTAR	$80	.1	.0001

Reaction Engines

These heat a reaction mass and eject it from the vehicle in order to generate thrust. Thrust is measured in Newtons (N), where 1 N will accelerate 1 kg of mass at 1 ms^{-2}. For space craft, this formula is used directly, for atmospheric vehicles, things are complicated due to atmospheric drag.

Most of the reaction engines listed here require a separate power source. The exception are chemical rockets, which burn their own fuel and use it as propellant. Turbojets also carry and use their own fuel, but these are listed in their own section, since they work somewhat differently to the reaction engines listed here – all these are space drives, for use outside an atmosphere.

Reaction Engines as Weapons

A reaction engine is hot, and in space it is practical to point your drives at the enemy and use them as a weapon (in an atmosphere, this is rarely practical since the only guaranteed result of such a manoeuvre will be loss of control). Generally though, accuracy and range of drives tends to be lousy, so such a manoeuvre is only of use to otherwise unarmed craft.

Damage is equal to 6d6 times the energy of the drive in MW (*not* thrust in newtons). Range (in metres) of such weapons is equal to exhaust velocity in kilometres per second, and damage falls off according to the square of the range. So a TL9 plasma drive with a Vex of 30km/s, would have a range of 30m, so it does full damage up to 30m, ¼ damage up to 60m etc. Accuracy is 5. For 50% extra cost, and 5% extra mass and volume, any drive can be built with its use as a weapon in mind. Accuracy becomes 10, and range is quadrupled.

Types of Reaction Engines

Chemical rocket: Chemical rockets are the standard reaction engine used for spacecraft before about TL9. Before TL8, they are often the only choice. Even at higher TLs though, they have their advantages. They are cheap, reliable and also relatively clean. Electro-thermal drives (plasma, ion, fusion etc) generally cannot be used in an atmosphere since the extreme exhaust heat causes the atmosphere to fuse (ie – *boom!*). Chemical rockets have no such problems.

Plasma drive: These are the earliest electro-thermal drives, heating the reaction mass up to plasma temperatures, and ejecting it at over 15km/s. The exhaust is *very* hot, and can be used as a short range weapon in an emergency. Doing so also causes 1 rad of radiation damage per 10 points of normal damage. Compared to the chemical drives that have been in use up until this time, they are very efficient, and allow a high thrust for a given energy. Common reaction masses are cadmium or mercury.

Ion drive: Ion drives are far more efficient than plasma drives, but also have much lower thrusts. Ion particles are accelerated up to high velocities using magnetic fields. Unlike plasma drives, they don't make very good weapons, doing one tenth normal damage if used as such, but they still cause 1 rad per 10 points of damage done. Hydrogen is often used as reaction mass.

Stealth drive: By TL9, combat between space craft becomes common enough to start seriously thinking about hardware. The most important technology is in the areas of detection and stealth – the first one to find their enemy, and get close enough undetected, is often the winner. To get close though requires thrust, and reaction engines are often bright and easy to see. The stealth drive is a 'cold' reaction drive, being a development from the railgun. Indeed, it *is* a railgun, firing slugs of depleted uranium to produce thrust. Accuracy is sacrificed for exhaust velocity and size. Because of their small size, they are often fitted to missiles. They have low efficiency, but produce almost no detectable exhaust heat.

Fusion drive: The fusion drive is the next step up from the Ion and Plasma drives. It has a very high exhaust velocity, and hence high efficiency and low thrust. The engine design though allows the velocity to be reduced by anything down to a fifth of maximum, increasing thrust by a factor of five, for a high loss of efficiency. Exhaust is very hot, and hence easy to detect. If used as a weapon, they have an armour divisor of (2), and cause 1 rad per 2 points of damage.

		Basic start up			***Per MW of energy***		
Type of Reaction Engine	***Vex***	***Cost***	***Mass***	***Volume***	***Cost***	***Mass***	***Volume***
TL6 Chemical rocket	4	$100	10	.01	$100	2	.005
TL7 Chemical rocket	5	$100	10	.01	$100	1	.0025
TL8 Chemical rocket	7	$90	9	.01	$80	.07	.002
TL8 Plasma drive	15	$25K	200	0.2	$150	.15	.001
TL9 Chemical rocket	10	$90	9	.01	$60	.05	.00175
TL9 Ion drive	100	$100K	150	0.1	$250	.07	.0007
TL9 Plasma drive	30	$50K	200	0.2	$100	.1	.001
TL9 Stealth drive	6	$10K	25	.0025	$25K*	100t*	100*
TL10 Chemical rocket	13	$80	8	.008	$50	.04	.0015
TL10 Fusion drive	250 †	$50K	250	0.1	$200	.1	.001
TL10 Stealth drive	8	$10K	15	.0015	$20K*	30t*	30*
TL11 Chemical rocket	16	$80	8	.008	$40	.03	.00125
TL11 Fusion drive	500 †	$50K	250	0.1	$150	.09	.0008
TL11 Stealth drive	12	$10K	10	.001	$15K*	10t*	10*
TL12 Chemical rocket	18	$70	7	.008	$35	.02	.001
TL12 Fusion drive	750 †	$50K	250	0.1	$125	.08	.0006
TL12 Stealth drive	16	$10K	5	.0005	$10K*	5t*	5*
TL12 Photon drive	300,000	$100K	175	0.2	$1000	.05	.001
TL13 Chemical rocket	20	$70	7	.007	$30	.015	.0008
TL13 Fusion drive	1,000 †	$50K	250	0.1	$100	.07	.0005
TL14 Chemical rocket	22	$60	6	.007	$25	.01	.0006
TL15 Chemical rocket	24	$60	6	.007	$20	.0075	.0005
TL16 Chemical rocket	25	$50	5	.006	$15	.005	.0004

* The stealth drive, though listed here for MW, is normally used in KW energy ranges, and scales

down to such levels linearly (ie divide cost, mass and volume by 1000 to get values per KW).

† The Plasma drive allows exhaust velocity to be lowered by anything down to a 1/5 of normal velocity. This allows greater thrust, at the expense of efficiency.

Exhaust velocity is in kms^{-1}, Mass is in kg and volume in m^3.

Options

Cheap: A cheap drive is half cost, and is only capable of half the normal exhaust velocity.

Expensive: An expensive drive is triple normal cost, and is capable of twice the listed exhaust velocity. Mass and volumes remain the same.

Advanced: An advanced drive has quadruple the listed exhaust velocity, but cost is ten times normal. Mass and volumes remain the same.

Out dated: A drive of a previous TL. Cost is one third listed cost.

Reaction mass used is often Cadmium, which has a mass of 8.65t/m^3, or water, which masses 1t/m^3.

Turbojets

Turbojets are a form of reaction engine which only works in an atmosphere. Many types of turbojets also require that atmosphere to have a healthy mix of oxygen, though some of the more advanced ones (such as hyperfans) carry their own oxygen supply.

		Basic start up			*Per KN of thrust*			*Fuel*	
Type of turbojet		*Cost*	*Mass*	*Volume*	*Cost*	*Mass*	*Volume*	*Usage*	
TL6	Early Turbojet	$150	100	.1	$3000	75	.02	.65	J
TL7	Basic Turbojet	$4000	100	.1	$2000	40	.01	.25	J
TL7	HP Turbojet	$8000	100	.1	$4000	20	.005	.5	J
TL7	Basic Turbofan	$5000	100	.1	$2500	50	.012	.2	J
TL7	HP Turbofan	$10K	100	.1	$5000	25	.006	.4	J
TL7	Turboramjet	$15K	200	.2	$7500	20	.005	.5	J
TL8	VB Turbojet	$2500	25	.025	$2500	30	.0075	.125	J
TL8	HPVB Turbojet	$5000	25	.025	$5000	15	.004	.25	J
TL8	Turboramjet	$12K	100	.1	$6000	10	.0025	.33	J
TL9	Hyperfan	$1000	25	.025	$2500	10	.0025	.125	HO
TL10	Hyperfan	$800	15	.015	$1500	5	.0015	.1	HO
TL11	Hyperfan	$600	10	.01	$1000	3	.001	.075	HO
TL12	Hyperfan	$500	7	.0075	$750	2	.0075	.06	HO

Mass is in kg, volume in m^3. Fuel usage is in litres per hour per KN of thrust.

At TL10 and above, a hyperfan can have an *orbital* option added. This adds +100% to cost, +25% to mass and +10% to volume. The result is that the engine can switch between atmospheric and orbital flight. The latter allows it to operate outside an atmosphere, but fuel usage rate becomes per second, instead of per hour.

Fuel

Fuels are listed in chapter 4.

Reactionless Drives

Reactionless drives have the distinct advantage in that they allow travel through space without the requirement of large amounts of reaction mass. They do not become available until TL14, when advances in quantum physics allows for the manipulation of space time.

The most common reactionless drive system is the *gravity shear drive*, which ‘creates’ a singularity (decently clothed by a black hole) ahead of the vehicle. The gravitational force of the singularity pulls the craft forwards towards it. Since the singularity is being ‘created’ at a fixed distance from the craft, it moves forwards as well, providing a continuous acceleration forwards. This method of pulling oneself up by your boot laces seems to defy physics as understood at lower TLs. But then, so does much of TL14 and upwards technology.

Gravity Shear Drives as Weapons

The problem with the use of a singularity to provide gravitational acceleration, is that it causes a severe gravitational incline around the singularity. *Anything* hitting it is destroyed. As such, vehicles which use such drive systems often require the use of smaller reaction thrusters for use during docking manoeuvres. Deliberate ramming of enemy vessels is also possible.

5 Power Systems

The most common high-tech power systems are either fusion plants, or anti-matter plants. The former are cheaper, but produce less energy for a given mass of plant, making anti-matter plants the most suitable for space vehicles. The production of anti-matter fuel is *very* expensive though, and before about TL13, requires a greater amount of energy expenditure to make, than it is obtained from the fuel when it is used, making it unsuitable for planet based power plants.

Power Plants

Fusion

Fusion plants are the most common up to about TL12. By TL13, anti-matter becomes cheap enough to produce to make anti-matter plants a better deal. The fusion of hydrogen into helium though better than other forms of energy production at this stage, is still only about 10% efficient.

Anti-matter

Anti-matter is expensive to produce, but once it has been made, it can be used in a plant where energy densities are more important than costs (such as a military spacecraft). Getting greater than 70% or 80% efficiency from anti-matter is very difficult, and 50% efficiency is more common.

Power Plant Table

	Basic start-up			***Per MW of energy***			***Fuel***
Type of power plant	***Cost***	***Mass***	***Vol.***	***Cost***	***Mass***	***Vol.***	***Usage***
TL8 Fuel cell	$200	5	.005	$25K	1000	1.35	2.2kg
TL8 Fusion plant	$1M	10,000	5	$100K	20	.5	.06
TL9 Fuel cell	$100	2	.002	$25K	1000	1.35	1.5kg
TL9 Fusion plant	$100K	1,000	0.5	$20K	5	.1	.05
TL10 Fusion plant	$10K	200	0.1	$4K	1	.02	.045
TL10 Anti-matter plant	$1M	5,000	5	$50K	.4	.008	.01
TL11 Fusion plant	$1000	40	0.02	$800	.2	.005	.04
TL11 Anti-matter plant	$20K	2,500	2.5	$5K	.1	.002	.008
TL12 Fusion plant	$100	10	0.005	$200	.04	.0025	.04
TL12 Anti-matter plant	$1000	1,000	1	$1K	.02	.001	.005
TL13 Fusion plant	$10	5	0.0025	$50	.02	.002	.04
TL13 Anti-matter plant	$100	250	0.25	$200	.01	.0005	.004

Fuel usage is in milli-grams per MW-H, except where noted to be in kilogrammes. Mass is in kg, and volume is in m^3.

Power Plant Options

Small plant: Designed for low outputs, reducing start-up costs and size, at the expense of efficiency. Multiply all start-up values by 10%, but multiply cost per MW by 5, and mass and volume per MW by 2. Small fusion plants use 25% more fuel, and small anti-matter plants use 50% more fuel for a given power output.

Outdated: A plant from the previous TL, is one fifth for all costs.

Cheap: A cheap plant is quarter cost (start-up and per MW), but only gives half the output.

Expensive: Triple normal start-up and per MW cost, but twice the power output.

Advanced: Decuple normal costs, but three times the power output.

Energy Banks

An energy bank is used to store electrical power. Unlike a power plant, they do not actually generate the energy themselves, so the amount of energy available is far more limited. They have the advantage though that if power is only required for short periods of time, then they can be cheaper and smaller than an equivalent power plant. They also generate less heat, making them far more stealthy. Capacity of a energy bank is measured in KWH.

Energy Bank Table

		Per KW-H of capacity		
TL	***Type***	***Cost***	***Mass***	***Volume***
TL7	Lead-Acid Battery	$100	30	.005
TL7-8	Lithium Battery	$50	15	.004
TL8	Advanced Battery	$10	2	.0001
TL8	Rechargeable Power Cell †	$40	.2	.00002
TL8	Power Cell	$20	.1	.00001
TL9	Rechargeable Power Cell †	$25	.15	.000015
TL9	Giga-capacitor Cell †	$30	.02	.000005
TL10	Casimir Generator	$10	.005	.000002
TL10	Giga-capacitor Cell †	$10	.01	.0000025
TL11	Casimir Generator	$5	.0025	.000001
TL11	Giga-capacitor Cell †	$4	.005	.0000015
TL12	Casimir Generator	$3	.00125	.00000075
TL12	Giga-capacitor Cell †	$2	.0025	.000001

†These cells are rechargeable.

Cost, mass and volume are per KWH of stored energy. Energy banks have a HT equal to twice their armour factor (figured from volume in the usual way).

Fuels

Price, mass and other characteristics of various fuel types are given below.

Type of fuel	*Mass (kg) Per litre*	*Fire*	*Cost*
Gasoline or propane	.72	8	$0.40
Aviation gas	.72	10	$0.50
Diesel	.72	6	$0.30
Jet fuel (kerosene)	.78	10	$0.80
Hydrogen	.06	10	$0.03
Hydrox	.60	10	$0.25
Rocket fuel	.60	10	$0.50
Alcohol	.72	7	
Mercury	13.55	0	$1.30
Water	1.0	0	—

6 Performance

Speed and Thrust

Use the following to calculate maximum speed of a vehicle.

Ground Speed Factor

Unpowered or Powered Wheels

with TL1-3 sails: 15 km/h
with TL4+ sails: 18 km/h
with aerial propellers, or reaction engines: 30 km/h
with ornithopter wing and powertrain: 25 km/h

Skids/runners

with TL1-2 sails: 12 km/h
with TL3 sails: 16 km/h
with TL4+ sails: 18 km/h
with aerial propellers or reaction engines: 25 km/h
with ornithopter wing and powertrain: 18 km/h

Powered wheels and wheeled drivetrain

TL5 design: 18 km/h
TL6 design: 40 km/h
TL7 design: 45 km/h
TL8 design: 48 km/h

7 Accessories

Computers

The following software is available. Each +1 to the skill of the software, doubles the cost. Every full +3 to the skill, adds 1 to the complexity of the software.

Program	*Complexity*	*Cost*	*Skill*	*Size*
Astrogration	4	$250,000	TL+5	125 MB
Damage Control	2	$2,000	TL+5	60 MB
Electronics Repair	2	$500	TL+5	60 MB
Environmental Analysis	3	$3,000	TL+5	250 MB
Gunner	4	$45,000	TL+5	30 MB
Hyper-astrogation	6	$1,000,000	TL+5	500 MB
Interpreter	4	$10,000	TL+7	250 MB
Medical	4	$40,000	TL+5	500 MB
Optical Recognition	4	$20,000	TL+7	250 MB
Piloting – Surface	3	$500	TL+7	30 MB
Piloting – Air/Space	4	$10,000	TL+7	60 MB
Sensor Operation	3	$1000	TL+5	30 MB

Defensive Systems

Compartmentalization (TL5+)

Only possible on vehicles with a volume of $10m^3$ or greater. *Heavy compartmentalization* divides air loss or amount of water taken on board by 5. Costs 50% of body cost, masses 50% of body mass, and takes up 5% of body volume. *Total compartmentalization* divides air loss or water taken on board by 10, and costs 100% of body cost, masses 100% of body mass, and takes up 10% of body volume.

Dischargers (TL6+)

One-shot launcher box for various decoys or smoke bombs. Each discharger holds one decoy, though at TL8+, they can automatically reload themselves for +50% to cost. This takes 5 seconds.

Chaff is designed to reflect radar signals. Discharger costs $100, masses 10kg and takes up $0.01m^3$ of volume. Refills are $50, 5kg and $0.005m^3$.

Flare dischargers release heat emitting flares to decoy IR-homing missiles. Discharger costs $100, masses 10kg and takes up $0.01m^3$ of volume. Refills are $50, 5kg and $0.005m^3$.

Smoke dischargers launch chemical smoke bombs. At TL8+, *hot smoke* (to foil IR as well) or *prismatic smoke* (to foil lasers) can also be used. Discharger costs $100, masses 10kg and takes up $0.01m^3$ of volume. Refills are $50, 5kg and $0.005m^3$.

Sonar Decoys are designed to emit bubbles or create false noise. Discharger costs $500, masses 50kg and takes up $0.05m^3$ of volume. Refills are $250, 25kg and $0.025m^3$.

Sand casters eject ‘sand’ or similar massive particles to block direct energy weapons. Available from TL8 onwards. Discharger costs $500, masses 500kg and takes up $0.5m^3$ of volume. Refills are $100, 250kg and $0.25m^3$.

Fire Extinguishers (TL4+)

Automatic Fire Suppression System (TL7+): Uses inert gases to put out fire sin milliseconds. Usable only on vehicles over $2m^3$ in size. It is $5,000, 100kg, $0.2m^3$ per $250m^3$ of vehicle size or part thereof. Divide cost by 10 at TL8+.

Compact Fire Extinguisher (TL8+): As an automatic fire suppression system, but miniaturised. It is $1,500, 20kg, $0.05m^3$ per $250m^3$ or fraction of body size.

G-Seat (TL7+)

Adds +2 to HT rolls to resist high-G manoeuvres. Adds $500 to cost of any seat.

Infrared Cloaking (TL7+)

Makes a vehicle less visible to IR and thermographs.

Basic IR Cloaking: Reduces IR signature by (TL-4). Costs $100 × sum of vehicles body, turret and superstructure armour factors. It has negligible mass and volume.

Advanced IR Cloaking: Reduces IR signature by (TL-2). Costs $500 × sum of vehicles body, turret and superstructure armour factors. Masses 0.05kg × sum of armour factors, and has a volume of $0.0001m^3$ × sum of armour factors. Quadrupling cost, mass and volume subtracts a further -1 from IR signature. Disabled if the vehicle looses power.

Zero Heat Shielding (TL10+): An ultra-advanced form of preventing IR detection, it is generally of use to missiles and other small, unmanned craft in space. Before flight, the vehicle is cooled down to near absolute zero temperatures, and kept there with use of thermal superconducting layers around the hull. The idea is for the vehicle to be as cold as background radiation, though this ideal temperature is rarely kept to for long. Reduces IR signature by (TL-6) × 10, and costs $1000 times the armour factors of the vehicle.

Stealth

Makes a vehicle less visible to radar, ladar and sonar, reducing its radar signature.

Partial Stealth: Reduces radar signature by TL-4. Costs $100 × sum of armour factors.

Radical Stealth: Vehicle *looks* stealthy. Cost is $500 × sum of armour factors, mass is 0.05 kg × sum of armour factors, and volume is $0.001m^3$ × sum of armour factors. Reduces radar signature by (TL-4)×2, and then by a further -1 for each doubling of cost, mass and volume.

Sensors

All sensors have a *scan* rating, which is modified by the signature of the target, and the distance to it. To detect a target, roll against sensor skill, adding the sensor’s *scan* rating, and modifying for range and target signature (normally based on the size of the target, but can be more or less, for example if the target has stealth capability, or is using a hot fusion drive). If the skill roll is successful, then the target has been detected.

Most active sensors can be made passive at a press of a button (indeed, an active sensor can also pick up signals passively while in active mode), an act which takes a turn. Active sensors gain a bonus to *scan* from the power of the signal – ie each tenfold increase in power for a radar gives a +1 bonus. When in passive mode, a sensor gains no power bonus.

A passive sensor can only pick up signals from active sensors (the exception is IR and optical). It gains +2 to basic scan, and *double* the power bonus from the active sensor being scanned.

Electro-Magnetic Induction Net (TL10+)

An ultra-tech sensory system which projects a strong magnetic field around the vehicle. By detecting changes in the field, caused by the movement of charged objects through it, the system can determine the position and velocity of any object moving in the vicinity of the vehicle. Generally, it is linked up to an automatic point defence system, and used for detecting missiles and projectiles directed at the vehicle.

The major failing of the system is that it can only detect charged or ferrous objects. The majority of ultra-tech missiles and projectiles are neither. To this end, the system is combined with an ionising field which is projected along the outer surface of the magnetic field. Any object is first ionised to give it a charge, and then detected as it disturbs the magnetic field.

The magnetic field projector costs $10,000 plus $100 per sum of armour factors of the vehicle. It masses 0.01 kg per sum of armour factors, and has a volume of 0.001m³ per sum of armour factors. It requires power equal to 10W per sum of armour factors of the vehicle. Each TL after 10, halve cost, mass and volume. The field is projected out to 100m from the surface of the vehicle.

The ionising projector costs $500 times sum of armour factors of the vehicle, has a mass of 0.005 kg times armour factors, and a volume of 0.002m³ times armour factors. These halve for each TL after TL 10.

Both the magnetic net, and the ioniser, have two blindspots, each directly opposite each other. Normally, these run along the axis of the vehicle, directly to the aft, and directly to the fore.

Radar (TL6+)

The most common form of sensors, until TL13 or so. Basic cost is $5000, mass is 2kg, volume 0.002m³, and power requirement is 50W. This gives a *Scan* of 2×TL. Each time cost, mass and volume is multiplied by ×8, +2 is added to the scan (effectively doubling range). A single, one-off quadrupling of cost will give a +1 to scan, and a quartering of cost will give -1.

Power requirement is independent of size, but each tenfold increase in power gives a further +1 bonus. This can be varied ‘on the fly’ during operation, taking a second to change power use.

The radar system can be made *passive*, in which case power requirement becomes negligible, and the sensor can only detect radar active targets – ie anyone using an active radar.

At TL 8+, a radar can be a lader, in which case scan is at -1, but the advantage of being able to ‘see’ the shape of the target is gained. At TL10+, and for 5×cost, Xader can be used, which allows limited scans of the interiors of targets.

Radar does not work at all underwater (maximum range is a few centimetres). Lader and Xader are both at -10 to scan underwater. A special *blue-green* ladar can be used which is -5 to scan both above and below water. At TL9+, for double cost, ladar can be mutli-frequency, allowing frequency to be shifted to the most optimal automatically (takes 1 second). At TL10+, this feature can be added to Xader (normal multi-frequency lader cannot be shifted to X-ray wavelengths).

Radar and all forms of Ladar can be used passively.

Radar, Distributed (TL8+)

The vast distances in space call for very large sensor arrays, often much larger than a reasonably sized spacecraft is able to use itself. Instead of using a single sensor dish though, many small sensor drones can be used to simulate a much larger sensor array than would normally be possible.

While stored, the drones cannot be used for detection. When needed (and when the spacecraft is not accelerating), the drones are moved out into position – sometimes in an array spanning several kilometres. When in position, the array acts as a very large sensor.

Base cost is $10,000, mass is 2kg, and stored volume is 0.002m^3. Power requirement is 100W, and scan is equal to 2×(TL-3). When extended into an array, radius of the array is equal to volume$^{3/2}$, in metres. For each doubling of the cost, mass and volume, the array gains +2 to scan.

The array takes 10 seconds plus 1 second per metre of radius to move into position, or pull back in. In an emergency, the array can be left behind.

Sonar

Uses pulses of sound to detect targets, normally used underwater where sound propagates much better than it does in air. Cost is $1000, mass 2kg, volume 0.002m^3. Power requirement is 1kW, and *scan* is 2×(TL-2). Each ×8 to cost, and ×10 to volume and mass gives +2 to scan. Scan assumes sonar is being used underwater. In air, sonar is at -20.

Advanced sonar are quadruple cost, and have +1 to scan. Cheap sonar are at quarter cost, and are at -1 to scan. Each tenfold increase in power requirement gives a +1 to scan rating.

Sonar can be used passively.