Vehicle design

The following section is a modified version of the vehicle design system in **Fire, Fusion and Steel**, adjusted for **T4**, and limited to a subset of vehicle types likely to be encountered or designed by characters. It can be used to create non-spacecraft vehicles of most sizes, and while it incorporates much of the Standard Starship Design rules, it has some exceptions needed for extremely small vehicles.

Basic equipment

Any commercial vehicle at any Tech Level will automatically come with any accessory that consumers at that culture demand. For personal land vehicles, the table below gives samples of this.

TL	Sample mandatory accessory
5	Headlights
6	Minimal entertainment radio receiver
7	Basic safety restraints
8	Airbags
9	Navigation computer
10	
11	Voice response system
12	

The exact features that come with a vehicle will depend on the vehicle and the culture involved.

Body

All vehicles will start with an internal volume. Like starships, in the end this will be measured in displacement tons (14m3), and when the term displacement is used, remember that it refers to volume, not mass. Within this volume, different components will have different densities, so one vehicle with a volume of 2 displacement tons may mass 14 metric tons, another might mass 25 metric tons. We use both numbers because cubic meters are a little more intuitive, but displacement tons help you figure out whether you can carry it in the hold of your ship.

You can figure your own exact displacements for small vehicles, but the following table gives appropriate amounts for different broad categories.

If the vehicle has wings, it is an “airframe” configuration, and will have more area than a simply streamlined version of the configuration. This extra area may be considered a separate “facing” for armor purposes, that is, you can have an airplane with wings that are armored more or less than the fuselage. Vehicles that are simply streamlined may only fly if their acceleration is greater than that of local gravity, and vehicles must be streamlined to be able to go more than 100m per second in a normal density atmosphere or re-enter an atmosphere from orbit.

First, find the approximate volume of the hull you want. This will give you the surface area that needs to be armored and the diameter of a spherical vehicle with that internal volume. Don't worry if your vehicle concept is longer than it is wide, we'll take care of that in a minute.

Displacement	Volume	hull factor	surface area	diameter	Normal mass	Typical for:
.05 (USP5)	.7m3	.038	3.8m2	1.1m	.1-.7m ton	Recon drone
.10 (USP5)	1.4m3	.061	6.1m2	1.4m	.3-1.5 m ton	Motorcycle and rider
.20 (USP6)	2.8m3	.096	9.6m2	1.7m	.6-3 metric ton	Security robot
.40 (USP6)	5.6m3	.153	15.3m2	2.2m	1-5 metric ton	Ultracompct car
.60 (USP6)	8.4m3	.200	20.0m2	2.5m	1.5-8 metric ton	Small car
.80 (USP6)	11.2m3	.242	24.2m2	2.8m	2-10 metric ton	Medium car
1.0 (USP6)	14.0m3	.281	28.1m2	3.0m	3-15 metric ton	Large grav car, large car
1.5 (USP7)	21.0m3	.368	36.8m2	3.4m	4-21 metric ton	Cargo truck
2.0 (USP7)	28.0m3	.445	44.5m2	3.7m	6-30 metric ton	Medium tank
3.0 (USP7)	42.0m3	.584	58.4m2	4.3m	8-50 metric ton	Heavy tank
4.0 (USP7)	56m3	.707	70.7m2	4.7m	10-60 metric ton	
5.0 (USP7)	70m3	.820	82.0m2	5.1m	12-70 metric ton	
7.0 (USP7)	98m3	1.03	103m2	5.7m	18-100 metric ton	
10.0 (USP7)	140m3	1.30	130m2	6.4m	50-150 metric ton	Small ship's boat or space fighter

Now, choose the approximate body shape you want for the vehicle. The numbers in the length, width and height columns are multiplied by the diameter to get the approximate vehicle dimensions. For instance a small car volume (8.4m3) has a diameter of 2.5m. If it uses a box configuration, it will be about 2.5m x 1.25 = 3.1m long, and 2.5m x .65 = 1.6m wide and high. A medium car would be 3.5 x 1.8 x 1.8m and a large car would be about 3.8m x 1.9m x 1.9m.

To get the chassis or structure volume of the vehicle, multiply its maximum acceleration in g's by the number in the Structure column, the hull factor from the previous table, and divide this by the toughness of the the chassis material. The chassis or structure mass is the volume times the density of the material. The cost of the chassis or structure is the cost of the appropriate volume of structural material times the Price column, to represent the difficulty of fashioning the appropriate vehicle framework. For instance, out small car (8.4m3) has a maximum acceleration of .5g. The Structure number for a box configuration is 1.2, the hull factor for an 8.4m3 vehicle is .200, maximum acceleration is .5g and it is made of fiber laminate, which has a toughness of 2. So, the chassis volume is 1.2 x .2 x .5 / 2 = .06m3. Since fiber laminate has a density of 1, the chassis has a mass of .06m3 x 1 = .06t, or 60 kilograms. This covers the minimum structural support to attach things to. If it were made of soft steel, the volume would be .03m3 and the mass would be .24t or 240kg. This does not count wheels, windows, body or anything else, just the minimum structure needed to attach vehicle components to.

Note - The maximum acceleration of a vehicle is not just the acceleration provided by its power plant, but how intensely it can maneuver. A fighter plane with a 1g structure because it has a 1g powerplant is not built to handle 8g turns. If you want the agility to pull these high-stress maneuvers off, the vehicle must be built to withstand them.

The volume of the armor is the base surface area of the vehicle in square meters, times the number in the Surface column, times the thickness of the armor in centimeters, divided by 100. The cost of surfacing or armoring the vehicle is total volume of the armor, times the cost of the material per cubic meter. For instance, our small car has a base surface area of 20.0m2, times 1.2 for a box configuration is 24m2. If made of fiber laminate, the minimum armor of 1 would have a thickness of .12cm, for an armor volume of 24m2 x .12cm / 100 = .029m3 and armor mass of .029m3 x 1 = .029t or 29kg. If faced with soft steel, the minimum thickness would be .1cm, so the volume would be 24m2 x .1cm / 100 = .024m3, and the mass would be .024m3 x 8 = .192t or 192kg. The fiber laminate body would cost .029m3 x .030MCr = 870Cr, while the soft steel body would cost .024m3 x .016MCr = 384Cr, and the 486Cr difference is probably why cars continued to be made with soft steel bodies long after fiber laminates became available.

CONFIGURATION TABLE

Form	**Length**		**Width**	**Height**		**Struc**	**Surf Price Example**
Open Frame	3.5			2.0	1.0	0.3	
Needle	3.0	.42	.42	1.3	1.3	0.7	
Needle Streamlined	3.0	.42	.42	1.3	1.3	0.8	Missile
Needle Airframe	3.0	.42	.42	1.3	1.69	1.2	Supersonic transport
Wedge	2.5	1.0	.64	1.5	1.5	0.5	
Wedge Streamlined	2.5	1.0	.64	1.5	1.5	0.7	Speedboat
Wedge Airframe 2.5	1.0	.64	1.5	1.95	1.5		
Cylinder	2.0	.58	.58	1.1	1.1	0.6	
Cylinder Streamlined	2.0	.58	.58	1.1	1.1	0.8	Submarine, missile
Cylinder Airframe	2.0	.58	.58	1.1	1.43	2.0	Subsonic aircraft
Box	1.25	.65	.65	1.2	1.2	0.4	Automobile
Box Streamlined	1.25	.65	.65	1.2	1.2	0.6	Sports car, grav car
Sphere	1.0	1.0	1.0	1.0	1.0	0.8	
Sphere Streamlined	1.0	1.0	1.0	1.0	1.0	1.0	Hover drone
Disk	1.5	1.5	.30	1.2	1.2	1.4	
Disk Streamlined	1.5	1.5	.30	1.2	1.2	1.6	UFO, motorcycle & rider (flip width/height)
Disk Airframe	1.5	1.5	.30	1.2	1.56	1.2	Flying wing
Close Structure	1.75			1.4	1.4	0.3	
Slab	2.75	.80	.25	1.5	1.5	0.5	
Slab Streamlined	2.75	.80	.25	1.5	1.5	0.7	Race car
Slab Airframe	2.75	.80	.25	1.5	1.95	1.5	

Wings

If designing a lift vehicle, the difference between the area of a Streamlined configuration and an Airframe configuration is the wing area. In general, the square root of this area, times 2 is the total wing width on a high performance aircraft, and times 3 is the wing width on regular aircraft. For instance, a wing area of 64m2 would be a 16m extra wingspan on a high-performance aircraft, and 24m on a regular aircraft. This adds to total vehicle width in case you need to know. This is one case in which you may end up with an aircraft with a lot of unused volume, as a certain size is needed to give the vehicle wings large enough to have a low takeoff speed. You may be able to design the equivalent of a flying tank, but it won't do you any good if it has to reach 700kph before it can get off the ground! Optionally, you may divide the minimum takeoff speed and maximum speed for a non-military aircraft by 1.5 to represent a design optimized for less energetic uses.

Armor

Not all vehicles are “armored”, but a minimum armor rating of “1” is needed. Vehicles may have body panels with an armor of 1, which is sufficient for protection from weather and minor dings, but does not have much effect vs. weapons. Low tech (TL3-8) vehicles may have an armor of 2-3, just from their massive body panels and supporting framework. Many high-tech civilian cars will have an effective armor of 1, especially if weight is a major consideration. Unless a material is completely supported by a complex internal framework, it must be at least .1cm thick or have a toughness of 1 to be self-supporting, whichever is greater.

TL	Material	Toughness of 1cm	Density	Mass per m3	price per m3
1	Heavy wood*	1	1	1t	.001MCr
3	Soft steel*	4	8	8t	.016MCr
5	Hard steel	6	8	8t	.020MCr

6	Light alloy	3	3	3t	.040MCr
6	Fiber laminate*	2	1	1t	.030MCr
7	Light composite	6	7	7t	.070MCr
8	Composite laminate	7	8	8t	.080MCr
10	Crystaliron	9	10	10t	.090MCr
11	Structurecomp*	3	1	1t	.040MCr
12	Superdense	11	15	15t	.014MCr
14	Bonded sd	14	15	15t	.028MCr
17	Coherent sd	16	15	15t	.035MCr

*These materials are commonly used as civilian structural materials until 1-2TL's after the introduction of the next one. They usually have limitations that render them impractical as heavy armor (flammable, etc.). Flexible spacesuits are considered to be fiber laminate or structurecomp with a -1 to the toughness, and rigid spacesuits are usually structurecomp.

Armor *does not* increase linearly with thickness. Rather, check the table below to get the total thickness of the armor, and then use the multiplier on the base toughness, rounding fractions down. The result is the effective armor rating.

Thickness	Multiplier
.01cm	x.2
.03cm	x.3
.06cm	x.4
.12cm	x.5
.21cm	x.6
.34cm	x.7
.51cm	x.8
.73cm	x.9
1.0cm	x1.0
1.3cm	x1.1
1.7cm	x1.2
2.2cm	x1.3
2.8cm	x1.4
3.4cm	x1.5
4.2cm	x1.6
5.0cm	x1.7
5.9cm	x1.8
7.0cm	x1.9
8.2cm	x2.0
9.5cm	x2.1
10.9cm	x2.2
12.5cm	x2.3
14.2cm	x2.4
16.1cm	x2.5
18.1cm	x2.6
20.3cm	x2.7
22.7cm	x2.8
25.2cm	x2.9
27.9cm	x3.0
30.8cm	x3.1
33.9cm	x3.2
37.3cm	x3.3
40.8cm	x3.4
44.5cm	x3.5
48.5cm	x3.6
52.7cm	x3.7
57.1cm	x3.8
61.8cm	x3.9
66.8cm	x4.0
71.9cm	x4.1
77.4cm	x4.2
83.1cm	x4.3
89.1cm	x4.4
95.4cm	x4.5
102cm	x4.6
109cm	x4.7
116cm	x4.8
123cm	x4.9
131cm	x5.0

Example - A TL7 anti-tank rocket has a penetration of around 18. This is about x1.63 times the base rating of superdense, so about 4.2cm of superdense is enough to stop it. A penetration of 18 is about x3.0 times the base rating of hard steel, so we can see that 27.9cm of hard steel is needed.

Example - A 1cm plank of heavy wood has a rating of 1. A medium pistol with a penetration of 2 would go through 8.2cm of this material, and a penetration 5 assault rifle would require 131cm to stop it (it seems like a lot, but it *does* match real-world data). On the other hand, a tenth of a millimeter of superdense would stop the pistol, and barely more than a millimeter would stop the assault rifle. Just so you know, the sheet of paper you are reading is approximately a tenth of a millimeter thick, and if made of superdense would mass about .1kg. A piece the same size that would stop a TL8 assault rifle (penetration 4) would be about as thick as six sheets of paper and mass almost half a kilogram.

Note - For comparison to starship USD armor values, divide the armor value by 6 to get the equivalent multiplier for armor steel, and then compare the thickness or hard steel corresponding to the multiplier to the chart in the starship design book.

Example - An 8.2cm thickness of superdense has an armor rating of 22. So, 22/6 = 3.66, which corresponds to the multiplier for between 48.5 to 52.7cm of armor steel. Checking the starships book, this is a USD value of 2.

Armor facings

Many vehicles will not have uniform armor. If you have determined the area of particular facings, you can calculate this normally for each face. If it is unclear or too much calculation, assume that the front or rear facings are 10% of the area each, the sides are 15% each and the top and bottom are 25% each.

Vehicles with open top or sides will have no overall mass savings, as the structural material lacking on the top, for instance, will have to be made up for by additional stiffness elsewhere. On open-topped vehicles, simply double the thickness of the bottom armor to compensate. On civilian vehicles, this may not be enough to increase the armor rating even by a point.

Example - An open-topped vehicle with a total of 10m2 of area and 1cm of armor will be counted as having 2cm of armor on the bottom facing. If the designer wants to put extra armor on the front, the front is 10% of the total area, or 1m2, and the mass and volume of extra thickness there can be calculated.

Vehicles with open frame configuration may not be armored at all (it is by nature an open network of girders and trusses). These vehicles are counted as having the armor of .1cm of the structural material used for the first 1m3 of volume, and doubled each time the volume is increased by a factor of 10 (round down). This armor rating only applies to structure hits on the vehicle.

Example - A 100m3 open frame vehicle would be counted as having .4cm of armor protecting the “structure” of the vehicle.

Armor sloping

Armor may be sloped to increase its apparent thickness from normal angles of attack. The mass of the armor is not increased, but the available volume of the vehicle is decreased:

Armor slope	Effective thickness	Volume penalty for one facing
Moderate	x1.5	-10%
Radical	x2.0	-20%

Example - A vehicle of 10m3 with radically sloped front armor and moderately sloped right and left side armor will have its internal volume reduced by 40%, to 6m3.

The top and bottom of a vehicle may normally not be sloped.

Stealth structures

If a vehicle is designed to be stealthy, and evade detection by active and passive sensors, this must be designed into the shape and structure of the vehicle, and cannot be retrofitted. In general, a stealthy vehicle is -3DM to be spotted by military sensors of the same or lower TL as the vehicle design, and civilian sensors of the vehicle's TL+1, but has no effect vs. sensors of higher TL's. Both the structure and armor of a stealthy vehicle are 5 times normal cost, and the configuration must be a streamlined or airframe type so that it has no jarring edges or surface gaps that would reflect signals or let internal energy escape. A stealthy vehicle is obviously different in appearance than a non-stealthy vehicle, and may draw attention to the vehicle if it is seen in a non-military context.

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Personal armor

A human has a surface area that needs protected of approximately 1m2, and a protected volume of .3m3, of which about .1m3 is the human. In the simplest case then, a knight in shining armor (soft steel) wearing .12cm plate will have an armor rating of 2 and be carrying around 9.2kg of extra mass. This assumes perfectly even coverage with no overlap of inefficiencies, which is not the case. The need for protection over a range of motion and adaptation to the human shape will double the mass of material used as body armor, so our knight is actually carrying 18.4kg of metal around, plus the padding required to make it wearable with any degree of comfort, plus any safety margin desired because TL2 armorers didn't have tables to tell them to make the plate exactly .12cm thick, and the knight doesn't want his expensive armor dented by blows that exactly match its rating.

This is the simplest way to handle using these rules for body armor. Torso armor is about .5m2, and everything else is .5m2 (the head is .1m2 of this). The forming and shaping to match the human body is not as simple as welding slabs of armor together, and the cost for body armor is generally x5 that listed per m3, and x2 for each TL below the introduction date of the material, if it can be worked at all (trying to work TL12 superdense over a TL3 forge would end up with armor having a cost of x2,560 normal, if you could bend the stuff at all!).

Inside a reasonably shaped suit of full body armor there is room for about .2m3 of equipment thinly layered over the body and under the armor, with room for another .1m3 attached to the outside in the form of a backpack, chest pack, hip packs, etc. While you can make an anthropomorphic (human-shaped) armor any size you want, to fit in a normal vehicle seat it cannot have more than .1m3 of extra equipment (which means that backpacks or hip packs will need to be detatchable, if used). That is, armor can have a total of .1m3 of extra equipment if you want to fit in normal seating, .2m3 if you want to fit in roomy seating, and .3m3 if you want to fit in roomy seating without a seatbelt on.

Augmented Battle Dress (powered armor) does not really become viable until TL10, and is not a long-term proposition until the introduction of Fusion+. ABD units use “leg” propulsion systems for determining top speed and propulsion system mass and volume. The maximum Strength a unit can exert is based on the power the propulsion system can handle:

Propulsion system	**Strength**
.001Mw	2
.002Mw	3
.003Mw	4
.005Mw	5
.006Mw	6
.007Mw	7
.011Mw	8
.014Mw	9
.017Mw	10
.021Mw	11
.025Mw	12
.034Mw	14
.044Mw	16
.056Mw	18
.069Mw	20
.084Mw	22
.100Mw	24

Internal equipment - Due to the ultracompact nature of an armor suit, electronics and sensors mounted on or in one are half the volume and mass of vehicle equivalents, and usually less capable in the number of channels monitored or used.

Combat - While armor may be designed as a very small vehicle, characters in such armor are not normally counted as vehicles for combat purposes, either for targeting or damage resolution. However, if a suit of armor with numerous subsystems is penetrated, it might be appropriate to see which subsystem was hit on the way to injuring the character.

ABD-12

Component	**Volume**	**Mass**	**Cost**
Human	.1000m3	100.0kg	-
subtotal			
Options			
Point def. laser (pen 3, v.long)(.??Mw)			
Automated fire control system computer			
TFAC-12 system			
Classified hardware			
Total			

Weapons (carried)

Movement (ground)

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Cockpit armor - In some cases, it is not practical to armor an entire vehicle, but it is desired to protect the crew from harm. Armored seating arrangements will protect the occupant from hazards in most directions, and have a volume of .1m2 inside the vehicle. This allows for up to 4cm of armor to protect the person in that seat from any non-area attack from all but one arc (usually the front). This armor is *not* cumulative with personal armor. Use only the highest of personal or cockpit armor to resist penetration from crew or passenger hits.

Note - There is no easy way to “layer” armor in Traveller. The only way to get an accurate value is to figure the total thickness of all armor, and generate an armor rating from that. For instance, a person armored in .5cm of superdense behind a tank armor of 25cm of superdense has got 25.5cm of superdense, *not* the armor rating of each added together. Using only the highest applicable armor is the easiest way to handle this.

Turrrets

A turret is used to mount weapons or optional equipment. A turret will have the same armor on its facings as the appropriate vehicle facing (except for the bottom, of course). This includes any bonus due to sloped armor. The volume of the equipment is multiplied by the following factor to get the actual internal volume taken. If the equipment is required to only face a given direction, the volume taken by the equipment is counted as though the turret were one TL higher. Fixed elevation or non-traverse mount (60° total movement) are also counted as one TL higher for purposes of internal volume..

Note - Many guns or other long-barreled weapons mounted in a turret only have half their volume inside the turret. The rest protrudes outside the vehicle and is not protected by the vehicle's armor. Vehicles with externally mounted weaponry need only dedicated volume for the crew of these weapons (1m3 per person), but the volume of the weaponry will add to the storage requirements and dimensions of the vehicle.

TL	Turret multiple
6	x4
7	x3
8	x2
9+	x1.5

Example - A gun with 1m3 of normal internal volume is put in a TL8 limited traverse turret. The gun will take up 1.5m3 of internal volume.

Hardpoints - A hardpoint is an accessable part of the vehicle structure to which fixed-facing external weapons can be mounted. All vehicles are considered to have hardpoints or their equivalent, but non-military vehicles will have them in inconvenient spots. Weapons mounted on hardpoints still count towards vehicle volume, but military hardpoints always use TL9+ turret multiple volume, and retrofitted civilian ones always use TL8 turret multiple volume. Hardpoints allow a flexibility that an internal turret does not, since weapons can be easily dismounted and changed for different roles. Hardpoints may not be used on any vehicle that must survive atmospheric re-entry or has a top speed of more than 5000 meters per turn.

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Storing vehicles

Many vehicles will be transported by starship to their ultimate destination. Unless a cargo hold is especially configured for a particular vehicle when the ship is built, the vehicle will require double its actual volume in cargo hold space. The only way to get around this is to use all the open space around the vehicle for small flexible cargo items, stuffing them under the chassis, on the hood, and so on, completely burying the vehicle in other stuff. While this is permissable, it may take hours to extricate the vehicle, during which time all the other material must be stored elsewhere, since there is no extra cargo space in which to put it. This could be in hallways, staterooms or outside on the ground if conditions permit. Take these factors into account if you have paying passengers who would be offended by sacks of Rigellian marbles littering the corridors while they try to disembark.

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Armor modifiers

Aside from requiring life support, a vehicle designed to operate in an insidious or corrosive atmosphere will have double the armor and structure cost (each). Much of this is testing to make sure the vehicle is proof against the environment, while the rest is in the form of special coatings and sealants. These coatings and sealants protect all surface-mounted equipment such as windows, antennae, etc.

Vehicles with a closed body and life support are automatically counted as having pressure support for a 1 atmosphere differential, which allows safe vacuum use, *and* use underwater to a depth of 10m. Increased pressure support requires +3 armor rating for 10 atmospheres of pressure, and each time this is multiplied by 10 (100, 1000, etc.).

Example - A research submarine capable of withstanding 100 atmospheres of pressure (1,000m depth) will be required to have an armor rating of at least 7.

Armor cost for extra pressure support is multiplied by x10. This takes into account expensive pressure seals on any part of the vehicle that could admit the outside environment (hatches, windows, sensors, fuel ports, propulsion links, etc.)

Weapons

Vehicle weaponry will be covered in more detail in the **Third Imperium Weapons** sourcebook, but until that time, the following is a list of light vehicular weaponry. Weapons will have a volume of .5m3 per ton, and require crew space for the listed number of people.

Weapon	Penetration	Range	Shots	Mass	Reload	Cost	Crew	Note
Medium machinegun-5 (2kJ,7mm)	4	Long	200	.009t	.003t	.0005M	1	
Medium machinegun-8 (4kJ,7mm)	5	Long	200	.011t	.004t	.001MC	1	
RF medium machinegun-11 (11kJ,5mm)	7	V.long	2000				1	Half volume external
Light cannon-3 (500kJ,110mm)	8	Short	1				2	
Light cannon-5 (200kJ, 30mm)	9	Medium	1				2	
Light autocannon-8 (200kJ, 30mm)	9	Long	100				1	
RF lt. autocannon-8 (200kJ, 30mm)	9	Long	1000	1.800t	1.500t	21KCr	1	
Light autocannon-11 (500kJ, 30mm)	11	V.long	100				1	
RF lt. autocannon-11 (500kJ, 30mm)	11	V.long	1000				1	
Heavy cannon-3 (4mJ,150mm)	14 (expl.)	Short	1				3	
Heavy cannon-5 (10mJ,90mm)	17 (expl.)	V.long	1	1.340t	.035t	50KCr	3	Half volume external
Heavy cannon-8 (16mJ,100mm)	19 (expl.)	V.long	1				2	Half volume external
Heavy cannon-11(25mJ,100mm)	21 (expl.)	E.long	1				1	Half volume external
Light missile-5	18 (expl.)	V.sht.	1				1	
Light missile-8	22 (expl.)	Short	1				1	
Light missile-11	25 (expl.)	Medium	1				1	
Heavy missile-5	25 (expl.)	Short	1				2	
Heavy missile-8	34 (expl=22)	Long	1	.055t	.055t	3.4KCr	1	Dexterity 4, +2DM
Heavy missile-11	41 (expl.)	Region	1				1	
Unguided bomb-5	55 expl.	Contac	1	.250t	.250t		1	
Unguided bomb-8	58 expl.	Contac	1	.250t	.250t		1	
RF point defense laser-12	3	Short	-				1	??Mw/hr/turn
VRF point defense laser-14	4	Medium	-				1	??Mw/hr/turn
RF laser-11	8	Long	-				1	??Mw/hr/turn
RF laser-13	9	Long	-				1	??Mw/hr/turn
VRF gauss MG-11	9	V.long	3000				1	??Mw/hr/turn
VRF gauss MG-13	11	V.long	3000				1	??Mw/hr/turn
Lt. vehic. particle beam-11	11	V.long	-				1	??Mw/hr/shot
Lt. vehic. particle beam-13	13	V.long	-				1	??Mw/hr/shot
Hv. vehic. particle beam-11	30	E.long	-				1	Half vol. ext.,??Mw/hr/shot
Hv. vehic. particle beam-13	40	E.long	-				1	Half vol. ext.,??Mw/hr/shot

Note - Missiles are “generic” at this point, but should be specified as to type when bought, usually one of the following categories: Unguided (line of sight), Unguided (artillery), Anti-land vehicle, Anti-air vehicle, or Anti-ship. Guided missiles will only be effective vs. targets of their designed type. Unguided missiles can be fired at any target, but only get the fire control DM of the firing vehicle.

Power plant

All vehicles will have some form of power plant. The following tables cover most historical and hypothetical power plants. The efficiency of the power plants does not include losses from turning the raw output into useful form, such as mechanical transmission losses. This is covered by the locomotion part of vehicle design.

TL	Description	Pow/ m3	Mass/ m3	Min m3 &output	Cost/ m3	Area per m3	100hr Fuel/m3	Fuel	Maint
TL1	Rowers	.05Mw	1.0t	.100/.005Mw	-	1.0m2	.10m3	food	-
TL1	Sail	.15Mw	1.0t	.015/.002Mw	.001MCr	20.0m2	-	wind	600hr
TL3	Early steam	.10Mw	2.0t	.250/.025Mw	.002MCr	.90m2	.20m3	wood	600hr
TL4	Steam	.20Mw	2.0t	.150/.030Mw	.002MCr	.70m2	.30m3	coal	3000hr
TL4	Int. combust.	.30Mw	1.0t	.015/.045Mw	.004MCr	2.0m2	.60m3	hcarb	600hr
TL5	Steam turbine	.35Mw	2.0t	.200/.070Mw	.008MCr	.60m2	.50m3	hcarb	3000hr
TL5	Imp.Int Comb.	.40Mw	1.0t	.003/.001Mw	.008MCr	1.0m2	1.00m3	imhyd	3000hr
TL7	Gas turbine	.50Mw	1.0t	.500/.250Mw	.020MCr	.40m2	1.50m3	imhyd	3000hr
TL8	MHD turbine	.60Mw	1.0t	.500/.300Mw	.060MCr	.50m2	1.20m3	imhyd	3000hr

Note - All of the above power plants require external oxygen sources, and cannot operate in vacuum or atmopsheres lacking oxygen unless on-board stores are available. If on-board liquid oxygen is used (TL6+), use double the listed fuel conusmption as being required for the oxygen (total of triple normal fuel volume). This does mean you can use internal combustion engines underwater if the vehicle is properly designed.

TL7	Fuel cell	.40Mw	1.0t	.003/.001Mw	.020MCr	-	24.2m3	lhyd	9000hr
TL12	Fuel cell	.75Mw	1.0t	.003/.002Mw	.020MCr	-	18.7m3	lhyd	9000hr
TL14	Fuel cell	1.5Mw	1.0t	.002/.003Mw	.020MCr	-	3.00m3	lhyd	9000hr

Note - All fuel cells produce liquid water as a byproduct in quantities equal to total fuel used.

TL6	Photoelectric	.001Mw	2.0t	-	.005MCr	12.0m2	-	-	-
TL7	Photoelectric	.0015M	2.0t	-	.006MCr	12.0m2	-	-	-
TL8	Photoelectric	.002Mw	2.0t	-	.006MCr	12.0m2	-	-	-
TL9	Photoelectric	.0025M	2.0t	-	.006MCr	12.0m2	-	-	-
TL10	Photoelectric	.003Mw	2.0t	-	.006MCr	12.0m2	-	-	-
TL11+	Photoelectric	.004Mw	2.0t	-	.007MCr	12.0m2	-	-	-

Note - In the case of solar panels, the area figure represents the panels themselves, which must be oreinted to face the sun, and thus are limited to a maximum power output equal to the area of the largest face of the vehicle that can be facing the sun.

TL6	Fission	.30Mw	6.0t	40.0/12.0Mw	.200MCr	2.0m2	.001m3	radioa	9000hr
TL7	Fission	.60Mw	6.0t	20.0/12.0Mw	.150MCr	1.5m2	.001m3	radioa	9000hr
TL8	Fission	1.0Mw	6.0t	10.0/10.0Mw	.100MCr	1.0m2	.001m3	radioa	9000hr

TL9	Fusion	2.0Mw	4.0t	1250/2500Mw	.200MCr	2.0m2	.003m3	deuter	9000hr
TL10	Fusion	2.0Mw	4.0t	500/1000Mw	.200MCr	2.0m2	.003m3	deuter	9000hr
TL10	Fusion+	3.0Mw	2.0t	.020/.060Mw	.010MCr	3.0m2	.150m3	water	600hr
TL11	Fusion	2.0Mw	4.0t	250/500Mw	.200MCr	2.0m2	.003m3	deuter	9000hr
TL11	Fusion+	3.8Mw	2.0t	.015/.057Mw	.010MCr	3.8m2	.150m3	water	1200hr
TL12	Fusion	2.0Mw	4.0t	12.5/25.0Mw	.200MCr	2.0m2	.003m3	deuter	9000hr
TL12	Fusion+	4.8Mw	2.0t	.010/.050Mw	.010MCr	4.8m2	.150m3	water	1800hr
TL13	Fusion	3.0Mw	3.0t	1.70/5.0Mw	.200MCr	3.0m2	.003m3	deuter	9000hr
TL13	Fusion+	6.0Mw	1.5t	.007/.042Mw	.010MCr	6.0m2	.150m3	water	2400hr
TL14	Fusion	3.0Mw	3.0t	1.70/5.0Mw	.200MCr	3.0m2	.003m3	deuter	9000hr
TL14	Fusion+	7.7Mw	1.5t	.006/.046Mw	.010MCr	7.7m2	.150m3	water	3000hr
TL15	Fusion	6.3Mw	2.0t	.800/5.0Mw	.200MCr	6.3m2	.003m3	deuter	9000hr
TL15	Fusion+	9.8Mw	1.0t	.004/.039Mw	.010MCr	9.8m2	.150m3	water	3000hr

TL - The TL the power plant is introduced at. It can be used at higher TL's, and is generally more reliable as it has the bugs worked out, but it not more efficient.

Description - The simple description of the power plant type

Power per m3 - The power output in megawatts per m3 of power plant

Mass per m3 - The mass in metric tons of 1m3 of power plant

Minimum disp/output - The minimum size in m3 the power plant can be constructed at, and the output it has at that size. A dash means that the power plant can be made extremely small and has no practical minimum size.

Cost per m3 - The cost in MCr of 1m3 of power plant

Area - The external vehicle surface required for cooling radiators for 1m3 of power plant. For stationary installations, this is irrelevant if there is sufficient real estate for the radiators. If there is a nearby source of pumpable fluids, radiator area is quartered. Note that this will usually apply to water vehicles.

Fuel/m3 - The amount of fuel consumed per 100 hours (4 days) of full power output, per 1m3 of power plant. The actual volume of fuel will depend on its type, and this figure usually applies to fuels of approximately the same density of water, such as liquid hydrocarbons.

Fuel

Different power plants use different types of fuel. The volume of fuel will vary with type. The cost on the tablebelow refers to the cost for the final volume.

TL	Fuel type	Volume x	Cost per metric ton
1+	Wood	x2.0	50Cr
2+	Coal	x.5	100Cr
3+	Liquid hcarb	x1.0	250Cr
5+	H.grade hydrc	x1.0	500Cr
6+	Liquid hydrog	x14	1000Cr
6+	Fission fuel	x.05	.7MCr
7+	Deuterium	x1.0	.15MCr
7+	Enrich. water	x1.0	7000Cr

Fuel - The normal fuel used for this power plant at its initial TL. This may vary with culture.

Maintenance - The time between scheduled maintenance for the power plant. A dash means the power plant is essentially maintenance free (check it out once every 10 years or so). Failure to provide maintenance will result in power plant failure on a 2D roll of 12+. Success means a 10% drop in power output and a cumulative +1DM on future maintenance rolls (which resets upon actually getting maintenance). Maintenance takes 10 hours per displacement ton of power plant (minimum of 1 hour), and costs 5% of power plant cost. Repairing a power plant failure costs 2D times 5% of power plant cost.

Maint time	equivalent
300 hr	≈2 weeks
600 hr	1 month
3000 hr	4 months
9000 hr	1 year

TL	Description	Pow/ m3	Mass/ m3	Min m3 &output	Cost/ m3	Area per m3	100hr Fuel/m3	Fuel	Maint
TL4	Storage bank	.04Mw/hr	2.0t	-	.001MCr	-	-	-	500hr
TL5	Storage bank	.06Mw/hr	2.0t	-	.001MCr	-	-	-	1000hr
TL6	Storage bank	.08Mw/hr	2.0t	-	.001MCr	-	-	-	2000hr
TL7	Storage bank	.10Mw/hr	2.0t	-	.001MCr	-	-	-	3000hr
TL8	Storage bank	.20Mw/hr	2.0t	-	.001MCr	-	-	-	6000hr
TL9	Storage bank	.40Mw/hr	2.0t	-	.002MCr	-	-	-	9000hr
TL10	Storage bank	.80Mw/hr	2.0t	-	.003MCr	-	-	-	18khr
TL11	Storage bank	1.0Mw/hr	2.0t	-	.004MCr	-	-	-	27khr
TL12	Storage bank	1.5Mw/hr	2.0t	-	.005MCr	-	-	-	36khr
TL13	Storage bank	2.0Mw/hr	2.5t	-	.008MCr	-	-	-	-
TL14	Storage bank	2.5Mw/hr	2.5t	-	.010MCr	-	-	-	-
TL15	Storage bank	3.0Mw/hr	2.5t	-	.015MCr	-	-	-	-

TL	Discharge time	Cost multiple
4+	.1 hour	x1
5+	30 seconds	x2
6+	3 seconds	x4
7+	.3 seconds	x9
8+	.03 seconds	x16
9+	.003 seconds	x25

Example - A vehicle at TL10 has 1 metric ton of storage banks (chemical batteries). These contain .80 megawatt hours of energy per metric ton. These are used to power an energy weapon, and are bought with the minimum possible discharge time, for a cost multiple of x25. The total cost of the storage banks is therefore .003MCr per metric ton x 1 ton x 25 for discharge multiple = .075MCr.

Power plant descriptions

Rowers - Any form of power provided by the muscles of living beings, such as rowers, draft animals, etc. Unlike other power plants, rowers can run without fuel (food) for a while, losing 10% of output per day until they collapse. Rowers can also double output for up to an hour, at the cost of half output for the next three.

Sail - Power provided by the wind, either against a stationary sail like a sail ship, or a rotary sail like a windmill. At TL3-, sails can only be used to go in the direction the wind is blowing to, plus or minus a bit. At TL4+, sail ships can sail against the wind at up to a quarter the wind velocity. The normal maximum speed of any sail vessel is 15% of the wind speed times the TL of the sails and hull for water vehicles, and 25% of the wind speed times the TL of sails and chassis for land vehicles (assuming otherwise optimum conditions). Wind speeds of more than the TL x 3 in meters per second require a maintenance check per hour to avoid damage or failure. Note that the area of sails is external to the vehicle itself. In combat, the actual sail area is ignored and most hits are assumed to pass through with little effect. Hits that actually are rolled against the power plant are assumed to be against an armor of 1, and are hits to vital rigging components that will quickly affect performance.

Early steam - Steam engines are external combustion power plants, where an outside heat source heats a boiler of water, and the steam pressure generated turned into mechanical energy. At TL3 they are not particularly efficient, but are the best that is available. They almost always run off of solid fuels like wood or coal.

Steam - A more advanced version of the steam engine, which may be designed to run off a particular class of fuel (solid or liquid).

Steam turbine - Instead of using reciprocating pistons, a steam turbine takes the expanding steam and runs it through a series of turbine blades, converting the steam pressure directly into rotary motion. This will be run through a gearbox to get whatever final power or revolutions per minute is desired.

Internal combustion - This is a broad class of engine, covering regular petrol engines, diesel engines, rotary engines and the like. Fuel injected into a confined space is ignited and the resulting mini-explosion is converted to mechanical energy by a moving piston.

Improved internal combustion - A more advanced version of the internal combusion engine, which may include concepts like fuel injection, electronic ignition, multiple fuel valves and electronic sensors, depending on actual TL.

Gas turbine - Similar in concept to a steam turbine, except that the expanding hot gas from burning fuel is used to power the turbine.

MHD turbine - Magnetohydrodynamic power is running the hot combustion gases through a series of magnetic fields to directly extract electrical power. The hot exhaust is somewhat cooled by the extraction of energy, and the remainder is run through a conventional turbine to generate mechanical energy which often powers a regular generator. It requires advanced materials to withstand the high operating temperatures used.

Fuel cells - Fuel cells use a catalytic process to extract electrical power from the energy released during a chemical reaction, the most common of which uses oxygen and hydrogen, and has water as a byproduct.

Photoelectric - Photoelectric cells convert light directly into electricity. They are not very efficient, but are maintenance-free, and require no mass for carried fuel, making them important for any long-duration application. The figures for solar panels assume they are integral to the surface of the vehicle, which provides the structural support and backing needed. If the panels are individually deployed like wings, the surface area may exceed the normal area of the vehicle body, but the panels will mass ten times as much per m3, times the acceleration of the vehicle (minimum of 1). If these panels are retractable and can be stowed inside the vehicle, they mass twice as much per m3.

Fission - Fission reactors use the heat generated by radioactive decay to produce either electrical or mechanical power, often through heating water and powering a steam turbine. Due to their shielding requirements and heavy elements used, they are not mass efficient, but they are extremely fuel efficient. They are superceded entirely by fusion power at TL9+ except in the few TL9-12 applications where the smaller fission reactor is the only viable power source.

Fusion - This is traditional “hot” fusion, a million degree ball of fusing plasma that is contained by powerful magnetic fields. The heat from the plasma and heat generated by passage of subatomic particles through the reactor wall is used to either power some form of steam turbine, an MHD plant or both. Fusion plants normally require a fractional second startup pulse from storage banks equal to their output, and such a storage bank is included in the mass of any fusion plant.

Fusion+

Fusion+ is, in a nutshell, the technology that makes the Imperium possible. By Imperial year 0, any world with a civilization has learned how to be self-sufficient. The ones who couldn't, died. With the various cultures at approximately the same level of technology, and not having a need for other people's products, the incentive for interstellar trade is not that great.

Fusion+ changes all that. It is a size breakthrough in fusion power plants that opens up a whole new realm of technological possibilities. And Sylea is the *only* planet that has it. If you want it, you buy it from

Sylea. And, if you're a Sylean trader looking to sell this hot commodity, the only place to get it is through Cleon Industries.

Fusion+ is a variant of “cold fusion”, using a solid-state matrix to fuse deuterium-enriched water and use the resultant heat flow to directly generate electricity with no moving parts. It actually runs at substantial temperatures (a few hundred degrees C), but is capable of producing substantial power within a minute of activation, and when not in use, its insulation retains heat for days, allowing near-instant startups.

Compared to “hot fusion”, Fusion+ is more efficient in terms of cost and mass/power ratios. However,it has drawbacks that make it less practical for starship use. First, it is not very fuel efficient, consuming several times the fuel a regular fusion plant would. A great deal of this is required for cooling purposes, and is boiled off as a small steam plume. Last, Fusion+ requires regular maintenance and replacement of the solid-state cores, which become polluted and degraded by constant bombardment of fusion byproducts. At the first maintenance interval a Fusion+ unit needs to roll 12+ on 2D to fail. On asuccess, output is reduced by 10% and the failure roll gets a cumulative +1DM. Apply another +1DM if questionable fuel was used at any time during that interval. Failure usually takes the form of rapidly varying power output, and excessive operating temperature, which if left unchecked will damage the core and cause an automatic shutdown. The final stages of this failure usually take several minutes to cascade to their ultimate outcome.

Fusion+ units were originally manufactured starting in year-28 at TL11 levels of output. Until year 3, the only place a unit could be serviced was on Sylea (5% of power plant cost). On other worlds, maintenance was handled by core replacement (10% power plant cost). The reason for this is that all units were “factory sealed” encapsulated units, with a great deal of effort put into preventing reverse-engineering of the units, usually involving non-explosive self-destruction of the unit and the critially important monitoring and feedback hardware. Eventually, of course, someone managed to reverse-engineeer and duplicate the technology, at which point Cleon Industries released the TL12 version to keep its competitive lead. Of course, there will be incremental increases in capability and features, but for the most point, from year 3 the early Third Imperium will be using TL10-12 Fusion+ units.

Cleon is willing to take some financial risks to expand the Imperium, sacrificing short-term profit for long-term gain.To this end, several “standard” Fusion+ models are available, in the following power output:

Cleon Industries Standard (TL12)

Output	Mass	Volume	Cost	Area	Fuel per 100 hrs	Maintenance interval
.05Mw	21kg	.01m3	75Cr	.05m2	.0015m3/1.5kg	1800 hours
.20Mw	83kg	.04m3	300Cr	.20m2	.0060m3/6kg	1800 hours
1.0Mw	.42t	.21m3	1.5KCr	1.0m2	.031m3/31kg	1800 hours
2.0Mw	.83t	.42m3	3.0KCr	2.0m2	.063m3/63kg	1800 hours
5.0Mw	2.1t	1.05m3	7.5KCr	5.0m2	.157m3/157kg	1800 hours

You'll note that the retail price of these units is 25% less than the standard price, and pretty much undercuts what any less advanced culture can produce, decreasing competition for the product, even taking into account interstellar transport costs. Wholesalers can get the standard discount on these prices, and can choose to make as much profit on them as the market will bear. Sylean vehicle manufacturers take advantage of these units wherever possible, as the standardization of parts makes acquisition and maintenance a simple proposition.

For general trade purposes, Fusion+ units can be considered high-tech goods, and early in the history of the Imperium, can be considered unique as well.

Storage banks

The difference between a power plant and a storage bank is that the storage bank holds a fixed quantity of energy, while power plants have a constant output. For instance, a storage bank that holds 1 megawatt-hour can supply 1 megawatt for 1 hour, .1 megawatts for 10 hours or 10 megawatts for .1 hours, multiplying the output by the time in each case to get a power x time of 1. Storage banks can be recharged from a powerplant at the same rate as they are discharged. Normally, a storage bank can be completely discharged in 1 hour, and increased cost will represent technologies that can discharge faster, such as capacitors or homopolar generators. Only the absolute shortest time on the chart can be used for the high-speed pulses needed for energy weapons.

Power plant options

Multiple power plants - A vehicle may have multiple power plants driving the propulsion system. This may be because of the safety of redundancy, the inability to make a single power plant large enough for the vehicle, or the cost savings of using a standard power plant produced by someone else. Multiple powerplants will be x1.2 propulsion cost per power plant. The only exception to this is rowers, where the "power plant" is usually many beings.

Example - A twin-engine jet will have x1.2 the propulsion system cost for the total power plant output of both engines.

Afterburners - Many power plant types can be temporarily boosted to unsafe levels of performance. This could be through adding extra fuel or oxidizer, running at dangerously high temperatures, etc. If a power plant is deemed capable of this behavior, it can double power output for x10 fuel consumption, and must immediately undergo a maintenance check for engine failure when this is attempted. If the power plant does not fail, there are no ill effects in terms of performance or future DM's, but if it fails, it does so catastrophically.

Propulsion
This is the broad category that covers how the power plant makes the vehicle move. The SCDS will not go into as much detail as FFS, but it will allow you to make the vehicle a lot faster than before. The base velocity of vehicle in meters per turn is (megawatts of power/mass in metric tons), x 3000, and this only applies in cases where there is a drag on the vehicle, such as wind resistance, surface friction or water turbulence.

The base acceleration of a non-contragrav vehicle in g's is the square root of (megawatts of power/mass in metric tons), rounding to nearest .1. Contragrav vehicles simply divide tons of thrust by tons of mass to get acceleration in g's (round to nearest .1). The propulsive machinery also includes volume for the controls (inlcuding power plant controls), and special surfaces for that means of propulsion (a rudder for water vehicles, for instance). The mass of all propulsion systems is .5 metric tons per m3 of volume.

Example - A vehicle with a 1Mw power plant and a mass of 50 metric tons will have a base velocity of (1/50) x 3000 = 60 meters per combat turn and an acceleration of $(1/50)^{.5}$ = .1g.

<sidebar>
Acceleration and personal combat
How does vehicle acceleration relate to the personal combat scale? Assuming each turn is 5 seconds, and each outdoor square is 15 meters, the following accelerations in g's will translate into a number of squares accelerated per turn. Note that accelerated adds to any existing velocity, so a vehicle that can accelerate 3 squares per turn will go 3 squares from a standing start, 6 squares the second turn, 9 the third turn and so on. If there is a number with a "/", use the first number

Acceleration	**Squares per turn**	**Turns to: 10m/s**	**20m/s**	**30m/s**	**40m/s**	**50m/s**	**100m/s**	**200m/s**	**500m/s**
.1g	1	2	4	6	8	10	20	40	100
.2g	2	1	2	3	4	5	10	20	50
.3g	3	<1	<2	2	<3	<4	<7	<14	<34
.4g	3	<1	1	<2	2	<3	5	10	25
.5g	4	-	<1	<2	<2	2	4	8	20
.6g	5	-	<1	1	<2	<2	<4	<7	<17
.7g	6	-	-	<1	<2	<2	<3	<6	<15
.8g	7	-	-	<1	1	<2	<3	5	<13
.9g	7	-	-	-	<1	<2	<3	<5	<12
1.0g	8	-	-	-	<1	1	2	4	10
1.5g	12	-	-	-	-	<1	<2	<3	<7
2.0g	17	-	-	-	-	<1	1	2	5
2.5g	21	-	-	-	-	-	<1	<2	4
3.0g	25	-	-	-	-	-	<1	<2	<4
3.5g	29	-	-	-	-	-	<1	<2	<3
4.0g	33	-	-	-	-	-	<1	1	<3
4.5g	37	-	-	-	-	-	-	<1	<3
5.0g	42	-	-	-	-	-	-	<1	2
6.0g	50	-	-	-	-	-	-	<1	<2
7.0g	58	-	-	-	-	-	-	<1	<2
8.0g	67	-	-	-	-	-	-	<1	<2
9.0g	75	-	-	-	-	-	-	<1	<2
10g	83	-	-	-	-	-	-	<1	1

Example - A TL8 jet fighter with an acceleration of 1g can go from a standing start to 8 squares in one turn, and if it has a takeoff speed of 100m/sec, it can reach that speed in 2 turns.
<end sidebar>

Mass multiples - Vehicles heavier than 10 metric tons will get a multiplier on their final top speed:

10-20 metric tons	x1.2
20-40 metric tons	x1.5
40-80 metric tons	x1.9
80-160 metric tons	x2.4

This takes into account the increased momentum and volume to area ratio of large vehicles, making them less susceptible to drag effects.

TL	Descr.	Cost per m3	Volume/Mw	Speed	Area per Mw
8	Legs	.080MCr	7.7m3	x.10	22m2
9	Legs	.060MCr	4.2m3	x.20	18m2
10+	Legs	.045MCr	2.8m3	x.30	15m2
4	Tracks	.165MCr	4.9m3	x.30	17m2
5	Tracks	.140MCr	3.6m3	x.40	14m2
6	Tracks	.115MCr	2.8m3	x.45	12m2
7	Tracks	.095MCr	2.1m3	x.50	10m2

8+	Tracks	.080MCr	1.5m3	x.55	8m2
4	Wheels	.050MCr	2.8m3	x.40	6m2
5	Wheels	.045MCr	2.2m3	x.45	5m2
6	Wheels	.035MCr	1.8m3	x.50	4m2
7	Wheels	.030MCr	1.4m3	x.60	3m2
8+	Wheels	.025MCr	1.0m3	x.70	2m2
5	Hoverskirt	.020MCr	4.1m3	x.20	45m2
6	Hoverskirt	.017MCr	3.2m3	x.30	35m2
7	Hoverskirt	.013MCr	2.5m3	x.40	30m2
8+	Hoverskirt	.010MCr	2.0m3	x.50	25m2
5	Helicopter	.250MCr	1.1m3	x.60	-
6	Helicopter	.220MCr	0.9m3	x.70	-
7	Helicopter	.180MCr	0.7m3	x.90	-
8	Helicopter	.150MCr	0.5m3	x1.1	-
9+	Helicopter	.120MCr	0.4m3	x1.2	-
4	Aircraft	.380MCr	4.6m3	x.80	-
5	Aircraft	.340MCr	3.6m3	x1.0	-
5	H.perf aircr.	1.35MCr	4.3m3	x1.2	-
6	Aircraft	.310MCr	2.8m3	x1.1	-
6	H.perf aircr.	1.25MCr	3.4m3	x1.4	-
7	Aircraft	.280MCr	2.1m3	x1.2	-
7	H.perf aircr.	1.10MCr	2.5m3	x1.6	-
8	Aircraft	.250MCr	1.5m3	x1.3	-
8	H.perf aircr.	1.00MCr	1.8m3	x1.9	-
9	Aircraft	.230MCr	1.1m3	x1.5	-
9	H.perf aircr.	.900MCr	1.3m3	x2.2	-
10+	Aircraft	.200MCr	0.8m3	x1.6	-
10+	H.perf aircr.	.800MCr	1.0m3	x2.6	-
4	Prop.(water)	.085MCr	.7m3	x.08	2.1m2
5	Prop.(water)	.070MCr	.6m3	x.10	1.7m2
5	H.perf water	.210MCr	1.0m3	x.15	3.5m2
6	Prop.(water)	.055MCr	.4m3	x.12	1.4m2
6	H.perf water	.165MCr	.6m3	x.20	2.9m2
7	Prop.(water)	.045MCr	.3m3	x.15	1.2m2
7	H.perf water	.135MCr	.5m3	x.25	2.4m2
8	Prop.(water)	.035MCr	.2m3	x.20	1.0m2
8	H.perf water	.105MCr	.3m3	x.30	2.0m2
9+	Prop.(water)	.025MCr	.1m3	x.25	.8m2
9+	H.perf water	.075MCr	.2m3	x.35	1.6m2
9+	Contragrav*	-	-	-	-
4+	Lighter than air†				

† see text

*Contravgrav is a direct energy-thrust conversion with no intermediate steps. See Contragrav section

*Flying vehicles that rely on aerodynamic forces for lift will need to be able to reach a speed of (mass in metric tons/total wing area) x 400 in meters per turn in order to become airborne. This will be the minimum flying speed of the vehicle.

Area is is the area per megawatt taken by the propulsion machinery. This includes not only the parts touching the ground (in the case of land vehicles), but also open areas inside fender wells and any surface that cannot mount other machinery due to proximity to other moving parts.

Propulsion descriptions

Legs - The vehicle has individually powered articulated legs that allow it to walk much like a person, insect or animal, depending on vehicle configuration and size. It has excellent mobility on broken ground, but has a low top speed and large mechanical requirements.

Tracks - The power plant turns an endless belt with a large amount of ground contact, usually with one belt on either side of the vehicle. It gives excellent traction and off-road performance, but is noisy and relatively slow.

Wheels - A typical wheeled system as found on an automobile or motorcycle.

Hoverskirt - A system where the power plant creates an air cushion underneath the vehicle, and turns fans to provide forward thrust. It has low mechanical complexity, but takes up a lot of vehicle surface area. The bottom surface of the vehicle must have at least as much area as the propulsion system area, which places limits on vehicle dimensions. Also, since a lot of power is used to maintain the air cushion, it has less available for forward thrust. Hoverskirt vehicles have the advantage of being immune to the effects of any type of flat terrain, and function equally well on snow, ice or water.

Helicopter - A mechanically complex system where a rotating wing surface provides both lift and forward propulsion to the vehicle. It is fairly expensive, and has lower top speed than regular aircraft, but has the advantage of having no minimum speed, and can hover, fly sideways or backwards as needed (at a quarter of forward speed). Helicopters may not have a movement per turn of more than 750, regardless of TL or power available.

Aircraft - A typical aircraft, with either a propellor or jet engine of some type. Much of the large volume requirement of an aircraft is dedicated to wing structures and control linkages. High performance aircraft have more of these and more wasted volume due to streamlining needs.

Propellor (water) - This covers any means of water propulsion, including paddlewheels, waterjets and propellors, depending on TL. High performance watercraft are usually hydrofoils, and the increased volume and surface area is largely due to these structures.

Contragrav and thruster plates
All three types of plates listed above operate on the same general principles. The difference is at the quantum gravitational level. The low-efficiency contragrav only works in a strong gravitational gradient, while thruster plates can work in miniscule gradients and high-efficiency contragrav is somewhere in between. Low-efficiency contragrav becomes all but useless within 1 diameter of a world, while high-efficiency contragrav is good out to 10 diameters, and thruster plates work out to around 1,000 diameters, *and* can operate off a solar diameter instead of a planetary diameter.

Combined with Fusion+, small scale long-endurance contragrav vehicles become practical for the first time during Cleon's reign (and are also a valuable trade commodity). Even low-efficiency contragrav vehicles easily have the potential to reach orbit, and while they don't have the interplanetary capability of a normal ship's gig, they are also a *lot* more affordable, an important consideration when you look at monthly operating costs.

Contragrav plates require a certain area, which represents the thrust plates and their integral heat dissipation sinks. The former can be inside the vehicle, protected by armor,and the latter are designed to be part of the outer surface of the vehicle, and share the characteristics of that material (armored, etc.). Contragrav shares the visible blue-white effect caused by gravitic decay byproducts, and will appear on or near the surface of the vehicle that has the contragrav plates.

Note - Remember that if you are designing a vehicle with contragrav plates, you usually need a thrust at least equal to the vehicle mass to offset gravity. Any thrust after this can apply to forward acceleration of the vehicle. For determining the top speed of a contragrav vehicle in atmosphere, simply use the power input to the contragrav drive left over after countering gravity, with a speed multiplier of x1.0.

High efficiency contragrav plates

TL	Thrust per m3	Pow per m3	Mass per m3	Min v/min thrust	Cost per m3	Area per m3
TL9	33t	.60Mw	1.25t	.10m3/3.3t	.004MCr	.60m2
TL10	50t	.70Mw	1.00t	.05m3/2.5t	.008MCr	1.0m2
TL11	50t	.70Mw	1.00t	.02m3/1.0t	.008MCr	1.0m2
TL12+	50t	.35Mw	0.65t	.01m3/.50t	.010MCr	1.0m2

Thruster plates

TL	Thrust per m3	Pow per m3	Mass per m3	Min v/min thrust	Cost per m3	Area per m3
TL11+	40t	1.00Mw	2.00t	1.0m3/40t	.250MCr	.20m2

Lighter than air
Balloons or blimps have special requirements. The lifting capacity of a lighter than air vehicle is approximately .1t per ton of gas envelope, plus .01t for each TL over 3, and reduced by .01t for each .1 of surface modifier for its configuration greater than 1. Add .01t to lift per ton if hydrogen is used, and subtract .01t if hot air is used. Both of these are available at TL3-4, and helium is available at TL5+. Helium is available on 50% of habitable worlds with a TL of 5+. Hot air requires fuel as for 1m3 of any type of available power plant per 1000m of gas envelope. Lighter than air gases can be stored in compressed or liquified form at 1 ton per 1m3 of storage volume, with a compression ratio of TL^2:1 (e.g. a TL8 gas cylinder will hold 8x8=64 times its volume in compressed gas).

If you assume that the total volume of the gas envelope is approximately 1000m3 per ton, it won't be too far off, and the dimensions of the gas envelope depend on its configuration. Lighter than air vehicles with an airframe configuration have double the lift per ton of envelope (after modifiers are taken into account), but have a minimum takeoff speed as for normal aircraft if loaded to a level where they are heavier than air.

Example - A sphere has a surface configuration modifier of 1.0, so the lift of a 1 ton TL13 envelope would be .1t, plus .1t for 10 TL's past TL3, for a total of .2 tons of surplus lift. If it were a cylinder configuration, it would lose .01t and drop to .19 tons of surplus lift, since a cylinder has a surface multiplier of 1.1. A cylinder airframe would lose .043t and drop to .157 tons of lift per ton of envelope, but this would be doubled to .314 tons of lift when the craft was moving at “takeoff speed” or more.

The top speed of a lighter than air vehicle is figured as for a normal aircraft at that TL, with a maximum speed per turn of 10 times the TL of the vehicle, times the length modifier for its configuration. Acceleration for lighter than air vehicles is always less than 1g. For instance, a sphere configuration has a length modifier of 1.0, for no adjustment to speed, while a cylinder would multiply top speed by its length modifier of 2.0. Lighter than air vehicles may not have a gas envelope that is not streamlined, unless it is a balloon (unstreamlined sphere).

For combat targeting, use the USP size equivalent of the gas envelope for determining chance to hit, which will usually be 1 point larger than the rest of the vehicle. Hits that exactly hit the vehicle hit the gondola or other carried items, and all other hits are to the gas envelope, which is counted as having an armor of 1. Aside from slow loss of lift gases, most envelope hits will have no effect unless a) explosive weapons are used, or b) hydrogen is used for lift and the attack has a heat or fire component. In either case, roll for “system damage” for each such attack. Any explosive damage to a gas envelope that results in penalties will immediately collapse one or more sub-cells, and the vehicle will lose .1t x 1D of lift. Any heat or fire-based penalty at all on a hydrogen-filled gas envelope will result in immediate and irreversible ignition of the gas envelope, and all occupants have 2D turns to escape a fiery death.

Note - These rules are rather simple, and will not delve into the detailed operation of ballast, mooring, tethering, etc.

Propulsion system options

Adverse condition propulsion system - This is any modification to the propulsion system that allows the vehicle to operate effectively in conditions that would otherwise be difficult for that propulsion system. Examples would be a supercharger for high-altitude aircraft, anti-fouling props and weed guards for swamp boats, skid plates and extra-heavy suspension for off-road vehicles, etc. Each of these modifications is a x1.1 multiple to volume of the propulsion system (and therefore its cost), and may be applied multiple times as needed.

Secondary propulsion system - This is an add-on to the basic propulsion system that allows very limited use in a subset of the vehicle's normal environment. It allows movement and acceleration of x.1 the normal amount in conditions that would normally be impassable. An example would be waterjets and floatation screens for an armored personnel carrier, so that it can traverse rivers, or a boat with very limited submarine capability. This is a x1.1 multiple to the volume of the propulsion system (and therefore its cost), and must be reasonable and strictly defined. Crossing a river is reasonable for an APC. Crossing a canyon is not.

Crew and passenger stations

A control station for a human-piloted vehicle is 1m3 in volume. This volume may in some cases (motorcycles) be external to the volume of the vehicle itself, in which case .2m3 is used, but the driver has no armor or structure protection. Side or top protection adds .2m3 per side, and front or back protection is .1m3 per facing. So, a motorcycle where the driver gets the protection of the front armor (windscreen) would have .3m3 dedicated to internal volume.

Passenger seats require 1m3 of volume, unless the passenger is hanging onto the vehicle, in which case they require zero volume (but do add to the external dimensions of the vehicle).

Bunks or other minimum vehicle accomodations require 2m3 per person. For very short-term use (a few days at most), regular passenger seats can fold back to form a sleeping area, provided there is 1m3 of unused cargo volume behind each seat to make up the difference. Regular quarters and starship quality accomodations are figured as in starship design, which includes accessways and other space needed to reach these quarters.

Life support - Vehicles operating in hostile environments will require life-support for shirt-sleeve working conditions. The mass required for a sealed vehicle is counted as a special adverse conditions propulsion system, since the places where power is transferred outside the vehicle will require the lion's share of special sealing provisions. Basic life support includes atmosphere recirculation, temperature and humidity control. Standard life support also provides water and waste handling on any vehicle large enough to dedicate an extra 1m3 to these facilities (usually per 20 passengers or crew). If an extra 2m3 is dedicated to life support, it can include a shower or other means of cleaning up (vehicles with a decontamination lock can route regular water through the system to use it as a shower if needed). Vehicles at TL7- do not have regenerative life support, and must use consumables for each passenger per day of operation. Use the TL8 numbers for mass, power, volume and cost, but add consumables of .01t per day per passenger per TL below 8. An exception can be made for TL7 submarines, which can extract oxygen from water. They can halve consumables by using double the power requirement.

Basic life support

TL	volume supported per m3	Mass per m3	Power per m3	Cost per m3
8	1400m3	1.0t	.05Mw	.06MCr
9	1700m3	1.0t	.04Mw	.06MCr
10	2100m3	1.0t	.03Mw	.06MCr
11	2500m3	1.0t	.02Mw	.06MCr
12	3000m3	1.0t	.02Mw	.06MCr
13	3600m3	1.0t	.02Mw	.06MCr
14	4300m3	1.0t	.02Mw	.06MCr
15	5200m3	1.0t	.02Mw	.06MCr

Standard life support

TL	volume supported per m3	Mass per m3	Power per m3	Cost per m3
8	850m3	1.0t	.10Mw	.06MCr
9	1000m3	1.0t	.07Mw	.06MCr
10	1200m3	1.0t	.05Mw	.06MCr
11	1450m3	1.0t	.04Mw	.06MCr
12	1750m3	1.0t	.03Mw	.06MCr
13	2100m3	1.0t	.03Mw	.06MCr
14	2500m3	1.0t	.03Mw	.06MCr
15	3000m3	1.0t	.03Mw	.06MCr

Grav compensators

Vehicles with high accelerations often lead to degraded performance by the crew, and complaints from passengers. Vehicles at TL10+ may install gravity compensators to partially or completely negate accelerations due to a linked contragrav system. The system relies on precise communiction between the two units, both to insure maximum effect, and to prevent catastrophic injury to the passengers should the compensators fail. Compensators have mass and power requirements as below, but their thrust is applied only to the total compensated mass, and cannot exceed the acceleration of the vehicle on this unit. That is, you can never compensate more acceleration than the vehicle is currently experiencing due to its own contragrav.

Starships can apply the same technology if desired, and gravity compensation on passenger ships is a major cost, both in terms of volume, power and credits. Whether or not a small vehicle can exceed the compensation allowed in the starship design rules is a matter of preference.

Grav compensators

TL	Volume per g per m3	protected maximum	Mass per m3	Power per m3	Cost per m3
10	.0100m3	1g	2t	.70Mw	.05MCr
11	.0050m3	2g	2t	.70Mw	.05MCr
12	.0030m3	3g	2t	.70Mw	.05MCr
13	.0025m3	4g	2t	.70Mw	.05MCr
14	.0020m3	5g	2t	.70Mw	.05MCr
15	.0015m3	6g	2t	.70Mw	.05MCr

Optional! - While not normally done for efficiency purposes, grav compensators can be “stacked” to generate more compensation than is practical with single units. To get greater grav compensation, take the desired level, divide by the maximum normally allowed, and cube the result. This is the multiple to compensator volume required to get the compensation needed. This becomes prohibitively costly for starship-class vehicles, and in fact the process begins to break down on extremely large volumes, but for small civilian or military vehicles it can be done without too much trouble. Assume that a minimum of 2m3 of compensated volume is required for military pilots to insure that their ejection seat and all controls are within the compensated envelope.

Example - A TL12 grav car with 6m3 of passenger and cargo space wants compensation vs. 3g accelerations. This has a volume of 6m3 x 3g x .003m3 = .054m3, a mass of .108 tons, a power requirement of .0378Mw and a cost of .0027MCr. To boost this up to 6g of compensation would require (6/3)^3=8 times as much, or .432m3, .864 tons, .3024Mw and .0216MCr. Using similar math, we can get 10g of compensation for a TL12 fighter pilot for .666m3, 1.333 ton, .4667Mw and .0333MCr.

Airlocks - A vehicle with life support of any kind is assumed to be sealed, and to have environment-tight doors or portals. An absolute minimum airlock (1 person, cramped) has a volume of 1m3. A normal one-person airlock is 3m3. Neither has any appreciable mass or power requirements, but will cost an extra .001MCr for structure, sealing, etc.

Decontamination lock - Decontamination showers or apparatus may be added to an airlock for a volume of 1m3 and a mass of 1t. This is sufficient for 100m3 of decontamination, so the total number of decontamination cycles will be based on the internal volume of the airlock. Decontamination procedures generally take about 20 turns (1-2 minutes) to complete.

Electronics

Vehicle electronics serve much the same function as the same items on starships, but with substantially less range and capabilities.

Communicators - These allow transmission and reception between compatible units. Higher tech units are more likely to be able to adapt to the signals of lower tech units than vice versa. Signals at TL5-6 are voice, at TL7-8 may be voice or video, and at TL9+ are flat or three-dimensional video. Communicators have a mass of 2t per 1m3, a cost of .5MCr per 1m3 and require an antenna area equal to ten times the power requirement in Mw (included in cost). These numbers are for full capability starship-equivalent units, capable of simultaneously transmitting and receiving on up to TL^2 channels at once. For instance, a TL10 orbital range communication system can handle 100 simultaneous video phone calls, and has a size and power requirement to match.

“Small vehicle” systems are less capable. They have the same frequency range and type of communication, but can handle a maximum of TL simultaneous signals, and sometimes only handle one or two. Cost of “small vehicle” electronics will be lower by a factor of 2, volume will be lower by a factor of 10, and power reduced by a factor of 100 due to not having to be integrated with other vehicle systems. Any task that is not automatic for a communication system is at -2DM is using a small vehicle system.

Vehicle communicators			Tech Level						
Range	Power req.	Cost	5	6	7	8	10	12	14
subregional(10km)	.0001Mw	75Cr	.05m3	.01m3	.001m3	.0001m	.0001m	.0001m	.0001m3
regional(30km)	.001Mw	250Cr	.1m3	.05m3	.01m3	.001m3	.0001m	.0001m	.0001m3
subcontinent(300km)	.01Mw	500Cr	.15m3	.1m3	.05m3	.01m3	.001m3	.0001m	.0001m3
continent(3,000km)	.1Mw	5KCr	.3m3	.15m3	.1m3	.05m3	.01m3	.001m3	.0001m3
orbital(30,000km)	1Mw	30KCr	.7m3	.3m3	.15m3	.1m3	.05m3	.01m3	.0001m
far orbit(300,000km)	10Mw	90KCr	-	.7m3	.3m3	.15m3	.1m3	.05m3	.01m3

Small vehicle communication systems			Tech Level						
Range	Power req.	Cost	5	6	7	8	10	12	14
subregional(10km)	1 watt	40Cr	.005m3	.001m3	.0001m	.0001m	.0001m	.0001m	.0001m3
regional(30km)	10 watts	125Cr	.01m3	.005m3	.001m3	.0001m	.0001m	.0001m	.0001m3
subcontinent(300km)	100 watts	250Cr	.015m3	.01m3	.005m3	.001m3	.0001m	.0001m	.0001m3
continent(3,000km)	1,000 watts	2.5KCr	.03m3	.015m3	.01m3	.005m3	.001m3	.0001m	.0001m3
orbital(30,000km)	10,000 watts	15KCr	.07m3	.03m3	.015m3	.01m3	.005m3	.001m3	.0001m3
far orbit(300,000km)	100,000 watts	45KCr	-	.07m3	.03m3	.015m3	.01m3	.005m3	.001m3

Note - Each .01m3 of communicator is about 20 kilograms. Power requirement for communication systems is peak load. Actual total draw may be significantly less, but the power supply used must be able to handle this level of peak output.

Communication between compatible units is automatic out to the listed range if they both have the same range and no interference is present. Otherwise, each level of range beyond the range of the less capable unit is an increased difficulty rank (first range band is Average), and would be rolled vs. Intelligence or Communications skill.

Example - A grav car with a regional range radio is trying to get a message through to a ship in far orbit. This would be a Formidable task, with a -2DM if the grav car was using a small vehicle system.

Skill with communications equipment represents the ability to tweak the equipment or find ways of cutting through interference, ranging from twiddling knobs to extreme measures like using simple on-off codes to send a low-speed binary message.

Full vehicle grade systems are assumed to be of “military” quality, rugged, protected against electromagnetic disruption and well-encrypted to prevent eavesdropping if so desired. Small vehicles generally do not have all these options.

Communicator options

Military grade - Military grade communicators are protected much more thoroughly against electromagnetic pulses, and have stronger encryption than similar TL civilian units by 2 points (civilian communicators can have encryption if you want privacy). The dedicated encryption hardware and ruggedization multiplies the cost of the unit by ten.

Directional antenna - This increases the effective range of the communicator by one band, provided you can accurately aim the antenna at the intended recipient of the message, and decreases it by one in all other directions. This adds .1MCr per 1m3 of communicator volume.

Direction finder - This allows accurate bearings to be taken on the source of a signal, and aside from being able to track down signals, it is also required to aim a directional antenna at a moving target. This adds .1MCr per 1m3 of communicator volume.

Communicator types

Radio communicators - This is the default, a system that uses various parts of the radio spectrum to transmit information.

Laser communicators - These operate on visible or near visible wavelengths of light. Their advantage is that they are extremely difficult to intercept, but they must be precisely aimed at their target. Laser communicators are bought using the above table, but are incompatible with normal communicators and are only possible at TL7+. Antenna area is one-tenth normal, and they may not have directional antenna or direction finder options.

Maser communicators - These use a coherent radio beam to carry information. Like a laser, their advantage is that they are extremely difficult to intercept, but they must be precisely aimed at their target. Maser communicators are bought using double the mass on the above table, but they are compatible with normal communicators (if aimed at them) and are only possible at TL7+. Antenna area is one-tenth normal, and they may not have directional antenna or direction finder options.

Jammers - A communicator may be bought as a jammer. Subtract one range band from its listed rating. It normally subtracts one range band from any communicator within that distance. If blocking a particular, known signal, it can subtract two range bands. Each 2 TL's the jammer is greater or less than the communicator being jammed adds or subtracts one range band to the jamming effect.

Example - A jammer bought as a subcontiental range communicator (300km) would subtract one range band from any communicator within 30km (regional range). If attempting to jam a particular signal, it would subtract two range bands from that communicator so long as it was within 30km (regional range).

Sensors

Small craft sensors do much the same as the varying starship sensors, but with less capability. They will be classified as active, passive, civilian and military. When sensors are bought, the designer will need to delineate what kind they are. If you want to keep things simple, just double the volume and cost of any TL10+ sensor and assume it is an active multi-spectrum device capable of picking up and categorizing most kinds of signals at the default resolution.

Civilian sensors - Sensors designed or approved for civilian use are generally meant to make life easier for the pilot or driver, as well as for the local governmental authorities. They generally do not and cannot be retrofitted to accept or transmit targeting data to or from weapons. They generally are made to standard specifications and interface well with other civilian sensors of the same TL, especially if from the same world. The cost of civilian sensors is one tenth the cost listed.

Military sensors - Sensors designed for military use are designed to provide optimum information for the pilot or weapon officer for combat use. They may or may not be compatible with or conform to civilian electronics specifications, and may be custom designed for a specific application. A military sensor will be able to communicate with a compatible fire control system, allowing weapon use through obscured conditions or at ranges beyond naked-eye sighting (subregional or more). They generally are designed to accept or transmit to weapon systems, and are usually restricted or classified items at their TL of introduction. Military sensors cost as listed.

Active sensors - Active sensors work by emitting a signal and sorting the information provided by the delay and nature of the reflected signal. The quantity and quality of this information increases with TL. A TL5-6 sensor might only provide position of targets that reflect the signal. TL7-8 sensors have the ability to discriminate targets by size, direction of movement and velocity, and sometimes by specific type in the case of a trained operator and/or with access to a computer database of reflected signals to draw from. TL9+ sensors simply increase the detail available and increase the range and the conditions under which this detail can be gained. In general:

TL	Target resolution
5	to within 10m per kilometer of range
6	to within 2m per kilometer of range
7	to within .5m per kilometer of range
8	to within .1m per kilometer of range
9	to within .02m per kilometer of range
10	to within .005m per kilometer of range
11	to within .001m per kilometer of range
12	to within .0002m per kilometer of range
13	to within .00005m per kilometer of range
14	to within .00002m per kilometer of range
15	to within .000005m per kilometer of range

Naturally, this resolution is only under optimum conditions, and the maximum TL a sensor has for resolution purposes depends on the nature of the sensor. Conditional DM's that affect spotting chance may also decrease the effective TL of the sensor for resolution purposes.

Example - A TL11 spy satellite orbiting at 100km can resolve ground targets down to .1m in size. However, if there is any atmospheric disturbance that gives a +1DM to detect something, it also drops the resolution to .5m if the target is spotted at all.

Sensors Tech Level

Range	Power req.	Cost	5	6	7	8	10	12	14
subregional(10km)	.0001Mw	.03MCr	.150m3	.090m3	.050m3	.030m3	.010m3	.005m3	.002m3
regional(30km)	.001Mw	.08MCr	.450m3	.300m3	.150m3	.090m3	.030m3	.010m3	.005m3
subcontinent(300km)	.01Mw	.25MCr	1.40m3	.800m3	.450m3	.300m3	.090m3	.030m3	.010m3
continent(3,000km)	.1Mw	.80MCr	4.20m3	2.40m3	1.40m3	.800m3	.300m3	.080m3	.020m3
orbital(30,000km)	1Mw	2.3MCr	12.6m3	7.30m3	4.20m3	2.10m3	.800m3	.200m3	.050m3
far orbit(300,000km)	10Mw	7.0MCr	33.0m3	19.0m3	11.0m3	6.30m3	2.10m3	.700m3	.250m3

Note to GDW-beta list - If FFS is the Bible, then call me a blasphemer, dip me in motor oil and throw me to the gearheads. The small craft design system is not going to have 27 different tables for 27 different kinds of sensors. This table is it, and there will be modifiers listed for the type of sensor on the paragraphs below. If you feel you need a special table for that TL13.5 Mucosal Activity Sensor, I'm sorry, you ain't gettin it.

Note - In starship terms, a 300,000km broad spectrum military small vehicle sensor is the equivalent of a “basic” sensor system, and the two have roughly the same size and power requirements at TL10-12. Doubling the volume of the 300,000km small vehicle sensor would upgrade it to “improved” level, and quadrupling volume and multiplying power requirements by eight would be roughly the same as a “small military” class starship sensor array.

Passive sensors - Passive sensors work by detecting and analyzing information emitted by a target or blocked by a target from other sources. This could be a heat signature, spatial distortions caused by thruster plates, stray nucelar emissions from a reactor, and so on. As with active sensors, the resolution of the information gathered is based on the TL and type of sensor. The range of a passive sensor is theoretically unlimited, but in practice is strongly dependent on the strength of the target signal. The “range” category of the passive sensor indicates its sensitivity and ability to discriminate extremely weak signals from the background noise. Passive sensors use x.1 the power of active sensors, but have the same mass and volume. Their biggest advantage is that an active sensor is easily spotted due to its emissions, while passive sensors do not betray their presence.

Sensor options

Dispersed sensor array - By doubling the antenna area of a sensor, you can increase the effective TL for resolution purposes by 1. However, you may not exceed the resolution for that class of sensor. This is especially effective for optical sensor arrays.

Multiple sensor array - Doubling the number of linked identical sensors to form an array will give +1TL to the resolution of the array. However, you may not exceed the resolution for that class of sensor. This process does not increase the range of the sensor, just its resolution.

Jammers - A sensor may be bought as a jammer. Subtract one range band from its listed rating. It normally subtracts one range band from any sensor within that distance. If blocking a particular, known signal, it can subtract two range bands. Each 2 TL's the jammer is greater or less than the communicator being jammed adds or subtracts one range band to the jamming effect.

Example - A jammer bought as a subcontinental range sensor (300km) would subtract one range band from any sensor of the same type within 30km (regional range). If attempting to jam a particular sensor, it would subtract two range bands from that sensor so long as it was within 30km (regional range).

Radar - This is the default active sensor type, and is the reflection of a high-frequency radio signal off a target to gather information. Radar is possible at TL6+ and reaches maximum resolution at TL12. Varying wavelengths can be used to penetrate certain types of non-metallic materials, and radar can be tuned to find shallow buried structures or terrain features covered by silt, sand or shallow water. Its cost is the default.

Lidar - This uses reflected pulses of laser energy to gather information. The much shorter wavelength of light compared to radio waves gives Lidar a better resolution, and its resolution is counted as one TL higher than the actual TL of the unit. Lidar is possible at TL7+ and the maximum resolution is reached at TL15. Lidar will not penetrate any visually opaque substance, regardless of its thickness, but may be tuned to use frequency windows in atmospheres that may be opaque to visible wavelengths. Its cost is x2, and antenna area is x.1 normal.

Sonar - This uses reflected ultrasonic sound to gather information, and is only useful in non-compressible mediums like water. Sonar is possible at TL5+ and reaches maximum resolution at TL8. Its cost is x.5, and antenna area is normal. Unlike most other sensor types, sonar has a very slow response time, and even at relatively close ranges may take a significant fraction of a second to send and receive a signal.

Nuclear - This is a passive sensor type, and maps out the distance and intensity of subatomic particle sources. Nuclear sensors are possible at TL8+ and reach maximum resolution at TL11. Nuclear sensors may be blocked by masses significant enough to absorb the radiation being searched for. Most reactors have sufficient shielding to block nuclear sensors, but fusion drives, radioactive cargo or even cosmic rays interacting with hull material will give off detectable signals. Its cost is x10 and antenna area is normal.

Gravitic - This is a passive sensor type and maps out the distance and intensity of all gravitational fields, including contragrav and thruster plates. Gravitic sensors are possible at TL9+ and reach maximum resolution at TL11. Gravitic sensors are only blocked by the presence of a larger gravitational source between the sensor and a target. Its cost is x5 and antenna area is x.1.

Optical - This is a passive sensor type and simply provides a detailed visual image of long range targets, including infrared and ultraviolet wavelengths. Normally used under computer control with sophisticated image processing software. Optical sensors are available at TL5+ and reach maximum resolution at TL15+. Their resolution is counted as one TL higher than the actual TL of the unit. Optical sensors will be countered by any visually transparent or non-reflective substances, regardless of thickness, but may be able to detect wavelengths in atmospheres that are opaque to visible wavelengths. Optical sensors will also be able to pick up and analyze reaction engine plumes and can spot laser, particle beam or meson gun fire through the tiny fraction of the energy that is lost on the way to the target. Its cost is x2 and antenna area is x.1.

Sensor use

Using sensors in play is a Formidable task vs. Sensors skill, increased in difficulty by 2 levels per range band outside the sensor, and decreased by 1 level per range band inside the sensor. That is, using a Orbital range sensor against a Far Orbital target would be an Impossible task, while using it against a Continental range target would be a Difficult task. DM's on the task are the USP size code of the target-6, -3DM if target is Stealthy, -1DM for each TL a military target exceeds your sensor TL, and -1/2D DM for any conditions that degrade the signal but do not block it entirely.

If a target is spotted, it stays spotted until it can make itself harder to be seen. If a target is hidden, it remains so until it is easier to be seen. In either case, a new spotting roll is made.

Example - A TL12 grav car is trying to evade a TL8 fighter with Subcontinental range radar. The range is currently Regional, so the fighter pilot has a Difficult task. The grav car is Size 6, for +0DM, but the grav car pilot is trying to hug the ground, for a -1/2D DM. If the pilot succeeds, he has sufficient target information to use weapons. If not, he loses them in the ground clutter.

Finding an item with vehicle sensors by criss-crossing a search grid is a time consuming task, and success is determined mainly by the patience of the searchers and whether or not they are looking in the right place with sensors of sufficient resolution to pick up the object. Provided the searchers have a chance of finding the object of the search, it is usually a Formidable task on Sensors or Survey skill to correctly interpret the data or program the computers to alert someone when objects matching search parameters are found. DMs apply for how much the object blends in with the background. In general, assume that a computer-directed search can cover up to 10 times the rating^2 square kilometers per minute (minimum of 1), divided by the TL of the resolution used, also squared.

Example - Looking for a companion's lifeboat from a radar-equipped TL12 grav car, the pilot flies up to 10km and sets the radar to TL9 resolution. At this height, the radar will be able to pick out objects as small as .2m, so the lifeboat or even a floating person should show up. The vehicle computer has a rating of 2, so the search area is 10 x 2^2/TL9^2=.5 square kilometers per minute, or 30 square kilometers per hour. This is not just sweeping the area looking for radar returns, but actually cataloging and classifying the returns from each .2m x .2m piece of ocean, over 750 million such returns in a hour.

<sidebar>

TL11+ Small Craft package

In order to qualify for a Sylean suborbital or orbital use license, a small craft must have the following equipment package in either normal or small vehicle types of equipment. The listed statistics are suitable for any vehicle of 140m3 or less.

Equipment:
Continental range communicator (nominal 3,000km range)
Regional range (30km) civilian active sensors (radar)
Roadgrid remote operator system
Basic life support
One emergency wall patch per crew or passenger compartment
A whole-vehicle fire suppression system

Structure, etc.
Front armor rating of 3
Other facings armor rating of 2
Acceleration of 1.5g or more
Backup power supply for contragrav if used (30 seconds)

The mass, volume and cost of this will vary depending on TL and vehicle size. If a vehicle is custom-built, analysis of the design files can be used to determine if the criteria have been met.

<end sidebar>

Amenites, options and safety

Roadgrid - The remote vehicle operating system on Sylea is called Roadgrid, but similar concepts may occur on other worlds. Computer controlled remote vehicle operation is possible at TL6+, sophisticated enough to be usable at TL8+ and practical on a large scale at TL10+. The basic equipment interfaces with most vehicle control systems if installed during manufacture (retrofit is difficult), costs .1MCr per 1m3 (minimum cost 500Cr), and has a volume of .001m3 per 1m3 of vehicle, with a mass of 500kg per 1m3. It allows a central traffic computer to monitor all vehicle vital signs, navigate the vehicle and communicate with the crew or passengers. All the passenger has to do is request a destination, and the computers will do the rest. By TL12, Sylean Roadgrid technology is extremely reliable, to the point where parents will trust children on unaccompanied trips, and businesspeople can call their empty cars to pick them up at a pre-determined time and place. Normal Roadgrid maintenance is handled by a mileage surcharge that comes out to around 1Cr per 10 kilometers of travel.

Note - Roadgrid is essentially the same as the Autopilot subsystem, with a built in communicator, satellite navigation system and large quantity discount price. Each vehicle in the TL11 roadgrid system is considered to be operated by a rating 4 computer, so the skill with maneuvering vehicles is effectively a 9, since normal DM's cancel each other out.

Kitchen - A compact food preparation area will be 1m3 and mass 200kg empty, with capacity for up to 50kg of food or utensils. Exact features will depend on TL, and may include rough weather options for low-tech ocean vessels, zero-g options for pre-contragrav space vehicles or refrigerator/freezers at TL6+. Each 1m3 provides cramped but usable space for preparation of up to four meals at a time. Each 1m3 of kitchen will consume .002Mw when in use.

Recreation space - This is usually at a premium in small vehicles, and is generally a table and seating for several people to talk, eat or plan. It has no cost or mass, but occupies 1.5m3 per person. Minimum bunk space can be assumed to be folding bunks, and recreation space can be created by converting bunk space to empty space for an extra .5m3 of volume per bunk.

Fire extinguisher - If an energy-intensive vehicle system suffers damage, there is always the possibility of fire igniting inside the vehicle (roll 3D of greater than or equal to the vehicle TL). A vehicle fire suppression system will extinguish such fires within one turn on a 2D roll of the system's TL or less (portable fire extinguishers roll 3D vs. their TL to be effective). A vehicle fire suppression system has a volume of .001m3 per 1m3 of vehicle volume, a mass of 500kg per 1m3 and a cost of .050MCr per 1m3. The minimum system is .001m3, .5kg and 50Cr.

Wet bar - Any vehicle can have a small food/beverage locker for .2m3 of volume, 300Cr and 20kg (full). The actual amenities will depend on TL, but higher TL's will provide hot/cold water on demand, or have a part of the locker suitable for storing perishable goods.

Entertainment center - Any vehicle of TL7+ can have a sophisticated entertainment system, using whatever technology is appropriate for the TL, ranging from high-quality audio to flat-screen video to full holographic display. It generally occupies a total volume of .02m3, has a mass of 10kg and costs 1,000Cr.

Cargo compartment - Any space leftover when a vehicle is designed may be designated as cargo, at no cost. On military vehicles this will likely be in a less useful shape or amount of contiguous space than on a civilian vehicle, but it is still there. However, having area designated as cargo space implies it is being used for this, and all cargo space is assumed to be full for vehicle performance figures, at a mass of .5t per 1m3 of cargo. If a vehicle is not designated as having cargo space when designed, it may not be retrofitted into this space at a later time.

Trailers - A trailer is designed as the same type of vehicle as the one towing it, and trailers are usually restricted to ground vehicles. The trailer must have the same level of structural support and propulsion system as the vehicle towing it, but usually has no power plant of its own. Top speed and acceleration of the pair are based on total mass, and any maneuvering agility is halved (round down), and all pilot or driving tasks get a -1DM for each USP size of the vehicle+trailer total that is over 5. For instance, any driving task on a USP8 vehicle+trailer combo would be at -3DM.

Anti-theft system - Any vehicle or TL5+ can be equipped with an anti-theft device or burglar alarm. The sophistication varies with TL. At TL7+ it may include power/fuel cutoffs, remote signaling to authorities and remote engine start capability. It is a Formidable task to bypass an anti-theft system, with the following DM's:

Condition	**DM**
Each TL alarm exceeds tools/knowledge of thief	-2DM
Each TL alarm is below tools/knowledge of thief	+1DM
10 turns spent	+1DM
100 turns spent	+2DM
Each x2 cost spent on alarm	-1DM (up to -3DM)

Anti-theft systems have a base cost of 100Cr, which protects up to 5 access points (doors, hood, trunk, etc.). Extra access point protection is 20Cr per, which is also multiplied for extra system cost.

Anti-hijack system - Available at TL7+. Similar in concept to an anti-theft system, this hopefully deters would-be theives from trying to bypass anti-theft devices by taking the vehicle while you are still in it. On command, all access panels have their latches locked and electrified with a penetration 2 non-lethal jolt. An indelible skin dye sprays from concealed nozzles to identify the attacker later, and if any crew or passenger access doors are opened from the outside, the power plant will shut down in 5 turns and it will remain disabled for 100 more. An anti-hijack system generally costs around 1,000Cr and has a mass of 10kg and volume of .01m3.

Construction equipment - A vehicle designed for specialized lifting, earthmoving or digging will require special tools to do so. Consider each type of tool to be a 1 ton, 1m3 weapon in a turret mounting, and having an inherent armor rating of TL/2 (round up). Lifting tools will have a maximum load of 1 ton per TL, with a power requirement of .01Mw per ton. Earthmoving tools will move TL x 10 cubic meters of earth per hour with a similar power requirement and digging tools can dig up to TL/2 meters down (round up) and excavate TL cubic meters of earth per hour with a similar power requirement.

Example - A 1 ton cargo crane on a TL10 truck will have a volume of .1m3 and mass .1 ton, consuming .001Mw in operation.

Access panel (sunroof) - Any vehicle with 1m2 or more of top surface can have an access panel large enough to climb out of (.5m2). On a civilian vehicle, this is usually a sunroof, while on a military vehicle it is a hatch. In either case it can have the full armor of the vehicle. A manually operated access panel will have a default cost of 100Cr x armor rating, and an automated one (electric, pneumatic, whatever) will cost 200Cr x armor rating. Either kind takes one turn to open or close, and automated ones have a Strength of 3 for civilian vehicles of most types, and (armor rating/2) for military vehicles or ones more concerned with pressure integrity than the fingers of the occupants.

Ejection seats - Ejection seats or something similar are available at TL6+. They violently propel the occupant of the seat out of the vehicle, and then deploy some means of getting the occupant safely to the ground. In general, ejection seats give an occupant of a catastrophically destroyed vehicle a chance to escape with their lives. The base chance is a 2D roll less than the TL of the ejection seat. DM's are:

Condition	**DM**
deliberate ejection by occupant	+3
unfavorable vehicle position (too close to ground, etc.)	-3
occupant has pilot skill-1 or more	+1

Success means the occupant takes 1D of wounds, and makes it safely out of the vehicle, before it disintegrates if applicable. Failure means the stress of ejection killed the character (broken neck) or that the ejection seat failed in some way (parachute failure), and if the character isn't killed outright, they have taken 6D in wounds as a result.

Ejection seats have a volume of .2m3, a mass of .1t and a cost of .1MCr each. For double this volume, mass and cost, an entire passenger or crew compartment (up to 6 crew/passenger's worth) may be ejected as a “pod”. This is normally only a feature on vehicles that can expect to keep crew compartment integrity. It has the advantage that if intact, it keeps pressure support for the crew, an important feature if a high-altitude bailout is needed without a vac suit. It has the disadvantage that the fate of all involved are linked to one survival chance.

Smart coatings

The same technology that makes Screens possible can also be applied to vehicle surfaces. For corporations with a high public presence to maintain, this is a regular feature. Every Ontag Fruit Drink truck that makes deliveries to markets and stores will undoubtedly have animated displays extoling the virtues of their product, for instance. These display units are generally not up to broadcast quality standards, but are sufficent for most use. The technology can be applied on Sylea at any number of commercial outlets (off-world franchise opportunies available!) at around 50Cr per square meter, plus 200Cr for a central control unit which can interface with most computers or store pre-programmed visual loops. Add 10Cr per square meter if you want the display to be illuminated for night use.

The military camoflauge applications are obvious, but are not that effective against high-tech forces. While the coatings can mask, confuse or alter the outline of a vehicle, at any TL of 9+, hardly anyone relies solely on visual target acquisition.

Black hole-11

System defense boats and other purely deep space craft often add a blackbody coat on top of any other stealth coat. This is a microporous deep black coating, with pits that trap incoming light and force several reflections in the microscopic pits, stopping a fraction of the already miniscule reflected light with each bounce. A vessel with such a coating appears to be a hole in space, if you can detect it at all, like someone removed of piece of reality and forgot to put it back. This coating is not that difficult to apply, and only costs 10Cr per square meter. Its drawback is that the coating is extremely fragile. Atmospheric re-entry will demolish it, any form of damage will remove it in spots,and even abrasion from space dust will “polish” it if the ship engages in extended high-g maneuvering. In game terms it provides an extra “edge” against optical sensors such as lidar and gives an extra +2DM to be spotted by any optical tracking device (including the naked eye).

Note - This *can* be applied to personal armor and equipment, but its effects are extremely temporary in most cases. Treat it as a layer of wet black paint for purposes of durability.

Combat notes
Personal vehicles and small craft can be used in the same time and distance scale as personal combat, and there is a subset of vehicle actions that can be done in a turn just as there are personal actions.

Ranged attack - Character may load (if necessary), or aim or fire a vehicle weapon. One character may usually be aiming a vehicle weapon while another is loading.
Evade - The driver or pilot of a vehicle may engage in evasive manuevers.
Exit - Any passenger or crew may open an access port or door and exit the vehicle. Heavily armored or powered doors take a turn to open, and may be exited on the following turn.
Use subsystem - Anyone with appropriate controls at hand may use, activate or deactivate a particular subsystem. This includes things like checking radar for targets, turning the power plant on or off, or using a communication device.

Attacks by vehicle weaponry - All vehicle mounted weapons of TL6+ may have fire control appropriate to their TL. A fire control system has a cost of DM x 10KCr, and can provide a maximum +DM of TL/2, rounding down. The mass and volume is subsumed in the weapon controlled. The fire control DM only applies to aimed fire from that weapon, and is in addition to any DM for the aiming charactertistics of the weapon itself. Aimed fire is possible only if any penalty DM from evading and terrain is less than the bonus for fire control. For instance, a TL8 fire control system can allow aimed fire and give up to a +4DM, so long as the penalties for caroming along over rough terrain are *less than* a -4DM. Once these penalties reach or exceed a -4DM, the fire control can no longer keep the weapon on target, the +4DM is lost and the shot may not count as aimed fire.

Terrain - Most land or water vehicles will take additional penalty DM's on rough ground or in rough seas.

Terrain DM's	
Moving over even terrain	-1DM
Moving over uneven terrain	-3DM
Moving over extremely uneven terrain	-6DM
Evading	-1DM (minimum)
Moving over half maximum speed	-2DM

Water vehicles always count terrain as one level worse, so a stationary ship on smooth water still takes a -1DM.

Example - A TL8 land tank driving over rough terrain takes a -3DM for terrain. Its fire control DM is maximum at TL8/2 = +4DM, so it is capable of using aimed fire in these conditions and gets a net +1DM in addition to the aiming bonus. Someone standing in a hatchway firing a pintle-mounted machinegun would not get the fire control bonus, and would take the full terrain penalty, so they would have a -3DM, and would be unable to use normal aiming.

Automated fire control - At TL8+, vehicle weapons can be set on automatic. Through a computer, the fire control system can operate any linked military sensor and weapon with a skill of half its TL (round up), and engage any targets detected that meet pre-designated firing parameters (“shoot at incoming objects larger than 5cm”, or “fire at any objects 5m in size or greater that come within 3km”). These firing parameters are limited by the resolution and abilities of the sensor. Automated fire control requires a computer dedicated to the task with a rating of 2, or a general purpose computer running appropriate software with a rating of 3. Each rating point less than this is a -2DM because of the lag in processing time, but each rating point in excess of what is needed is a +1DM. The weapon will use its regular rate of fire, and will use aimed fire only if programmed to. These rules will apply for point defense weapons of most types, and be sure to apply any autofire DM's as appropriate. Each point defense attack after the first in a turn gets a -3DM.

Autofire - Is covered as under the basic rules. If a weapon is capable of extremely rapid fire, it may get a bonus DM to offset the normal autofire penalties. Most weapons do not get this bonus. A rapid fire (RF) weapon will get a +2DM to autofire attacks, and a very rapid fire weapon will get a +4DM to autofire attacks. This corresponds to a rate of fire of approximately 100 shots or 200 shots per turn, respectively, and the weapon must expend this amount of ammunition or energy to qualify. RF and VRF weapons may use autofire at regular rates of ammunition consumption if desired.

Example - A VRF gauss rifle shooting at Medium Range (range number of 3) would take a -3DM to autofire for range, but would get a +4DM for its rate of fire, for a net +1DM. Adjacent targets would take a -6DM for range and +4DM for rate of fire, for a net -2DM.

Autopilot - A vehicle with a computer and a guidance system that allows accurate positional information (possible at TL6+) may have an autopilot for .1MCr per 1m3 (minimum cost 500Cr), and has a volume of .001m3 per 1m3 of vehicle, with a mass of 500kg per 1m3. An autopilot has a Pilot skill of half its TL (round down), plus twice the rating of the computer running its autopilot software. Most manuevering tasks handled by an autopilot are Average tasks, with the following DM's.

Outside navigational aids (radio beacons, etc.)	+2DM
Maneuvering through cluttered environment	-2DM (most ground vehicles take this)
Any DM a human pilot would take for conditions	as appropriate

Rolls would normally be needed for pre-flight maneuvering, takeoff, each course change, landing, and pot-flight maneuvering. Autopilots on air vehicles are also capable of terrain-following or nap-of-earth (NOE) flight. This counts as maneuvering through a cluttered environment, but if the total skill of the autopilot is equal or more than the TL of any sensors deployed against it, the vehicle is close enough to the ground to get the -1/2D DM for being lost in the ground clutter.

For autonomous combat purposes, an autopilot has a skill of half its TL (round down), plus half the rating of its computer (round down).

Evading - A vehicle that is evading takes a penalty DM on all its vehicle-mounted weapons equal to the acceleration of the vehicle in g's (round fractions up). Hand-held weapons fired from a moving vehicle take double this penalty. This latter category includes pintle mounted weapons, weapons used through firing ports and any weapon which while mounted on the vehicle is aimed entirely by direct muscle power.

Agility - All vehicles will have an agility rating for use on the scale of personal combat. This number is the USP size code of the vehicle, minus its maximum acceleration in g's (round up), minus 4. The result is the DM applied to all attacks against the vehicle when evading at maximum potential.

Displacement	**USP size code**
.1 to .99	5
1.0 to 9.9	6
10 to 99	7

Example - A 1 displacement ton grav car with an acceleration of 3g's will have an agility of 6 (size code) - 3g - 4 equals -1. All attacks against the vehicle while evading take a -1DM to hit.

Airframe vehicles may use up to their structural limits when evading or using agility, but this amount of maneuvering acceleration will decrease the speed of the vehicle, and may be a penalty DM to piloting tasks if attempted in close conditions like NOE flying.

Advanced Damage Locations

When a vehicle is hit by an attack, roll 2D and consult the following table for a hit location. If a system is not applicable, roll again. If there are multiple systems matching that description, choose one randomly. Weapons with area effect (explosive missiles, grenades, etc.) roll two system hits. Follow any notes regarding damage and armor effects. Certain attack types are unlikely to hit certain systems, and re-rolls may be appropriate in such cases (a land mine being unlikely to hit the sensors of a tank, for instance).

2D	**System**
2	Communications (halve armor rating before applying damage, round down)
3	Weapon station, weapon or ammo
4	Power plant
5	Fuel or energy storage
6	Crew compartment
7	Passenger compartment
8	Vehicle structure (double armor rating or use 4, whichever is higher)
9	Cargo compartment
10	Propulsion (halve armor rating before applying damage, round down)
11	Other system (life support, grav compensation, etc.)
12	Sensors (halve armor rating before applying damage, round down)

Anytime a weapon penetrates the armor of a vehicle and strikes a system, roll 2D with a DM of twice the amount that penetrated armor, with a maximum of the original penetration-1 if there is any armor at all. On a result of 12+, that system suffers damage and either takes a permanent -3DM to use, or loses half its current output or capability, whichever is more appropriate. On a result of 14+, the system is completely knocked out of commission or fails catastrophically in whatever manner is appropriate to that system. And, 1D is subtracted from the remaining penetration and the remainder applied to a different system.

Example - If a penetration 5 rifle bullet hits the power plant of a car with an armor of 2, 3 points got through armor. The system failure DM is twice the remaining penetration, or a maximum of the original penrtration-1, for a +4DM. On a 2D+4 roll of 12+, the power plant takes a -3DM to use, or as is more appropriate, loses half its power. On a 2D+4 roll of 14+, the power plant shuts down entirely, 1D is subtracted from the remaining penetration of 3, and if there is anything left, it hits another vehicle system.

Optional - For large vehicles, systems may break down far too frequently. If appropriate, apply a -DM of twice (the USP size of the vehicle, minus 6). For instance, a USP size 8 vehicle would have a -4DM on all system damage rolls to represent that it has larger and harder to damage subsystems.

In the case of occupied compartments being hit, roll 9+ for each occupant or appropriate cargo item, choosing randomly. The first occupant that gets 9+ is hit by the residual penetration. If penetration remains after going through armor (twice), subtract 3 from it and roll for a second passenger hit. If no occupant rolls 9+, the damage penentrated the compartment with no ill effect other than breaching body integrity.

Note! - Due to the massive energies involved in vehicle weapons, what penetrates into the vehicle is significantly higher than just the armor - penetration. If a Penetration 20 weapon goes through an armor rating of 18, the residual energy is a *lot* more than a penetration 2 pistol shot. This is why the residual penetration after going through armor is doubled, unless of course it would make the penetration equal or higher than the original shot.

It go Boom!

If a system with a large amount of stored energy (fuel, ammunition, batteries for energy weapons) catastrophically fails, it usually has collateral effects. Such systems generally apply 3D of penetration per 1m3 of catastrophically failed system to another system (round damage up in 1D increments), which may in turn fail, and so on. If a vehicle ever has a catastrophic failure of its structure, it disintegrates or breaks into chunks. Any emergency safety measures will deploy, even if they won't do any good.

Surface breaches

Much of the time a penetration by an anti-vehicle weapon has more important consequences than the hole it left behind. However, for unprotected individuals in a vehicle losing air to a vacuum, or the crew of a submarine looking at a high pressure stream of water filling their ship with watery doom, that hole can be very important indeed. Each turn after such an important surface breach, roll 2D. If the result is less than the residual penetration of the weapon (or a roll of 2), everything in that section of the vehicle takes a -1DM to use if affected by the adverse external conditions (water, vacuum, corrosives, etc.). The roll is repeated based on the USP size of the vehicle, once per turn for vehicles of Size 6 or less, once per 10 turns for USP Size 7 vehicles and once per 100 turns for USP Size 8 vehicles. Once the DM equals the size of the vehicle, that vehicle subsystem is completely under the influence of the adverse conditions. Even if a vehicle system is unaffected by the conditions, it will make repair or maintenance of the system difficult until the breach is repaired and the atmosphere restored.

Vehicle designs

The following vehicles are a fair sampling of what we can expect to find in operation within and around the Imperium. These are the standard vehicles based on official Imperial plans or templates or available models. Limited variations to these designs are tolerated to allow local manufacture.

All TL12+ Imperium military vehicles operate using fusion modules; they can operate on airless worlds. Unless specifically stated, the interior of the vehicle is not sealed for airless worlds, and occupants would need to wear vacc suits on such worlds.

For GDW list

If anyone feels like designing a particular vehicle that has only a name next to it, feel free and I'll see that you at least get definite rules credit for it.

High-performance motorcycle, TL11

Displacement: .1 (USP5)			
Volume:	1.400m3	-	-
Configuration: Disk Streamlined			
Dimensions: 2.1m long x 2.1m high x .42m wide (approximate)			
Structural material: TL11 Structurecomp			
Chassis: 1g rated	.0244m3	.0244 ton	.0016MCr
Armor: .34cm TL11 Structurecomp	.0249m3	.0249 ton	.0010MCr
Armor rating: 2 on all facings, no crew protection top or rear			
Power plant: TL7 gas turbine, .0938Mw output	.1875m3	.1875 ton	.0038MCr
Fuel consumption: .2813m3 per 100 hours			
Fuel volume: x 1 (high grade hydrocarbons)			
Fuel carried: 10 hours	.0281m3	.0281 ton	.00001MCr
Propulsion: TL8+ wheels (x.7 speed multiplier)	.1250m3	.0625 ton	.0031MCr
Crew: 1 Driver, protected all but top and rear	.7000m3	.1000 ton	-
Options: TL11 Sm. veh. regional range (30km) comm.	.0001m3	.0002 ton	.0001MCr
Sylean roadgrid control	.0050m3	.0025 ton	.0005MCr
TL11 anti-theft system (-1DM)	.0010m3	.0010 ton	.0002MCr
Lockable cargo box (.20m3)	.2000m3	.1000 ton	-
Total:	1.396m3	.5311 ton	.0103MCr(10.3KCr)

Performance: Top speed = 371 meters per turn (25 outdoor sqaures), acceleration = .4g

Notes: A fairly capable machine, used for personal transport on improved roads throughout Sylea. Members of touring organizations may travel in groups under manual control, avoiding mandatory roadgrid areas when possible.

Personal off-road vehicle, TL11

Displacement: .2 (USP6)			
Volume:	2.800m3	-	-
Configuration: Box			
Dimensions: 2.12m long x 1.11m high x 1.11m wide (approximate)			
Structural material: TL11 Structurecomp			
Chassis: 1g rated	.0384m3	.0384 ton	.0006MCr
Armor: 1cm TL11 Structurecomp	.1152m3	.1152 ton	.0046MCr
Armor rating: 3 on all facings			
Power plant: TL11 storage bank, .25Mw/hour power	.2500m3	.5000 ton	.0010MCr
Power plant duration: 5 hours			
Propulsion: TL8+ wheels, .050Mw (x.7 speed multiplier)	.0500m3	.0250 ton	.0013MCr
Adverse condition propulsion system	.0050m3	.0025 ton	.0001MCr
Secondary propulsion system (special tires, floatation)	.0050m3	.0025 ton	.0001MCr
Crew: 1 Driver	1.000m3	.1000 ton	-
Options: Backup generator (.05Mw gas turbine)	.1000m3	.1000 ton	.0020MCr
100 hours fuel	.1500m3	.1500 ton	.0001MCr
TL10 Sm. veh. subcontinental range (300km) comm.	.0001m3	.0002 ton	.0003MCr
TL10 Sub-regional range (10km) civilian radar	.0100m3	.0050 ton	.0030MCr
One passenger seat behind driver or 1.0m cargo	1.000m3	.5000 ton	-
Total:	2.769m3	1.536 ton	.0131MCr(13.1KCr)

Performance: Top speed = 97 meters per turn (6 outdoor squares), acceleration = .2g

Notes: A fully enclosed but not environment-sealed 4-wheeled all-terrain vehicle. It has wide synthetic rubber tires which allow it to cross soft terrain and propel it through calm water. It has good ground clearance and is capable of either long-term use in a breathable atmosphere, or limited use in vacuum or non-oxygenated atmospheres. Prices of these vehicles will drop sharply after introduction of Fusion+ units, as the battery/turbine combination is neither commercially viable or necessary. Fusion+ units are lighter, have better cargo capacity and have better overall performance (top speed 10 squares per turn, acceleration of .2g).

Ground attack aircraft, TL8

Displacement: 5.0 (USP7)				
Volume:	70.0m3			
Configuration: Cylinder airframe				
Dimensions: 10.2m long x 5.7m high x 16.1m wide (approximate)				
Structural material: TL6 light alloy				
Chassis: 6g rated		1.804m3	5.412 ton	.1443MCr
Armor: 1cm TL6 light alloy		1.173m3	3.518 ton	.0469MCr
Armor rating: 3 on all surfaces				
Power plant: 2.0Mw TL7 gas turbine x 2		8.000m3	8.000 ton	.1920MCr
Fuel consumption: 12.0m3 per 100 hours				
Fuel volume: x 1 (high grade hydrocarbons)				
Fuel carried: 4 hours		.4800m3	.4800 ton	.0002MCr
Propulsion: TL8 High performance aircraft (speed x 1.9)	7.200m3	3.600 ton	7.200MCr	
Crew: 1 Pilot	1.000m3	.1000 ton	-	
Cockpit armor, 1.7cm TL8 composite laminate (rating 9)		.0850m3	.6800 ton	.0068MCr
Ejection seat		.2000m3	.1000 ton	.1000MCr
Options: TL8 Subcontinental range (300km) communications		.0100m3	.0200 ton	.0050MCr
TL8 Regional range (30km) military radar sensor		.0900m3	.0450 ton	.0800MCr
TL8 Regional range (30km) military optical sensor		.0900m3	.0450 ton	.1600MCr
TL8 fire control system (+4DM on autocannon)		-	-	.0400MCr
TL8 RF light autocannon (x1.5 internal volume)		.9000m3	1.800 ton	.0210MCr
TL8 fire control system (+4DM on missiles)		-	-	.0400MCr
TL8 Heavy missile x 8 (x1.5 volume hardpoints)		.2200m3	.4400 ton	.0272MCr
Total:		21.25m3	24.24 ton	8.063MCr

Performance: Top speed = 941 meters per turn (63 outdoor squares), acceleration = .4g, takeoff speed = 358 meters per turn (24 outdoor squares)

Notes: A lightly armored ground attack aircraft, designed to engage armored ground targets with either a rapid-fire cannon or explosive guided missiles. The aircraft is designed to be durable and provide the pilot with a high degree of protection from ground fire. Its radar and optical sensor package give it all-weather capability.

Heavy tank, TL5

Displacement: 2 (USP7)				
Volume:	28.0m3	-	-	
Configuration: Box				
Dimensions: 4.63m long x 2.41m high x 2.41m wide (approximate)				
Structural material: TL5 Hard steel				
Chassis: 1g rated		.0890m3	.7120 ton	.0007MCr
Armor: 3.4cm TL5 Hard steel		1.816m3	14.52 ton	.0363MCr
Armor rating: 9 on all, 18 front(+1.060m3), 15 side(+2.674m3)		3.734m3	29.87 ton	.0746MCr
Power plant: TL5 Imp. internal comb., .800Mw x 2		4.000m3	4.000 ton	.0384MCr
Fuel consumption: 4.0m3 per 100 hours				
Fuel volume: x 1 (high grade hydrocarbons)				
Fuel carried: 20 hours		.8000m3	.8000 ton	.0004MCr
Propulsion: TL5 tracks, 1.6Mw (x.4 speed multiplier)		5.760m3	2.880 ton	.8060MCr
Crew: 1 Driver		1.000m3	.1000 ton	-
1 Weapon loader		1.000m3	.1000 ton	-
1 Observer		1.000m3	.1000 ton	-
1 Gunner		1.000m3	.1000 ton	-
Options: TL5 Fire control system (+2DM on cannon)		-	-	.0200MCr
Heavy cannon-5 in turret		2.680m3	1.340 ton	.0500MCr
Medium machinegun-5 in same turret		.0160m3	.0090 ton	.0005MCr
Medium machinegun-5 in fixed forward mount		.0060m3	.0090 ton	.0005MCr
Heavy cannon ammunition x 50	.8750m3	1.750 ton		
Medium machinegun reloads x 5		.0075m3	.0150 ton	
TL5 regional range (30km) comm.		.1000m3	.2000 ton	.0025MCr
Cargo racks		1.000m3	.5000 ton	-
Roof hatch x 2 (at observer & driver stations)		-	-	.0018MCr
Total:		24.883m3	57.01 ton	1.032MCr

Performance: Top speed = 34 meters per turn (2 outdoor squares), acceleration = .2g

Notes: A heavy assault vehicle, designed to engage infantry and similar armored units. Due to lack of sensor equipment, is unable to operate effectively at night or in obscured conditions.

Utility vehicle (4 person)
Utility vehicle (6 person)
Truck 2 ton
Truck 5 ton
Truck 10 ton
ATV Wheeled
ATV Wheeled
Tank Light Tracked
Tank Medium Tracked
Tank Heavy Tracked
Tank VHeavy Tracked
ATV Legged
Troop Carrier Squad
Troop Carrier 2 Squad
Prime Mover Tracked
Prime Mover Wheeled
Recovery Wheeled
Recovery Tracked
Command Wheeled
Command Tracked
Car / Sedan
Car / Limosine
Dirtmover Tracked

Ski / Snow Variants
Sealed Environment Variants
Flotation Kits
Trailer Wheeled
Trailer Tracked

Grav Craft
Grav Tank Light
Grav Tank Medium
Grav Tank Heavy
Grav Troop Carrier Squad
Grav Troop Carrier 2 Squad
Grav Prime Mover
Grav Cargo Carrier 2 Ton
Grav Cargo Carrier 5 ton
Grav Cargo Carrier 10 ton
Grav Rider 1 person
Grav Speeder (coupe)
Grav Speeder (sedan)
Grav Platform (fighter)

Gtrailer

Modules for placement on Prime Mover, Cargo Carrier or Gtrailer

Artillery
Rocket Launcher (Multi)
Missile Launcher (SSM)
Missile Launcher (SAM)
Air Defense
Sensor (various)
Portable Quarters
Command Post

Grav Vehicles are technically aircraft.
Aircraft
(various sizes)
(to be determined)

Personal
Executive Transport
Cargo
Liner

Lifeboat
Minimal armor hull

Ablative coat
basic life support
.1g thruster plate
1g contragrav
Fusion+ unit
Communication gear
12 bunks
4 kits

Hostile environment lander (TL12)
airlock
decontamination
radiation prot
sensors
overpressure
insidious/corrosive
redundant power/propulsion
armor
laser

Lifeboat (TL11)
12 bunks
3 survival kits
regional range radar
far orbital communicator
Armor rating 4
1.0g contragrav
.1g thruster plate
Fusion+ unit
Solar panel
Storage bank
Standard life support
control station
vehicle fire suppression system
rating 3 computer
operator's manual

Research submersible (TL8)

Grav car (TL12)

Ground car (TL12)

Grav tank (TL11)

Grav fighter (TL12)

Ground tank (TL9)

Grav cycle (TL12)

Ground cycle (TL7)

Personal ATV (TL8)

Hostile environment rover (TL9)

Modular drone (TL11)

bulldozer/ARV

flying pulpit TL9

TL8 groundcar

TL12 gravbike

TL9 hover recon craft

TL8 blimp

TL12 blimp

TL12 research sub

TL10 pleasure yacht

TL10 ship's boat (battery operated)

Vehicle worksheet

Vehicle type: __________________________ Tech Level: ________

Displacement: USP Size: ___ Volume: ___m3 Hull factor: ______ Surface area: ____m2 Diameter: ___m

Configuration: Length factor: x___ Width factor: x___ Depth factor: x___

Length: _____m Width: _____m Depth: _____m

Structure factor: x_____ Surface factor: x_____ Price factor: x_____

Maximum acceleration: _____g

Structure material: ______________ Base toughness: ____ Density: ____ Price per m3: _______Cr

Structure volume: Acceleration x Structure factor x Hull factor / Base toughness of struct. matl = ______m3

Structure mass: Structure volume x Density = ______ tons

Armor rating: Base toughness of armor material x thickness multiplier

Armor volume: Surface area x Surface factor x thickness in cm / 100 = ________m3

Individual facing area:
Front: Surface area x Surface factor x .10 = _____m2
Rear: Surface area x Surface factor x .10 = _____m2
Right: Surface area x Surface factor x .15 = _____m2
Left: Surface area x Surface factor x .15 = _____m2
Top: Surface area x Surface factor x .25 = _____m2
Bottom: Surface area x Surface factor x .25 = _____m2

Armor slope effect: front, rear, right, left
Moderate slope, per facing: Actual thickness x 1.5 -10% volume
Radical slope, per facing Actual thickness x 2.0 -20% volume

Airframe area (lift vehicles only): (Surface area x surface factor of airframe configuration) - (Surface area x surface factor of streamlined configuration) = _____m2

Power plant

Tech Level: _____ Type: ______ Power per m3: ______Mw Mass per m3: ______tons

Cost per m3: ______MCr Area per m3: ______m2 Fuel per 100 hours per m3: ______m3

Power plant mass: ______tons

Total output: ______Mw

Power plant volume: ______m3

Power plant area: ______m2

Power plant cost: ______MCr

Base fuel capacity: ______m3 Duration of fuel capacity: ______hours

Fuel volume multiplier: ______

Fuel tankage: Fuel volume multiplier x base fuel capacity = ______m3

Propulsion

Tech Level: ______ Type: ______ Cost per m3: ______MCr Volume per Mw: ______m3 Speed: x_____

Area per Mw: _____m2

Volume: Total power plant output x volume per Mw = ______m3

Cost: Volume x cost per m3 = ______MCr

Vehicle speed per turn: Total power plant output/total vehicle mass x 3000 = _____ meters per turn

Acceleration: Square root of (total power plant output/total vehicle mass), round to nearest .1 = ______g

Takeoff speed (lift vehicles only): (total vehicle mass/airframe area) x 40 = _____ meters per turn

Crew stations

Driver: 1m3 Outside driver: .2m3 with front protection: .3m3 with front and side protection: .7m3

Passenger: 1m3 Outside passenger: As for driver

Crew and passenger mass: .1 to .2 tons each

Weapons

Tech Level: _____ Weapon: _______________ Weapon system volume: ______m3

Weapon system mass: _______tons Weapon system cost: ______MCr

Turret multiple: TL6 = 4 Limited traverse: +1 effective TL
TL7 = 3
TL8 = 2
TL9+ = 1.5

Internal weapon space: Protected weapon volume x turret multiple = _____m3
Ammunition space: Volume per round x number of rounds = _____m3

Grav compensation

Tech Level: _____ Volume per g per m3 protected: ______m3 Maximum compensation: Tech Level-9

Mass per m3: _2 tons_
Power per m3: _.70Mw_
Cost per m3: _.05MCr_

Volume protected: ______m3

Acceleration compensated: _____g

Excess compensation factor: (Acceleration compensated - Max. compensation), cubed (min. of 1)=x_____

Volume req.: Volume protected x volume per g per m3 x acceleration x excess compensation factor = _____m3

Power required: Volume x power per m3 = _____Mw

Cost: Volume x cost per m3: ______MCr

Sensors

Tech Level: _____ Type (active/passive): ____________ Range: __________ Power req.: ________Mw

Volume: ______m3 Area: Power requirement x 10 = ______m2 Base cost: ______MCr

Options:
Dispersed sensor array: Area x 10 = ______m2

Radar (active): Area x 1 = ______m2 Cost x 1 = ______MCr
Lidar (active): Area x .1 = ______m2 Cost x 2 = ______MCr
Sonar (active): Area x 1 = ______m2 Cost x .5 = ______MCr
Nuclear (passive): Area x 1 = ______m2 Cost x 10 = ______MCr
Gravitic (passive): Area x .1 = ______m2 Cost x 5 = ______MCr
Optical (passive): Area x .1 = ______m2 Cost x 2 = ______MCr

Communicators

Tech Level: _____ Type: ____________ Range: __________ Power req.: ________Mw

Volume: ______m3 Area: Power requirement x 10 = ______m2 Base cost: ______MCr

Options:
Directional antenna: .1MCr x volume = _____MCr
Direction finder: .1MCr x volume = _____MCr
Military quality (base cost + options) x 10 = ______MCr

Other

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr

Item: ______________ Tech Level: _____ Mass: ______tons Volume: ______m3 Cost: ______MCr