CORPS™

7103

VDS™

VEHICLE DESIGN SYSTEM

BTRC

Greg Porter

VDS 1.0™

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Dedicated to: Cathy

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Intro to the .pdf edition

The **CORPS VDS** is one of the more ambitious hypertext projects **BTRC** has produced. **Slag!** was probably harder, as the entire book had to be reformatted for on-screen viewing, while **VDS** is meant for either large-screen monitors or printing on inkjet or laser printer. But **VDS** required *a lot* more number crunching and research, which we hope was not in vain.

As usual for **BTRC** hypertext documents, text in **red** is usually a hyperlink to someplace. Due to some printing problems, we've left out the blue destination links. Colored text boxes serve the same function as in **CORPS**, **green boxes** for general info, **blue ⚠ boxes** for alerts and **red boxes** for things you just shouldn't be doing. Items in reversed text are just for visual contrast and have no special function other than a major subject heading.

Printing this

This should print well on normal 8.5“ x 11“ paper, and on the European A4 size as well. For best color printing we suggest a resolution of 360dpi or better, and the use of diffusion dither rather than regular halftones. The color mix is designed to be either a pure CMYK color or a 50-50 mix of two of them. Red is 50% magenta and 50% yellow, for instance. On laser printers, a modern 600dpi printer should do an excellent job. If you can adjust the level of halftone screening, it should be at least 85 lines per inch. Laser printers of 300dpi resolution provide adequate output for all but a few pages, notably the contents, which has both an illustration and small type competing for the same laser dots.

Other hyperlinks

If you noticed the art credits, you would see that every picture in here was taken from some public domain or copyright-free source, like various branches of the US government. Our taxes paid for them, so we might as well use them. For more neat vehicle illustrations and general interest vehicle web pages, try the following:

DefenseLINK
http://www.defenselink.mil/photos/index.html
Lots of Defense Department photographs, many dealing with military exercises, so there are lots of pictures of vehicles in normal operation.

Center for Military History
http://www.army.mil/cmh-pg/nmusa3.htm
Of general interest to military history buffs, and includes links to various US Army museum web pages.

OHA's Page of Defense Related Information
http://www.ifi.uio.no/~oddharry/dsfmc/mill.html
More links than you can shake a stick at, including manufacturers, government links, journals, theory, sensors, computers and a host of other topics appropriate to vehicle or weapon design and use.

Army Vision 2010
http://160.147.68.21/2010/
From the introduction: “Army Vision 2010 is the blueprint for the Army's contributions to the operational concepts identified in Joint Vision 2010. It is the conceptual template for how the United States Army will channel the vitality and innovation of its soldiers and civilians and leverage technological opportunities to achieve new levels of effectiveness as the land component member of the joint warfighting team.” BTRC translation: “The new ways and means with which we will kick people's asses.” No pictures, but gives an idea of doctrine and tactics for high-tech warfare.

NASA Image eXchange
http://nix.nasa.gov/
NIX is a searchable index of NASA photos, including spacecraft, satellites and experimental aircraft.

The Canadian Air Force Photo Archive
http://www.achq.dnd.ca/archive/
An indexed selection of photos from the Canadian Air Force, going back as far as WWI aircraft.

Air Force Link Photos
http://www.af.mil/photos/
A selection of fairly recent publicity or news photos of aircraft and Air Force exercises. Also has links to other Air Force-related art web pages.

MarineLINK Image Library
http://www.usmc.mil/images.nsf
This page has a large selection of Marine Corps and Marine-related illustrations and photos. It has a large selection of subject matter and a searchable index. Definitely worth checking out as it continues to expand.

The Military Network
http://www.military-network.com/default3.html
An extensive collection of military resources, including links for foreign government and military web pages. Good starting point for any search of current weaponry or vehicles.

Sci-Fi Hollywood
http://www.scifihollywood.com/
An on-line gallery of science fiction props, including weapons, spaceships and items for sale. A source for pictures of vehicles that we haven't invented yet.

America OnLine
While I don't think the material is available over the Web, AOL has a large collection of images in the 3D Special Interest Group area (keyword: 3DSIG), including a number of excellent spaceship designs and scenes. Note that these images are copyrighted by the creators and while you can view or print them for your own personal use, putting them in any form of published or commercial work without the creator's permission is not a good idea.

Contents

1 Introduction

Basics

The **CORPS Vehicle Design System** (or **VDS**) is not based on strictly historical concepts, since it is for **CORPS**, a universal system. Using the **VDS**, you can create vehicles for *any* Tech Level or background, and know that they will be consistent within that background and within any other background using that system. Like **3G^3**, this system lets you design things that never were, and are unlikely to have ever been. This is *your* problem, not ours. If you decide that Leonardo DiVinci got a fat government grant and started cranking out steam-powered tanks, we disavow all responsibility for damage to your continuum or sanity.

To keep vehicles portable within genres and systems, many components are "generic". For instance, you may find terms like "exotic power plant", which is not defined as any particular type. In a modern game, it might be a jet turbine. In a fantasy game it might be a captive elemental, and in a science fiction game it might be antimatter. What matters is the game effects, and you can call it whatever is reasonable for the world the vehicle is created for. Likewise, many other vehicle aspects are given effects, and the implementation is left to the designer. It doesn't matter in the design process if you want sliding doors or gull-wing doors, four large wheels or six smaller ones, or whether you have leaf springs, struts or unequal length A-arms. What matters is how it works in *your* game world when someone stomps on the accelerator.

You *can* design hideously large and complex vehicles with **VDS**, up to and including battleships, but it really isn't designed for that. **VDS** is meant as a *role-playing* aid, *not* the front end of a vehicle combat system. If characters start to get more worried about getting lost inside than in using the vehicle, then you've probably gone too far.

A mundane vehicle is usually very fast to design. It has a power plant, power train, fuel, structure, some degree of streamlining and incidental armor, basic passenger seating and a fuel tank. All other characteristics of the vehicle such as acceleration, handling, cargo capacity, range and such all are functions of these items.

Vehicle components

Almost all vehicles will be based on the following components, each of which has a separate section of rules:

Performance

The details of what you get out of what you put into the vehicle. Oddly enough, vehicle performance is first on your design list. Once you know what it will take to get the top speed, acceleration and other vehicle characteristics, the better you will be prepared to make the decisions on power plant, structure, streamlining and other actual vehicle components. You will probably have to reference this section numerous times during vehicle design as you change its other features. Some of the things you will read here will be duplicated elsewhere for ease of reference. **See pages 6-12**.

Power plant

That which provides energy to make the vehicle go, and/or power other items such as the stereo, headlights or particle cannon. **See pages 13-28**.

Power train

The power train takes the output of the power plant and converts it into the actual method of propulsion, such as wheels, tracks, propeller, etc. **See pages 29-35**.

Structure

The frame of the vehicle, which handles the stresses placed on it by the power plant. It also includes the power train and the interior furnishings for any vehicle that carries passengers. This can be as basic as bench seats, or as complex as scientific laboratories. **See pages 36-47**.

Surface treatment

Some special item added to the basic structure of a vehicle for a particular purpose, like streamlining, armor, wings, waterproofing, etc. A vehicle may often have several surface treatments that work towards a common theme. For instance, a sub needs waterproofing, a pressure hull and streamlining, all of which are surface treatments. **See pages 48-62**.

Accessories

Anything else that is left, like electronic equipment, sensors, spare parts, fuel tanks and so on. **See pages 63-88**.

Weapons

Examples of weapon and sensor systems for various Tech Levels. To design new weapon systems, you should use BTRC's **3G^3** weapon design system. **See pages 89-91**.

Combat

What to do with those weapons, including rules to cover situations not in the basic **CORPS** rules. **See pages 92-101**.

Campaigning

And last, how to use vehicles in your game world, and the trials and tribulations they will encounter. **See pages 102-119**.

Terminology

A number of terms will be used throughout the rules, and you will need to understand them, or convert them to terms you are more familiar with.

xN	This is a multiplier on some part of vehicle cost, mass, volume or other characteristic. If more than one of these applies, they multiply together. If there is a "+N" that applies to a multiplier, it *adds* to *that* multiplier before this calculation. For instance, a x2 multiplier and a x.5 multiplier with a +.1 addition gives a final result of 2 x (.5 + .1) = 1.2 times the cost of the item in question.
armor value	Also called AV. A relative measure of the ability of a vehicle component to resist damage.
damage value	Also called DV. A relative measure of the ability of a weapon or effect to cause damage.
hex	A normal hexagon as used in many game maps. In **CORPS**, a hex is 1 meter from face to face and has an area of .75 square meters.
kilogram (kg)	A unit of mass, equal to 1,000 grams, 35.2 ounces or 2.2 pounds.
kilometer (km)	A unit of distance, equal to 1,000 meters, 3,281 feet, or .62 miles.
kilowatt (kw)	One thousand watts, about 1.33 horsepower.
kilowatt hour (kwh)	The total energy produced in one hour by a source of one kilowatt (1,000 watts for 3,600 seconds). For comparison, a typical car battery holds from .5 to 1 kilowatt hours worth of energy.
kph	Abbreviation for kilometers per hour.
kps	Abbreviation for kilometers per second.
megawatt (Mw)	One million watts, about 1,333 horsepower
meter	A unit of distance, equal to 100 centimeters, 39.37 inches or 3.28 feet.
m/sec	A velocity of one meter per second, or 3.6 kilometers per hour, or 2.24 miles per hour.
m^2	Square meters, a surface area equal to an area one meter long and one meter wide. About 10.76 square feet.
m^3	Cubic meters, a volume equal to a cube one meter on each side. About 35.31 cubic feet. One cubic meter of water masses 1,000 kilograms (about 2,210 pounds).
mph	Abbreviation for miles per hour.
Tech Level	Abbreviated as TL. A term that encompasses the general development of various types of technology in a given historical period. For instance, the development of atomic power marks a change in Tech Levels.
ton	A metric ton, or 1,000 kilograms.
watt	A unit of energy output. One metric horsepower is 750 watts.
watt-hour	The total energy produced in one hour by a source of one watt (one watt for 3,600 seconds). For comparison, a rechargeable "D" cell battery holds about 5 watt-hours worth of energy.

Where to begin?

It would be nice if we could just give you a step-by-step sequence to follow, ending in a completed vehicle that requires no changes, but it isn't going to happen. Too many vehicle factors are interdependent, and the sequence of steps you use to design a vehicle will depend on the *type* of vehicle designed. The most important thing to remember is that *form follows function*. Once you decide what you want the vehicle to do, that will help you decide what problems you want to tackle first.

Cargo vehicle

Cargo volume is most important. Decide this first, and with this volume in hand, get a rough idea of the length, width and height of the vehicle. Then decide how much the vehicle will mass fully loaded. How much internal volume you sacrifice for power plant, power train, fuel, etc. will be based on the level of performance you are willing to accept.

Passenger vehicle

Passenger volume is most important. Decide how many passengers and how much luggage the vehicle needs to carry, and for what duration and in what level of comfort. This gives you a rough idea of the vehicle dimensions. Since most passenger vehicles operate in the proximity of other such vehicles, and passengers want to get where they are going at a reasonable speed, the power plant and power train will need to be up to the task, in addition to providing spare power for any creature comforts appropriate to the Tech Level.

Armored vehicle

A dedicated armored vehicle needs three things figured out first: the loaded mass of the vehicle and the mass of armor it will carry, and the dimensions of the vehicle. Between these you can get an idea of how much armor you can get on each facing, and then see what kind of performance you can cram into the volume remaining after weapons, fuel, seats and ammunition is taken into account.

A vehicle that is incidentally armored or upgraded from unarmored status needs to alter performance based on the new mass and any increased engine capacity.

Space vehicle

Since you have as much volume as you need, the most important thing is *total* vehicle mass and area. With this, you can figure out the acceleration of the vehicle, the mass of the structure needed for this acceleration, how much fuel you can carry and optionally how much area you have for internal heat dissipation. Once it has a maneuvering duration suitable for your needs, you can worry about other aspects of its design mission. With the addition of crew volume, life support, airlocks, bulkheads, sensors and other systems, you fill out the total vehicle mass, and then see what volume the sum of the systems comes out to.

Lighter-than-air vehicle

A zeppelin, blimp or balloon is going to be *large*. Don't worry too much about the volume of the gas bag. Rather, decide how much lift you are going to need to get your payload aloft, and then design a large enough gas envelope to lift it with whatever safety margin you want. The acceleration of these large vehicles will be minimal if they are going to be able to lift a shape-supporting structure.

Other air vehicles

There are a lot of variables to consider, and the importance you give each depends on the mission of the vehicle. The most important thing is to have a set of wings capable of lifting the vehicle with the engines you can put in it, with enough surplus power to provide a reasonable climb rate. These wings should also be sturdy enough to handle the stresses of any maneuvering the vehicle is designed to do (e.g. a fighter will want to have more maneuverability than a cargo plane).

Water vehicles

These are easy enough. You should however, decide the maximum loaded mass of the vehicle and its dimensions before you do anything else. If its volume in cubic meters is less than its mass in metric tons, it has a density of greater than water, and won't float (oops). A submarine, on the other hand, needs to have a density almost equal (but a little less) than water. That way, when you flood ballast tanks, the density becomes greater than water and the vessel submerges.

Combinations

If your vehicle has several types of “major mission”, you will have to compromise somewhere. An armored cargo vehicle is going to sacrifice payload volume or armor coverage, since you probably can't have a lot of both (why do you think APC's have less armor than tanks?). Until you gain experience with the system, you will probably have to go back and forth, altering vehicle components until you get something that gets close to your ideal.

Mass and volume

We try to keep the mass vs. volume problem to a minimum in **VDS**. Most systems will fall into one of four categories:

1. Open space that has variable volume and mass, like passenger quarters or seats, with the mass varying by type of component.
2. Lightweight systems, or ones with a lot of room for moving parts, like a vehicle suspension. This is .5 metric tons per cubic meter.
3. Equipment that you can get at, like an engine with space to do normal maintenance. This is 1 metric ton per cubic meter.
4. Equipment that you can't get at easily, like the engine of a tank or jet, where keeping the volume under armor to a minimum is important. This is 2 metric tons per cubic meter.

This is not perfectly accurate, but it works for most purposes, and keeps an already detailed subject at a manageable level of hair-pulling recursive calculations.

Tech Levels

One of the most overriding concepts in **VDS** is that of Tech Level. Think of the difference between a modern battle tank and one from 20 years ago, or 40 years ago. This is a difference of 1 or 2 Tech Levels. The difference in equipment in Operation Desert Storm was only 1 Tech Level in most cases.

Tech Level	Date	Historical/postulated vehicle tech
1	Pre-history	Oared or poled boats/rafts
2	10,000BC	Sailboats, vehicle carts
3	3,000BC	Warships
4	0AD	Solid rockets
5	1400AD	Armored wagons, windmills
6	1700AD	Low pressure steam engines, balloons
7	1800AD	High pressure steam engines, dirigibles
8	1900AD	Internal combustion engines, tanks, aircraft
9	1930AD	Jet engines, liquid fuel rockets
10	1960AD	Fission reactors, supersonic aircraft
11	1980AD	Commercial space vehicles
12	2000AD	Fusion reactors
13	2100AD	Faster-than-light travel
14	2200AD	Antimatter reactors, antigrav
15	2300AD	?
16+	?	?

The differences in weapons and sensors also apply to power plants, power trains and other vehicle components, and people trying to break performance barriers are scratching and scrabbling to get their fingernails over the next Tech Level. This will cause design problems when you are near a Tech Level boundary, or when multiple Tech Levels apply to a single vehicle. There can be cases in **VDS** where a demonstratably superior technology is not actually better, because it is built at the same Tech Level. So, for instance, a propeller-driven steamboat at Tech Level 6 will have the same top speed as a sternwheeler at Tech Level 6, if all other vehicle stats are the same. You'll need to make your own value judgements as to whether a given advance is actually better (and probably a Tech Level higher), or just a *different* way of getting the *same* performance.

Freebies

While there are a lot of minutia in the rules, this is supposed to be a fast system to learn and use. Any enclosed vehicle can have any or all of the following items desired for its designed TL or lower for a total of 2% of vehicle volume, a mass of 1,000kg per cubic meter of freebie volume, and a cost of 100Cr per kilogram of freebie volume.

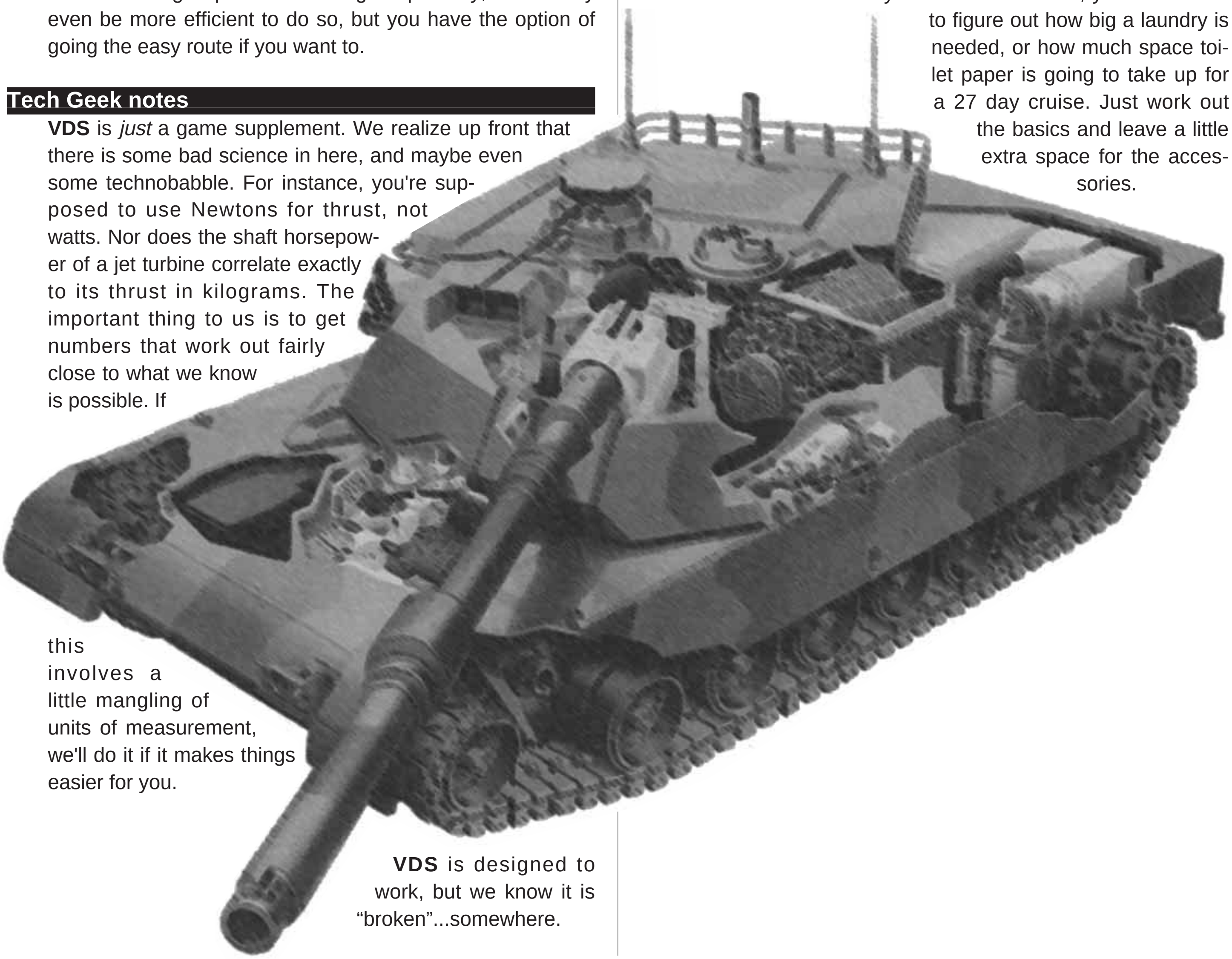
Tech Level	Freebie
9	Head/taillights, electrical wiring, locks, intercom
10	Basic entertainment system
11	Basic escape device (seatbelts or higher TL equiv.)
12	Two-way communications, anti-theft alarm
13	Navigation computer, voice interface
14	Autopilot or remote navigation system
15	Basic foul-weather sensor suite

Example - If you design up a 10m^3 van for TL14 use, for a volume of .2m^3, 20kg and 2,000Cr you can have autopilot, nav computer, car phone, burglar alarm, air bags for all occupants, stereo, and of course headlights and door locks.

You *can* design up all these things separately, and it may even be more efficient to do so, but you have the option of going the easy route if you want to.

Tech Geek notes

VDS is *just* a game supplement. We realize up front that there is some bad science in here, and maybe even some technobabble. For instance, you're supposed to use Newtons for thrust, not watts. Nor does the shaft horsepower of a jet turbine correlate exactly to its thrust in kilograms. The important thing to us is to get numbers that work out fairly close to what we know is possible. If this involves a little mangling of units of measurement, we'll do it if it makes things easier for you.



VDS is designed to work, but we know it is “broken”...somewhere.

There are too many permutations and possibilities in something like vehicle design to cover them all exhaustively. We hope that the real-world data points we've used to generate **VDS** are good enough to work for most of your needs.

Author's Note

VDS is for a *role-playing system*. It is *not* rocket science. You aren't supposed to spend more time designing vehicles than characters, or worrying about how many digits you should keep track of in calculations (the first three are sufficient until you're done, and then drop it to two).

If all else fails, check the back of the book. There is a wealth of tables derived from the numbers in each chapter, and maybe you will find something to make your life a little easier.

Vehicles, if you'll pardon the repetition, are a *vehicle* for adventure, *not* the destination. If you are designing vehicles as the GM, the most important things to have are the floor plans, and its performance stats. As a player, you need these and how much it costs to keep running. If you design a thousand ton destroyer with a crew of 80, you don't need to figure out how big a laundry is needed, or how much space toilet paper is going to take up for a 27 day cruise. Just work out the basics and leave a little extra space for the accessories.

2 Performance

Basics

To begin with, you probably have some conception of what you want the vehicle to do in terms of top speed, acceleration, handling and so forth. Before you get into the nuts and bolts of vehicle design, you should probably get an idea of the power requirements, modifiers and vehicle dimensions required to get these figures. If there is something you don't understand, don't worry about it. It just means that the appropriate rules will be explained in detail in another part of the rules and that you are just seeing a sample case here.

If your figures are reasonable, the design will be fairly simple. If not, you may have to cut corners, sacrifice interior space, strength, money and safety to get what you want. You don't think they used to make planes out of wood and lacquered cloth because they liked sniffing the fumes, now did you?

We would like to make the **VDS** purely sequential, but odds are that you will be making changes and referring back to this section on a regular basis. The best way to minimize hassles and speed your design is to set a firm limit on the mass and dimensions of your vehicle. Most of the performance variables are affected by these quantities, and as long as you decide that you *won't* tack on that extra little bit of armor, or add a tidbit of extra length to get more passenger room, then you won't have to go back and recalculate everything else.

If all else fails, note which way a given table rounds numbers. For instance, if you can make a vehicle a fraction of a meter longer or wider and still keep it on the same table for some derived characteristic, then you get the benefits of extra interior volume without having to recalculate that characteristic.

Vehicle Performance

Note that vehicle performance numbers assume "normal" modes of transport. For instance, water vehicles have a lower top speed because of the lower efficiency of pushing water as opposed to rubber on pavement. It does not consider the performance of a wheeled vehicle operating in a water-dense atmosphere on a heavy gravity planet. These are special cases, and will be dealt with separately.

Top speed

The *base* top speed of a vehicle is the (its effective power in watts times its mass in kilograms)$^{.61}$, divided by its mass in kilograms, and modified by the type of power train and optionally its streamlining. Remember that to convert to kph, multiply m/sec by 3.6, and for mph, multiply by 2.24.

Base top speed = (Power in watts x Mass in kg)$^{.61}$/Mass in kg

or

Base top speed = (Power in kw x Mass in tons x 10)$^{.61}$/Mass in tons

	Vehicle Mass						
Power	100kg	200kg	500kg	1,000kg	2,000kg	5,000kg	10,000kg
10kw	46m/s	35m/s	24m/s	19m/s	14m/s	10m/s	7.6m/s
20kw	70m/s	53m/s	37m/s	28m/s	22m/s	15m/s	12m/s
50kw	122m/s	93m/s	65m/s	50m/s	38m/s	27m/s	20m/s
100kw	186m/s	142m/s	99m/s	76m/s	58m/s	40m/s	31m/s
200kw	284m/s	217m/s	152m/s	116m/s	88m/s	62m/s	47m/s
500kw	497m/s	379m/s	265m/s	202m/s	155m/s	108m/s	82m/s
1Mw	759m/s	579m/s	405m/s	309m/s	236m/s	165m/s	126m/s
2Mw	1158m/s	884m/s	618m/s	472m/s	360m/s	252m/s	192m/s
5Mw	2024m/s	1545m/s	1081m/s	825m/s	629m/s	440m/s	336m/s
10Mw	3090m/s	2358m/s	1650m/s	1259m/s	961m/s	672m/s	513m/s
20Mw	4717m/s	3599m/s	2518m/s	1921m/s	1466m/s	1026m/s	783m/s
50Mw	8248m/s	6295m/s	4403m/s	3360m/s	2564m/s	1794m/s	1369m/s

Power train	Top speed modifier	kg/kilowatt	Cost
Wheels	x.80	50/TL	5Cr/kg
Tracks	x.60	100/TL	5Cr/kg
Legs	x.40	100/TL	5Cr/kg
Indirect to dense medium(water)	x.50	10/TL	5Cr/kg
Indirect to avg. medium (dense gas)	x1.0	20/TL	5Cr/kg
Indirect to thin medium (air)	x2.0	30/TL	5Cr/kg
Indirect to vacuum (reaction engine)	∞	30/TL	5Cr/kg

Modifiers	speed	kg/kilowatt	Cost
Muscle-powered drive train	x1.0	x3.0	x2.0
Tech Level 1-2	x.50	x1.0	x1.0
Tech Level 3-4	x.60	x1.0	x1.0
Tech Level 5-6	x.70	x1.0	x1.0
Tech Level 7-8	x.80	x1.0	x1.0
Tech Level 9-10	x.90	x1.0	x1.0
Tech Level 11-12	x1.0	x1.0	x1.0
Tech Level 13-14	x1.1	x1.0	x1.0
Tech Level 15	x1.2	x1.0	x1.0

In atmosphere, use the "indirect to thin" multiple for reaction engines, but multiply the output of the reaction engine by its fuel consumption first.

Example - A 100kw(131hp) power plant driving a 1,000kg car will give it a theoretical top speed of (100,000 watts x 1,000kg)$^{.61}$/1,000kg = 75.9m/sec (273kph/170mph). The top speed modifier for wheels is x.8, so the adjusted top speed is 75.9m/sec x .8 = 60.7m/sec (218kph/136mph). Any type of streamlining would further modify the top speed (basic streamlining would drop it to 55.7m/sec (200kph/125mph).

The indirect numbers assume the medium the power transfer is occurring to is the same medium the vehicle is moving through, and takes *some* drag effects into account. Further modifiers to top speed will apply based on the degree of streamlining and again on the medium the vehicle is moving through. A boat propelled by an air-pushing propeller has a power train mass for a thin medium, but has a top speed modifier for the dense medium the vehicle is moving through. You always use the densest of the mediums the vehicle is moving through for top speed purposes, regardless of the power train type, and this *can* be cumulative.

Example - A legged vehicle would take x.4 for legs. If the vehicle was designed to walk through water, it would take an additional modifier on top speed based on its level of streamlining for a water environment, and would be even slower if it hadn't been designed to walk through water to begin with (see **Secondary Power Trains**, **p.31**).

Acceleration

Vehicle acceleration will be in terms of meters per 1 second turn or m/sec. The number given for a vehicle is its maximum acceleration from a standing start. For acceleration at speed, divide the *current* speed by the vehicle acceleration. This number (rounding up) *subtracts* from the base acceleration, with a minimum acceleration of 1.

Example - A car with an acceleration of 6 can go from zero to 6m/sec (22kph/13mph) in 1 second. If the car is travelling 22m/sec (79kph/48mph), it can accelerate (6m/sec minus (current speed/6)) = 2m/sec, up to 24m/sec (86kph/52mph).

⚠ Reaction engines are a special case (**see p.19**). If acceleration is not in any way dependent on friction or retarded by drag in the medium the vehicle is moving through, acceleration is a *constant*. It does *not* decrease as the vehicle speed increases. For most purposes, you can assume that the only thing which reduces the acceleration of a rocket is atmospheric drag on the vehicle due to streamlining effects, i.e. if the wind drag is -4m/sec at a given speed, then you would subtract 4 from the vehicle's acceleration at that speed.

The acceleration of any vehicle is based on whether or not it is limited by its environment. Wheels, tracks, propellers, turbines and so on are limited in how fast they can mechanically interact with the environment and their acceleration decreases as their speed increases. Rockets and other reaction engines are environment independent and their acceleration is a constant. All vehicles have an acceleration of (Power in watts x mass in kg x .1)$^{.5}$/(mass in kg x .5), keeping fractions until vehicle-specific adjustments are made. Air vehicles going down may add up to local gravity (10m/sec on Earth). Vehicles with an acceleration of "0" *can* accelerate, but so slowly that it is unlikely to be usable in a role-playing sense. The numbers on the table below are rounded nearest and are intended as a general guide.

Base accel. = (Power in watts x Mass in kg x .1)$^{.5}$/(Mass in kg x .5)

or

Base accel. = (Power in kw x Mass in tons x 100,000)$^{.5}$/(Mass in tons x 500)

	Vehicle Mass						
Power	**100kg**	**200kg**	**500kg**	**1,000kg**	**2,000kg**	**5,000kg**	**10,000kg**
10kw	6	5	3	2	1	1	1
20kw	9	6	4	3	2	1	1
50kw	14	10	6	5	3	2	1
100kw	20	14	9	6	5	3	2
200kw	28	20	13	9	6	5	3
500kw	45	32	20	14	10	6	5
1Mw	63	45	28	20	14	10	6
2Mw	89	63	40	28	20	13	9
5Mw	141	100	63	45	32	20	13
10Mw	200	141	89	63	45	28	20
20Mw	283	200	127	89	63	40	28
50Mw	447	316	200	141	100	63	40

Example - A 1,000kg sports car with a 200,000w (266hp) power plant will have a base acceleration of about 9 (8.94).

The previous number is the *base* acceleration. *Actual* acceleration will be based on the means of power transfer between the vehicle and environment. Round fractions nearest for numbers greater than 1.

Transfer type	Effective acceleration
Transfer to liquid (boat propeller, waterjet)	Base acceleration x .1
Transfer to rarefied gas (airplane in upper atmosphere)	Base acceleration x .2
Transfer to gas (airplane propeller, jet engine)	Base acceleration x .5
Transfer to dense gas	Base acceleration x .7
Transfer to solid (tires to pavement, tracks to ground)	Base acceleration x 1.0
Transfer independent of medium (reaction engine)	Base acceleration x 1.0

Example - A TL11 jet engine with a mass of 3,673kg will have an output of 4.0mw. If this jet engine is pushing a 10,000kg aircraft, *base* acceleration will be 12.6, and the final acceleration will be 12.6 x .5 = 6.3, rounding to 6. If this jet were in the upper atmosphere, acceleration would be only 12.6 x .2 = 2.5, rounding to 3.

Climb rate

This is a subcase of acceleration, and is basically any spare power that can be devoted to vertical acceleration after you are through with horizontal acceleration. On a plane, this is computed as normal acceleration, but only using the power left after you subtract that needed to keep the plane aloft (see "**Wings**" in the **Surface Treatments** section, **p.55**). On Earth, assume that an acceleration of 10 is sufficient to counteract gravity and climb vertically without any assistance from wings.

Just because an air vehicle has an acceleration of more than local gravity, it does not mean it is capable of controlled hovering or delicate vertical maneuvering. This involves special controls. **See p.34**.

Example - If, after taking the power to stay aloft into account, an air vehicle has sufficient power for an acceleration of 6, it can split this acceleration between forward acceleration and increasing its altitude.

Any air vehicle which has an acceleration of 10m/sec (or local gravity) may climb straight up, regardless of horizontal velocity. A land vehicle doesn't require more than a foot on the brake to maintain any particular "altitude", but gravity will constantly be opposing any attempts to climb hills.

Note that the subtraction to a vehicle's acceleration is to its *adjusted* acceleration, i.e. the acceleration it can do at the speed it is *currently* moving.

Slope	Equivalent	Effect on → acceleration
1°	.17m ↑ per 10m →	-.2
2°	.34m ↑ per 10m →	-.3
3°	.52m ↑ per 10m →	-.5
4°	.70m ↑ per 10m →	-.7
5°	.87m ↑ per 10m →	-1
10°	1.7m ↑ per 10m →	-2
20°	3.6m ↑ per 10m →	-3
30°	5.7m ↑ per 10m →	-5
40°	8.4m ↑ per 10m →	-6
50°	11.9m ↑ per 10m →	-8

Example - A car trying to drive up a 5° slope has its acceleration reduced by 1. If its adjusted acceleration was already 1, it would not be able to speed up at all, only maintain its current speed.

Example - The airplane from a previous example has an available acceleration of 6. Using the above table we can see that the plane can maintain its speed and climb at a 40° angle.

This does not take into account the decrease in effective friction for vehicles powered by their wheels at very high degrees of slope (or low degrees of slope in slick conditions).

Note that a vehicle with "negative" acceleration will decelerate when climbing a hill too steep for it, and a decrease in acceleration also is matched by an equal decrease in top speed. The reason such small slopes are listed is for vehicles like trains, which will often have extremely low accelerations due to their loaded mass, and therefore be unable to handle more than the most gentle slopes.

Note that a land vehicle with an acceleration of more than 10 *cannot* drive up a wall or cliff, since there is no force holding the vehicle against the surface it is climbing. Presumably, a climbing vehicle could lift itself vertically if it had an acceleration of 10 or more, or a rocket or jet vehicle could "drive" up a wall if there was thrust to push it against the wall. However, with that kind of acceleration, it is just a specialized air vehicle.

Gravity as power

For game purposes, a vehicle may use gravity for power whenever it is possible to lose altitude inside a gravity well. Normally this will be when coasting down a hill or gliding down through an atmosphere.

For land vehicles, just use the reverse of the numbers on the slope table on the previous page. For instance, a vehicle coasting down a 5° slope will have +1 acceleration, *and this is unaffected by current speed*. As long as the vehicle is capable of taking advantage of this acceleration (usually only wheeled vehicles), it can accelerate each turn without any application of engine power, and the top speed of the vehicle is increased by 10 times this amount.

Air vehicles are a little more complex (actually a *lot* more complex), and the actual figures are based on vehicle mass, wing type, speed, drag coefficients and a lot of other tedious stuff. A good approximation is:

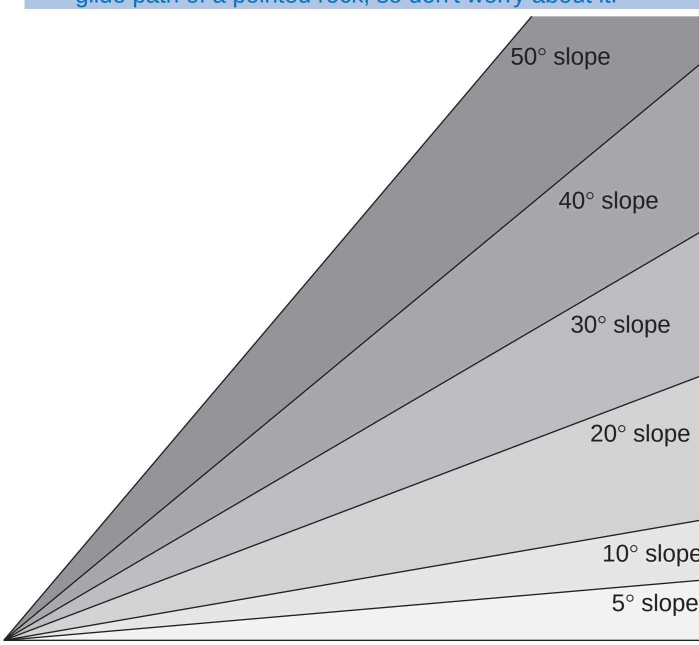
Glide ratio = $300/(\text{mass in kg}/\text{wing area in m}^2)^{.7}$

Like many equations in **VDS**, this is one that works, but is not necessarily the most correct one from an engineering standpoint.

Example - A 500kg glider with 20m^2 of wing area has a glide ratio of $300/(500\text{kg}/20\text{m}^2)^{.7} = 31.5{:}1$.

Example - A 10,000kg jet fighter with 30m^2 of wing area (an F-16) loses power and must attempt to ”glide” down. It has a glide ratio of $300/(10{,}000\text{kg}/30\text{m}^2)^{.7} = 5.1{:}1$.

Yes, some of these calculations are obnoxious, but you only have to do them once. If you've designed a glider, its glide ratio is obviously important. If it is a fighter jet, it has the glide path of a pointed rock, so don't worry about it.



Deceleration

The deceleration of a vehicle is number of meters per second that it can reduce its velocity, under optimum conditions. It is based on the method of deceleration, the medium the vehicle moves through and the mass of the vehicle.

Base deceleration = $20/(\text{Mass in kg})^{.2}$

Transfer type	Modifier
Very high contact with env. (tracks)	x2.0
High contact with env. (wide wheels)	x1.5
Average contact with env. (wheels, air brakes)	x1.0
Low contact with env. (narrow wheels)	x.5
Very low contact with env. (boat propeller)	x.3
Friction with solid surface (tires to pavement, tracks to ground)	x1.0
Friction with liquid (boat hull)	x2.0
Friction with dense gas	x.5
Friction with gas(air brakes)	x.2
Friction with rarefied gas (airplane in upper atmosphere)	x.1
Vacuum (reaction engine)	x0

Vacuum is a specialized case. Any reaction engine can be pivoted 180°, if only by spinning the vehicle around, and the acceleration of the vehicle can be used as a deceleration instead. This does of course use up fuel.

These base deceleration numbers assume the power train of the vehicle has brakes, air flaps or some means of interacting with the medium of choice. Most ships, for instance, do not have “water brakes”, and might be counted as having lower quality controls (turning radius and braking not usually a priority for large ships). The control quality (see next page) will be a further modifier on acceleration.

If you want to be precise, any amount of drag a vehicle is experiencing can be added to deceleration at high speeds. For instance, if your airplane loses 8m/sec from its top speed due to drag, you get an extra +8 on deceleration if you hit the air brakes while going your normal maximum speed. Since this amount varies with speed, it is not normally included due to the complexity of looking it up for each change of velocity. A propeller driven plane or jet which cannot adjust the pitch of its props or configure its intakes (advanced quality controls or better) will automatically apply a deceleration of 1, which means that gravity power will need to supply an acceleration of 1 as well as keeping the vehicle level.

Turn mode

This represents how tightly the vehicle can turn. It is based on the length to width ratio of the vehicle, its height to width ratio, and the amount of ground contact if appropriate. First, divide the length of the vehicle by its width, rounding fractions nearest. This is the base Turn Mode.

Length/width	Turn Mode	Height/width	Modifier
1	7	.5	+0
2	6	1	-1
3	6	2	-2
4	5	3	-3
5	5	4	-4
6	5	5	-5
7	5	6	-6
8	5	7	-7
9	4	8	-8
10	4	9	-9

The basic formula for Turn Mode is $7 - (\text{length/width})^{.5}$, rounding to the better Turn Mode and ignoring the 1:1 ratio.

Example - An automobile is 4m long and 1.8m wide, for a length/width ratio of 2.2, rounding to 2. This gives the vehicle a base Turn Mode of 6. If the auto is 1.8m high as well, its height/width ratio is 1, giving a -1 modifier on the base Turn Mode, dropping it to 5.

A winged vehicle can automatically have a Turn Mode equal to its maximum wing loading, although this only applies when it is airborne (see **Surface Treatments**, **p.55**). It is presumed that large enough control surfaces are on the vehicle to generate this Turn Mode. Other vehicle stats may reduce this, and it may have to be bought back up.

Vehicles that can lean into turns (usually ones with two wheels or legs) are always considered to have a height to width ratio of not more than 1:1.

Continue to add or subtract to the Turn Mode based on the overall length of the vehicle, rounding fractions nearest.

Overall length	Modifier	Example
1m	+2	Motorcycle
2-4m	+1	Automobile
5-9m	+0	Limousine, truck
10-16m	-1	Large truck, small fighter
17-25m	-2	Tractor-trailer, large fighter
26-36m	-3	Small airliner
37-49m	-4	Medium airliner
50-64m	-5	Large airliner
65-81m	-6	Large cargo aircraft
82-100m	-7	
101-121m	-8	Los Angeles-class sub
122-144m	-9	Knox-class frigate
145-169m	-10	
170-196m	-11	Typhoon-class sub
197-225m	-12	Long Beach-class cruiser

Example - This automobile is 4.0m long, which modifies the Turn Mode by +1, back up to 6.

Then, apply a modifier based on the amount of ground contact the vehicle has. This step *only* applies to land vehicles, and is the amount of "rubber on the road". You can choose any amount that you want, but amounts over a certain minimum will decrease top speed from rolling resistance, although they will increase deceleration and turning capacity.

Ground contact	Turn Mode & Decel	Top Speed
Maximum (wide tracks)	+3	-3m/sec
V.good (tracks, race car)	+2	-2m/sec
Good (sports car, many wheels)	+1	-1m/sec
Average (average land vehicle)	+0	+0m/sec
Poor (wagon wheels, bicycles)	-1	+1m/sec
Minimal (trains)	-2	+2m/sec
None (hovercraft)	-3	+3m/sec

Example - This automobile has wide tires to give it good traction, for a +1 Turn Mode, which modifies the Turn Mode by +1, up to 7, but subtracts 1m/sec from the *base* top speed for a wheeled vehicle.

The default ground condition for a wheeled vehicle is normal paved roads or good unpaved ones. This is considered to have a Difficulty of 1 for travelling over, and the suspension of the vehicle has a rating of 1. As long as the rating of the suspension is higher than or equal to the Difficulty of the terrain, the vehicle will have no problems.

Off-road suspensions allow travel over more difficult terrain, but the increased ruggedness of the suspension and other factors will decrease the Turn Mode of the vehicle.

Terrain type	Rating	Turn Modifier	Typical vehicle
Specialized	0	+1	Race car
Normal pavement	1	+0	Most cars
Poor road	2	-1	Truck, some cars
Marginal road	3	-2	Heavy duty 4WD
No roads	4	-3	Tank, dirt bike
Rugged and broken	5	-4	Legged vehicles only
Eventually impassible	6	-	n/a

Example - A typical truck can handle worse roads than the average car. So, the truck has a suspension rating of 2, which allows it to automatically pass over rough roads that would eventually stop a sports car, but at the cost of -1 to its Turn.

A terrain with a Difficulty of 6 or more will eventually put a stop to any land vehicle movement, because no land vehicle can have a suspension with a rating of more than 5. Hovercraft do not have suspensions, and can cross impassable boggy terrain unimpeded. In general, a Rating 1+ terrain type will alter the usable maximum speed of a vehicle by $1/(\text{Rating}^2)$, which does take twisted paths as well as their ruggedness into account.

Last, take the result and multiply it by the following amounts to represent the quality and Tech Level of the suspension, rudders, ailerons, etc., rounding nearest. Apply the cost multiplier to the cost of the entire power train of the vehicle.

Control quality	Turn Mode	Cost
Best	x1.2	x5.0
Advanced	x1.1	x2.0
Basic	x1.0	x1.0
Crude	x.8	x.7
None	x.6	x.5

TL	Adjustment	Cost
1	-.2	x1.0
2	-.1	x1.0
3	-.1	x1.0
4	-.1	x1.0
5	+.0	x1.0
6	+.0	x1.0
7	+.0	x1.0
8	+.0	x1.0
9	+.1	x1.0
10	+.1	x1.0
11	+.1	x1.0
12	+.1	x1.0
13	+.2	x1.0
14	+.2	x1.0
15	+.2	x1.0

Example - This automobile is TL10, and has an advanced suspension, for a x1.1 Turn Mode, which modifies the Turn Mode up to 7 x (1.1+.1) = 8.4, rounding to 8.

For those who wish to cram this into a spreadsheet program, the Tech Level multiplier is +(Tech Level$^{.6}$ - 3)/10, rounding to the nearest .1.

Secondary Turn Mode

A vehicle usually has a standard method of operation (land, water, air, space, etc.). If the vehicle can operate in a secondary manner (a plane driving on a runway, an amphibious vehicle in the water, etc), then the secondary mode of operation has a Turn Mode based *solely* on the dimensions of the vehicle (including surface treatments like wings), and this number takes a -4.

Aircraft landing gear	-4
Using a secondary vehicle characteristic for turn mode	-4

Example - An armored personnel carrier with a Turn of 5 has an amphibious mode. If the basic Turn of the vehicle (based on its dimensions) was 5, then in the water it would have a Turn of 1.

Example - A jet fighter with a Turn of 50 based on its wings would only have a Turn based on its dimensions for taxiing down the runway, and this would have a -4 applied to it.

Turn Limits

A vehicle with a Turn Mode of 0 or less is assumed to have a Turn Mode of 1. Unless a vehicle can pivot in place, most vehicles have the limit that they cannot change facing unless they move forwards or backwards a distance at least equal to the vehicle length.

For practical purposes, a vehicle is not going to have a Turn of less than 1 unless it is so structurally fragile that only the gentlest of maneuvers are allowed.

Turning in place

A vehicle which spends an *extra* 2Cr per kilogram of the power train may have it built so the vehicle is capable of turning on its own axis. The best example is a tank pivoting its tracks in opposite directions to spin in place, or a Harrier jet or helicopter hovering and turning. This maneuver is independent of the Turn of the vehicle, but may only be performed if the vehicle is stationary. If the vehicle only needs to turn in place with its secondary Turn mode, it only pays the extra 2Cr per kilogram only on whatever power train is required for this secondary maneuvering capability. An example might be small motors on the landing gear of a plane so that it can pivot around on a small patch of ground.

Ground pressure

This is an optional land vehicle stat which represents how much of the vehicle's mass is distributed over the area of the tires, treads, etc. Vehicles with high ground pressure will have a different suspension rating for purposes of soft soil or marshy areas, but are otherwise treated normally.

Vehicle mass / (length x width)	Soft terrain Rating
<60 (4 wheel ATV)	+1
61-200 (average car, truck)	+0
201-600 (wheeled APC)	-1
601-2000 (medium tank, tracked APC)	-2
>2000 (heavy tank)	-3

Ground pressure	Soft terrain Rating
Ext. low (wide tracks, huge feet)	+2
Very low (narrow tracks)	+1
Low (wide/many tires, average feet)	+0
Average (average tires)	-1
High (wagon wheels, bicycles, small feet)	-2
Very high (skates)	-3
None (hovercraft)	n/a

Example - A poor road has a Difficulty of 2, and most trucks can traverse one since they have suspension ratings of 2. A truck with normal tires on a poor road that is wet and boggy would take a -1 to its suspension rating, and is more likely to get stuck as a result.

Am I Doing This Right?

Basics

Each chapter will end with a few examples of the rules presented in it. If this makes it like a textbook, well, it *is* like a textbook of sorts. And, these examples will help you avoid pitfalls and double-check your own accuracy.

Question #1:

What is the base and adjusted top speed and acceleration of a 1,000kg automobile with a 100 horsepower engine?

Calculations:

One horsepower is 750 watts, so a 100 horsepower engine produces 100hp x 750 = 75,000 watts.

The base top speed is (75,000 watts times 1,000kg)$^{.61}$, divided by 1,000kg = 63.6m/sec (229kph/142mph). The modifier for wheels is x.8, so the final top speed is 63.6m/sec x .8 = 50.9m/sec (183kph/114mph).

Acceleration is (75,000 watts x 1,000kg x .1)$^{.5}$, divided by (1,000kg x .5) = 5.48, which rounds to 5.

Answers:
Base top speed = 63.6m/sec
Adjusted top speed = 50.9m/sec
Acceleration = 5

Question #2:

What is the Turn Mode of a TL12 racing bicycle that when the rider is included, is 1.5m long, 1.5m high, and .5m wide?

Calculations:

Turn mode is based first on the length to width ratio of the vehicle, in this case 3:1, since it is 1.5m long and .5m wide. This gives it a base turn mode of 6.

The height to width ratio is also 3:1, but since this is a vehicle that can lean into turns, it is counted as 1:1. This gives a -1 to turn mode, dropping it to 5.

The overall length of the vehicle is less than 2m, so it gets a +1, raising it to 6.

The bicycle has poor ground contact, which is a -1 to Turn Mode, dropping it to 5 again, and incidentally dropping deceleration by 1 because of the reduced friction.

The suspension is suitable for normal pavement, which is no modifier to Turn Mode.

We'll assume the quality of the controls is the best, since this is a racing bicycle, which multiplies Turn Mode by x1.2. The fact that it is TL12 raises this by another +.1 to x1.3. A Turn Mode of 5, times 1.3 equals 6.5, which rounds to 7.

Answer:
The Turn Mode of this racing bicycle is 7.

Question #3:

What are the performance figures (top speed, acceleration, deceleration, turn mode) for a 10,000 ton ship that is 100m long, 20m wide and 20m high, that is powered by a 20,000 horsepower engine?

Calculations:

Base top speed is (20,000hp x 750 watts per hp x 10,000,000kg)$^{.61}$, divided by 10,000,000kg, or (15,000,000/10,000,000)$^{.61}$ = 44.4m/sec (160kph/99mph). The power train is an indirect to dense medium variety, for a multiple of x.5 on this, dropping top speed to 44.4m/sec x .5 = 22.2m/sec (80kph/50mph).

Acceleration is (20,000hp x 750 watts per hp x 10,000,000kg x .1)$^{.5}$, divided by (10,000,000kg x .5) = .77. This is a transfer of power to a liquid, for a multiple of x.1, dropping acceleration to .77 x .1 = .077, which we'll round to .08 (or .1 if you prefer).

Deceleration is a base of 20/(10,000,000kg)$^{.2}$ = .80, with a x.3 multiple for a boat propeller, x2 for hull friction, for a final deceleration of .80 x .3 x 2 = .46, rounded to .5.

The base Turn Mode is is based on the length/width ratio, which is 5:1, for a base turn mode of 5. The 1:1 height/width ratio subtracts 1, making it a 4. The overall length drops it by 7 more, to -3, and since Turn Mode can't go lower than 1 for game purposes, it becomes a 1.

Answers:
Adjusted top speed = 22.2m/sec
Acceleration = .1
Deceleration = .5
Turn Mode = 1

3 Power Plant

Basics

The power plant is whatever is used to provide the energy the vehicle needs to move. This could be man or animal power, steam, wind, rockets, magic or whatever. Each kilogram of power plant will provide a base output in watts, and the effective output will be determine by the specific type of power plant. **Each kilogram of power plant has a base cost of 10Cr**. **Each 1,000kg of power plant takes up 1m^3**. This includes a small amount of room for basic access to the power plant, although this does not have to be convenient in any sense of the word. Anyone who has ever had to crawl under a car and stick their arm at unnatural angles up into the engine bay to get at a component knows what is meant by that. If you wish to *double* the required time spent for maintenance, you may have the power plant take up 1m^3 per 2,000kg of mass (also see **Retrofitting**, **p.113**). Also, biologic power plants (animals) have special volume requirements (see **p.41**).

Tech Level	Year equivalent	Raw power output per kg	Historical power source developments
1	30,000BC	1w	Animal
2	10,000BC	4w	Wind
3	3,000BC	9w	
4	0AD	16w	
5	1400	25w	
6	1700	36w	Steam
7	1800	49w	
8	1900	64w	Internal combustion
9	1930	81w	Jet engine
10	1960	100w	Atomic
11	1980	121w	
12	2000	144w	Fusion (we hope)
13	2100	169w	
14	2200	196w	Antimatter
15	2300	225w	

One metric horsepower is 750 watts of output.

Example - A TL10 base power plant has an output of 100 watts per kilogram. Since there are 750 watts per horsepower, a 15kg engine at TL10 would have a base output of 1,500 watts, or 2 horsepower, before adjustments for engine type.

Power plant design

The actual type of power plant will have a significant effect on its output. A race car engine will have much more power than an engine of similar size in a family car, for instance.

Type	Output Modifier	Durability	Cost	Fuel economy
Biologic (always TL1)	x9	1000hr	x.2	x.002
Durable (diesel, steam)	x2	4000hr	x.5	x.03
Normal (normal auto engine)	x4	1000hr	x1	x.10
Enhanced (sports car engine)	x6	250hr	x2	x.20
Exotic (race car,jet)	x9	60hr	x4	x.40
Dangerous (rocket)	x12	15hr	x8	x.65
Ext. dangerous (nuclear)	x16	4hr	x16	x1.0
Suicidal (antimatter)	x20	1hr	x32	x1.5

Example - If our previous 15kg engine was a “normal” TL10 technology, like a gasoline engine, it would have an output modifier of x4, so its adjusted output would be 100 watts x 4 = 400 watts per kg, or 6,000w for a 15kg engine, or 8 horsepower. If it was an “exotic” technology like a turbine engine, the output would be 900 watts per kg, for a total output of 15kg x 900 watts/kg = 13.5kw, or 18 horsepower.

Durability

The durability number represents the number of hours the power plant can go without maintenance before risking failure or performance degradation. The base time is divided by fuel effects, and the result is the recommended maintenance interval. Each time the interval comes up, the engine needs 1 hour of maintenance per 100kg of power plant, with a usual minimum of 1 hour, regardless of power plant size.

Example - A high performance automobile engine has a base durability rating of 250 hours, so it needs maintenance every 250 hours of use. If the engine masses 200kg, it requires 2 hours of maintenance.

You can double or halve the base durability of an engine by doubling or halving the cost, i.e. an engine that costs twice as much will have double the recommended maintenance interval, and one which costs half as much will have half the recommended maintenance interval. Power plants with very high output modifiers like fission reactors will have their reliability inherently higher than other types of power plant, and this will be taken into account in their greatly increased cost.

Each time a power plant needs maintenance and *doesn't* get it, you check for performance loss or engine failure. A performance loss is a Difficulty 4 task, using a “skill” of the number of maintenance intervals missed. Breakdown is a Difficulty 6 task, based on the same number and the same roll, i.e. if a roll *succeeds* vs. a Difficulty 4 task, you lose performance, but if that same roll would have *succeeded* vs. a Difficulty of 6, you have a breakdown. Performing basic maintenance is a Difficulty 4 task on the appropriate skill for the vehicle (a more skilled person *can* accomplish the maintenance in a shorter amount of time).

Technologically advanced power plants should use the fission, fusion or antimatter fuel types. This way, they can use the more powerful output modifiers and still have good reliability. The combination allows power plant outputs far above what pre-fission cultures can manage.

Fuel economy

The fuel economy rating is the number of kilograms of fuel per hour the *each kilogram* of the power plant consumes at *full* power. This is based on power plant type, but the fuel itself is also a factor. Fuel consumption may vary within 10% or so within each category. For instance, both gasohol and premium gasoline are "normal" fuels, but a tank of premium has more energy, and a properly adjusted car can go farther on it. Fuel has a *default* cost of 1Cr per kg (adjusted by local levels of scarcity) and *default* volume of $1m^3$ per 1,000kg. Batteries are considered "fuel" for power plants like electric motors, and the multiple simply represents the weight of batteries discharged per hour of use. Special notes on handling and storage of bulky fuels (cryogenic liquids) or compact or hazardous fuels (radioactives) are on p.118.

Fuel	Fuel consumption	Cost	Durability	Example
Very crude	x2.0	x.5	x4	Wood, charcoal
Crude	x1.4	x.7	x2	Coal
Normal	x1.0	x1	x1	Natural gas, medium grade petrol
Enhanced	x.50	x2	x.5	High-grade or modified petroleum
Exotic	x.25	x4	x.25	Low-grade rocket fuel (solid & liquid)
Dangerous	x.10	x9	x.1	High-grade rocket fuel (cryogenic liquids)
Ext. dangerous	x.06	x16	x.06	Radioactive isotopes
Suicidal	x.04	x25	x.04	Antimatter
-	x.03	x36	x.03	
Special case modifiers				
Fission-based	x.0050	x1000	x100	Fissionable isotopes,
Fusion-based	x.0020	x10	x100	Deuterium, tritium
Antimatter	x.0005	x1000	x100	Antiparticles
Battery	x(10000/TL^2)	x.40	x1	Chemical batteries, flywheels
Use-based consumption				
Full output	x1.0			
Cruising (80%)	x.70			
Trolling (40%)	x.30			
Maint. (10%)	x.05			

Example - A "normal" TL10 power plant that massed 10kg would go through 1kg of "normal" fuel per hour at maximum output (10kg of power plant, x .1 fuel efficiency x 1.0 for normal fuel). If on the other hand, the engine burned some exotic, high-powered racing fuel, the output of the engine would not increase, but the fuel consumption would be multiplied by x.25 instead of by x1.0 and the maintenance interval multiplied by x.25.

Note that the fuel type is mainly based on *energy content*, not on fuel quality. You could run a steam engine on wood, coal or oil. The power output would be the same, but the quantity of fuel used would vary. Crude fuel *quality* (as opposed to energy content) would halve the maintenance interval for the power plant.

For durability purposes, the fuel rating multiplies the engine rating, so using dangerous fuels with a dangerous engine means that you will need to maintain it a lot.

Example - An "exotic" engine like you might find in a race car has a maintenance interval every 60 hours of operation. If powered by "exotic" fuels, it requires maintenance every (60 hours x .25) = 15 hours of operation. This fuel won't make the engine perform any better, but the car will burn less of it, allowing for a smaller (and lighter) fuel load.

Some types of power plant will have special effects regarding fuel consumption. For instance, turbine engines can't be run at the "Maintenance" level. Even when idling, they are consuming fuel at the "Trolling" rate. You have to turn the engine off, with only brief periods on to get the maintenance fuel consumption. This would *seem* identical, but not if you have to move in a hurry and the engine is cold.

You can mix and match fuel and special case modifiers to get the effect you want. You could have both "normal" fusion batteries for a x.005 fuel consumption rate, or a "dangerous" but more efficient fusion fuel delivery system for a x.0005 fuel consumption rate and x.1 durability on the *battery* (not power plant). Likewise, you could say a TL15 "normal antimatter battery" would have a total fuel consumption modifier of $(10{,}000/15^2)$ x .0005 = x.0222.

Multiple fuel engines

In the case where a power plant burns multiple types of fuel at the same time, the two fuels may be of different levels of toxicity, hazard, etc. You may take the average fuel type used, and split it into two different types, each the same distance from the average, in opposite directions.

Example - You could say an engine burning "enhanced" fuel actually burns a two part mixture of exotic and normal fuel. One is a row down from enhanced, the other is a row up.

The power plant is assumed to get 25% of its output from the *less* energetic fuel, and 75% from the *more* energetic fuel, and fuel consumption of each component is therefore based on x.25 and x.75 of total fuel consumption.

Example - You design a power plant which uses "exotic" fuel and decide that this is a two component mixture of aviation kerosene (an enhanced fuel), and liquid oxygen (a dangerous fuel). The fuel consumption for each is based on half the engine mass and the fuel efficiency of that particular fuel. So, if the engine massed 100kg, and was a "dangerous" power plant, it would have a base fuel consumption multiplier of x.65, or 65kg of fuel per hour of operation, or 65kg x .25 = 16.25kg for the enhanced fuel and 65kg x .75 = 48.75kg for the dangerous type of fuel. The enhanced fuel (the aviation kerosene) has a multiplier of x.5, so its share is 16.25kg x .5 = 8.125kg per hour. The dangerous fuel (liquid oxygen) has a multiplier of x.1, so its share is 48.75kg x .1 = 4.88kg per hour.

If a normally air-breathing power plant is run using stored oxygen, multiply fuel consumption by *twice* the *output modifier* for that power plant type. This *extra* fuel consumption is liquid oxygen, and given a "dangerous" fuel multiplier.

Batteries

Batteries or other "rechargable" energy storage devices are considered to be "fuel" for some other type of power plant (typically an electric motor). Batteries are not consumed, their nature is just converted from one which produces electricity to one that doesn't. Therefore, mass of a vehicle with discharged batteries is the same as one with charged ones.

An electric motor will use a certain number of kg/hour of batteries while running, and compared to *total* battery mass, this will give you a running time in hours. Since the power available in batteries is available for other vehicle purposes, a battery is also a power plant of sorts. While you could figure out the capacity by seeing how long a normal motor of a given output would run, we'll just give you the table below which gives applicable numbers for "normal" batteries.

Tech Level	watt/hours per kg	$3G^3$ watt/hours per kg*
1	.00w/hr	-
2	.06w/hr	-
3	.32w/hr	-
4	1.0w/hr	-
5	2.5w/hr	-
6	5.2w/hr	-
7	9.6w/hr	-
8	16.4w/hr	6.9w/hr
9	26.2w/hr	13.9w/hr
10	40.0w/hr	27.8w/hr
11	58.6w/hr	48.6w/hr
12	82.9w/hr	76.4w/hr
13	114w/hr	111w/hr
14	154w/hr	146w/hr
15	203w/hr	201w/hr

*BTRC's **$3G^3$** design system allows the manufacture of energy weapons back to TL8, but technically an electric power source can be made at any TL which has two different metals and an electrolyte.

Example - A 1kg normal power plant at TL10 produces (100 watts x 4) = 400 watts of power, and consumes .1kg of normal fuel per hour. A battery has a fuel multiple of 10,000/($TL10^2$), or x100, so it would use .1kg x 100 = 10kg of batteries per hour. An output of 400 watts, divided by 10kg of batteries is 40 watt-hours per kilogram.

A watt/hour is 1 watt of output for one hour, and the amount of energy can be multiplied or divided by any amount of time within reason (generally not more than a factor of 100). Batteries may be of different fuel types, so you could have exotic batteries that give more power for a given mass. It is worth noting that due to the special nature of batteries or similar storage devices, they do not affect the maintenance interval of the power plant they run. Rather, they assume that the battery is a "normal" power plant, and apply the fuel type modifier to itself. This is how often the *battery* needs serviced, with new electrolyte, plates, etc.

Example - A battery with 1,000 watt/hours will drive a 1,000 watt power plant for an hour, a 10,000 watt power plant for a tenth of an hour, or a 100 watt power plant (or radio transmitter or whatever) for 10 hours.

Remember that battery rules can also apply to flywheels or compressed air for pre-electric cultures, and in this case, mechanical energy is stored instead of electrical energy. It will still require a power plant and power train to move this energy through.

Also note that the special case modifiers for things like fission or fusion power can be applied to batteries. Just invert the fuel consumption number to get the multiplier to total capacity. For instance, a "fission battery" would hold (1/.005)= x200 the power of a normal chemical battery.

At this point it is worth mentioning again that the power plant and fuel types are *concepts*. Correlation with the real world is based solely on what *your* "real world" is. A **VDS** TL12 boosted and tweaked "suicidal" power plant with "exotic" fuel isn't an experimental antimatter reactor. It would be a dragster engine. It produces a lot of horsepower, tears itself apart after a few runs at full power, and will occasionally catch fire and explode on you.

Storage banks

While a vehicle may have a battery for constant power loads, weapons may require very large pulses of power for short periods of time. Batteries or generators are seldom able to handle the peak power load, and instead are used to charge up special energy banks capable of handling the rapid discharge required. At TL's of 12 or less, these are provided by capacitors, homopolar generators or other genre-specific technologies. These store less energy per unit mass than a battery, but can entirely discharge in a second or less. At TL's of 13 and up, larger amounts of energy are available for instant discharge. Both types of fast-discharge storage banks mass 1,000kg per $1m^3$ and cost 100Cr per kilogram.

TL	Low-density storage	High-density storage
8	400 watt-seconds/kg	-
9	800 watt-seconds/kg	-
10	1200 watt-seconds/kg	-
11	1600 watt-seconds/kg	-
12	2000 watt-seconds/kg	-
13	2400 watt-seconds/kg	125,000 watt-seconds/kg
14	2800 watt-seconds/kg	250,000 watt-seconds/kg
15	3200 watt-seconds/kg	375,000 watt-seconds/kg

Example - A TL13 laser cannon that has a 4 megawatt input pulse would require 32 kilograms of high-density storage banks per shot (4,000,000/125,000 = 32). The rate of fire of this weapon would depend on how fast this storage bank could be recharged, or the weapon could have multiple storage banks.

Note - These figures are taken directly from the **$3G^3$** weapon design system numbers for similar storage for energy weapons.

Special cases

It is important to remember that until *you* define it otherwise, a power plant is "generic", and uses equally "generic" fuel. It is *your* game world and the laws of nature in it that makes you say a spacecraft uses a rocket as a power plant instead of a coal-fired etherwave projector, or that an automobile uses reciprocating pistons instead of a turbine or a rotary engine. **VDS** doesn't lock you into fixed technologies, and you can use it to generate realistic or consistent vehicles for *any* game background. There are *lots* of special cases and rules for power plants, and hopefully the following will cover most of them. Everything from here to the end of the chapter are "special cases", which covers odd power plant types and real world notes that may or may not be worth your trouble.

Armor Value

The default AV of a power plant is (cube root of its final output in kilowatts) / (one quarter the output modifier for that type of power plant), plus 1 (round up). Reaction engines (see **p.19**) *do not* apply their increased output for any part of this equation. Biologic plants have the AV of the creature.

$$AV = ((\text{final output in kw}^{.33})/(\text{output modifier x .25}))+1 \text{ (round up)}$$

Power output	2 Durable	4 Normal	6 Enhanced	9 Exotic	13 Dangerous	Extr. Dangr.	20 Suicidal
10kw	AV5	AV4	AV3	AV2	AV2	AV2	AV2
20kw	AV7	AV4	AV3	AV3	AV2	AV2	AV2
50kw	AV9	AV5	AV4	AV3	AV3	AV2	AV2
100kw	AV10	AV6	AV5	AV4	AV3	AV3	AV2
200kw	AV13	AV7	AV5	AV4	AV3	AV3	AV2
500kw	AV17	AV9	AV7	AV5	AV4	AV3	AV3
1.0Mw	AV21	AV11	AV8	AV6	AV5	AV4	AV3
2.0Mw	AV27	AV14	AV10	AV7	AV5	AV5	AV4
5.0Mw	AV36	AV19	AV13	AV9	AV7	AV6	AV4
10Mw	AV45	AV23	AV16	AV11	AV8	AV7	AV5
20Mw	AV56	AV29	AV20	AV14	AV10	AV8	AV6
50Mw	AV75	AV38	AV26	AV18	AV13	AV11	AV7
100Mw	AV94	AV48	AV32	AV22	AV16	AV13	AV9
200Mw	AV118	AV60	AV40	AV27	AV19	AV16	AV11
500Mw	AV160	AV81	AV54	AV37	AV26	AV21	AV14

Example - A 100kw power plant that is a normal auto engine (x4 output modifier) will have an AV of 6.

The AV of a power plant is an *average* amount, and is a median between easily damaged parts like a radiator and ignition cables, and sturdy parts like an engine block.

Personnel notes

People will have to interact with most vehicles during their operation. An obvious case is the driver or pilot. However, sometimes the interaction is with the power plant itself.

Crew

A vehicle may require crew just to run the various machinery that keeps the vehicle going. A power plant of 100kg or less requires 1 crew member, and each time you double the *total* power plant mass (round down) you add 1 to the number of crew required. From this amount you can subtract the power plant's Tech Level/2 (round down). A vehicle *can* have a crew of zero or less, meaning that the power plant does not need *constant* tending and fiddling with in order to stay running properly. A power plant that is shut down obviously requires no crew, and one that is running at maintenance levels (like off-duty animals) has a maximum required crew multiple of x.25 the normal amount (round up).

Power plant mass	Crew	Tech Level	Modifier
<100kg	1	1	+0
100-199kg	2	2-3	-1
200-399kg	3	4-5	-2
400-799kg	4	6-7	-3
800-1,599kg	5	8-9	-4
1,600-3,199kg	6	10-11	-5
3,200-6,399kg	7	12-13	-6
6,400-12,799kg	8	14-15	-7

Power plant type	Modifier	Example
Biologic (dumb)*	-3	Reptiles
Biologic (average)*	-4	Cattle
Biologic (smart)*	-5	Horses, elephants
Biologic (sentient)*	-7	People (-5 if slaves)
Durable	-1	Diesel, steam engine
Normal	+0	Petrol engine
Enhanced	+0	Sports car engine
Exotic	+1	Race car engine
Dangerous	+1	Rocket
Ext. dangerous	+2	Nuclear
Suicidal	+2	Antimatter

*Biologic power plants are always considered to be at TL1, regardless of the vehicle.

Example - A durable 10,000kg power plant in a TL8 locomotive will require a crew of 8, -4 for the Tech Level, and -1 more for the power plant type, for a total crew of 3.

In general, crew will have to make an appropriate skill roll once per hour to keep the power plant running properly. This is a Difficulty 4 task, +1 per missing crew member, +1 for each missed maintenance interval, and plus or minus any amount based on situational modifiers. Failing the roll means the power plant conks out sometime during that hour (or one of multiple plants does). It will require an equally difficult skill roll to start it up again, with a base time of an hour.

Overall performance modifiers

These are tricks and tips and kludges that designers use to get that little bit of extra output, usually with an added cost or undesirable side effects.

Boosting

For negligible mass and x1.5 cost, a power plant may be “boosted”. This is some temporary measure that dramatically increases engine output, but at a fuel and wear cost. The engine is treated as having the output of an engine one type more powerful (e.g. a normal power plant would act like an enhanced power plant), with the same maintenance and fuel consumption of that engine. However, the vehicle is assumed to accumulate 1 maintenance interval *immediately* upon shutting down after using this boost (or within an hour). This can cover things like nitrous boost, overreving, feeding your draft animals amphetamines, etc. If the roll for performance loss or breakdown indicates no problems, there is no adverse effect, but the vehicle has still crossed a maintenance interval, making the next time the boost is used a riskier proposition.

Tweaking

For negligible mass and x1.5 cost, a power plant may be “tweaked”. This may be things like a custom electronic ignition, fuel injection, tuned exhaust, or a combination of many small performance advantages. This has the effect of increasing effective output of the power plant to that of an engine 1 Tech Level higher. It does not increase any maintenance interval, but the increased power plant cost *will* increase the maintenance cost. Biologic power plants may not be tweaked, but magical ones may be.

You may wish to assume that selective breeding programs can be applied to animals used for power plants, and the increased cost represents the premium placed on these animals. These specially bred animals would have an output modifier of x13 rather than x9, and double normal cost.

Specialized power plants

Some power plants don't fall into the easy category of “pour fuel in, get mechanical energy out”. If you haven't thought of how to design your power plant yet, it's probably in this sub-section.

Animal power

For healthy animals used as power plants, assume that they are Tech Level 1, i.e. 1 watt per kilogram of mass, x9 for the power plant type. At this level of energy expenditure, the animal can work more or less constantly, less 8 or so hours a day for sleep. Animal power is usually considered to be a “biologic” power plant. Normal food is considered “crude” fuel, and high quality food is “normal” fuel. Animals can be “boosted”. In **CORPS** terms, one level of boosting is like a level 3 exertion, or 1 exertion point per 10 seconds. Two levels of boost is like a level 5 exertion, or 1 exertion point per second. Normal maintenance does not apply for post-boost effects, but the lost stamina will require time to recover. Maintenance for animals is adequate food and water, rest, and basic medical care to cover sprains, bruises and sore muscles. Each point of HLT temporarily lost to exertion is roughly a 20% drop in top speed until it is recovered (30% if boosted, 40% if boosted twice).

Example - An 80kg oarsman has an output of 720 watts. In a moderate exertion situation, the base output would be 1440 watts, and in a crisis situation, this could be increased to 2880 watts, but only for a few seconds (like a sprint).

Assuming listed HLT for exertion purposes by a biological power plant, using extra effort will result in the following performance losses over time for a Level 3 exertion (1 level of “boost”).

			Top speed			
HLT	**130%**	**100%**	**75%**	**50%**	**25%**	**total**
1	10 sec	-	-	-	-	10 sec
2	20 sec	10 sec	-	-	-	30 sec
3	30 sec	20 sec	10 sec	-	-	60 sec
4	40 sec	30 sec	20 sec	10 sec	-	100 sec
5	50 sec	40 sec	30 sec	20 sec	10 sec	2.5 min
6	60 sec	50 sec	40 sec	30 sec	20 sec	3.3 min
7	70 sec	60 sec	50 sec	40 sec	30 sec	4.2 min
8	80 sec	70 sec	60 sec	50 sec	40 sec	5.0 min
9	90 sec	80 sec	70 sec	60 sec	50 sec	5.8 min
10	100 sec	90 sec	80 sec	70 sec	60 sec	7.5 min

Example - A crew of HLT 5 rowers can push a trireme to 130% of normal speed for a maximum of 50 seconds.

⚠ This level of exertion assumes the person or animal is of at least average strength and stamina for their mass, and is willing and capable of using it in a way conducive to moving the vehicle. For instance, it would be difficult to design a vehicle based on “anaconda power”, and more difficult still to imagine a snake intelligent enough to be trained to do it.

⚠ This level of exertion is also unrealistic, but has been applied to make the numbers work out for the top speed of animal powered vehicles, especially light ones where the mass of the power plant (i.e. a person) is most of the total vehicle mass. The *actual* normal sustained output of a person is about 1w per kilogram of mass.

Electric motors

Are enhanced power plants for most design purposes. They may be tweaked or boosted, but are always considered to be no better than an enhanced power plant, that may only be powered by batteries or some other power plant driving a generator. Low-tech oddities like spring-wound vehicles will use the electric motor and battery rules to represent flywheels, springs and mechanical gear trains. The only functional difference is in the special effects of damage, types of maintenance, etc.

Power generation

Many power plants provide mechanical energy, while most vehicle subsystems at higher Tech Levels require electricity. Using a power plant as a generator involves some loss of energy.

Specialized	Output modifier	kg/kilowatt	Cost
Electrical power generation	x.8	25/TL	5Cr/kg

Example - You have a 10kg gasoline engine at TL10 that you want to use for electrical power generation. The engine has a base output of (10kg x 100w per kg x 4 for a normal engine) = 4,000 watts. To convert this mechanical energy to electricity will require a generator with a mass of (25kg per kw x 4kw/TL10) = 10kg to be attached, which will have an efficiency of x.8, for an electrical output of (4,000 watts x .8) = 3,200 watts.

You may have a generator of any size less than the maximum. In such a case, part of the power plant output is devoted to generating electricity, and the rest may be used to move the vehicle. The generator of a passenger car is a typical example, providing electricity for the lights, radio and accessories.

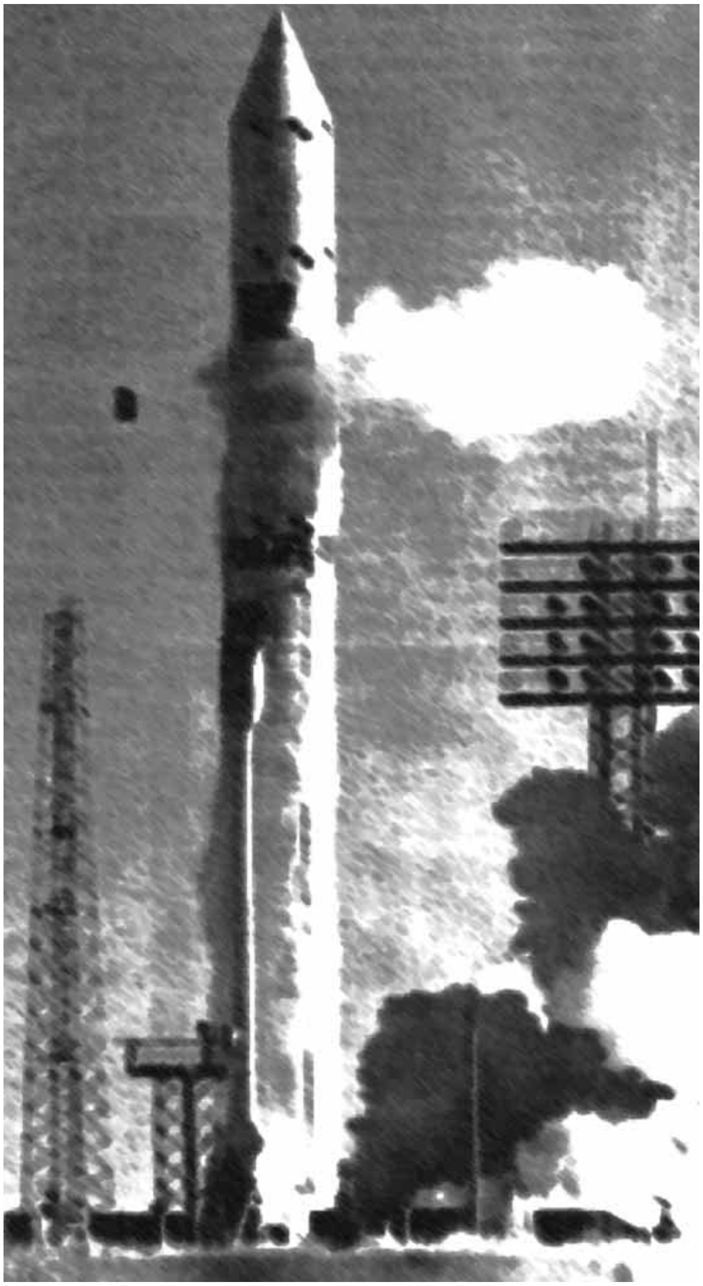
Example - A TL11 passenger car has a 100kw power plant, but needs 500w to run all the electric accessories and keep the battery charged. This requires an input of 625w because of losses, so a generator with a input of 625 watts will mass (25kg per kw x .625kw/TL11) = 1.4kg. The bolts to mount it on the engine probably mass more than the generator itself.

⚠ As a general case, any TL9+ vehicle comes with a basic electrical system for free. This is sufficient to handle minor electrical loads. It will also apply to any military vehicles that do not have extraordinary power demands from sensors or other equipment.

Pony engines

A "pony engine" is a small power plant designed to start a much larger one. The starter of a car is such a case. At lower tech levels, or for certain applications, one internal combustion engine may be used to start another. For instance, a diesel bulldozer needs no electrical system (no spark plugs), so it might have a small engine to start the much larger diesel power plant. Such a starter motor must have an output of at least 1% of the main power plant. In general, a person can start an *internal* combustion power plant of 75 kilowatts or less by muscle power, like a hand crank, foot pedal or spring-wound crank. Things like steam engines or rockets do not usually need them.

For simplicity's sake, assume that any TL9+ vehicle that needs one, has one. TL8- internal combustion plants must buy them separately or be manually started.



Reaction Engines

A rocket derives its massive power from burning massive amounts of fuel. This subsection is going to get dense, even in **VDS** terms, but it *is* an advanced topic, so be warned.

Reaction engines are an annoying "break" in the power plant rules because the way they move a vehicle is unlike that of any other type of vehicle. Instead of converting fuel energy to turn wheels, propellers, ducted fans, turbines, etc., a pure reaction engine either turns chemical energy of fuel into heat or uses some other type of power plant to heat the fuel. In both cases the fuel is also the reaction mass. How much thrust you get depends on how fast this reaction mass is pumped out the back. How fast the reaction mass is moving depends on how much energy you can pump into it. In general, the lighter the fuel or reaction mass, the less energy it takes to get it up to a given exhaust velocity. This is why hydrogen, despite the problems in handling it, is a good rocket fuel. It is the lightest element *and* generates the energy used to accelerate it when combined with oxygen and ignited.

The most important stat of a reaction engine is its Specific Impulse, or I_{sp}. We're going to mangle the scientific definition, but bear with us. The I_{sp} of a reaction engine *for VDS purposes* is its output in watts divided by its fuel consumption per hour, times .013.

$$I_{sp} = (\text{output in watts/fuel per hour in kg}) \times .013$$

Example - A TL10 rocket engine massing 1kg will have an output of 1kg x 100w/kg x 12 for dangerous power plant = 1200 watts. Its base fuel consumption multiple is x.65, and we'll use a dangerous fuel (cryogenic propellants) for another x.1, so our 1kg engine consumes 1kg x .65 x .1 = .065kg per hour. The I_{sp} is (1200w/.065kg) x .013 = 240.

The *thrust* of a reaction engine is the I_{sp} times the fuel consumption *per second*. How reaction engines get their enormous power is that you can run extremely large amounts of fuel through them, on the order of the engine mass per second in some cases. Technology limits the multiple of normal fuel consumption that is allowed, as per the following table.

Tech Level	Maximum fuel multiple	Durability	Historical reaction engine developments
1	x60	x.50	
2	x125	x.50	
3	x250	x.50	
4	x500	x.25	Solid fuel engines
5	x1000	x.25	
6	x2000	x.25	
7	x4000	x.25	
8	x8000	x.125	Liquid fuel engines
9	x16k	x.125	
10	x32k	x.125	Fission engines
11	x64k	x.0625	
12	x125k	x.0625	Fusion engines
13	x250k	x.0625	
14	x500k	x.0312	Antimatter engines
15	x1000k	x.0312	

Example - Our 1kg rocket engine has a fuel consumption of .065kg per hour. At TL10, we can multiply this by up to x32,000, to 2,080kg per hour, or 2,080kg/(3600 seconds in an hour) = .58kg per second. The I_{sp} of 240 times .58kg of fuel per second equals 139.2kg of thrust.

Note that we are producing an output in kilograms of thrust rather than watts of power. The acceleration of a rocket is simply the thrust over the total mass of the ship. If a vehicle has rocket propulsion *and* some other type, the acceleration of the rocket *adds* to the current acceleration of the other propulsion type. Reaction engines can use less than the maximum fuel multiple for their TL, and their durability is based on the fuel multiple used.

A reaction engine can have multiple fuel types, but reaction engines are almost always optimized for a particular percentage of each and are touchy about modifications. The I_{sp} of a multiple fuel rocket is the power output of the engine times the fraction of each type of fuel. Most solid rockets are just going to be an exotic fuel type. Early liquid rockets (TL9) will be about a 50-50 mix of exotic and dangerous fuels (kerosene and liquid oxygen). Later ones (TL10-12) will use all dangerous fuels (liquid hydrogen and liquid oxygen). Reaction engines using fission, fusion or antimatter have a broad range. They could use just their radioactives. A pure fission engine would be an Orion rocket, detonating bombs behind the rocket to push it. A pure fusion engine would be propelled by hot fusion plasma, and a pure antimatter engine would probably magnetically channel the pions created by a proton-antiproton reaction. These can use *a lot* of your expensive fuel. An ion rocket would be a “pure” reaction engine of some kind that is using no more than x60 its normal fuel consumption and cannot use more. The fuel or some outside power source of equivalent energy is converted to electricity, which is usually used to accelerate heavy metal ions (cesium, mercury, etc.) to produce thrust.

A high-thrust, high-fuel consumption engine is one that combines fission, fusion or antimatter fuel with something like liquid hydrogen. The expensive high-energy fuel provides perhaps 1-10% of the fuel consumption, and the cheap reaction mass is the rest.

Example - We'll design a TL10 fission engine of 1kg. Base output is 1,600w for an extremely dangerous (nuclear) power plant. Base fuel consumption is 1.0kg per hour, x.06 for extremely dangerous fuel (isotopes) and x.005 for being fission-based fuel, for a total of .0003kg per hour. The I_{sp} is (1,600w/.0003kg) x .013 = 69,333. This is extremely high, but is also a pure fission design. Its *maximum* thrust would be this I_{sp} times the fuel consumption per second with a x32,000 multiple. This is 69,333 x (.0003kg/3600 seconds per hour) x 32,000 = 184.9kg of thrust, and 2.7 grams of fissionables consumed per second (about 9.6kg per hour). Looking at the fuel chart on **p.14**, we can see that fuel has a base cost of 1Cr per kg, x16 for an extremely dangerous fuel, x1000 for fission fuels. Our 9.6kg of fuel for one hour's operation costs about 154KCr.

Now, let's redesign the engine as using 2% fissionables and 98% liquid hydrogen. The I_{sp} will be the I_{sp} of each type of fuel times the fraction it contributes. For the fissionables it is simple. The I_{sp} is 69,333 x .02 = 1,387. For the liquid hydrogen we take the base fuel consumption for this type of engine (1.0kg per hour), x.1 for a dangerous fuel, for a result of .10kg per hour. The I_{sp} of the engine using only dangerous fuel is therefore (1,600w/.10kg) x .013 = 208. The hydrogen is 98% of the total used, so its I_{sp} fraction is 208 x .98 = 204. The two I_{sp}'s added together give a final I_{sp} of 1,387 + 204 = 1,591. Now, if we use this I_{sp} and the x32,000 fuel multiple at TL10 we can figure the thrust. This is I_{sp} x (fission fuel/second + hydrogen fuel/second) x 32,000. We figured the fission fuel at (.0003kg/hour x .02) and the hydrogen at (.10kg/hour x .98). Adding the two, dividing by 3600 to get the consumption per second and plugging it into the equation (whew!) gives a result of 1,386kg of thrust and a total fuel consumption of .87kg per second or 3,209kg per hour. However, only .19kg of that is fissionables, costing 2,880Cr, and the hydrogen is the rest, costing 23.1KCr, a cost savings over pure fissionables of over 100KCr. The problem is the fuel takes up a lot more mass and room. For short, high power bursts, the combination is more efficient and has more benign exhaust, but for long-term flights the pure fission engine is a better.

Rocket exhaust is dangerous. *How dangerous?* Aside from the obvious things like the intensity of a hydrogen-oxygen flame, the I_{sp} of a reaction engine is the exhaust velocity in meters per second and is related to the temperature of that exhaust in thermal engines. Considering that an antimatter engine at TL15 has a maximum **VDS** I_{sp} of over 2,000,000 (2,000 kilometers per second and *really* hot any way you want to measure it), the exhaust wake of a high-tech ship is something to be avoided for quite a distance.

Technological limitations - The *real* reason we aren't using I_{sp} 60,000 fission engines is because we can't keep them in one piece. Aside from ion rockets which have thrust limitations inherent in their design, most fission engines are limited by the technology available to hold the engine together. Until magnetically confined fusion engines become available (≈TL12-13), reaction engines will be limited by the melting temperature of the materials they are made of. Chemical engines have a limit of the chemical energy available in the fuel, and the maximum I_{sp} of a TL15 dangerous power plant using dangerous fuel is around 540 (the real world limit is closer to a **VDS** “Dangerous” power plant and “Ext. dangerous” fuel, which would be I_{sp} of 484 for a TL11 Space Shuttle engine). Fission engines become technically possible around TL9, and have a maximum I_{sp} of $(TL-5)^4$, topping off at either TL13 or TL14.

Maintenance - Maintenance for reaction engines is a nightmare. Consider our 1kg chemical engine from the previous example. If used at maximum power it has a maintenance interval of 15hr (base) x .1 (dangerous fuel) x .125 (fuel consumption multiple) = .1875 hours, or 11.25 minutes. The fission engine by virtue of using fission fuels has a maintenance interval of 18.75 hours, but it is completely “hot” in a radioactive sense. To make high-powered reaction engines with a decent half-life, you need to double the cost to double the maintenance interval, and do it multiple times.

A jet engine *may* use extra fuel for extra acceleration, also known as afterburners. Raw fuel is dumped into the jet exhaust, where it burns, expands and adds velocity to the exhaust stream. To work this out, figure the “I_{sp}” of the jet engine and multiply by x1000. You can use up to double the engine's fuel consumption rate to get thrust based on this imaginary I_{sp} and the *extra* fuel burned. A jet engine capable of using afterburners will have a x1.2 multiple on mass and cost.

Example - A 1000kg jet engine (exotic power plant using enhanced fuel) at TL10 has an “I_{sp}” of (900,000w/200kg fuel) x .013 x 1000 = 58,500 and a normal fuel consumption of 200kg/hr or .056kg/sec. So, if you add .056kg/sec to the fuel consumption, you can generate an extra 58,500 x .056 = 3,276kg of thrust.

As a historical note, the Rocketdyne F-1 engines used in the Saturn V booster massed 8,416kg, developed 689,000kg of thrust, and consumed 3,000kg of fuel per second (I_{sp} of 230). The **VDS** equivalent at TL10 (I_{sp} of 240) with the same mass and fuel consumption would develop 720,000kg of thrust.

Multiconfiguration Power Plants

The technology referred to as a scramjet is the main example. This operates as a ramjet in an atmosphere, and as a reaction engine when you run out of atmosphere. This is designed as a multiple fuel reaction engine, but has the advantage that part of the reaction mass is the atmosphere itself (which must have enough oxygen to support combustion, and is counted as “normal” fuel). While in an atmosphere, only one fuel type is consumed. The cost of the power plant is x2 if it can act as two different types of power plant.

Solar

Solar power is any technology that converts light or radiant heat from a sun into a form of energy usable by the vehicle. This could be solar cells, solar powered steam boilers or other creative ways of harnessing the energy. This is an odd case, since solar power is not the engine, but the fuel. Solar collectors are considered durable engines for output purposes, but cost x10 as much and only produce x.1 the watts appropriate for their Tech Level, assuming full sunlight on an Earth-normal world. They have no “fuel” cost, and for maintenance purposes the fuel multiple is assumed to be x1 (maintenance interval of 4,000 hours).

Solar panels output may be supplied to a separate power plant or stored in a battery or other device. However, each 10 kilograms of collector takes up $1m^2$ of vehicle surface, and the maximum effective hull collector area is a number of square meters equal to the two dimensions of the vehicle corresponding to the sides facing the sun, multiplied together.

Example - A TL11 solar-powered golf cart is 2 meters long and 1 meter wide, so it can have 20 kilograms of solar panels, for a base output of 484 watts ($2m^2$ times 12.1 watts per kilogram x 2.0 for a durable engine). This turns out to be about .65 horsepower, so you know the top speed of the vehicle will not be that high.

Larger collector arrays are possible for vehicles like solar sailers and other low acceleration space vehicles. Solar wind or photon pressure is assumed to produce .00001 watt of “power” per square meter at a photon pressure equal to sunlight at Earth's orbit, and the mass of the power plant and power train (indirect to thin medium) is actually the solar sail and mooring lines. A solar sail will have a mass of $1/(TL^2 \times 20)$kg per square meter, or $1{,}000/(TL^2 \times 20)$tons per square kilometer. This is an extremely specialized case, and normal armor and damage rules will not apply. Such a sail can be damaged by *anything*, but its size is such that anything other than large explosions is usually insignificant.

Example - A $1km^2$ (1,000m x 1,000m) solar sail at TL10 will have a mass of $1{,}000/(10^2 \times 20)$ = .5 tons = 500kg, and at the default distance from the sun will have an output of 1,000m x 1,000m x .00001w = 10w. A power of 10w on just the mass of the sail gives it an acceleration of .09 (about 1/100th of a gee).

Wind power

Wind powered vehicles may be bought at any Tech Level, but the base output is based on the wind velocity. The *maximum* output cannot exceed the power output for the appropriate type of power plant of that Tech Level, or a relative wind velocity equal to the Tech Level x 2 in m/sec (a vehicle racing with the wind is not experiencing the full force). Sails may be durable, normal, or enhanced, and may cover any technology that uses the wind to propel the vessel.

Example - A Tech Level 4 ship with "normal" sails will have an output of (16 watts/kg x 4.0) = 64 watts per kilogram of sails. This output is at the maximum safe wind velocity of (Tech Level x 2) = 8m/sec (29kph/17mph). If the winds were only 4m/sec, then output would only be half this, or 32w/kg.

Encountering winds greater than the vessel is designed to handle will increase the maintenance requirements, but not provide any extra power. Use the multiple of wind velocity over the output modifier for the engine to determine the new maintenance interval.

Example - Durable sails have an output modifier of x2, and a maintenance interval of 4,000 hours. If the vessel was under double the maximum safe wind speed for that Tech Level, the "output" would go to x4 (output for normal sails x 2) for maintenance purposes only. This is the same as normal sails, so the maintenance interval would be 1,000 hours. Normally, you would just count each hour of this wind as 4 hours towards the next maintenance interval. If the wind was five times the maximum safe wind speed for that Tech Level, you would count the output as x10 (output for normal sails x 5) for maintenance purposes, the same as enhanced sails, or one maintenance interval per 250 hours, or count each hour of this wind as 16 hours towards the next maintenance interval.

There is a table in the **reference section** listing the power output of various sails at different TL's.

Sails can be furled in poor weather to prevent damage, but do not provide power for the vessel, making it less able to handle rough seas. Those sails that are left out *will* provide power, but also suffer the wind effects. Assume that at least "maintenance" power is required to steer a vessel in a storm.

A TL6 ship (circa 1700) with normal sails would have them make a maintenance check after 15 hours of hurricane-force winds, if it had just been maintained before the storm.

Wind powered vessels at higher TL's may use airfoils, rotating cylinders or other non-sail means of getting motive power from the wind, but the same rules will apply. Sails and masts will have an area in addition to the hull area equal to .5m^2 per kilogram, and a vessel cannot have more mass in sails and masts than 10% of its loaded mass.

If the sails are the "power plant" of a sailing vessel, the masts are the "power train", and have certain special effects on design. Masts cannot be taller than the ship is long, nor the sails broader than three times the vehicle width, and masts must be separated from each other and the ends of the vessel by at least a quarter of their height. Power train mass is x2 the calculated amount if the masts are taller than 5m, x4 if taller than 10m, x8 if taller than 20m, etc. The "engine crew" of a sailing vessel is multiplied by the number of masts, and a sailing vessel always requires a "engine crew" of 1 to keep an eye on things.

Sail mass is independent of TL because a higher TL sail has to be tougher so that it can withstand the higher wind load allowed at that TL. Also, the mast height and sail width guidelines will not work for *very* small boats.

Example - A 500 ton (500,000kg) ship that is 50m long and 10m wide can have a maximum mast height and sail width of 50m and 30m respectively, or 50m x 30m = 1,500m^2 per mast. At TL8, sails have an area of .5m^2 per kilogram. The maximum sail/mast mass is 50,000kg, for a maximum area of 50,000kg x .5m^2 = 25,000m^2. However, masts 50m tall must be separated from each other and the ends of the vessel by 12.5m, so this ship can carry a maximum of two masts that height, for a total sail area of 3,000m^2 (6,000kg of sail). If it carried this much and was optimally streamlined, this TL8 ship would have a normal top speed of 10m/sec (36kph/22mph) in a 16m/sec (58kph/36mph) wind.

In addition, sails are an asymmetric thrust, and tend to make the vessel fall over and sink unless there is an appropriate countermass to prevent it. The default countermass is equal to x.1 of the sail mass + power train mass. This is divided by the number of hulls the sail vessel has (up to 3), and multiplied by the mast height/hull depth ratio. Ballast has no cost, and a volume appropriate to the material used (rocks are 1m^3 per 2,000kg and iron bars or chunks are 1m^3 per 7,000kg). Vessels that can only sail with the wind do not need a countermass.

Example - If the ship in the previous example had a hull depth of 5m, then the amount of ballast required in addition to sail and mass mast is (6,000kg sails + power train mass) x .1 x 50m mast/5m hull depth. Somewhere in the bottom of the hull is likely to be several tons of rocks.

Windmills

Windmills are a special case of sails, and generate power in much the same way. This power is usually in the form of rotational mechanical energy, which can be used to run machinery or turn a generator. You could have a windmill turn a mechanical gear train which in turn drives wheels, although this would be less efficient. The area of windmill vanes will be the same as sails, though for stationary setups, there are no limits on how large the vanes can be (we recommend 5m diameter per TL).

Real-world Minutia

This covers things that may be a concern in the real world, but are unlikely to be more than a footnote or occasional hassle in game terms.

Cooling

Something that is a serious real-world consideration is getting rid of the waste heat from your power plant, as anyone whose radiator has overheated will understand. *On many vehicles, you can just ignore this*, but for realistic considerations, use the following guidelines.

All of a vehicle's power output *eventually* turns into waste heat, whether from combustion, friction, electrical resistance, atomic decay or whatever else is involved in generating the power. For instance, a 10,000 watt gasoline engine has to be able to get rid of 10,000 watts of heat every second when running at full power, or it will overheat in short order. And this is with the liberal assumption that the amount of energy wasted in a power plant is never more than its output, which is not actually the case.

All of this waste heat has to be gotten rid of somehow, or the temperature of the vehicle and power plant will inexolerably rise to the point where things stop working (think nuclear meltdown). The exception is the case where the energy leaves the vehicle system somehow. For instance, a generator can deliver the power to someone else, and some of the waste heat becomes their problem. In this case, assume that only x.2 of the transferred energy total remains in the system as heat.

There are several ways of getting rid of waste heat, depending on the power plant and the environment the vehicle operates in. A vehicle that operates in an atmosphere can use radiators, and transfer the heat to the surrounding air, or much more efficiently to water if that is available. A vehicle with a reaction engine automatically transfers the heat to the fuel, and expels it, but in engines that cannot cool down rapidly like fission piles, a sudden stop in the fuel flow could cause catastrophic and near instantaneous overheating. A vehicle in space must radiate the heat or eject a heated mass, which is much less effective than transferring it to an atmosphere. All space vehicles with significant power plants *will* have problems with heat radiation. Most people don't know that the inside of the Space Shuttle hangar doors are heat radiators, and they are required to be open just to keep the 100 ton shuttle from overheating from its own waste heat, and this is with its negligible power output of a few hundred kilowatts at most.

Vehicles will require a surface area dedicated to cooling equal to $10m^2$ per 1,000 watts of waste heat, divided by the effective Tech Level (minimum of 1), cubed, rounding to the nearest three digits, with a minimum of $.001m^2$ per 1,000 watts of output. The Tech Level component of the equation represents both more efficient cooling systems, and materials able to handle higher temperatures. The cooling system for a power plant is already part of its cost and mass, and is not something that affects anything but utilization of surface area. Vehicles that occasionally have high heat loads may store the heat internally and eject a heated mass (like water), or slowly radiate the heat later will be able to absorb 10,000 watt seconds of waste heat per kilogram of storage per Tech Level. This method of heat management *does* have an extra mass of the “heat bunker”, but no extra cost. Rather than making you figure this out for yourself, the table below shows how much area or mass you need.

Base radiator area = (Power in kw x 10)/TL^3

Tech Level	Heat sink area per 1000w	Heat storage per kg
1	$10.0m^2$	10,000 watt-sec
2	$1.25m^2$	20,000 watt-sec
3	$.370m^2$	30,000 watt-sec
4	$.156m^2$	40,000 watt-sec
5	$.080m^2$	50,000 watt-sec
6	$.046m^2$	60,000 watt-sec
7	$.029m^2$	70,000 watt-sec
8	$.020m^2$	80,000 watt-sec
9	$.014m^2$	90,000 watt-sec
10	$.010m^2$	100,000 watt-sec
11	$.008m^2$	110,000 watt-sec
12	$.006m^2$	120,000 watt-sec
13	$.005m^2$	130,000 watt-sec
14	$.004m^2$	140,000 watt-sec
15	$.003m^2$	150,000 watt-sec

Modifiers	Area required	Effective capacity
Stationary	x1.0	-
Velocity <50m/sec	x.6	-
Velocity <100m/sec	x.4	-
Velocity>100m/sec	x.2	-
Dense env. (water)	x.2	-
Average env. (air)	x.5	-
No env. (space)	x5	-
Ejected mass	-	x5

Example - A 100,000,000 watt TL10 stationary nuclear power plant has 20,000,000 watts of waste heat (since it sends most of its power elsewhere in the form of electricity). 20,000,000w/1,000w = 20,000 units of 1,000 watts, so this plant needs a base of 20,000 x $.10m^2$ = $1,000m^2$ of heat sinks. This is multiplied by x.5 for using air for cooling for $500m^2$, or an array of radiators 50 meters long and 10 meters high. If it used a nearby water source for cooling and didn't care about the output temperature of the water, it would need less area.

Example - A TL10 automobile engine with an output of 100kw requires 100 x .01 = 1.00m^2 of heat sinks, modified by x.5 for being used in an air environment, and x.6 if it is only at full output while moving, for a total of 1.00 x .5 x .6 = .3m^2 of heat sinks. Practically, it would be designed without the x.6 modifier because someone might try just running the engine at full power while not moving.

Example - A TL15 space fighter with a 10,000,000 watt fusion plant to power its weapons has a disposable thermal mass of 500kg. This will dispose of 500kg x 150,000 x 5 = 375,000,000 watt-seconds of waste heat, or enough to run the power plant at full output for 37.5 seconds. The power plant has a "maintenance" power output of x.05 normal, or 500,000 watts in standby mode, which is 500 units of 1,000 watts, which in space has a heat sink requirement of 500 x .003 x 5 = 7.5m^2 of heat sinks.

Certain types of space vehicles are simply impossible without massive radiator arrays, much larger than the basic surface area of the ship can provide. This can be handled by giving the spaceship "wings". These do not provide lift or maneuverability, but in all other respects are treated as regular wings, and must be stressed to handle the acceleration of the spacecraft. They have mass and an area in addition to the hull or body of the vehicle, and may be used as heat sink area. They could be "variable pitch" wings, in which case they could be folded or deployed as needed. For radiative cooling of a spacecraft, the limits on heat sink wings are no more than 4 wings, and each wing may not be longer or wider than the vehicle's longest body dimension.

Example - A spherical ship 30 meters on a side could have a total heat sink wing area of 3,600m^2, since it can have up to 4 wings, each no more than 30m x 30m. This would be in addition to any area on the hull of the vehicle dedicated to heat dissipation.

Heat effects

You could conceivably figure out how long it would take a power plant or vehicle to overheat without sufficient cooling, but for **VDS** we are just going to assign it as a maintenance interval every 100 seconds times the fraction of needed capacity, with associated effects if the roll is failed.

Example - A vehicle running at full power on 90% of its heat sinks (or heat sinks that have taken a +1 impairment) would have to make a maintenance check every 100 x .9 = 90 seconds. Our space fighter with only enough heat sinks for 5% of its output would be making checks every 100 x .05 = 5 seconds after had vented the last of its thermal mass.

In addition, vehicles with hot radiators are easy to spot when infrared sensors become available. Technologically this is TL9, but magic spells or paranormal powers could also duplicate the effect. The heat signature of a vehicle is based on its total power output divided by the total radiator or heat sink area. Reaction engines are assumed to have a total area of 1m^2 of heat sinks for purposes of this calculation. Vehicles that store heat internally are counted as having 1m^2 of heat sinks for this calculation, but only on a turn in which they actually vent some or all of this heat. Vehicles which can fit all of their heat sinks onto one vehicle facing can reduce this signature by 2 when being observed from an adjacent facing, and by 4 from the opposite facing.

per 1m^2 of heat sink	Thermal signature	Example
<100w	+0 Difficulty	
<1000w	-1 Difficulty	Human being
<10kw	-2 Difficulty	
<100kw	-3 Difficulty	Auto radiator
<1Mw	-4 Difficulty	
<10Mw	-5 Difficulty	Jet tailpipe

Example - An F-100 jet engine (TL11) has a mass of 1,400kg and an output of about 1.5Mw. A fighter using two of these would have a total output of 3.0Mw, divided by two engines at 1m^2 each, for an output per 1m^2 of 1.5Mw and thermal signature of -5 Difficulty to spot, since it has an effective heat sink area of 1m^2. This output is all from the rear of the vehicle, so it is -3 to be spotted from the sides, and -1 to be spotted from the front.

Vehicles *can* have *more* than the required minimum amount of heat sinks, provided they have the area for them. This and reducing power plant output is the only way of reducing the overall thermal signature of the vehicle. Heat sinks in excess of that which a power plant gets for "free" will have a volume of 1m^3 per 1,000kg, a mass of 100kg per 1m^2 and a cost of 500Cr per 1m^2. Or, if you want to look at it another way, heat sinks are .1m thick and have a density of 1,000kg per 1m^3 and a cost of 5,000Cr per 1m^3.

Maintenance fuel

Certain vehicles have a fuel cost that must be paid whether the vehicle is being actively used or not. The best example is gas leakage in a helium or hydrogen lift balloon, or fuel used to heat the air in a hot-air balloon. In the case of a balloon or blimp, you need to figure out the size of a "normal" engine at that TL which can provide a base acceleration of 10 to the vehicle (an acceleration of 10 will exactly counter 1g of gravity). Ignore streamlining or other possible effects in the calculation. The vehicle will require maintenance fuel equal to normal fuel consumption x.05.

Example - A 1,000kg balloon at TL10 requires an engine with an output of 250kw (333hp) to have an acceleration of 10 (**see p.7**). This calculation lets you create a "virtual engine" that lets the balloon hover. A *normal* engine at TL10 with this output would have a mass of 250,000w/(100w/kg x 4 for a normal power plant) = 625kg, and therefore a fuel consumption of 62.5kg per hour. Maintenance fuel for this engine would only be 5% of this, or 3.125kg per hour. So, in order to maintain neutral buoyancy, this vehicle will need to either add 3.1kg of compressed gas per hour, or burn 3.1kg of fuel per hour to generate heat to provide lift.

Both helium and hydrogen are considered enhanced fuels, and so less of them will be required. Helium is non-flammable, and hydrogen is *extremely* flammable. The special effects of a hydrogen-filled gas bag are pretty well known, and actual game mechanics are left to your imagination.

A single-use balloon like a weather balloon will simply be equipped with more buoyancy than it needs, and will not begin to descend until slow leakage gives it less than neutral buoyancy. You can also see as a game mechanic that higher TL balloons need smaller "virtual" engines, and thus have less fuel consumption/leakage. Remember that fuel for a balloon can simply be ballast that is dumped to compensate for reduced lift.

Startup time

All power plants will take time to reach full power from a cold start. In general, this is:

$$\text{time in seconds} = (\text{mass in kilograms}^{.5}/\text{final output modifier}) \times K/TL$$

where K is based on the power plant type. For most power plants K is 10, including chemically powered reaction engines. For power plants that must reach an overall operating temperature, K is 100, and for power plants that must reach a *high* operating temperature, K is 1000. For fusion plants, K is usually 100, and K is usually 1000 for fission plants. Note that *operating* temperature is different than *fuel* temperature. A normal car engine has hot combustion chambers, but the engine will work passably well even if the rest of the engine is icy cold. A steam engine on the other hand requires that the entire boiler be close to operating temperature, and a nuclear reactor has to heat the entire core *and* the water or other means of transferring heat to a generator. If an engine is extremely cold and needs extra warmup time, double the calculated amount, and if the engine has missed a maintenance interval, double it for each interval missed. At any time before full power is reached, the power plant provides output proportional to the fraction of startup time. If the power plant is already running at the "maintenance" rate, it only takes a tenth as long to bring it up to full power.

Example - A 100,000kg TL10 steam engine has an output modifier of x4, so it has a startup time of $(100{,}000^{.5}/4)$ x 100/TL10 = 790 seconds, or about 13 minutes. A normal TL11 auto engine that masses 100kg has an output modifier of x4, so it has a startup time of $(100^{.5} / 4)$ x 10/TL11 = 2.3 seconds (round to 2 sec). If the engine were poorly maintained *and* it was very cold out, it would take 2.3 x 2 x 2 = 9.2 seconds to reach full operating capacity (round to 9 sec).

Magic Power

Left for last is the case of using a paranormal power source, such as magic, elementals, psionics, etc. as the power source of a vehicle. The way you handle this should be consistent with the game world is run, both in a short and long-term way. Magic as a vehicle power source or magically powered vehicle accessories are a problem. Most magic items in **CORPS** are based on generating a particular effect, not providing climate control, off-road capability and so on.

For vehicle design purposes, magic will have its own “Tech Level”, which will represent how advanced and efficient the magical sciences are, and how this relates to a conventional Tech Level will fundamentally affect the way magic works in society.

For instance, if the magic TL is several levels higher than technology, there will be no impetus to ever develop scientific means of solving problems, since science will be so inefficient compared to magic.

But, if the magic TL is several levels lower than technology, it will be so inefficient that it is pointless to develop it, at least as a power source for vehicles. It may still be able to generate effects impossible with technology, but the raw kilowatts needed for vehicle power is not one of them.

If the magic TL is slightly higher than the technology TL, then the extra effort and danger required in learning and using magic does have a payoff in terms of efficiency, but is not overwhelmingly more useful than conventional power sources. It will be present, but uncommon and expensive. And, like conventional power plants, magic power plants can be dangerous, boosted, tweaked or any combination of the above.

If the magic TL is higher than the technology TL, but only in a special set of circumstances, then magic will take the place of technology in those circumstances. For instance, if you could generate electricity with magic at an effective TL of 13, in an otherwise TL6 world, you might develop crude, ugly, inefficient TL6 electric vehicles that are still practical because of the massive amounts of electrical power available to their magical builders.

Another way to look at it is to see what types of vehicle effects you want to generate with magic, and use that as your baseline magic TL.

Magic and conventional power plants are interchangeable, and may be combined in any way that makes sense. For instance, you could have a blimp powered by a djinn cranking a propeller, a locomotive with a fire elemental under the steam boiler, a mana battery driving an electric motor or a thousand undead gerbils running in little exercise wheels.

Basics

All magical vehicle devices will have a cost multiple to represent how common magic is in society. A general number would be x10 cost, to reflect the years of training needed to become an enchanter, the quality of the workmanship required for magic items, the physical drain and time spent, and of course a hefty profit margin.

As for powering a magical vehicle system through your own power, a human wizard can provide 1,000 watts of power for each point of POW^2 that can be devoted to an effect.

Example - A wizard with a POW of 6 has a POW Aptitude of 2, so they can provide 2^2 x 1,000 = 4,000 watts of power to other magical vehicle components. This would be on a constant basis. If they wished to drain themselves quickly, they could use their full POW, which would give 6^2 x 1,000 = 36,000 watts. In terms of **CORPS** paranormal powers, this could either be a Drain task on POW or HLT, depending on the game background.

Magic may be used in a variety of ways. First, the vehicle can be entirely magical. A magical power plant drives a magical power train which makes the vehicle move. Or, it could be a combination of magic and technology. A magical power plant drives a magical conversion device to provide electricity, which powers conventional vehicle components (of any Tech Level).

Magical items require magical fuel, which may be of any nature. A magical power plant might burn demon's blood, which is presumably an exotic or dangerous fuel. Magical “radioactivity” usually represents some captive force which is constrained to do the wizard's bidding. The very low fuel consumption reflects the self-replenishing nature of the captive force.

A self-sustaining fuel source, like a living creature, can provide “fuel” capacity equal to its ability to generate energy from its POW. A wizard can do this voluntarily, but creatures and non-wizards can only have it coerced out of them.

Example - A 10kg TL10 magical power plant will have an output of 10kg x 100w/kg x 4 for a normal power plant = 4,000 watts. Fuel consumption is x.1 power plant mass per hour, so either 1kg of magical supplies is consumed per hour, or you could use four captives, each with a POW Aptitude of 1 (since a POW Aptitude of 1 can constantly supply 1,000 watts, and the power plant has an output of 4,000 watts, ergo, four captives at 1,000 watts each). You could also just use *one* captive, who would supply a quarter of the energy needed with their POW, and the rest of the fuel (.75kg per hour) would be literally drained out of their body until they were nothing but a dried up husk.

Assume that living creatures drained in such a way die when they lose half their body mass, and each 5% of body mass lost is a +1 lethal impairment with broken bone side effects on *each* +1 impairment (having the flesh waste off your bones takes a *long* time to heal). A power plant which uses non-living "fuel" still requires that this fuel be made of essences of the type of creature desired. The crudest and most common fuel is made from slaughterhouse animals, their fleeting life essences captured and contained for later use. The fuel equivalences to conventional types are below.

Fuel	Fuel consumption	Cost	Durability	Example
Very crude	x2.0	x.5	x4	Plants, bugs
Crude	x1.4	x.7	x2	Cow, any animal
Normal	x1.0	x1	x1	Human, any sentient creature
Enhanced	x.50	x2	x.5	Any paranormal creature (unicorn)
Exotic	x.25	x4	x.25	Sentient paranormal creature (dragon)
Dangerous	x.10	x9	x.1	Supernatural creature (ghost)
Ext. dangerous	x.06	x16	x.06	Creature of divine origin
Suicidal	x.04	x25	x.04	Sentient creature of divine origin (angel)
Modifiers				
Undead-based	x.01	x1000	x10	Zombies
Battery	x(10000/TL^2)	x.40	x1	Power gems, mana batteries
Use-based consumption				
Full output	x1.0			
Cruising (80%)	x.70			
Trolling (40%)	x.30			
Maint. (10%)	x.05			

This also means that the effective power output of a creature is multiplied by its "fuel efficiency".

Example - A magical power plant that ran off of unicorn essences would only have half the fuel consumption of one which ran off human essences, and about a third the consumption of one running on cattle essences. It also means that a unicorn would only be drained at half the normal rate, although its power output would still be the same.

Lethal injuries done to a biologic power plant that is being magically drained *will* count towards the +10 impairment needed to kill it, because of the extra shock to the creature's system.

Undead

Undead are usually considered to be biologic power plants with the undead-based fuel consumption figure. They are only capable of performing mechanical work, and can't be drained of power like living things. Neither can they boost, be tweaked or work harder than normal. Creation of them is based on the game world, but presumably they do not eat, breathe, sleep or form unions and strike for better working conditions. They do require maintenance, or they will slowly go to pieces on you (Zombie maintenance is a separate skill and combines skills of a physician and mechanic). In addition, their fuel is themselves, and they slowly consume their own bodies, gradually and disgustingly losing efficiency. Or perhaps you could feed them the equivalent of zombie motor oil (made from condemned criminals) to offset these losses and keep them in prime condition.

Example - A beefy 100kg zombie oarsman will have a power output of 900w, and consume (100kg x .002 x .01) = .002kg of "fuel" per hour. If each 5% of this zombie's mass lost (5.0kg) will cause it to take a +1 impairment to doing other things, then each (5.0kg/.002kg per hour) = 2,500 hours of work will cause the zombie to take a +1 modifier to its ability to follow directions, *although it will still pull oars just as hard until it falls apart*. This will be quite a while, since it has a base durability number of 10,000 hours. According to these figures, such a zombie would have a market value of around 200Cr (100kg x 2 for biologic power plant). However, since the power plant is its own fuel, and will cease to work after it takes a +10 impairment (half its mass, or 50kg), we also have to add (50kg x 1Cr per kg x 1,000 for undead-based fuel) = 50,000Cr, for a total cost of 50,200Cr. Expensive, but then again, it can provide an output of 900w, 24 hours a day for over a year without any maintenance, and has a useful life of up to 25,000 hours of work (24 hours a day maximum output for nearly 3 years). At 2Cr per hour, it is a lot cheaper than minimum wage, and the only people who complain about the treatment of zombies are the weirdos at PETU (People for the Ethical Treatment of Undead).

At the maintenance fuel consumption rates, the above zombie would have a "standby" life of 57 years. If you had a way to turn them "off", they would have a more or less indefinite shelf life.

Am I Doing This Right?

Question #1:

What is the adjusted power output and fuel consumption of a TL10 gasoline powered mower engine that masses 7kg?

Calculations:

At TL10, base power output is 100 watts per kilogram, so a 7kg power plant has a base output of 7kg x 100 watts = 700 watts. This is assumed to be a normal engine type, for an output modifier of x4, so final output is 700w x 4 = 2,800 watts. Since there are 750 watts in 1 horsepower, an output of 2,800 watts is about 2,800/750 = 3.73hp.

Since this is a normal power plant, it has a fuel economy of x.1, so it burns 7kg (its mass), times .1 (its fuel economy) = .7kg of fuel per hour. Since it burns normal fuel, the fuel consumption rate is unaffected.

Answers:

Adjusted power output = 2,800 watts
Fuel consumption = .7kg per hour

Question #2:

An old sorcerer wants to assist his aging legs by using zombie gerbils in exercise wheels to help pedal his bicycle. Assuming he only wants 5kg worth of gerbils, how much power output will they have, and what will they cost him?

Calculations:

Animal power plants are TL1, and have a base output of 1 watt per kilogram, x9 for biologic power plant type, so a 5kg biologic power plant will produce 45 watts of power. They have a base cost of 2Cr per kilogram, for a base of 5kg x 2 = 10Cr.

Since the undead are their own fuel, and can function until half their mass is gone, 2.5kg of the gerbils are counted as undead-based fuel, which has a x1,000 multiplier. This will add 2.5kg x 1,000 = 2,500Cr to the cost, for a total gerbil cost of 2,510Cr.

Answers:

Adjusted power output = 45 watts
Power plant cost = 2,510Cr

Question #3:

How much does the power plant of a TL10 portable jet pack weigh, assuming it has a vertical acceleration of 12 (2 more than gravity), and it and the wearer mass a total of 150kg?

Calculations:

Jump back to the **Performance** chapter first (p.6). Since we have the total mass (150kg), we can figure what our base acceleration needs to be. Our desired acceleration is 24 because transfer to a gas (a jet engine) multiplies base acceleration (24) by x.5, to our final acceleration of 12. The power required ends up being 86,400 watts (115hp).

At TL10, each kilogram of power plant produces 100 watts, and an "exotic" power plant like a jet engine has a x13 power multiplier. Our jet engine then masses 86,400 watts/(100 watts per kilogram x 13) = 66.5kg.

Answers:

Power plant mass = 66.5kg
(note: the power train and other factors will increase this, so it really isn't possible to make a practical TL10 jet pack). You *could* design a reaction engine pack, though.

Question #4:

How many kilograms of durable sails does a TL5 vessel need to carry in order to generate 20hp in a 5m/sec wind?

Calculations:

Output is based on wind velocity and Tech Level. TL5 sails have a base output of 25 watts per kilogram, with a x2 for "durable" sails, for a total of 50 watts per kilogram. This 50w/kg output is at the maximum rated wind velocity of TLx2 = 10m/sec. Since we are asking for the output in 5m/sec winds, the output is halved, or 25 watts per kg of sails.

Since there are 750w per horsepower, and we want 20hp of output, this is (20hp x 750w/hp) = 15,000 watts. At 25w/kg from the sails, this gives a sail mass of (15,000w/25) = 600kg, and at .5m^2 per kilogram, an area of 300m^2.

Answer:

Mass of durable sails = 600 kilograms

Question #5:

How many engine crew are needed on a battleship, assuming they use TL9 power plants that mass a total of 1,000,000kg?

Calculations:

Expanding the crew table gives us a base crew of 15. It is a durable power plant, which subtracts 1, and we also subtract half the TL (round down), for 4 more, leaving 10.

Answer:

Required engine crew = 10
(note that if engines run all the time, you need 10 *per shift*)

4

Power Train

Basics

Once you have a power plant, you need to find a way to get that power to move the vehicle. This is referred to as the power train. The power train also includes minimum controls for one person to operate the vehicle as part of its mass. **The power train of the vehicle takes up 1m^3 per 500kg of mass**. This includes the denser components of the power train, and the small open spaces surrounding the moving parts. **Power trains take up surface area equal to 1m^2 per 1,000kg of power train**. This does not affect armor mass, but is area unavailable for other uses, and the power train area cannot exceed the area of the two largest vehicle facings.

Power train descriptions

Power trains will be of several generic types, one of which should handle the needs of your vehicle. Special effects of these may be listed in the **Performance** section (p.6).

Wheels

The power plant mechanically drives wheels that are in contact with the ground. The actual number of wheels depends on the use and dimensions of the vehicle, and as long as their quantity and placement is reasonable, it is up to your discretion. In practical terms, wheeled vehicles use some quantity of standardized parts, in order to reduce cost.

Tracks

The power plant drives a continuous belt that has a large amount of ground contact, as you would see on a bulldozer or tank. The extra friction reduces top speed and the mass of this power train is greater than that of wheels, but it has superior off-road characteristics and is generally stronger.

Legs

This is a specialty case, and historically, no large vehicles have ever been built with a leg-based power train. The power plant drives a number of articulated legs that allow the vehicle to walk like an animal or insect. It is not practical for most purposes, but the mobility is superior to tracks, and it has found limited use on robot probes of difficult terrain.

⚠ Foot size on a legged vehicle affects the mass which the engine must move. Heavier feet mean heavier legs, more wasted energy, and a lower top speed.

Indirect to dense medium

This is some sort of power transfer to a non-solid but fairly dense medium, like water. Efficiency is lost because some of the energy is spent creating turbulence in the medium instead of providing thrust, and also because the drag of this medium retards the movement of the vehicle in general. On the other hand, the power train can be very simple and light.

Indirect to average medium

This is a power transfer to a less dense medium, like a thick atmosphere. There is not as much drag as in a dense medium, but the reduced density also means that the surfaces you use for the power transfer must be larger and heavier. This is not a "real world" case, since the Earth's atmosphere is not that dense.

Indirect to thin medium

This is the power transfer that would apply for sail ships and most aircraft, pushing against or redirecting air flow. This would usually be propellers, turbines or turbofans. The actual method is up to the designer of the vehicle, and special effects should be consistent with that design. For instance, a propeller-driven plane can't have afterburners, nor can it be supersonic (adjusted top speed > 300m/sec). Note also that a sail vessel uses this power train mass, but *also* applies the dense medium multiplier on its top speed, for a net multiple of x1.0.

Power train	Default terrain rating	Top speed modifier	kg/kilowatt	Cost
Wheels	1	x.8	50/TL	5Cr/kg
Tracks	4	x.6	100/TL	5Cr/kg
Legs, small feet	3	x.5	80/TL	5Cr/kg
Legs, average feet	4	x.4	100/TL	5Cr/kg
Legs, large feet	5	x.3	120/TL	5Cr/kg
Indirect to dense medium(water)		x.5	10/TL	5Cr/kg
Indirect to avg. medium (dense gas)		x1.0	20/TL	5Cr/kg
Indirect to thin medium (air)		x2.0	30/TL	5Cr/kg
Antigrav		x1.0	30/TL	10Cr/kg
Jump drive		∞	30/TL	10Cr/kg

Modifiers	speed	kg/kilowatt	Cost
Muscle-powered drive train	x1.0	x3.0	x2.0
Rating -2 (minimum of 0)	x1.0	x.25	x1.0
Rating -1 (minimum of 0)	x1.0	x.50	x1.0
Rating +1 (maximum of 5)	x1.0	x1.5	x1.0
Rating +2 (maximum of 5)	x1.0	x2.0	x1.0
Rating +3 (maximum of 5)	x1.0	x2.5	x1.0
Tech Level 1-2	x.5	x1.0	x1.0
Tech Level 3-4	x.6	x1.0	x1.0
Tech Level 5-6	x.7	x1.0	x1.0
Tech Level 7-8	x.8	x1.0	x1.0
Tech Level 9-10	x.9	x1.0	x1.0
Tech Level 11-12	x1.0	x1.0	x1.0
Tech Level 13-14	x1.1	x1.0	x1.0
Tech Level 15	x1.2	x1.0	x1.0

Example - You have a 250kg power plant in a Tech Level 10 car (say a normal gasoline engine). Since this Tech Level power plant has an output of 100 watts/kg, and the gas engine is x4, the engine will have an output of (250kg x 100 watts/kg x 4) = 100,000 watts, or 100kw (133hp). A wheeled power train for this vehicle will have a mass of (50kg per kw x 100kw/TL10) = 500kg. This covers the transmission, drive shaft, differential, steering, axles, wheels and tires for a vehicle of minimum mass using that engine and power train. The 500kg power train will occupy 1m^3 of internal volume, and use 5m^2 of vehicle surface area. For a wheeled power train, and a loaded vehicle mass of 1,000kg, the base top speed is (100,000w x 1,000kg)$^{.61}$/1,000kg = 75.8m/sec, and the adjusted top speed is (75.8m/sec x .8) = 60.7m/sec (218kph/136mph). This is multiplied by x.9 for TL10 to get 54.6m/sec (197kph/122mph), rounded to 55m/sec.

The "rating" number in the modifiers column refers to the ability of certain types of land vehicle suspension to handle less than perfect ground conditions, and the default rating of these suspensions (see **p.10**).

Example - If the car in the previous example were designed for rugged off-road use, say Difficulty 3 terrain, then we would want to beef up the suspension components and add larger tires, which would be a x2 multiple on the mass and therefore the cost of the power train.

> The Tech Level of a muscle-powered *drive train* may vary, even if the *power plant* is considered to be TL1.

All these numbers assume the medium the power transfer is occurring to is the same medium the vehicle is moving through, and take some drag effects into account. Further modifiers to top speed will apply based on the degree of streamlining and again on the medium the vehicle is moving through. A boat propelled by an air-pushing propeller has a power train mass for a thin medium, but has a top speed modifier for the dense medium the vehicle is moving through. A land vehicle with tracks that has an air-pushing propeller has the power train mass of both types, and the top speed of a tracked vehicle.

> You always use the densest of the mediums the vehicle is moving through for top speed purposes, regardless of the power train type, and this *can* be cumulative.

Example - A legged vehicle moving through water would take *both* the modifier for legs *and* x.5 for dense medium.

> A reaction engine is assumed to be an indirect to thin medium power train and will only operate in a medium of average density or less. You *do* need to buy a power train for the reaction engine power plant, to represent controls, a venturi suitable for the atmospheric pressure the reaction engine is used in, etc.

Armor Value

The AV of a power train is usually subsumed in the structure AV of the vehicle. However, the key parts that handle the most energy from the power plant may have a differing value depending on power train type. The base AV of power train components is their (mass in kilograms)$^{.33}$, round up. This represents an average toughness and resistance to damage. The weakest parts are usually down to half this (round up), while the toughest ones are up to double. And since these parts are not "armor" certain weapon types may count as armor-piercing vs. them.

Example - Our car has a power output of 100kw. The 500kg power train has an average AV of 500kg$^{.33}$ = 8. The heavy-duty off-road suspension (1,000kg) has an average AV of 1,000kg$^{.33}$ = 10. The tires of the regular car might have an AV of 4 (halved again vs. some attacks), while the transmission, drive shaft and axles might have an AV of 16.

> If you substitute mass in kg for kw, you can use the "normal" engine column to get power train AV (**p.16**). Tires are at the low end of the AV range, while tracks are at the high end.

The effects of the quality of the controls and ground contact are further described in the **Performance** section of the rules (**p.10**). Bear in mind that these will affect vehicle cost, so your power plant + power train combination may change in cost before you finish.

Turning in place

A vehicle which spends an *extra* 2Cr per kilogram cost on the power train may have it built so the vehicle is capable of turning on its own axis. The best example is a tank pivoting its tracks in opposite directions to spin in place. This maneuver is independent of the Turn of the vehicle, but may only be performed if the vehicle is stationary, and does so at the vehicle's normal acceleration, applied from the tips of the vehicle. Vehicles designed to operate in space can usually pivot about any axis with an acceleration of 1 while moving for no extra cost, but may use normal vehicle acceleration if they pay the extra cost on the power train. Optionally, this extra cost could count as an articulated vehicle, which has a smaller minimum turning radius, useful for tight corners.

Example - A car with the ability to pivot all its wheels and spin in place would have a power train cost of 7Cr per kilogram instead of 5Cr per kilogram.

Reverse speed

If a vehicle is capable of reverse speed as a normal movement, the top speed is usually one quarter of the forward speed. If the vehicle is capable of reverse speed only under exceptional circumstances, the top speed is usually only a tenth the forward speed. The former case might be a typical car, and the latter case might be a plane on a runway with variable pitch propellers or thrust reversers.

Secondary power trains

A vehicle may be capable of more than one mode of operation, such as an amphibious armored vehicle. If the vehicle can be propelled by its *normal* power train in this mode, it does so with penalties. It takes *double* the speed penalties that apply for *both* the power train *and* the medium. If the vehicle has a *separate* power train for this secondary mode of travel, it only takes normal power train effects. If there is a speed *advantage* that applies, it is *not* doubled.

Example - An amphibious tracked vehicle has a top speed (before power train modifiers) of 20m/sec. With tracks, its actual top speed is 10m/sec. Propelled in the water by its tracks, it takes an *extra* x.5 speed modifier for tracks, *and* the x.5 modifier for water propulsion, *twice*. So, its actual water speed is (10m/sec x .5 x .5 x .5) = 1.25m/sec. If the vehicle has separate propellers or waterjets for propulsion, its top speed would be its base speed times the waterjet modifier, or (20m/sec x .5) = 10m/sec. It would also have a separate power train mass for this means of propulsion.

Secondary power trains often save on mass by being built for less than the full power plant output. For instance, our amphibious vehicle moves faster in the water than you might expect, and this is mainly because the secondary power train *can* handle the full power plant output. We also neglected the fact that this vehicle probably doesn't have any streamlining. Most secondary power trains are rarely used, and just have to work, not work well. An APC doesn't need to tow water skiiers, it just has to ford rivers, and the performance needed is minimal.

Special cases

Everything from here to the end of the chapter is specialized power trains or power train notes, so if you are having trouble figuring out what you need the vehicle to do, keep going. Otherwise you're done with the power train.

Antigrav

Antigrav works on principles unknown. In **VDS** terms, it is a solid-state chunk of computer controlled machinery which manipulates forces on the quantum level to generate a field which pushes against local gravity (or, it could be magic, or precessing gyroscopes of any other technobabble term you want to create). The closer to the gravity source, the stronger the push. While incredibly convenient, the power requirements are immense.

Each 1kg of antigrav plates soaks up (TL/30) kilowatts of *electrical* power, and converts it directly to thrust. The antigrav plates have a density of 2,000kg per 1m^3, which assumes there is a lot of empty space in them for cooling fins or other means of dissipating excess heat. They take no surface area and can thus be protected by armor.

The speed of an antigrav thrust vehicle is based on the power it consumes and its TL. It acceleration is based on the power consumed and vehicle mass, and is independent of the medium the vehicle is in (x1.0 modifier). After this is calculated, the *actual* acceleration of the vehicle is determined by the distance from the nearest gravitational body for the drive to act against.

Distance from gravitational body	Acceleration
1m	x5.0
10m	x4.5
100m	x4.0
1000m	x3.5
10km	x3.0
100km (very low Earth orbit)	x2.5
1000km (medium Earth orbit)	x2.0
10,000km (high Earth orbit)	x1.5
100,000km (v.high Earth orbit)	x1.0
1,000,000km+	x.5

In game terms, a gravitational body is something big enough that the thrust against it by the vehicle will have no significant effect on it. For instance, a grav scooter thrusting away from even a small asteroid would qualify, even though the asteroid has a negligible gravity well.

The “tail” of the antigrav effect is about a 60° cone away from the grav plates. So, if you have a gravitational body at your back, you still have to thrust *away* from it, but you still have some leeway in your ship facing.

Example - A 100,000kg spaceship has a reactor with an electrical output of 10 megawatts. The acceleration (from the **Performance** chapter, **p.7**) would be (10,000,000w x 100,000kg x .1)$^{.5}$/(100,000kg x .5) = 6.3 x efficiency of 2.0 = 12.6, rounded to 13. The advantage over a fuel-guzzling reaction engine is that the vehicle can maintain it more or less indefinitely using nothing but reactor fuel, which can still be considerable. A 10 megawatt power plant at TL13 would require 250m^2 of heat sinks in space, which if you had a neat wedge shaped ship, would take up the entire rear face on a ship 53m long.

The "Tech Level" of magic may allow magic-powered anti-grav vehicles, which can make for some interesting hybrids, especially if materials technology is limited to wood and simple metal forgings.

Example - A 50kg fusion reactor at TL14 will have an output of (50kg x 196 watts/kg x 16 for an extremely dangerous technology) = 156,800 watts, or 156.8kw, with a x.8 multiplier for electrical power generation makes 125.4kw. If mounted in a grav sled with a total mass of 1,000kg, it would have an acceleration of (125,400w x 1,000kg x .1)$^{.5}$/(1,000kg x .5) x efficiency at ground level of 5.0 = 35, which means it could negate local gravity (which is a downward acceleration of 10), and have 25 points of acceleration to spare for other acceleration. And it only needs about 1.3m^2 for radiators.

An important side effect of this particular antigrav system is that it makes grav-tanks and other *low-altitude* anti-grav vehicles extremely practical for high-tech cultures.

As noted in the first example, the total acceleration provided by grav plates can be used for any combination of horizontal and vertical acceleration. Normally, they are directional. Enough are mounted in a fixed pattern to negate local gravity (and are protected by any underbody armor or structure), and any used for lateral movement are mounted on swivels for directional control. Normal aerodynamic surfaces may also be used at high speeds, if the vehicle has them.

Artificial gravity

The grav plate rules will also apply in the **Seating & Accommodations** section (**p.41**), since they can be used to provide artificial gravity. They would actually tend to *push* people towards the "floor" rather than *pulling* them down, but the felt weight effect is about the same. In general, you will assume that all vehicle areas provided with artificial gravity will require *separate* grav plates sufficient to provide an acceleration of the desired amount for a mass in kg equal to x10 the volume of those areas *plus cargo holds, corridors, etc*. Assume that these plates are operating at x5.0 efficiency, and are grouped in units that offset a certain amount of gravity for 100m^3 of passengers and cargo. That is, artificial gravity plates are bought so that their acceleration is calculated for a "vehicle mass" of 1,000kg (100m^3 of volume x 10), with total mass based on how many of these units are used.

Example - A spaceship with 100m^3 of "staterooms" will need to be able to provide an acceleration of 2 to a mass of 1,000kg in order to have 1g of artificial gravity. We can reverse calculate that this requires 10kw of power.

	Gravity required				
Volume used	1g	2g	3g	4g	5g
100m^3	10kw	40kw	90kw	160kw	250kw
200m^3	20kw	80kw	180kw	320kw	500kw
300m^3	30kw	120kw	270kw	480kw	750kw
400m^3	40kw	160kw	360kw	640kw	1.0Mw
500m^3	50kw	200kw	450kw	800kw	1.25Mw
1000m^3	100kw	400kw	900kw	1.6Mw	2.5Mw

This gravity compensation can also be used to offset high ship accelerations (as inertia dampers) and/or as a quite effective anti-intruder system. Remember that the power used for gravity compensation requires heat dissipation as well.

If you are into "hard" science fiction, remember that reactionless drives violate natural law as we know it, and that you can make a perfectly workable universe without the convenience factor of clean and neat propulsion systems.

Articulated vehicles

"Snake-like" vehicles are counted as legged vehicles for power train purposes, as are ornithopters. Fully articulated vehicles can make a full-circle turn in less distance than their rigid counterparts. The normal minimum turning *radius* for a vehicle without a special power train is its length, but articulated vehicles can do it in half their length.

Example - A city bus 30m long would have trouble with making turns on street corners. An articulated bus would have much less difficulty.

Ornithopters will have a speed based on the average of legs with small feet and indirect medium power transfer (x1.25 in air) and a cost and mass based on the average as well (55/TL kilograms per kilowatt, and 5Cr per kilogram for air vehicles). Ornithopters cannot be supersonic, nor have streamlining better than partial optimum (**p.53**). The extra cost associated with the power train allows ornithopters to have a stall speed of zero, and the capability for vertical takeoff and landing.

In the real world, ornithopters build up appalling amounts of metal fatigue in short amounts of time. Consider them to need *structural* maintenance as an exotic power plant (every 60 hours of use), which is often and quickly gets expensive.

Earthborers

Earthborers are an extremely specialized type of vehicle, and normal "adventuring" is not going to have much use for a large noisy vehicle capable of an astounding movement rate measured in meters per day. Treat the earthboring machinery as a generator attached to a power plant. It will require 1.0Mw to bore through a tenth of a meter of rock per second over an area of $1.0m^2$. The vehicle itself will need a legged power train to push itself along through a bored area. The chewed up (or melted) rock is then passed behind the vehicle, where it either fills in the area just passed through, or is carried off by other machinery. This rate of movement is further impeded by the necessity of scanning for pockets of flammable gas, underground water, etc.

Hoverskirts

Hovercraft and other ground effect vehicles ride on a cushion of air a short distance from the ground. They are counted as using an indirect to thin medium type of power transmission, and a fraction of engine output must be used to maintain the air cushion and is not available for acceleration or top speed. The power drawn for maintaining the air cushion is the mass of the vehicle squared, divided by the area of the air cushion (which is usually the entire bottom facing of the vehicle), times .4. Since the air cushion is not perfect and the hoverskirts are often in contact with the medium the hovercraft travels over, hovercraft have a top speed multiplier of x1.0, not x2.0 like an aircraft, although other power train calculations remain the same.

Hovercraft minimum power in watts = ($Mass^2$/bottom area) x .4

Example - A hovercraft that is 4m x 2m on its bottom facing, with a loaded mass of 500kg, requires an engine output of 12,500 watts to maintain its air cushion, so if the power plant had a total output of 20,000 watts, only 7,500 watts would be left for horizontal vehicle acceleration and top speed.

Since the relationship between vehicle mass, power and acceleration is not linear, you can use the table that follows to get a quick estimate of what it will take to make a hovercraft work. Note that you might want some surplus power in case the hoverskirts lose efficiency due to damage (a +1 impairment is +10% power required). And remember that this power is just that required to get the hovercraft effect. You will need more to make the vehicle go forward.

While it requires some more calculations, a hovercraft that allows you to shift power from the engine to both the hoverskirts and thrusters allows you to shift power to whatever system needs it most.

	Power required for area of						
Loaded mass	**$5m^2$**	**$10m^2$**	**$20m^2$**	**$30m^2$**	**$40m^2$**	**$50m^2$**	**$100m^2$**
200kg	3.2kw	1.6kw	800w	533w	400w	320w	160w
400kg	13kw	6.4kw	3.2kw	2.1kw	1.6kw	1.3kw	640w
600kg	29kw	14kw	7.2kw	4.8kw	3.6kw	2.9kw	1.4kw
800kg	51kw	26kw	13kw	8.5kw	6.4kw	5.1kw	2.6kw
1000kg	80kw	40kw	20kw	13kw	10kw	8.0kw	4.0kw
1500kg	180kw	90kw	45kw	30kw	23kw	18kw	9.0kw
2000kg	320kw	160kw	80kw	53kw	40kw	32kw	16kw
2500kg	500kw	250kw	125kw	83kw	63kw	50kw	25kw
3000kg	720kw	360kw	180kw	120kw	90kw	72kw	36kw
3500kg	980kw	490kw	245kw	163kw	123kw	98kw	49kw
4000kg	1.3Mw	640kw	320kw	213kw	160kw	128kw	64kw
5000kg	2.0Mw	1.0Mw	500kw	333kw	250kw	200kw	100kw
7000kg	3.9Mw	2.0Mw	980kw	653kw	490kw	392kw	196kw
10000kg	8.0Mw	4.0Mw	2.0Mw	1.3Mw	1.0Mw	800kw	400kw
20000kg	32Mw	16Mw	8.0Mw	5.3Mw	4.0Mw	3.2Mw	1.6Mw

Really large hovercraft require *a lot* of power. The Soviet Aist-class hovercraft mass 270 tons loaded, and have a total power plant output of 35.8Mw. In **VDS**, all but about a megawatt is taken up just maintaining the air cushion.

Example - If you wanted a 7,000kg light armored hovercraft that was 6.7 x 3.0 meters in size, it would need at least 975kw (1,300hp) just to maintain the air cushion.

More detail on power and acceleration is in the **Performance** section (**p.6**).

An effect similar to hovercraft is observed in low-flying aircraft. An aircraft can maintain an altitude of its wingspan or less for 20% of the power output normally required to stay airborne. However, it can only make the most sweeping of slow turns at this altitude, and the engine thrust must be evenly applied. A twin-engine plane with one engine out would have trouble, for instance. Such ground effect planes can usually fly at higher altitudes, but require significantly more power, and sacrifice fuel economy as a result.

Hovercraft and other ground effect craft are *not* considered flying vehicles for purposes of Turn, since this requires banking maneuvers these vehicles are not capable of.

Helicopters & Jump Jets

Helicopter rotors are a special subcase of wings, and are handled in the **Surface Treatments** section (**p.55**). The power train will have the same mass as a propeller driven aircraft, but the rotor will have certain dimensions based on the power requirements and vehicle maneuverability, and these will add to its mass. A regular aircraft which has an adjusted acceleration of 10 or more may not act as a vertical takeoff (VTOL) vehicle unless it is equipped with a best quality controls *and* a secondary power train capable of directing sufficient power to hover or liftoff vertically. This is a x.2 normal mass (i.e. x1.2 normal power train mass and volume for full VTOL power). A Harrier jet is a good example of this, with ductwork and machinery to route the full power of the engine. See **p.58** for more details.

Jump Drive

This is a technical can of worms, since we have no idea how it might work or what size or shape it will be. To solve this problem, we will simply make something up, and supply you with mass and power figures. If you wish to alter the mechanism of operation for a particular genre, be our guests.

Jump drive operates by opening a hole in space or creating a field around the ship in which normal matter and energy relations no long have effect. The ship has exited the known universe into "hyperspace", through which it travels at a speed which would be impossible in the normal universe. We will assume this rate is .1 parsec times the TL^2, per 100 hours, and leave to the poor vehicle designer a way of rationalizing a TL1 Jump Drive ("Og, look what happen when I bang these rocks together real hard!").

Since communication between a ship in hyperspace and the normal universe is impossible, travel is based on aiming your ship in the right direction, turning on the drive, and then turning it off again when you think you are close to the destination, based on your drive and time spent in hyperspace. Errors in distance are based on your skill at astrogation and any precision added by computers. Jump drives require a negligible gravity well before they can function, and gravity is one of the few forces that can affect a ship in hyperspace. You usually need to be well away from a planet or star in order to go into hyperspace, and passing too near one while in hyperspace can cause the drive to shut down unexpectedly, and often with significant damage or loss of calibration.

That said, a jump drive will mass (ship mass/TL)kg, and consume power while operational equal to (TL/300)kw per kg of Jump Drive. This works out to a power consumption of 3.33kw per ton of ship, regardless of TL. Higher tech jump drives just take up less space. Optionally, a jump drive can require a high-energy one second pulse of x100 its operating power to make the transition into hyperspace, which has to be supplied by storage banks (**p.16**). Power poured into a jump drive disappears into "hyperspace", so only the 20% loss in generators (**p.18**) goes into heat sinks.

Example - A 300 ton TL13 ship will have a jump drive that masses 300,000kg/TL13 = 23,077kg, and requires 23,077kg x (TL13/300)kw = 1,000kw (1.0Mw) of power when operational (3.33kw x 300t), which means a 1.25Mw power plant. Space-based heat sinks at TL13 are able to dissipate 1kw per .025m^2, so the 250kw of lost power will require 6.25m^2 of heat sinks. If the drive needed a 100Mw starting pulse, at TL13 this would take 100,000,000 watts/125,000 watt-seconds per kg = 800kg of charged high-output storage banks.

It would be reasonable to increase or decrease the "speed" of a drive by altering the fraction of ship's mass used up to 50%, e.g. a drive 10% larger would make the ship go 10% faster, or a drive 50% smaller would only give 50% of the hyperspace speed. The tweaking and boosting rules could also be applied if needed.

Railroads and monorails

Rail vehicles are a specialized case of wheeled power trains, which can *only* operate on tracks, making their Turn statistic irrelevant. Top speed gets an additional x2 multiple. The rails themselves will have a mass per meter of the ((vehicle mass in kg/vehicle length) x maximum safe speed in m/sec), divided by (40 x TL), with a cost per meter of (rail mass x .5Cr). Electrified tracks or other ways of delivering power (overhead cables) will multiply cost by x5.

Example - A set of TL9 rails designed to handle 100,000kg cars (100 ton) that are 15m long at speeds of up to 20m/sec (72kph/45mph) will have a mass of ((100,000kg/15m) x 20m/sec)/(40 x TL9) = 370kg per meter, which covers track, railroad ties, spikes and anchor plates. The cost per meter is 185Cr, or 185KCr per kilometer.

Towing

If a vehicle is going to tow another vehicle, it simply suffers performance losses appropriate to its new mass, length and width. However, the vehicle being towed must have a power train, even if it has no power plant. The power train of a *towed* vehicle must be able to handle the full output of the *towing* vehicle's power plant, and this represents its wheels, suspension and structure needed to handle the towing stress. This is in addition to the normal structure the towed vehicle will require. A towed vehicle can have less power train than needed, but this means that the power train *and* structure of the vehicle are assumed to be overstressed if at any time the towing vehicle uses too much power. It will count as having missed maintenance when its maintenance interval arrives (see **p.114**). In addition to this power train, a towed vehicle will need an appropriate towing assembly to link necessary vehicle controls (like turn signals, brake lights, brakes, etc.) to the towing vehicle. This will have a separate cost and mass. See **Accessories**, **p.66**.

Am I Doing This Right?

Question #1:
How much power does a 1,000kg TL13 grav car need, if it only needs to hover 1m off the ground, and how many kilograms do the antigrav plates weigh?

Calculations:
Since you only need to hover 1m off the ground, the multiple on effective acceleration is x5.0. Since you need an acceleration of 10 to hover, we can divide 10 by the multiple (x5.0) to get 2. If the grav plates can give an acceleration of 2, the multiple for ground proximity will give us the effect we need.

Looking at the table on page 7, we can see that a 1,000kg vehicle needs 10kw of power to have an acceleration of 2. Doing the calculations, we find this number is exactly correct (10,000w x 1,000kg x .1)$^{.5}$/(1,000kg x .5) = 2.

A TL13 grav car has a power train mass of (30/TL13) = 2.31kg per kilowatt of power, so at 10kw of power required, the car only needs 23.1kg of antigrav plates and a source of 10kw of electrical power.

Note - To allow this vehicle to reach 10m would require 12.3kw of power and 28.5kg of grav plates, and to reach 100m would take 15.6kw of power and 36.0kg of grav plates.

Answers:
Grav plates needed = 23.1kg
Power required = 10kw

Question #2:
What is the power train mass of a TL3 trireme powered by 240 men, each of whom mass about 100kg? What is the speed of this vessel if it has a mass of 100 tons?

Calculations:
A 100kg person has a power output for this system of 900w, so 240 men will have a combined output of 240 x 900w = 216,000w (216kw). The base power train mass for a TL3 indirect to dense medium vessel (oars) is (10/TL3) = 3.33kg per kilowatt, for a power train mass of (216kw x 3.33kg) = 719kg. However, this is a muscle-powered vehicle, so this is multiplied by a further x3.0 to 2,160kg, or about 9kg (20lb) per person.

The base speed is (216,000w x 100,000kg)$^{.61}$/100,000kg = 20.1m/sec (73kph/45mph). However, it has the multiples of x.5 for power train type, x1.0 for muscle-powered, and x.6 for Tech Level adjustments. The final multiple on top speed is x.30, for an adjusted top speed of (20.1m/sec x .30) = 6.0m/sec (22kph/14mph). This does not count streamlining effects, which would drop it to about 4.0m/sec (15kph/9mph).

Answers:
Power train mass = 2,160kg (plus 24,000kg of oarsmen)
Adjusted top speed = 6m/sec

Question #3:
What is the power train mass and final speed of an 8,000kg TL13 combat walker (average feet) powered by a 1,000kw (1,340hp) power plant?

Calculations:
The base speed is (1,000,000w x 8,000kg)$^{.61}$/8,000kg = 137.3m/sec (494kph/308mph).

The power train has a mass of (100/TL13) = 7.69kg per kilowatt of power plant output, for a mass of 769kg, and a cost of 3,850Cr. TL13 gives a speed multiple of x1.1, but the power train type gives a multiple of x.4, for a total multiple of (1.1 x .4) = x.44.

The base speed of 137.3m/sec times a multiple of x.44 equals 60.4m/sec (217kph/135mph). Streamlining considerations (see **Surface Treatments**, **p.53**) would probably reduce this to about 55.4m/sec (199kph/124mph).

Answers:
Power train mass = 769kg
Adjusted top speed = 60m/sec

5 Structure

Basics

The structure of the vehicle is that portion of its mass responsible for holding the various pieces together, along with any parts of other vehicle categories that are affected by overall vehicle mass. It may, but is not required to be structural elements.

Configurations

Vehicles can come in an infinite number of shapes, each with a particular surface area, volume and relative dimensions. This makes volume and armor calculations a potential infinite headache. To reduce this, the following table lists a useful subset of vehicle shapes, along with other handy information. For this table, length(l) is always assumed to be 1, and the width(w) and depth(d) are the fractions of total length that apply. Area is the total vehicle area in square meters for a length of l meters. Volume is the total vehicle volume in cubic meters for a length of l meters. Front(F), Rear(R), Side(S)(each), Top(T), Bottom(B) are the fractions of total area that these facings take up.

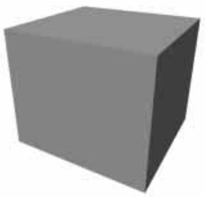
Type	l	w	d	Area/Vol	F	R	S	T	B
Sphere	1.0	1.0	1.0	$A = l^2 \times 3.1$ $V = l^3 \times .52$	.17	.17	.16	.17	.17
Cube	1.0	1.0	1.0	$A = l^2 \times 6.0$ $V = l^3$	.17	.17	.16	.17	.17
Slab	1.0	.50	.25	$A = l^2 \times 1.76$ $V = l^3 \times .13$	.07	.07	.15	.28	.28
Box$_1$	1.0	.50	.40	$A = l^2 \times 2.2$ $V = l^3 \times .20$	.09	.09	.19	.22	.22
Box$_2$	1.0	.20	.15	$A = l^2 \times .76$ $V = l^3 \times .03$	.04	.04	.20	.26	.26
Cylinder$_1$	1.0	.20	.20	$A = l^2 \times .69$ $V = l^3 \times .03$	.05	.05	.23	.22	.22
Cylinder$_2$	1.0	.10	.10	$A = l^2 \times .33$ $V = l^3 \times .008$	.03	.03	.24	.23	.23
Half cyl.$_1$	1.0	.20	.10	$A = l^2 \times .55$ $V = l^3 \times .016$	.02	.02	.20	.36	.20
Half cyl.$_2$	1.0	.10	.05	$A = l^2 \times .27$ $V = l^3 \times .004$	.01	.01	.20	.38	.20
Prism$_1$	1.0	.30	.15	$A = l^2 \times .60$ $V = l^3 \times .045$	.08	.08	.11	.50	.12
Prism$_2$	1.0	.10	.05	$A = l^2 \times .25$ $V = l^3 \times .005$	.02	.02	.18	.40	.20
Disk	1.0	1.0	.25	$A = l^2 \times 2.4$ $V = l^3 \times .20$	.09	.09	.08	.33	.33
Wedge	1.0	.60	.30	$A = l^2 \times .75$ $V = l^3 \times .03$	.18	.12	.17	.18	.18

Most vehicles with wings will have an additional surface area taken up by aerodynamic surfaces. The designer may choose to either treat these as having armor like the body of the vehicle (top and bottom facings only), or to be separate from the body of the vehicle in terms of AV, in which case these surfaces are covered/armored separately. This extra surface will not affect the vehicle's internal volume, but see **Surface Treatments** (**p.55**) for more details.

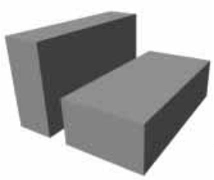
Example - You decide to design a car, and figure it is about 4 meters long. Selecting the Box$_1$ configuration, you find that it has a total area of $4^2 \times 1.1 = 17.6$ square meters, a total volume of $4^3 \times .2 = 12.8$ cubic meters and dimensions of 4m x 2m x 1.6m. If you wanted to armor it, and put a different amount on the front, you could see that the front area of the car is $.09 \times 17.6 = 1.58$ square meters (round to 1.6 square meters).

A more comprehensive listing of vehicle dimensions is in the tables in the back of the rules.

Sphere - Provides optimum internal volume for a given surface area, and is suitable for spacecraft or other applications where efficiency is an issue. Not recommended for ground vehicles due to performance limitations, and will limit the top speed of any air vehicle due to streamlining considerations.

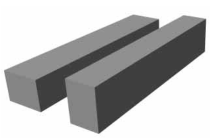


Cube - Fairly efficient space utilization, easy to figure armor and volume for. Not many real-world vehicles use this.



Slab - A flattened rectangular solid. Its dimensional ratios approximate those of the hulls of most modern tanks, making it the configuration of choice for duplicating these vehicles. Transposing width and depth gives a high, narrow vehicle, approximating the ratios of most motorcycles.

Box$_1$ - A rectangular solid of approximately the ratios found in a modern automobile. Width and depth may be transposed to generate higher, narrower vehicles like delivery vans.



Box$_2$ - A much longer, narrower rectangular solid. This could be used for buses, train cars or engines or other long slab-sided vehicles like oil tankers or cargo carriers.

Cylinder$_1$ - A short cylinder. Suitable for space station modules, small submersibles or some types of spacecraft.

Cylinder$_2$ - A long cylinder. Suitable for many types of aircraft, torpedoes, cruise missiles, submarines and spacecraft having long, spine-mounted weapons. Also usable for large naval vessels with extended superstructures.

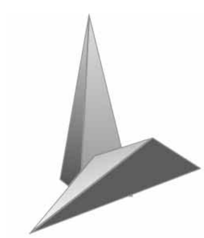
Half cylinder$_1$ - Identical to Cylinder$_1$, but cut in half lengthwise. Suitable for many types of water vessels, especially low tech sailing vessels.

Half cylinder$_2$ - Identical to Cylinder$_2$, but cut in half lengthwise. May be suitable for some types of naval vessel.

Prism$_1$ - A short, flattened prism. May be more suitable for some types of naval vessels (like Viking longboats) than a half cylinder. Inverted, it may be the basis for some armored vehicles.

Prism$_2$ - A longer version of the Prism$_1$. May work for naval vessels like aircraft carriers, with large flat decks and relatively flat sides.

Disk - A very short cylinder. Suitable for some types of flying wing aircraft, UFOs, hovercraft and some varieties of mini-sub.



Wedge - A flattened pyramid, turned on its side. May work for a variety of vehicles, including some types of sports car, spaceships, lifting body aircraft, motorboats, etc.

Keep in mind that you can play with the actual dimensions with a limit of about 10% or so, subtracting from one dimension to get a little more on another. It's a game, not rocket science. You can also turn configurations around to get the vehicle concept you want. So, if you want a centipede-like land crawler, the best way to get it is to use a half-cylinder, and turn it upside down. Instant centipede shape!

Internal Structure

First, you need to determine if your vehicle even needs an internal skeleton. This is determined by the AV of the vehicle surface. If you haven't gotten to that point yet, don't panic. This subsection just lets you know if you have an extra design step later. Vehicles with heavy armor have some inherent structural strength from the armor alone. For instance, tanks seldom need a traditional "chassis". Vehicle drive components and internal fixtures are attached directly to the armor, and the armor provides all the structural strength the vehicle needs.

If it makes the concept any easier to visualize, a beetle is a shell structure. All its structural strength comes from its outer surface. A human is a frame structure. Our surface (skin) does not have the strength to support us, so we have an internal framework of bones to which our various "vehicle components" are attached.

All vehicles need an internal framework with enough material to give the *entire* surface of the vehicle an AV equal to the square root of (larger of (final acceleration, deceleration or Turrn/10, times the mass in tons), rounding up. Land vehicles have a minimum structure AV of the suspension rating (p.10), plus 1. If the vehicle is going to end up with more than 50 times this AV on three or more of its six facings, you can ignore the internal frame altogether as a design simplification step. The cost of a structural framework is the same as the cost of the equivalent amount of armor.

Example - A city bus with a loaded mass of 10 tons, an acceleration of 3 and Turn of 5 will need an internal frame with the same mass and volume of $(10 \times .5)^{.5}$ = 3 points of AV on the entire surface of the vehicle. A tank with a mass of 50 tons and the same acceleration and Turn would need a frame with the mass and volume of $(50 \times .5)^{.5}$ = 5 points of AV on the entire surface of the vehicle, but if three or more of the tank's six facings have an AV of 250 or more, you can just ignore the need for an internal frame.

The frame can be made from any available material. If there is plenty of volume, you can use a light but bulky material to make the frame. If space is cramped, you can use denser, heavier materials to make the frame.

Normally, you never end up with *exactly* the vehicle you want in terms of dimensions and mass. Make sure you use a frame that is a bit heavier than you actually expect the vehicle to end up needing. It's a lot easier to take a little bit of frame out of the calculations than to put some in after you've already filled all the available volume.

The *actual* AV of the vehicle frame for purposes of resisting damage is equal to five times the AV previously calculated. So, the actual structural frame of our city bus has an AV of x 3 x 5 = 15, which would only be used in the rare instance the actual frame was the target of an attack.

A piece of composite armor with an area of $1m^2$ and a thickness of 10mm (1cm) will have a default mass of 50kg, a cost of 500Cr and a volume of $.01m^3$ for structural purposes.

AV by Tech Level per 10mm thickness

TL	Armor	Structure	Historical armor material
1	1	1	Wood, leather, bone, stone
2	2	1	Copper
3	3	2	Bronze
4	5	3	Iron
5	7	4	
6	10	5	Steel
7	13	7	
8	17	9	Face-hardened steel
9	21	11	
10	26	13	Aluminum alloys
11	31	16	
12	37	19	Ceramic-metal composites
13	43	22	?
14	50	25	?
15	57	29	?

To use genuine *armor* technology as a *structural* material is x4 cost. Structural materials are classified as Organic, Light, Composite, Heavy, Extra Heavy and Transparent, with the following differences. Composite structure is the default to which other materials are compared. If you use out of date structural materials (below current TL), you save 20% of structure cost per TL below the current one (maximum 90% discount). For instance, using TL8 structure materials on a TL10 automobile saves 40% on the structure cost.

	For a given AV			A $1m^2$ sheet of 10mm composite equiv.		
Armor type	Volume	Mass	Cost			
Organic	x5.0	x.70	x.50	50mm	35kg	250Cr
Light	x1.5	x.70	x2.0	15mm	35kg	1000Cr
Composite	x1.0	x1.0	x1.0	10mm	50kg	500Cr
Heavy	x.80	x1.2	x2.0	8mm	60kg	1000Cr
Ex.Heavy	x.70	x1.3	x2.5	7mm	65kg	1250Cr
Transparent*	x3.0	x1.4	x4.0	30mm	70kg	2000Cr

Example - If our city bus was 13m long and used the Box_2 configuration, it would have a total area of $.38 \times 13^2$ = $64.2m^2$. At 50kg per $1m^2$, this is a mass of $64.2m^2 \times 50kg$ = 3,210kg for 10mm of composite material. Using TL11 *lightweight* structural materials, *15mm* has AV16. The bus only needs AV3, so we only need AV3/AV16 as much mass and volume as 15mm over the bus would take, or a total of 421kg, $.181m^3$ of internal volume and for lightweight material, a cost of $64.2m^2$ x 1000Cr x 3/16 = 12,038Cr.

Example - A TL15 spaceship with a mass of 30,000 tons and an area of $8{,}000m^2$ has an acceleration and Turn of 30 (3g's), so it needs an equivalent AV of $(30{,}000 \times 3)^{.5}$ = 300 for structure purposes. Using TL15 composite structural materials (AV29 for 10mm), we need 300/29 times the mass of 10mm of covering, or $8{,}000m^2$ x 50kg x AV300/AV29 = 4,138 tons, $827.5m^3$ and 41.4MCr for the ship structure.

Note - The only time an unarmored vehicle does not require the *normal* structural frame is if it will not have *any* acceleration capability at all (acceleration *and* Turn of less than .1 qualifies). For instance, a balloon is just a surface, with no internal structure unless it is needed to make the balloon into some unusual shape. A flying vehicle with no structure can be carried by prevailing winds at any velocity, but cannot be powered or it will become unstable, unmaneuverable and/or collapse.

As a possibility, you can use any available "force field" technology (**Accessories**, **p.67**) to structurally strengthen a vehicle structure to the required AV. Part of the AV is natural, while the rest requires a power supply of some kind.

Before you start using organic structures on all your vehicles because they are the least expensive, remember what you are getting into. Organic structures can rot, mold, mildew, and get eaten by all manner of vermin, in addition to usually being flammable. In addition, most *true* organic type structural materials level off at TL5 or so. Advanced chemical treatments of organic materials (like plastic laminated pressure treated wood trusses) are actually "lightweight" structures due to the increased cost of manufacture.

Characters may design custom vehicles for whatever money they care to throw at the project, but most vehicles are built by companies that need to show a return on the investment, and which are competing with other companies for a limited market. A company which makes a passenger car with a lightweight structure can't compete with a competitor using composite structure for a substantial savings in sticker price. Politics can also play a part. Mandatory fuel economy standards may force manufacturers to use lighter structures to get the same performance from smaller engines that use less fuel, for instance. Any society industrial enough to have standardized mass production also probably has government regulations and economic competition.

Structure loading

A vehicle which is retrofitted to carry more mass, like bolting armor plates to a vehicle, will need to have an increased structural mass to handle the load. Vehicles designed to push, pull, tow, shove or otherwise move *external* loads need to be designed with a structure mass equivalent to the mass of the vehicle *plus* the largest load it can move. This would apply to tractor trailers, locomotives, tow trucks, tugboats and so forth.

A wheeled vehicle with a power plant, power train and structure can be driven once you add seats, unless you want to stand or sit on structural members. In addition, note that most cars, trucks or other normal vehicles are overengineered (use double the best performance stat as a guide). No one wants their car to suffer *structural* damage because they put on better tires and put too much cornering stress on the chassis.

Typical volumes

The following mundane vehicles have the *approximate* volumes and masses listed below, with turrets, superstructures and the like affecting final dimensions and volume. You can use these as a guide when deciding how much you want your final vehicle mass to be, and how much volume you will need to meet its desired design goal. Note that the length x width x depth will not always equal the listed volume because not all these vehicles are simple rectangular blocks. They are adjusted to the listed structural shapes *when possible*, but actual vehicles may have superstructures or fins that extend beyond these dimensions, or are of a tapered or varying shape.

Vehicle	≈Mass	≈Volume	length	width	depth
Med. motorcycle*(Slab)	200kg	.44m^3	1.5m	.38m	.75m
Compact auto (Box$_1$)	1,000kg	6.6m^3	3.2m	1.6m	1.3m
Automobile (Box$_1$)	1,500kg	13m^3	4.0m	2.0m	1.6m
Van (Box$_1$)	2,000kg	18m^3	4.5m	2.3m	1.8m
APC (Box$_1$)	20,000kg	43m^3	6.0m	3.0m	2.4m
Battle tank (Slab)	50,000kg	45m^3	7.0m	3.5m	1.8m
Sm. cargo truck (Box$_1$)	7,000kg	69m^3	7.0m	2.8m	3.5m
Lg. cargo truck (Box$_2$)	40,000kg	276m^3	19m	2.9m	3.8m
Lg. bus (Box$_2$)	10,000kg	101m^3	15m	2.3m	3.0m
Light plane (Box$_2$)	1,500kg	15m^3	8.0m	10m	1.6m
Twin-eng. plane (Box$_2$)	4,000kg	30m^3	10m	15m	2.0m
TL9 fighter (Box$_2$)	6,000kg	30m^3	10m	10m	2.0m
TL12 fighter (Box$_2$)	15,000kg	101m^3	15m	10m	2.3m
Lg. passeng. jet (Cyl$_2$)	300 tons	2660m^3	70m	60m	7.0m
Hot air balloon (Sphere)	4,000kg	4,160m^3	20m	20m	20m
Sm. blimp (Cyl$_1$)	6,400kg	6,480m^3	60m	12m	12m
Lg. zeppelin (Cyl$_1$)	240 tons	240,000m^3	200m	40m	40m
Sm. speedboat (Prism$_1$)	1,000kg	12m^3	6.5m	2.0m	1.0m
Lg. speedboat (Prism$_1$)	3,000kg	45m^3	10m	3.0m	1.5m
Patrol boat (Cyl$_1$)	300 tons	810m^3	30m	6.0m	6.0m
Large yacht (Cyl$_1$)	800 tons	3,750m^3	50m	10m	10m
Destroyer (Cyl$_2$)	3,000 tons	8,000m^3	100m	10m	10m
Cruiser (Cyl$_2$)	20,000 tons	64,000m^3	200m	20m	20m
Attack sub (Cyl$_2$)	7,500 tons	8,000m^3	100m	10m	10m
Missile sub (Cyl$_2$)	25,000 tons	27,000m^3	150m	15m	15m
Battleship (Cyl$_2$)	60,000 tons	125,000m^3	250m	25m	25m
Carrier (Cyl$_2$)	80,000 tons	216,000m^3	300m	30m	30m
Supertanker (Box$_2$)	1,000,000 tons	1,920,000m^3	400m	80m	60m

*Volume of a motorcycle does not include the 1m^3 the driver occupies when riding it.

For instance, if you are designing a vehicle on a *mass* limit, it is helpful to know an approximate final volume for that class of vehicle. Or, if you are designing on a *volume* limit, you can get an idea of the mass similar vehicles might have.

Lighter than air vehicles

Balloons, blimps and dirigibles have special structure and fuel requirements that aren't handled well by the normal rules. In general, a vehicle relying on lighter-than-air gases or hot air for lift will have a lift of 1.1kg for $1m^3$ of hydrogen gas envelope, 1.0kg for $1m^3$ of helium gas envelope and .3kg for $1m^3$ of hot air envelope. This lift is *after* taking into account the mass of the gas or hot air itself, but *does not* include the mass of the envelope used to contain the gas.

The rules for lifting gas "consumption" are on **p.25**. Remember that depending on TL, lift or heating gas could also just be represented by ballast, which is "consumed" (i.e. dropped overboard) to counter gas leakage over time.

The structure of a *non-rigid* airship or balloon *is* the surface, and is figured as for other vehicles except you use the *exact* required AV (do not round), and the final mass is x.75 for airships and x.5 for balloons. Balloons are assumed to have an Acceleration and Turn of 1 for these calculations, but may not normally be powered at all. The actual AV of the vehicle is the structure AV, rounded up. A non-rigid gas envelope only maintains its shape when inflated, and the volume inside the envelope cannot be used for other purposes. The non-rigid structure limits blimps to a maximum powered velocity of TL x 2 meters per second.

A rigid airship or zeppelin must have a regular internal structure like other vehicles, but since much of the internal support is provided by the lift of the gas, the final mass is x.25. However, the entire surface must also be bought as armor with an AV of at least 1, which will add significant mass.

Example - A TL9 airship with a length of 300m using the $Cylinder_2$ configuration will have a volume of $216{,}000m^3$, and a surface area of $29{,}700m^2$. We know that since when flying, a lighter-than-air vehicle has neutral buoyancy, and with a volume of $216{,}000m^3$, it has a *helium* lift of 216,000kg, so its loaded mass is no more than 216,000kg (216 tons). If we give it a maximum Turn or Acceleration of 1, it will need an equivalent AV for structure purposes of $(216 \text{ tons} \times .1)^{.5}$ = 5. Structure AV at TL9 is 11, so our mass is 5/11 the listed TL9 amount. Using the lightweight armor type, this will have a base mass of $29{,}700m^2 \times 35kg/m^2 \times 5/11$ = 472,500kg, times x.25 is 118,125kg, or 118.13 tons. We will give the gas bag an armor (not structure) AV of 1 (the gondola could be more), and this will have a mass of $29{,}700m^2$ x 35kg per m^2 x 1/21 = 49,500kg, or 49.5 tons, for a total structure and surface mass of 167.6 tons, leaving about 48 tons for the gondola, engines, fuel, crew and supplies.

Most powered airships will use an acceleration *and* Turn of 1, both because they are limited by their size and the mass of the engines they can get aloft, and because their structures would be too heavy to fly otherwise. In general, an airship with a (mass in tons x acceleration) of more than 10 may be more efficient to buy as a rigid airship.

As a technical note, hydrogen is available in quantity at any TL with electricity, but helium can only be separated from natural gas with equipment or techniques of TL7+, and it will be difficult (x10 cost) until TL8+. If magic is available, production or separation of elements could be significantly easier.

If possible to stow the envelope (as in balloons and non-rigid airships), 100kg of stowed envelope takes up $1m^3$. Such vehicles that are self-propelled must have structure associated with the gas envelope, as well as for any other items attached to it. You may have different structure types associated with the gas envelope and gondola, though this is usually unnecessary.

A typical TL10 Goodyear blimp has a gas envelope of approximately $5{,}700m^3$, and is powered by a pair of 157kw power plants. In **VDS** terms it would be about a 55m long $Cylinder_1$ configuration ($4991m^3$ volume, $2087m^2$ area), with 3,536kg of its helium-based lift taken up by the mass of the gas envelope, assuming a surface AV of $(5.0 \text{ tons} \times (\text{Acc. of } 1)/10)^{.5}$ = .71 and non-armor lightweight material. After gondola, crew of 2 and engines, what surplus there is goes to the advertising light display. The TL9 rigid airship *Macon* has the volume of a 183m $Cylinder_1$ configuration (it was actually tapered and 231m long), and would end up with about 184 tons of helium-based lift, of which about 31.6 tons is usable after giving it a lightweight internal structure and a non-armor lightweight AV1 skin.

Seating and accommodations

From here to the end of this section deals with crew seating, accommodations or general crew notes. By now you know the volume of your vehicle, and have some idea of how many people it is supposed to carry. Now you get to see exactly how much space you can devote to their comfort, and what is left for special purposes areas such as cargo, hangars, labs and so forth.

Basics

A hex 1m across is assumed to be 1m^3, which makes it about 1.3 meters high (since a hex has an *area* of about .75m^2). A vehicle with standing room is at least 1 to 2 hexes high for any hex tall enough to stand in (or sit in when vehicle ground clearance is taken into account). If you already have the mass of the power plant and power train, the fuel storage and number of occupants and cargo room you want, you can get an idea of basic vehicle size. Optional equipment (of which there is an amazing amount) will also tend to suck up interior space.

A vehicle seat which has enough maneuvering room for a pilot, driver or other operator will have a minimum volume of 1m^3, although a high-tech cocoon where all controls can be accessed without actually moving more than eyes and fingers would only be .5m^3. Normal passenger seats also take up 1m^3 and assume that this much space is reasonably comfortable for humans of up to 100kg, and seating for exceptionally large individuals or individuals in bulky space suits or armor would be 2m^3. It can also hold 100 Size points of items that can be crammed into a space designed for a sitting person. Neither of these seats allows access to the seat from anywhere except an immediately adjacent exit on the outside of the vehicle (door, canopy, etc.), an aisle leading to such an exit, or an adjacent seat. Bench seats or other extremely basic passenger accommodations will have a volume of .75m^3, but are *not* comfortable nor give much maneuvering room (don't even think about trying to use a weapon). Standing room only space is .5m^3 per person, and is *extremely* cramped. Intermediate levels of comfort are possible if desired. Vehicle space devoted to occupants or their activities will have a mass that is mostly subsumed in the structure mass of the vehicle, with a small addition to reflect non-structural components. Most seating arrangements assume a floor plan space of 1 hex per person (2 hexes if reclining/prone, but only 1m high).

Example - A four-passenger car will have four hexes of space devoted to occupants, which will be a total volume of 4m^3.

Biologic power plants take up 2m^3 of volume for the first 100 kilograms of mass (an 80kg person takes up 1.6m^3), so a enclosed trireme which has 100 rowers will need to have at least 160 cubic meters of interior space. Add 2m^3 of volume each time you double a creature's mass, rounding up (a 400kg horse will take up 6m^3).

External seating takes *no* volume, although any added height or width of the vehicle/passenger combination will have to taken into account for magic spells or other effects such as low overpasses. An external passenger or driver normally gets no protection from vehicle armor (like a raft). Each .2m^3 of vehicle volume that is "occupant" will allow one facing of armor protection for that occupant. Motorcycles are examples. A passenger can be "protected" by another passenger in some cases.

Example - A motorcycle normally provides no armor to the driver. If .2m^3 of volume was the driver, then the front "armor" (windscreen) of the motorcycle would protect both the driver and any passenger immediately behind the driver.

In general, driver and passenger accommodations and options are the following:

None

The passengers sit on crude benches made from whatever material is locally handy. It provides no cushioning, back support or comfort. Each hour (cumulative, round down) riding like this counts as a task vs. current HLT. Succeeding means the character takes an overall +1 non-lethal impairment. These rolls are made *each* hour of travel, and impairments may not be recovered until you get out of the vehicle. On the good side, these passenger accommodations have no cost and no extra mass.

Example - After spending 3 hours in the back of a cramped truck, the vehicle would make 3 rolls vs. your HLT, with a skill of 1, 2, and 3. Each time the vehicle succeeds, you take a +1 non-lethal impairment.

Optionally, seating of this type on a man-powered vehicle may count as substandard seating instead, since the occupant presumably has room to move arms and legs, and the constant motion decreases any discomfort. This is the default for vehicles like bicycles.

Substandard

Some concessions to passenger comfort are made, but not many. The seats might have little cushioning, but are comfortable for short periods, and may possibly be adjustable to different positions. Think of a typical school bus seat. Each 2 hours (cumulative, round down) counts as a task vs. current HLT, as for the previous example. These seats cost 50Cr per person and mass 10kg per passenger.

Basic

A typical automotive seat. Cushioned, adjustable, comfortable for long periods of time. Each 4 hours (cumulative, round down) counts as a task vs. current HLT, as for the previous example. These seats cost 200Cr per person and mass 20kg per passenger. Basic or substandard seats for vehicles like motorcycles that have no back rests are half mass and cost.

Luxury/Ergonomic

An extremely nice automotive seat. Cushioned, heated, with stereo speakers, adjustable for angle, back support and other Tech Level-specific characteristics. Comfortable enough to easily fall asleep in while a passenger. Each 8 hours (cumulative, round down) counts as a task vs. current HLT, as for the previous example, and only because there is limited room to stretch and move around. These mass 40kg per passenger and cost 800Cr each.

In addition, a luxury vehicle usually also has the luxury of elbow room, and luxury seats should (but are not required to) take up 1.5-2.0m^3 per person.

Toilet

Basic sanitary facilities take 2m^3 (1m x 1m x 2m) and may include a toilet and a small sink or equivalent. On low-tech vehicles, the toilet opens onto the ground or water. At higher tech, it may have a holding tank, or even recycling facilities. Assume that a vehicle needs *at least* 1 toilet per 100 occupants for any trip of over two hours. For long-term missions, assume one per 20 passenger is required.

Tech Level	Typical description
1-6	A semi-private area (at best) with a hole or bucket and a place to sit.
7-8	Private area with primitive plumbing. Possibly a sink or washbasin.
9+	Varying levels of complexity depending on vehicle (spacesuit-compatible plumbing, or multi-lifeform compatible, for instance).

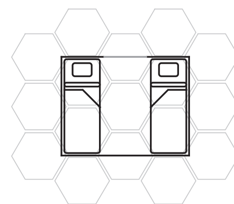
A shower requires an extra 2m^3 (1m x 1m x 2m) and a bathtub requires 4m^3 (2m x 1m x 2m) although a bathtub may include a shower at no extra cost or volume. Toilets and other sanitary facilities cost 100Cr per m^3 and mass 20kg per 1m^3. For long-term missions, how many showers are needed depends on the perceived need. For a shower per day per passenger, assume one per 20 occupants, and each person's shower will consume 10kg of water, which is used up or recycled, depending on the TL.

Naturally, if you are willing to put up with inconvenience, lack of privacy and possible embarrassment, you can often avoid the need to have sanitary facilities by simply hanging the appropriate part of your anatomy off the edge of the vehicle. This would be the norm for many vehicles at TL7 or less.

Staterooms

Private living quarters on a vehicle can take up as much space and be as opulent as desired. We won't assign a luxury factor to them, but just make basic assumptions and describe what you get for the *minimum* expenditure.

Stacked bunks

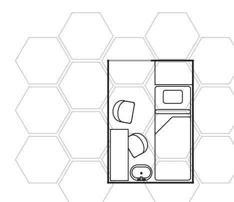


It is not a place for living, only for sleeping, with a .25m^3 footlocker at one end, and possibly a privacy curtain. Each one costs 100Cr, and takes up a horizontal 2m^3 (2 hexes of floor plan and 1.3m high) that can be crammed into anywhere it will fit, and will mass 10kg per 1m^3 (20kg per bunk). For purposes of accessways, each 2 bunks (round up) counts as a “room”.

Tech Level	Typical description
1-6	Hammocks and a place to hang a bag of stuff.
7-11	Hammocks or stacked wooden or metal bunks, footlockers or small vertical lockers.
12+	Personal “pod”, possibly with individual climate control, various types of electronic access (television, computer, etc.).

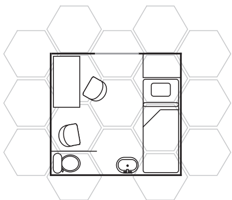
Minimum quarters

This is a private room, with a fold-down bed and desk, a small sink (TL8+) and a 2m^3 of personal storage space (wardrobe, drawers). It takes up 10m^3 of space (approximately 2.5m x 2m x 2m), costs 1,000Cr, and will mass 10kg per 1m^3 (100kg per unit)



Tech Level	Typical description
1-6	Fixed bed with storage underneath, chair, fold-down desk, perhaps washbasin and chamberpot.
7-11	Folding bunk, small closet/locker, desk with some storage capacity, washbasin or small sink & mirror.
12+	Extra amenities appropriate to TL, such as personal climate/atmosphere control, computer/video access.

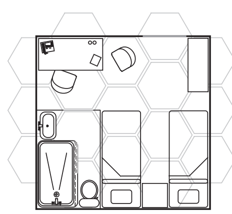
Basic quarters



A private room, with about double the space of minimum quarters, roughly 20m³ (approx. 4m x 2.5m x 2m). Any bed still folds down, but there is room for a few people to sit and chat, and may have its own toilet (normally TL8+). Such a room costs 2,000Cr, and will mass 10kg per 1m³ (200kg per unit). If a bunk bed arrangement is used, basic quarters can count as two minimum quarters.

Tech Level	Typical description
1-6	Fixed wooden bunk, small desk, wardrobe, washstand with water pitcher and chamberpot.
7-11	Folding bunk, semi-private toilet alcove, desk, two chairs, closet with lower drawers, personal intercom appropriate to TL (bell cord, speaking tube, etc.).
12+	Extra amenities appropriate to TL, such as personal climate/atmosphere control, computer/video access, spacesuit locke, passenger emergency gear or very minimal shower/toilet cubicle.

Full quarters

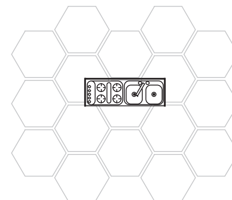


A moderate sized room, such as might be found on a modern passenger ship. It has approximately 40m³ of space (approx. 4m x 4m x 2.5m). It has conventional furnishings, two small beds or a larger folding bed, a small but serviceable bathroom and shower, and can actually be comfortable space for two people. Such a room costs 4,000Cr, and will mass 10kg per 1m³ (400kg per unit).

Tech Level	Typical description
1-6	Fixed wooden bunk(s), small table for work or dining, two or three chairs, large wardrobe, brazier or other cold-weather amenities, washstand with water pitcher and chamberpot. .
7-11	Folding bunks that convert into basic furniture, private toilet alcove with sink, small tub and/or shower, desk, chairs, closet & drawers, climate control appropriate to TL, personal intercom appropriate to TL (bell cord, speaking tube, etc.).
12+	Extra amenities appropriate to TL, such as personal climate/atmosphere control, computer/video access, spacesuit locke, passenger emergency gear, food dispenser, etc.

Just because a type of quarters doesn't list something like climate control doesn't mean it doesn't have it, just that it is not independent of the overall vehicle or is not personally adjustable.

Galley



Space for preparing food may be part of a vehicle, and takes up 2m³ per cooking station, each of which can provide 4 meals per hour. This space includes storage for cooking and eating utensils, cleaning them afterwards.

It may include an icebox or small refrigerator (up to .25m³) at TL8+. Larger facilities for cold storage are done as a climate controlled passenger space, except the temperature differential is based on the average temperature inside the vehicle. Normally, a -40°C shift will serve all freezing and refrigeration needs. Galleys cost 100Cr per 1m³, and will mass 20kg per 1m³.

Tech Level	Typical description
1-6	Dedicated fire-resistant area (masonry) with small stove, hanging pots and pans, sealable wooden barrels of supplies.
7-11	Improved cooking facilities based on TL, such as metal stoves, gas or electric heat, refrigerator, running water and storage cabinets.
12+	Extra amenities appropriate to TL, possibly including personal food preparation areas like microwaves, packaged meal dispensers, vending machines, etc.

Galley space may be pro-rated based on the number of meals that can be cooked. For instance, a tiny one-person galley (1 meal cooked in 1 hour) would only have a volume of .5m³.

Common areas

These are areas where passengers can move around and mingle, and could be dining areas, promenades, ballrooms, etc. They take up as much space as you want to devote to them. To be considered luxurious, at least 30m³ must be available per passenger that has access to them. Ships have an advantage in this regard, as the entire upper surface may be considered common area, with an effective volume of 3m³ per m² of surface area. Of course, you will want interior area as well. Passengers don't consider open air a luxury during storms... Common areas have no cost or mass except for any equipment provided in them.

Tech Level	Typical description
1-6	Open area with hanging lanterns and rough wooden benches and tables.
7-11	Seating appropriate to TL, including folding chairs and tables, storage for games, vending machines, semi-private alcoves, overall lighting and climate control. Intercom and public communications appropriate to vehicle and TL (television, radio, telephone, sound stage).
12+	Extra amenities appropriate to TL, such as multi-lingual/species communications, entertainment or dining facilities,etc.

Special purpose areas

These are areas that contain equipment or provide services that require more energy than a common area. Examples might be a sick bay, forge, machine shop, etc. These take up a volume appropriate to the task at hand, a sick bay requiring space for a patient to lie down, for instance. Special purpose areas have a mass of 100kg per $1m^3$, cost 1,000Cr per $1m^3$, and use *up to* 10,000 watts per $1m^3$ when they are active (obviously, a low-tech sick bay won't use a lot of power, but a low-tech forge would, in the form of wood or coal).

Sick bay

An examination table, a cabinet beneath it for supplies and/or equipment and room to stand next to it will have a volume of $10m^3$, like minimum quarters. Cost depends on the TL, equipment and supplies, but basic surgical tools, supplies and drugs should be at least 5,000Cr, in addition to the cost of the space. Add at least $5m^3$ for each patient bed after the first. Cramped vehicles will usually have patients treated in their quarters if possible.

Brig

Normally this is just an area the size of minimum quarters, with a securable door. If the basic structure of the vehicle does not provide a high enough AV, then an area the size of the walls, floor, ceiling and door will have to be armored to the desired level (an AV of 5 is usually sufficient to stop all but the most exceptional unarmed individuals).

Library

On high-tech vehicles this will be replaced by computer terminals, but access to physical books will take up about $1m^3$ and 500kg per 100 reference-sized works, plus $2m^3$ for a small desk and chair to read them at. The cost depends on the TL and rarity of the works, but 2,500Cr for the basic setup is not unreasonable. In general **CORPS** terms, a reference library lets you look up facts or knowledge that you don't know, a way to get a purely academic answer to skills outside your area of expertise. A $1m^3$ volume of reference works is sufficient to act as a skill of 3 on a Primary skill question, 4 on a Secondary skill question, and 5 on a Tertiary skill question, provided of course that $1m^3$ of books was dedicated to that field. If you already have the skill in question, the library's rating-3 can be used to decrease the Difficulty of any research-based task you can use it for. Doubling the volume of books on a topic adds 1 to the “skill” of the library. Simply having a set of general reference works (encyclopedias) is only worth a skill of 2, regardless of library size. Finding the knowledge you seek takes time appropriate to the Difficulty of the task plus 3, plus 2 more if the books are not indexed, and minus 2 if the index is computerized. The maximum effective skill that a person can use a library at is their AWR, and the maximum skill bonus they can get is half their AWR (round down).

Example - The flying brig *Petraska* has a $4m^3$ area devoted to the books of its wizard in residence. Of, this, $1m^3$ is general reference works (*Ye Knowne World Compendium*), $1m^3$ is a rating of 4 the Secondary skill of Occult History, and $2m^3$ is a rating of 4 for the Primary skill of Thaumaturgy. Even though the wizard may not have Occult History as a skill, if he has access to his books, he can still use an effective skill of 4 for answering historical questions of an occult nature. Since the wizard has Thaumaturgy already, the library just provides a -1 to the Difficulty of any research task he is working on.

Accessways

Once you have the internal living and working areas, you need to assign space to get to and from them. Crawlways (always unpopular) have a volume of $.5m^3$ per meter of length. Narrow hallways (around 1m wide, two can pass if they turn sideways) have a volume of $1.5m^3$ per meter of length. Regular hallways (about 1.5m wide, enough room for two to walk abreast) have a volume of $2.5m^3$ per meter of length and wide hallways (about 4m wide, room for four abreast) have a volume of $4m^3$ per meter of length. A vehicle usually requires 1m of accessway *length* times the number of separate “rooms” (including separate open deck areas) the vehicle has. For layout purposes, assume 1m of hallway is a square that completely encloses a hex. Vehicles that are completely open do not require accessways, as all areas are adjacent to each other. Crawlways are only allowed if there is no other choice. Special purpose military or civilian vehicles are an example. Military vehicles can have narrow hallways, non-passenger vehicles usually have regular or narrow hallways, and luxury passenger vehicles have a combination of wide and regular hallways.

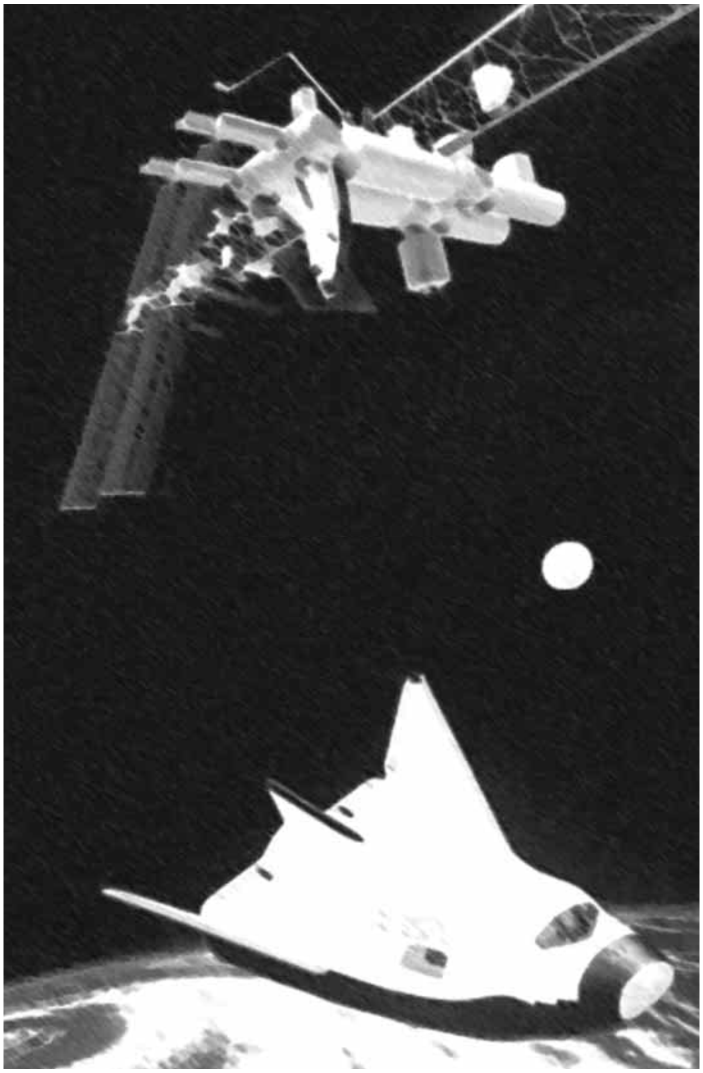
Example - A small motorhome has a driver's station and passenger seat, for $4m^3$. It also has a minimum galley ($2m^3$), food storage ($1m^3$), bathroom ($2m^3$), 4 sets of minimum quarters ($40m^3$), and a $4m^3$ common area with a stowable table and average seating for other passengers. This is a total of $53m^3$, plus $1.5m^3$ for the short accessway required for a separate bathroom. All the other sections are part of an open floor plan and require no separate accessways. If the vehicle is 3m tall and 2.5m wide, then it is at least 8m long, discounting extra storage space and the engine, fuel and drivetrain.

Example - A submarine has a total of six sets of quarters for officers, forty-eight bunk “rooms” for crew, a galley, mess/common area, engine room, control room, torpedo room and storage room. This is 60 “rooms”, so with narrow hallways, the sub requires $60 \times 1.5m^3 = 90m^3$ of volume dedicated to accessways, which take up about 60 hexes of floor plan in addition to the quarters themselves.

Overall opulence

In some vehicles, the aesthetic qualities of the furnishings are as important as their functionality. Unless otherwise described, the accommodations previously listed are functional, but not necessarily pretty. You can increase the luxury quotient by any amount desired, up to and including solid gold toilet fixtures. However, for those interested in general numbers, spending twice as much on accommodations puts them in an “upper class” level, spending five times as much makes them “luxurious”, and spending ten or more times as much would make them “opulent” or even “decadent” (depending on the culture). In addition to amenities, upper class accommodations usually assume a higher level of cultural privileges, such as access to the captain or vehicle commander, special observation lounges, boarding and debarking first, expedited customs clearance, etc.

Example - A spaceship with “luxurious” staterooms would spend five times as much per stateroom (20,000Cr instead of 4,000Cr). On a spaceship, this might mean a personal steward, better computer and entertainment access, adjustable gravity and atmosphere settings, closer proximity to dining lounges and a plethora of convenience appliances.



Special quarters

Some types of speciality living arrangements are simply combinations of quarters, bulkheads and duplicate life support arrangements (one set for humans, another for cryogenic methane breathers...). Different gravity can be handled by gravity repulsor plates (p.32), or by creating a spin habitat. Spin habitats have to be fairly large to avoid having their rotation disorient the passengers. You can set the geometry of your vehicle to whatever you want, but you may have to add volume for extra accessways to get from one rotating area to another. For structure purposes, the felt gravity induced by the spin is added to either Turn or Acceleration to get the number used for structure AV. In addition, while the vehicle can be of most configurations, the actual dimensions will be based on the gravity required, with a minimum dimension as follows.

Centrifugal gravity	.1g	.5g	1.0g
Vehicle diameter	20m	100m	200m

So, if you only have 200m^3 of living volume and want a .5g felt gravity, it's pretty clear you are going to have a habitat on the end of a long pod. You can design a vehicle that has no gravity when maneuvering, but felt gravity when coasting. For instance, the previous vehicle could be a 100m long ship with crew at one end and engines at the other. When not accelerating or decelerating, the ship is spun end over end to provide the necessary “diameter”.

Crew notes

This is as good a time as any to figure out exactly how many secondary crew a large vehicle is going to need. The **Power Plant** section (p.17) already gave you the number of crew needed to keep the power plant running. If the vehicle is operated continuously, then it will either be in two or three shifts, and the number of people required for each duty station will therefore be double or triple. If crew are “hot bunked” so that sleeping quarters are shared, this will reduce the amount of volume needed for quarters, but not the amount of consumables for life support, food, water and so forth.

The vessel will need a pilot or driver. If these duties require full-time attention and the vehicle has significant communication or sensor capability, then a communication or sensor operator is needed. This can be handled by a co-pilot, who will also cover for the pilot when nature calls. If the power plant crew of a vessel is required for steering functions, like the rowers of a trireme or the rigging crew of a sailing ship, then enough of these crew will have to be on duty as well.

If a vehicle has paying passengers, then a cleanup staff is needed. Military vehicles usually have people cleanup after themselves or rotating assignment to cleaning details. Assume one "housestaff" per 50 sets of *quarters*, and one "attendant" per 100 *passengers*. Attendants may be required for passenger assistance on most vehicles, even ones with a trip duration of only a few hours (flight attendants, conductors). If there are 10 or more housestaff or attendants, add a dedicated supervisory position, who would also serve as a concierge or liaison officer.

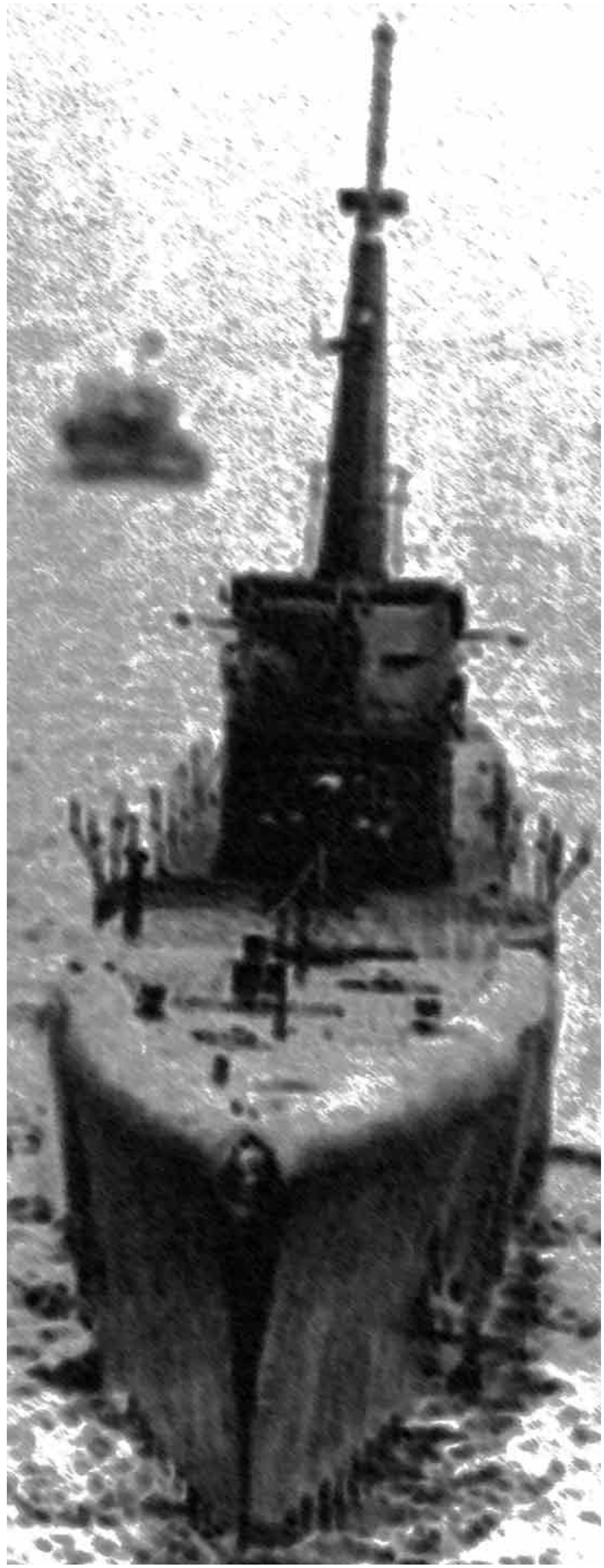
If there are security needs, a vehicle's crew are expected to serve as needed, but there should be one dedicated security personnel per 500 passengers (varies with culture).

Vehicles with weaponry will need sufficient crew to load, aim and fire these weapons. If a weapon is not self-loading, assume it requires at least two crew, one to load and one to aim and fire it. Sensors may also require dedicated crew.

Cooks and other food service personnel are required at the rate of 1 per TL x 10 meals per day that are served (TL x 20 for military or mass quantity food). If room service is an option, add 1 per 100 sets of quarters.

If the vehicle carries other vehicles with a dedicated crew requirement (a carrier's fighters, for instance), then quarters are needed for these other crew, plus any crew needed to supervise them, service their vehicles, etc. Vehicles with incidental crew (a ship's launch) are handled by the carrying vehicle's crew as needed.

For very large vehicles, maintenance is often done in small amounts on a continuous basis, rather than all at once. Assuming that only the power plant needs maintenance, figure out how many hours per year it needs if running all the time (assume 9,000 hours in a year). If the total maintenance is more than 500 hours a year, the vehicle probably has a full-time mechanic/maintenance worker. For each 2,000 hours in addition to this (round nearest) the vehicle requires another full-time mechanic to constantly keep things in working order. Mechanics will require tools and enough units of "spare parts" (**p.73**) to perform the maintenance required over the length of a trip, plus as many units of "generic" parts as deemed sufficient for handling any mid-trip emergencies. Mechanics and parts will also be needed for any carried vehicles that require maintenance.



Am I Doing This Right?

Question #1:

What is the structure mass and cost of a TL9 automobile which uses the Box_1 configuration and (length of 4m), has a loaded mass of 1,000kg, a Turn of 6 and Acceleration of 5?

Calculations:

The “structure AV” of the car is the square root of (its mass in *tons* times the *greater* of Turn/10 or Acceleration/10), or 1. However, a land vehicle has to have a structure AV of at least its suspension rating plus 1. Since a regular car has a suspension rating of 1, the minimum structure AV is 2. A Box_1 vehicle 4m long has an area of 35.2m^2. At TL9, 10mm of structure has an AV of 11, so we need 2/11th this amount, or (using composite structure) 35.2m^2 x 50kg per m^2 x 2/11 = 320kg. Cost is also 2/11th normal, or 35.2m^2 x 500Cr per m^2 x 2/11 = 3,200Cr. For damaging the structure, the AV is x5 the calculated amount, of AV2 x 5 = AV10.

Answers:
Structure mass = 320kg
Structure cost = 3,200Cr
Structure AV = 10

Question #2:

What volume and mass does a school bus require for driver and passengers? Assume 1 driving station and 60 passengers, all substandard seats. If it has 2m standing room and is 2.5m wide, how long is the passenger compartment?

Calculations:

We'll assume this is 60 adult-size seats (probably 90 child-size seats). Each passenger takes up 1m^3, for a total of 60m^3, with each seat massing 10kg and costing 50Cr, for a total passenger seating mass of 600kg and cost of 3,000Cr. The driver station has the same size, cost and mass as a single passenger seat, so this is added to the total, for 61m^3, 610kg and 3,050Cr. Dividing 61m^3 by 2m of height and 2.5m of width gives (61m^3/(2.5m x 2.0m)) = 12.2m of length.

Answers:
Volume = 61m^3
Mass = 610kg
Length of passenger compartment = 12.2m

Question #3:

If a nuclear attack submarine has a total complement of 120, with the following mix:

Captain (1)	Basic quarters
Other officers (9)	Minimum quarters
Crew (110)	Stacked bunks

How much volume will quarters, toilets, showers, galley, crew stations, a common area sufficient to seat two-thirds of the crew, two storage rooms, one torpedo room, and one control room (common area) sufficient to seat 10 take up?

Calculations:

The captain's basic quarters will have a volume of 20m^3. Each other officer's quarters will have a volume of 10m^3, for a total of 90m^3. The stacked bunks will have a volume of 2m^3 each for a total of 220m^3. The total for quarters is 20m^3 + 90m^3 + 220m^3 = 330m^3.

Using the guidelines of one toilet at 2m^3 per 20 passengers and one shower at 2m^3 per 20 passengers, this is (120 passengers/20) x (2m^3 + 2m^3) = 24m^3. We double this to 48m^3 because most of the use will be in groups between shifts.

The galley serves 3 meals/day to 120 people, or 360 meals per day. We can divide this by 24 hours to get a number of meals per hour, which is 15. At 4 meals per hour per 2m^3, we can round this up to 8m^3 required for food preparation. Note that this does not include any food storage space. This space would assume that food is being prepared constantly and stored for use at a designation mealtime. It would be more realistic to assume that say half the time available is used, and double the space, or 16m^3. This means that 30 meals can be prepared per hour. We add 10m^3 for each of two storage rooms, making the total volume 36m^3.

Crew stations are assumed to be like vehicle controls, and are 1m^3 per person, for a total of 120m^3. However, only half the crew is on duty at any time, so this is halved to 60m^3.

A common area for two-thirds of the crew (80 people) would be an additional 80m^3. This leaves room to move around for crew that is currently not on duty. The control room common area is another 10m^3, and we allot 40m^3 for a torpedo room.

Accessways are narrow hallways at 1.5m^3 per 1m of length, and the number of “rooms” is 10 (officer's quarters) + 28 (bunks) + 1 (showers) + 3 (galley + storage) + 1 (torpedo room) + 1 control room + 1 (common area) +1 (torpedo room) = 46, times 1.5m^3 = 69m^3 of accessways.

The total for all these is 330m^3 (crew) + 48m^3 (sanitary facilities) + 36m^3 (galley, storage) + 60m^3 (crew stations) + 130m^3 (common, control, torpedo room) + 69m^3 (access) = 673m^3.

Answers:
Total volume required = 673m^3

6 Surface Treatments

Basics

This is some enhancement to the outer structure of the vehicle for a specific purpose. Armor, vacuum sealing, waterproofing, streamlining, wings and so forth are all different types of surface treatment.

Armor

Armor is probably the most obvious and fussed over surface treatment on any player-designed vehicle, for good reason. A vehicle may be partially or fully armored, and armored on any of its six facings: Top, bottom, right, left, front and rear. Any vehicle that is not an open framework of girders and structural elements will have armor. Even the skin of a zeppelin will be bought as armor (but not much!) using the rules that follow. Minimal armor is not a problem to figure out, however, many combat vehicles have enough armor that it begins to subtract from the internal volume available. **VDS** gets around this by assuming that you design the volume of the vehicle first to fit what you want *inside*, and the armor of the vehicle goes from that point *outwards*.

So, the volume of armor is factored out of the equation, although in *extreme* cases you will need to readjust the *external* dimensions of the vehicle and possibly its performance figures (if armor on any two opposing facings is more than half a meter, you may want to check).

Armor comes in a number of flavors. The most basic is military vs. civilian, or armor vs. structure. Car bodies may be made of TL12 steels, but they are not TL12 *armor* steels. The protection afforded and cost will vary. As for structure, if you use out of date armor materials (below current TL), you save 20% of armor cost per TL below the current one (maximum 90% discount). For instance, using TL9 structure materials on a TL11 tank saves 40% on the armor cost.

Virtually any Tech Level can get any level of armor desired. Even a Cro-Magnon can hide behind a hill to stop a tank cannon. The question is, can you mount that hill on wheels?

AV by Tech Level per 10mm thickness

TL	Armor	Structure	Historical material
1	1	1	Wood, leather, bone, stone
2	2	1	Copper
3	3	2	Bronze
4	5	3	Iron
5	7	4	
6	10	5	Steel
7	13	7	
8	17	9	Face-hardened steel
9	21	11	
10	26	13	Aluminum alloys
11	31	16	
12	37	19	Ceramic-metal composites
13	43	22	?
14	50	25	?
15	57	29	?

A 1m^2 area of 10mm thick armor will have a default mass of 50kg and a default cost of 500Cr. Structural materials used as armors have the same mass and volume, but are x.25 cost. The volume per square meter of any 10mm thickness of armor is .01 cubic meter, and is only for purposes of internal bulkheads on the vehicle that have an AV of more than the base amount for the type of structure bought. While you can buy armor or structural panels in any thickness down to 2mm, the cost of working and shaping it will always have a minimum cost of a thickness of 5mm. Since historical armor has not been a uniform generic substance, below are some rules to let you customize armor types within a Tech Level.

	For a given AV			A 1m^2 sheet of		
Armor type	**Thickness**	**Mass**	**Cost**	**10mm composite equiv.**		
Organic	x5.0	x.70	x.50	50mm	35kg	250Cr
Light	x1.5	x.70	x2.0	15mm	35kg	1000Cr
Composite	x1.0	x1.0	x1.0	10mm	50kg	500Cr
Heavy	x.80	x1.2	x2.0	8mm	60kg	1000Cr
Ex.Heavy	x.70	x1.3	x2.5	7mm	65kg	1250Cr
Transparent*	x3.0	x1.4	x4.0	30mm	70kg	2000Cr

Don't let this confuse you. Just think of "10mm composite equivalents". If you wanted the AV of 24mm of TL9 heavy steel, you would multiply 10mm x .8 thickness = 8mm, and then divide the result into 24mm to get the number of "10mm composite equivalents", which is exactly 3 in this case. So the AV of 24mm of heavy steel is 3 times the AV of 10mm of composite armor.

Example - An armored car is plated in 4mm of TL11 armor steel, a heavy armor, with a total area of 40m^2. The table above says that 8mm of heavy armor is equivalent to 10mm of composite armor, so we have 4mm/8mm = x.5 of a "10mm composite equivalent". At TL11, this is AV31 x .5 = 15.5, rounding down to AV15. The table also says that 8mm of heavy armor is 60kg and 1000Cr per 1m^2. Since we have half that (4mm), the armor *mass* is 40m^2 x 60kg x 4mm/8mm = 1,200kg. The *cost* is based on a minimum of 5mm thickness, for a cost of 40m^2 x 1000Cr x 5mm/8mm = 25,000Cr.

Organic armors

These are made of natural materials of some kind, such as lacquered wood, resin-impregnated cloth, wicker, leather and so forth. At high tech levels they might represent some byproduct of advanced genetic research. Organic armors have x.7 the mass for a given AV, but are usually x5 thickness and x.5 cost for a given level of protection. Organic materials are usually flammable or support combustion. Historically they usually run from the TL2-5 level, and do not get a level of protection past the TL5 level without GM permission and/or some sort of rationale.

By these calculations, the density of an organic armor is .7 (water is 1.0, steel is 7.7)

Example - At TL1, 10mm of default armor has an AV of 1, and 1m^2 would mass 50kg and cost 500Cr. If this armor were wood or other organic armor, it would instead be 50mm thick, mass 35kg and cost 250Cr.

Organic materials do not improve with Tech Level until genetic engineering becomes possible, but means of preparing the organic materials do, and the types of organic materials considered for armor will change as well. In addition, experience will provide more effective means of applying, reinforcing or bracing the armor panels.

Light armors

These are made from plates of the best lightweight metal or materials available at that Tech Level. They have x.7 the mass for a given AV, but are usually x1.5 thickness and x2.0 cost for a given level of protection.

By these calculations, the density of a light armor is 2.3 (water is 1.0, steel is 7.7)

Example - At TL10, 10mm of default armor has an AV of 26, and 1m^2 would mass 50kg and cost 500Cr. If this armor were magnesium-aluminum alloy, it would instead be 15mm thick, mass 35kg and cost 1000Cr.

Composite armors

These are made from some combination of light and heavy materials, like iron-reinforced wood, steel-faced aluminum, plate armor over a padded gambeson, etc. These have the default mass and thickness.

By these calculations, the density of a composite armor is 5.0 (water is 1.0, steel is 7.7).

Example - At TL4, 10mm of default armor has an AV of 5, and 1m^2 would mass 50kg and cost 500Cr. If this armor were iron-faced wood, it would be the default thickness, mass and cost.

Not all armor types are available at all TL's, even if you can design them. No lightweight metals? No lightweight armor!

Heavy armors

These are made from plates of iron or similar density alloys available at that Tech Level. They have x1.2 mass for a given AV, and are usually x.8 thickness and x2.0 cost for a given level of protection.

By these calculations, the density of a heavy armor is 7.5 (water is 1.0, steel is 7.7)

Example - At TL12, 10mm of default armor has an AV of 37, and 1m^2 would mass 50kg and cost 500Cr. If this armor were a high grade of steel, it would be 8mm thick instead, mass 60kg and cost 1000Cr.

Extra heavy armors

These are made from plates of the best heavy metal or alloys available at that Tech Level. They have x1.3 mass for a given AV, and are usually x.7 thickness and x2.0 cost for a given level of protection.

By these calculations, the density of a heavy armor is 9.3 (water is 1.0, steel is 7.7)

Example - At TL12, 10mm of default armor has an AV of 37, and 1 square meter would mass 50kg and cost 500Cr. If this armor were a depleted uranium-tungsten alloy, it would be 7mm thick instead, mass 65kg and cost 1000Cr.

Transparent armors

These are made in such a way as to allow visibility and/or weapons fire through all or part of a facing. These are considered to be light armors, but twice as thick for the same level of protection. At TL's of 8 or less, transparent armors are grillworks, and only have a 50-50 chance of stopping an attack on that facing at all. Note that if the vehicle has inherent AV due to streamlining or structure, it will usually still get that. A transparent "structural material" would be normal or safety glass, while transparent "armor" is bulletproof glass or the equivalent.

Example - At TL11, 10mm of default armor has an AV of 31, and 1 square meter would mass 50kg. If this were a car window, it would mass 70kg, and be 30mm thick. Since an actual car window is perhaps 5mm thick of "structural" glass, its AV is proportionately lower, and probably AV2 or so.

Basically, to save extra calculations on civilian vehicles, just assume a normal car has windows with half the AV of the body, rounding up.

You can use these armor types to reverse engineer real-world vehicles you have numbers for. For instance, if an M-113 APC (TL10) has aluminum armor of 12-38mm, you would use the lightweight armor type and divide the thickness by x1.5 to get the equivalent composite thickness (8-25mm) and use the TL10 armor numbers to see that the Armor Value of an M-113 ranges from AV21 to AV65.

Hardened armor

An armor material (as opposed to a structural material) will ignore the armor-piercing effects of most weapons of a *lower* TL than the armor. Structural materials *will* suffer the effects of armor-piercing attacks of most TL's. Armor materials may be x1 or x2 hardened. A hardening of x1 protects the armor from armor-piercing attacks of the same TL or lower, and x2 hardening protects from attacks of the armor's TL+1 or lower. A hardening of x1 is a cost multiple of x2, and x2 hardening is a cost multiple of x4.

Radiation abatement

This is basically extra mass added solely to stop radiation or other hostile proximity effects. Normal vehicle armor of any type will stop half its AV in rads per hour (round down), and will protect against contaminated particles if the vehicle surface is airtight. Specialized radiation abatement armor will stop double its AV, has a mass and volume like composite armor or structure, but costs twice as much. For a vehicle which only has limited radiation protection, and which uses other vehicle components to shield the crew (like surrounding the passenger compartments with fuel), additional protection may be had. *If* the component layout is done to protect the crew, then half of the protecting systems can be counted as armor mass to get an equivalent AV for that area. Note that this means these items can't be maintained, serviced or repaired without leaving the protected area. Uncrewed vehicles do not need special radiation protection, but to represent hardened electronics, you can double the cost of all components like radios, sensors or computers.

Protection from	AV needed
Light contamination	2
Medium contamination	20
Heavy contamination	100
Heavy solar flares	200
Gas giant magnetosphere	500

Example - A TL12 space station with a crew of 10 has a “radiation vault” where they go to sit out massive solar flares. This has a shielding with an AV of 100, which is doubled to 200 for radiation protection (it could also be special purpose armor, see following). If each person is given 2m^3 of space (a minimum quarters bunk, p.42), this is a total protected volume of 20m^3, or 4m x 2.5m x 2m, which has a total surface area of 46m^2. At TL12, 46m^2 of composite armor with an AV of 100 will cost (AV100/AV37) x 46m^2 x 1000Cr = 120.4KCr, and will have a mass of (AV100/AV37) x 46m^2 x 50kg = 6,200kg (6.2 tons).

Special purpose armor

Some types of armor are exceptionally good at stopping a particular type of attack. These armors are x3.0 as effective and expensive per unit thickness as normal armor, but only x.1 as good (round down) vs. all other types of attack. Special purpose ablative armors are available the same Tech Level as the attack they protect against. Durable special purpose armors are available the Tech Level after the attack is introduced. Special purpose armors may be layered on top of regular armors, giving a dual Armor Value, like 50(70), where the number in parentheses is the total AV vs. a particular attack, and the number outside the parentheses is the value against all attacks. The special purpose armors may be bought to counter:

Heat or fire (flamethrowers, molotov cocktails)
A portion of the electromagnetic spectrum:
- Visible and near-visible light (IR, visible, UV)
- Charged particles (plasma weapons)
- Hard radiation (X-ray lasers)
- High energy radio waves (masers)

Plasma jets (shaped charges, fusion guns)

Stopping regular kinetic energy from projectiles is the basic purpose of all armor, and it cannot be bought as a special purpose armor for kinetic energy only.

Example - A TL11 space vehicle has lightweight armor tiles that are designed to be heat-resistant, and are 30mm thick. If we divide 30mm by x1.5 for lightweight armor, we get 20mm effective thickness, for an effective AV of 62. Since this is a special-purpose armor, it has x3.0 AV vs. heat, or 186, but only x.1 vs. other attacks, or an AV of 6.

If such a special armor is penetrated, assume that a portion of the special armor has been destroyed and will need to be replaced. This depends on the size of the attack and the vehicle, and is too cumbersome to figure out the exact chance of hitting the damaged portion again on a later hit.

Special purpose armors that are ablative will “burn off” after one use, and are suitable for single-use re-entry vehicles or other limited applications. These are x1.0 cost instead of x3.0 cost, but otherwise act the same. They are usually available one TL before a more advanced, multiple-use armor appears (e.g. ablative Apollo re-entry shield vs. reusable Space Shuttle tiles).

In general, a properly controlled atmospheric re-entry will act like a heat-based DV of 200 to the front of the vehicle and a heat-based DV of 100 to most other vehicle surfaces. An *Improper* re-entry can be as damaging as desired...

Body armor

This is obviously not a *vehicle* concept, but at some TL's, the difference between a large suit of armor and a small vehicle becomes very small.

It takes about 1m^2 of surface area to cover the front and back of a normal human, but about double this to armor them because of overlaps and spacing considerations. So, the mass and base cost of the armor can be based on a 2m^2 number. The complex shapes required to allow normal movement in this armor will increase the cost. Assume normal cost for body armor, but each joint in the armor that allows flexibility or access is a +.1 to this multiple, counting the fingers of a hand as five joints and toes of a foot as one joint. Armor with less than full coverage is pro-rated based on the number of hit locations involved (e.g. legs are 7-10 on a d10 hit location chart, so leg armor is x.4 cost, or x.2 cost each).

Location	Area	Joints	Cost
Head & neck	.20m^2	faceplate and gorget	x.24
Torso	.60m^2	waist	x.74
Arm(each)	.20m^2	shoulder, elbow, wrist, fingers	x.36
Leg (each)	.40m^2	hip, knee, ankle, toes	x.56
All	2.0m^2	-	x2.5

Example - An 10mm thick armored arm would have a base cost of x1, with additions for the shoulder(+.1), elbow(+.1), wrist(+.1) and fingers(+.5), increasing base cost to x1.8. Then a x.2 is applied for the arm being just .2m^2 of the whole body total of 2m^2, for a final multiple of x.36. A TL6 composite armor would have an AV of 10, and for the arm have a mass of 50kg x .2m^2 = 10kg, and a cost of 500Cr x .36 = 180Cr. A full suit would mass 100kg, and cost 1000Cr x 2.5 = 2500Cr (you get a discount on a full suit).

For vehicle purposes, the normal AV is used. For damage to a person inside *tightly* fitting or flexible armor (.1m^3), the blunt trauma value is equal to the total AV, so the final AV of 10 in the previous example would end up being 10/10. A person in rigid armor with padding, or powered armor (.2m^3) would take 60% of the blunt trauma value and *add* it to the soak value, rounding any fractions as desired so long as the total stays the same. If the AV of 10 in the previous armor were like this, it would be listed as 16/4. The thickness of worn armor should never exceed 10mm of armor for anything moved by the wearer's muscle power. For a roughly person-sized suit of powered armor, this could be doubled to 40mm maximum thickness.

Rigid body armors are easy to spot, and generally are not concealable under clothing. Flexible armors can be concealed under clothing if their torso thickness is 5mm or less and extremity thickness is 2mm or less. Most flexible body armor is designed as lightweight or “organic” (fabric) armors. Flexible metal armor like chainmail is visually concealable, but usually noisy when the person wearing it moves.

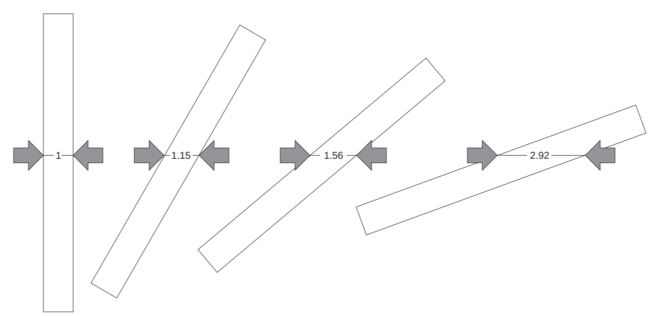
Sloped armor

Sloped armor is a special case that makes armor effectively thicker. For instance, look at a table top, 1m x 1m. It has a certain thickness. Now, look at it along a thin edge. If an attack hit *exactly* on that edge, the table would be 1m thick. If you looked at the table from a slightly higher angle, it would be less than 1m thick, but more than if you just measured it from one face to the other.

In game terms, sloping makes a vehicle larger without changing its internal volume. Sloping armor presumes you pivot it around its center, adding volume underneath, and taking it away on top.

Each facing of the vehicle that is sloped will extend an extra amount away from the center of the vehicle, the exact amount based on the angle of slope.

Sloping	Armor multiplier	Extra vehicle dimension
0°	x1.00	0m per 1m of height
20°	x1.06	.2m per 1m of height
30°	x1.15	.3m per 1m of height
40°	x1.30	.4m per 1m of height
50°	x1.56	.6m per 1m of height
60°	x2.00	.9m per 1m of height
70°	x2.92	1.4m per 1m of height
80°	x5.76	2.8m per 1m of height



Example - A 16m^3 vehicle is bought as being 4m long, 2m wide and 2m high. An AV of 50 is bought for the front, and sloped 60° for extra effect. The AV on the front of the vehicle is now 50 x 2 = 100, but the vehicle gains .9m of length for each 1m of height (or an extra 1.8m). The internal volume is still 16m^3, but the dimensions are now 5.8m long, 2m wide and 2m high. Handling characteristics would be based on the new vehicle dimensions.

Sloping only makes the armor *appear* thicker from a given angle of attack, normally the angle from which you expect the vehicle to be hit. The sloping bonus does not apply if attacked from an angle that negates the sloping effect.

⚠ One important side effect of sloped armor is that it adjusts the area of the top, front and bottom facings of the vehicle, which will affect the mass of any added armor on those facings. For instance, the front and bottom facings are usually larger, and the top facing smaller. If the sides are sloped as well, this adds even more complexity, and there isn't much we can do to help you except warn you in advance. Normally you will just ignore this particular effect, since it usually works to your advantage.

⚠ Also note that sloping is not inherent on *any* vehicle configuration. Just because you have a "wedge" vehicle does not mean it has a sloped front or sides. It could have a wedge profile in the form of a number of vertical and horizontal surfaces with no slope at all (like stairs), and does not get the benefit or limitation of sloped armor unless you buy it as such. For instance, a car with a long hood, near vertical windshield and flat roof might be designed as a "wedge" because that most accurately represents its volume and surface area for a given length, but you wouldn't assume it had sloped armor.

Waterline armor

Many naval vessels have less armor below the waterline, especially in Tech Levels where there are no torpedoes or underwater weapons. If you have figured out how much of your vessel you want to be underwater, then armor for a facing can be split into above/below waterline amounts. The percentage of a water vehicle that is below the waterline is its mass in tons divided by its volume in cubic meters.

Example - If a 100m^3 ship had a mass of 40 tons, then 40% of the ship would be below the waterline. If 40% of the ship's mass is below the waterline, you would simply use 40% of the surface area to determine the mass of armor below the waterline, and 60% of the surface area to determine the mass of armor above the waterline.

Battering rams

A reinforced front structure to deal ramming damage is bought as extra armor for the front facing of the vehicle, but only for an area of half the normal front facing. If the vehicle was designed to mount a ram, there is no additional structure mass needed. Retrofitting a ram requires extra structure mass equal to the ram mass, or a total extra mass equal to that of armoring the entire front of the vehicle. The armor protection of the ram protects the vehicle from damage it would take while ramming by stopping it and distributing the impact across the vehicle frame. The *actual* area of the ram (to see how big a hole it can leave) is assumed to be x.1 of the vehicle's front armor. See **p.99** for advanced rules on ramming and **p.97** for rules applying to taking on water from surface breaches.

Turrets

Turrets are normally pivoting weapon mounts placed on a large vehicle, and represent a modification of the "armor" surface treatment. In its most basic form is it simply a volume protected by armor, which contains some or all of a vehicle weapon, plus possibly space for people and equipment. You can either do this as a "vehicle-on-a-vehicle", like putting a turret slab on top of a tank slab, or more simply, just assume the turret is part of the overall vehicle volume, with a cost associated with the turret machinery. If designed as separate items, turrets can be armored to different levels than the vehicle itself. Armor area and mass would be figured as for the turret "vehicle" with the usual note that the bottom of the turret is usually open and has an AV of 0.

Weapons in turrets require a base 1m^3 of volume per 1,000kg of the weapon that is *protected by armor*, which includes space for the weapon to be loaded, pivoted and to some degree maintained. If the weapon is manually reloaded or aimed from the turret, then the turret must include enough volume for the crew to do this, and perhaps some space for extra ammunition.

The default turret allows the weapon to move up to a total of 30° in some combination of horizontal and vertical motion. Most turrets restrict the weapon to vertical motion, since horizontal motion (360° rotation) is taken care of by the turret itself. Each *extra* 30° of weapon freedom adds .2m^3 of volume per 1,000kg of protected weapon. You can limit weapon freedom by 15° and *subtract* .2m^3 of volume per 1,000kg of protected weapon. A turret has a base cost of 1,000Cr per m^3 of final volume in addition to weapon cost. A non-turreted gun mount has a cost of 500Cr per m^3 of final volume.

Example - A vehicle-mounted anti-aircraft gun needs to be able to fire straight up (90° of weapon freedom), so 1,000kg of protected weapon takes up 1.4m^3 (since the weapon has 30° of freedom normally, we just get an extra 60° for an extra .4m^3). A cramped Soviet tank might have 15° less weapon freedom than normal, and 1,000kg of protected weapon would only take up .8m^3.

You could work out some tedious calculations on a power plant, power train and so forth to calculate turret rotation. However, **VDS** will assume a default turret can make one complete rotation each number of turns equal to the cube root of its total mass (loaded turret mass$^{.33}$), provided the vehicle has power. If there is no power, it must be turned by hand, which for tank-sized turrets will be very slow (loaded turret mass$^{.5}$). At TL's of 10+, if you double turret cost, you can double traverse speed, once at TL10 and once more for each TL past 10.

Example - A TL12 turret could be bought with x8 rotation speed for x8 cost.

Streamlining

This cuts the wind or water resistance of the vehicle, and may also add to its aesthetic appeal. You may have already calculated the base top speed of your vehicle. Now, you have to see how the medium it operates in will reduce that top speed.

Medium effects

Most of the streamlining calculations reduce the the ability of a vessel to reach high speeds. The denser the medium the vehicle moves through, the more surface drag there is, and the lower the speed at which there are significant drag effects. Vehicles lose 1m/sec from top speed for each multiple of the listed speed (round speed down), based on the medium they are travelling through and their level of streamlining.

Medium	Lose 1m/sec per
vacuum	n/a
	45m/sec
thin (high atmosphere air pressure)	32m/sec
	23m/sec
normal gas (sea level air pressure)	16m/sec
	11m/sec
dense gas	8m/sec
very dense gas/very light liquid	6m/sec
liquid immersion (submersibles)	4m/sec
gas-liquid interface (boats)	3m/sec
	2m/sec
	1.4m/sec
	1.2m/sec

Streamlining type	Modifier
None	+3 row
Minimum	+2 row
Basic	+1 row
Partial optimum	+0 rows
Optimum	-1 row

Example - A normal car with basic streamlining has a top speed for its power plant and power train of 30m/sec. Since it operating in air, it normally loses 1m/sec for each 16m/sec, but since it only has basic streamlining, this is dropped one row to 1 per 11m/sec. Since 30/11 rounds down to 2, the car loses 2m/sec from its top speed and drops to a maximum speed of 28m/sec.

Streamlining types

The following guidelines can tell what types of streamlining are appropriate for your vehicle.

None

The vehicle has no streamlining whatsoever, and the only surface panels are those which are part of the structure, or absolutely required for vehicle operation, like keeping rain off the engine. An old farm tractor is an example of this. Balloons are assumed to have *no* streamlining unless they have enclosed and protected gondolas, and in this case the streamlining still only applies to the gondola. A vehicle with no streamlining has no extra cost.

Note that at high speeds, any form of debris becomes a damaging projectile. A 10 gram chunk of gravel has the following DV at the speeds below.

Velocity	DV	Velocity	DV
20m/sec (72kph/45mph)	1	150m/sec (540kph/335mph)	6
40m/sec (144kph/89mph)	2	200m/sec (720kph/447mph)	9
70m/sec (252kph/156mph)	3	250m/sec (900kph/559mph)	11
100m/sec (360kph/224mph)	4	300m/sec (1,080kph/671mph)	14

Since a vehicle with no streamlining has no windscreen, this type of debris can range from annoying to fatal if you decide to make a brute force machine with this kind of top speed. This type of DV is comparable to what you would get from a larger but squishier bird impact, which could be catastrophic if hitting an aircraft windscreen or jet intake.

Minimum

The absolute minimum required to keep unrestrained passengers from falling out and keeping the weather off them and the cargo space. An old military truck or utility vehicle is a good example. Any form of streamlining greater than "none" gives the vehicle doors and windows appropriate to the norm for that Tech Level, ranging from portholes to safety glass. At a minimum level of streamlining, these doors and windows may be removable at no extra cost. Assume a mass for a door of .5m^2 of vehicle armor per door, window or door+window combination. This *does not* add to streamlining mass, but is considered part of it. Vehicle mass *is* reduced when they are removed, but the streamlining effect is also lost. A vehicle with minimum streamlining has no extra cost except for the armor or structural panels required to cover at least 5 of its 6 facings.

Example - You want a two-door utility vehicle with removable doors. When they are off, the vehicle is lighter, and the passengers have no side protection.

Basic

Some small amount of aerodynamic thought went into the outer surface of the vehicle. Passengers and cargo may be fully protected from the elements. A typical car is a good example. A non-maneuverable re-entry vehicle like an Apollo capsule may get by with this level of streamlining, and blimps and dirigibles are assumed to have basic streamlining. Basic streamlining multiplies the cost of all vehicle armor by x1.2.

Partial optimum

Aerodynamic considerations played an important part in the vehicle design. This is only worthwhile on fast vehicles. Partial optimum streamlining includes any extra cost required for retractable landing gear on any air vehicle. It would include similar considerations on other vehicles that operate in multiple modes as well, like retracting wheels on an amphibious car. A good example of this level of streamlining is a utility boat, cargo aircraft or sports car. Any vehicle capable of maneuvering during atmospheric re-entry must at least have partial optimum streamlining. This level of streamlining poses some design restrictions. A vehicle with this level of streamlining must be at least 3 times as long as its shortest other dimension, not counting any additions to a dimension caused by wings or rotors. Partially optimized vehicles have an armor cost of x1.5. Vehicles with partial optimum streamlining do not *have* to get sloped armor, but on box configuration vehicles, a slope of 45° would be appropriate (the vehicle could be generally tapered without actually being sloped armor).

Optimum

A design where minimum drag is the ultimate arbiter of vehicle shape. Any vehicle that can push itself to supersonic speed (≥300m/sec) *must* be optimally streamlined. This cost includes retractable landing gear and minor aerodynamic surfaces. A good example is a fighter jet, speedboat, most military ships or submersibles or a Formula 1 race car. A vehicle with this level of streamlining must be at least 5 times as long as its shortest other dimension, not counting any additions to a dimension caused by wings or rotors. Optimum streamlining is seldom used on mundane vehicles, as it requires compromises in passenger comfort, size, placement of cargo capacity and so on. Fully optimized vehicles have an armor cost of x2. Vehicles with optimum streamlining do not *have* to get sloped armor, but on box configuration vehicles, a slope of 60° would be appropriate (the vehicle could be generally tapered without actually being sloped armor).

To speed the calculation of any streamlining effects in an Earth-normal atmosphere or water environment, use the following table. Find the normal top speed of the vehicle, and then subtract as appropriate to get the actual top speed, based on the level of streamlining.

Normal top speed	None	Minimum	Basic	Partial optimum	Optimum
5m/sec	-0/-4	-0/-3	-0/-2	-0/-1	-0/-1
10m/sec	-1/-8	-1/-7	-0/-5	-0/-3	-0/-2
15m/sec	-2/-12	-1/-10	-1/-7	-0/-5	-0/-3
20m/sec	-3/-16	-2/-14	-1/-10	-1/-6	-0/-5
25m/sec	-4/-20	-3/-17	-2/-12	-1/-8	-1/-6
30m/sec	-5/-25	-3/-21	-2/-15	-1/-10	-1/-7
35m/sec	-5/-29	-4/-25	-3/-17	-2/-11	-1/-8
40m/sec	-6/-33	-5/-28	-3/-20	-2/-13	-1/-10
50m/sec	-8/-41	-6/-35	-4/-25	-3/-16	-2/-12
70m/sec	-11/-58	-8/-50	-6/-35	-4/-23	-3/-17
100m/sec	-16/-83	-12/-71	-9/-50	-6/-33	-4/-25
150m/sec	-25/-125	-18/-107	-13/-75	-9/-50	-6/-37
200m/sec	-33/-166	-25/-142	-18/-100	-12/-66	-8/-50
250m/sec	-41/-208	-31/-178	-22/-125	-15/-83	-10/-62
300m/sec	-50/-250	-37/-214	-27/-150	-18/-100	-13/--75
500m/sec	-83/-416	-62/-357	-45/-250	-31/-166	-21/-125

Example - A car with a designed top speed of 50m/sec and given minimum streamlining would actually have a top speed of 44m/sec, since it takes a -6m/sec from the poor streamlining.

Example - A 1,000kg speedboat with a pair of 200hp outboards (300kw total) has a normal top speed of 148m/sec (533kph/332mph), modified by x.5 to 74m/sec (267mph/166mph) by its power train type. If it was partially optimum streamlined, its top speed would be 50m/sec (180kph/1112mph) and if optimum streamlined it would be 56m/sec (202kph/125mph).

Wings

Wings are any type of external vehicle surface that provides lift (and usually a portion of directional controls). To get airborne, a vehicle will require a number of square meters of lifting surface equal to its loaded mass, divided by the kilowatts of power devoted to getting airborne. Any excess power can be applied to the climb rate. This area is *one side* of the wing for purposes of lift. For purposes of armoring or surfacing the wing, multiply this amount by 2.

Wing area in m^2 = (mass in kilograms/power in kilowatts used)
or
Power in kilowatts = (mass in kilograms/wing area in m^2)

Example - A 1,000kg airplane with $20m^2$ of wing (1.5m deep and 6.7m long on either side of the airplane) will require ($1{,}000kg/20m^2$) = 50kw of engine output to maintain level flight. If this plane had a 100kw engine, the rest of the output could be used to gain a climb rate greater than zero.

⚠ This lift figure applies only in an Earth-normal atmosphere. In other mediums, the power requirements will be different.

In other mediums in which wings or lifting surfaces can be used, apply the following modifiers.

Medium	Power requirement
Vacuum	lifting surfaces do not work
Extremely thin (Mars)	x5.0
Thin (>10,000m altitude)	x2.0
Normal (sea level)	x1.0
Thick (dense atmosphere)	x.70
Liquid (water)	x.10

Lifting surfaces have a mass per $1m^2$ equal to the same proportion of mass to surface area of the vehicle's structure, plus the mass of the armor or structure covering *twice* the appropriate wing area. For instance, say a vehicle with a mass of 10 tons and a pre-wing surface area of $100m^2$ has 1 ton of structure per $10m^2$ of area. So, wings will *also* have 1 ton of structure per $10m^2$ of area. The maximum wing loading is the maximum *safe* turn rate the vehicle can handle. That is, an aircraft that can handle a turn of 30 (3g's) in a turn will have wings that mass 3 times as much as those on an identical aircraft that can only handle a turn of 10 (1g).

Example - A large aircraft with a structure mass of 120 tons and an area of $1{,}500m^2$, plus $200m^2$ of wing will have 120 tons/$1{,}500m^2$ x $200m^2$ = 16 tons of wing structure. If it uses 2mm of TL10 lightweight structural material as wing surface, this will have a mass of (2mm/35kg for 10mm of lightweight structural material) x $200m^2$ x 2 (both sides) = 2,800kg for wing surface, for a total wing mass of 18.8 tons. These, by the way, are approximate figures for a TL10 airliner with a total mass of 300 tons, with a Turn of between 30 and 40. It would require about 1,500,000 watts (2000hp) of power to maintain level flight with a wing this size.

Because of turbulence, wind shear and other effects, lifting surfaces that can handle less than 3g's are not recommended. Assume that breaking the sound barrier requires wings that can handle 5g's of stress. Gossamer-delicate wings like those found on man-powered aircraft may only handle .1-.2g of stress, and a moderate wind gust can snap them. Assume each 1m/sec of wind gusts can exert as much force as a turn mode of 1 (.1g).

⚠ Anything you choose to hang off a wing like missiles or bombs or power plants will not alter wing mass, but very large items like power plants may interfere with lift on that section of wing, necessitating more wingspan to get the same surface area. That is, if you have a $1m^3$ power plant on a wing, you are probably giving up 1m of wing length and lift to put it there.

Stall speed

The stall speed of an aircraft is the minimum level speed at which its wings provide sufficient lift to overcome gravity. This is the (mass of the aircraft$^{.5}$/amount of wing area)$^{.5}$, times 50m/sec, round nearest.

Stall/takeoff speed = (Mass in kg$^{.5}$/wing area)$^{.5}$ x 50m/sec

This is also the takeoff velocity of the aircraft. Once it has accelerated along the ground to this velocity, it may become airborne and use any *spare* power to climb. Horizontal takeoff vehicles with an acceleration greater than gravity (like a jet on afterburners) must still reach this speed before they can use lifting surfaces to angle the nose upward and get off the ground unless they can takeoff from a ramped surface. For a basic idea of stall/takeoff velocities, see the table below. Wings can be optimized for certain speed regimes at a later point (like STOL or high-speed aircraft), and stall speed is adjusted by the same factor as power for different atmosphere types.

Aircraft	Wing area						
mass	10m^2	20m^2	40m^2	80m^2	150m^2	300m^2	500m^2
500kg	75m/s	53m/s	37m/s	26m/s	19m/s	14m/s	11m/s
1,000kg	89m/s	63m/s	44m/s	31m/s	23m/s	16m/s	13m/s
2,000kg	106m/s	75m/s	53m/s	37m/s	27m/s	19m/s	15m/s
4,000kg	126m/s	89m/s	63m/s	44m/s	32m/s	23m/s	18m/s
8,000kg	150m/s	106m/s	75m/s	**53m/s**	39m/s	27m/s	21m/s
16,000kg	178m/s	126m/s	**89m/s**	63m/s	46m/s	32m/s	25m/s
32,000kg	211m/s	150m/s	106m/s	75m/s	55m/s	39m/s	30m/s
64,000kg	251m/s	178m/s	126m/s	89m/s	65m/s	46m/s	36m/s

Approximate figure for a loaded F-15 fighter jet
Approximate figure for U-2 reconnaissance plane
Approximate figure for Piper Super Cub

Example - The previous vehicle had a mass of 1,000kg and 20m^2 of wing area, so its stall speed is (1,000kg$^{.5}$/20m^2 wing)$^{.5}$ x 50 = 63m/sec (226kph/141mph).

The top speed of an aircraft (even an optimally streamlined one) is reduced by the amount of wing surface. Subtract *twice* the wing area from the kilowatts of output of the power plant for determining maximum speed.

Example - Normal top speed for an air vehicle is (power x mass)$^{.6}$/mass, multiplied by 2 for an indirect to thin medium power train (like a propeller). So, normal top speed for our 1,000kg, 100kw output airplane is (100,000w x 1,000kg)$^{.6}$/ 1,000kg x 2 = 126m/sec (454kph/279mph). However, since engine output is reduced by 40kw (to 60kw) by the 20m^2 of wing drag, the *actual* top speed is (60,000w x 1,000kg)$^{.6}$ /1,000kg x 2 = 93m/sec (334kph/205mph). This would be further affected by streamlining. As a note, this airplane cannot operate at high altitudes, as its stall speed in thin atmospheres (>10,000m altitude) is going to be higher than its maximum speed.

Speed regimes

A wing *may* be optimized for a certain flight speed. The default wing gives you an *average* stall speed. You may alter stall speed by 1m/sec for each 1m/sec you alter the top speed in the same direction. The maximum change allowed is an alteration to top speed equal to the drag effect of the wings or halving the stall speed (round up).

Example - Our previous aircraft had a base top speed of 126m/sec, an adjusted top speed of 93m/sec and a stall speed of 63m/sec. The difference between base and adjusted top speed is 33m/sec, so we can adjust stall speed by up to +33m/sec or -31m/sec (halving the stall speed). We can adjust performance from a minimum of 32m/sec stall speed and 62m/sec top speed to a maximum of 96m/sec stall speed and 126m/sec top speed.

Variable pitch wings

These provide the benefits of two different speed regimes, giving a lower stall speed when swept forward, and a higher top speed when swept back. The machinery to accomplish this has a mass of 1% of the wing mass per 1% that top speed is increased, and requires a number of watts to power equal to its mass times the maximum velocity in m/sec it may be used at. Altering wing pitch takes 1 second per 100kg of total wing mass (including machinery). This time may be doubled or halved by doubling or halving the mass of the machinery. The maximum speed before streamlining effects is still the base top speed of the vehicle.

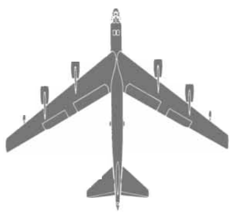
Example - A 10,000kg airplane with 45m^2 of wing (3m deep and 7.5m long on either side) will require (10,000kg/45m^2) = 222kw of engine output to maintain level flight. We'll say the wings have a total mass of 700kg. The plane has a stall speed of (10,000kg$^{.5}$/45m^2)$^{.5}$ x 50 = 75m/sec (268kph/161mph), and we'll say an adjusted maximum speed of 250m/sec (900kph/ 540mph). The designer wants variable pitch wings to increase top speed to 290m/sec (1044kph/ 626mph), or +40m/sec, an increase in speed of 16%. So, the increase in wing mass is 16%, or 112kg for the swept wing machinery. When fully swept back, stall speed is increased by 40m/sec, from 75m/sec to 115m/sec, but top speed is also increased, from 250m/sec to 290m/sec. The machinery to accomplish this draws 108kg x 290m/sec = 31,320 watts, or about 42 horsepower. This might seem like a lot, but it is swinging part of a 700kg wing forward against a 290m/sec headwind. Since the wings plus machinery mass 812kg, changing wing pitch normally requires 8 seconds.

Folding wings

Folding wings (or rotors) will increase the mass (and cost) of the wing structure by x1.1, but will halve the longest wing dimension for purposes of storing the vehicle. The energy and time required to fold/unfold the wings is as for a variable pitch wing at a speed of 1m/sec (i.e. watts equal to total wing mass in kg).

Wing profiles

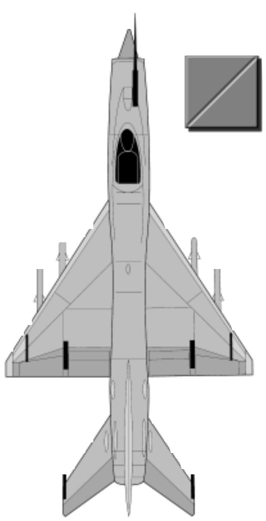
Once you have a given area of wing, the question remains as to what to do with it. Wings can be designed in a variety of configurations. The most common ones are below. The guidelines for dimensions are for your information, and are not carved in stone. For instance, all delta wings are not exactly at 45° angles, it's just that this makes calculations a lot easier.



Straight - The wings have a rectangular shape and stick out at right angles from the vehicle body, or at a slight angle. Normally they have a length to width ratio of 20:1 or less, with a -1 for each 50m/sec of maximum speed. Apply another -1 to the ratio for each .5g of wing loading, rounding both in favor of longer wings, and with a minimum length to width ratio of 2:1. Apply the surface area within these constraints to get the actual wing dimensions.

Example - A jet with a Turn of 40 and a top speed of 250m/sec has 50m^2 of wing area. The normal maximum length to width ratio is 20:1, with a -5 to this ratio for top speed, and -8 more for wing loading, making the adjusted maximum ratio 7:1 instead of 20:1. What remains is to find two numbers that have this ratio, and multiply to 50m^2. The answer is about 18.7m long and 2.7m wide, with half the length being on either side of the plane.

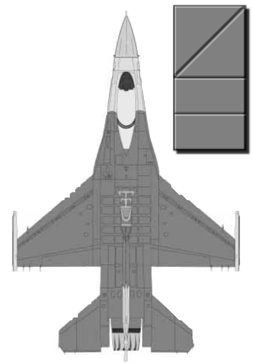
Special effects - The glide ratio of a plane cannot exceed the length to width ratio of the wings. There will not be any highly efficient stub-wing gliders out there.



Delta - The wing has a triangular shape, shortest at the front, and widest at the back. The wing dimensions for a delta wing with a 45° leading edge angle will be equal to the square root of total wing area.

Example - A delta wing of 50m^2 will be about 7.1m long and 7.1m wide at the widest point. The two wing sections are like a square that has been cut through a diagonal, and placed on either side of the plane.

A delta wing may be used at any speed the vehicle is capable of reaching, and the actual dimensions may be slightly stretched or shrunk to fit a given concept.



Truncated Delta - This is like a delta wing, but with the tips cut off, making it look like a combination between a straight wing and a delta wing. Divide the total wing area into two equal parts. Then make a delta wing from one of the parts, and apply half of the remaining part to each side.

Example - A wing with a total area of 50m^2 is made into a truncated delta. So, first you make a delta wing out of half the area (25m^2), or 5m long and 5m wide on each side. Then the remaining 25m^2 is split into a pair of 5m long sections, each of which ends up being 2.5m wide.

Other wing types can usually be considered variants of these three types. For instance, rhomboid wings can be treated as truncated delta wings with a rear slope as well as a front one. Or, a biplane would just be a pair of straight wings. Use your imagination.

Hydrofoils

Wings may be applied to water vehicles, and require only 10% of the power needed in air for a vehicle of the same mass (see table on p.55). If a vehicle has "water wings" sufficient to lift its mass completely out of the water, it is a hydrofoil, and uses "dense gas" numbers for streamlining purposes when "airborne". However, the vehicle must have a "gas-liquid interface" top speed high enough that its wings get it out of the water first. Hydrofoils *must* have wing loading at least equal to the gravity of the planet they are used on, and like airplanes, their maximum maneuverability is based on how much stress the "wings" can take.

Example - A 50 ton boat has hydrofoils that provide 55 tons of lift (base, plus a safety margin), and a calculated "stall speed" of 15m/sec. If the horsepower not devoted to generating lift cannot get the vehicle to a speed of 15m/sec, then the hydrofoil cannot get "airborne". If it can, then the *new* top speed of the vehicle is based on the revised drag level.

A hydrofoil has an altitude above the water equal to half the depth of the hydrofoils. This extra distance is not counted towards vehicle volume, but does increase the draft of the vehicle when stationary or not planing.

Example - A hydrofoil has a length of 10m, a width of 3m, and a depth of 3m. Its hydroplanes have a depth of 2m, so it skims at up to 1m above the waves (it can't "fly" if the waves are much more than 1m high). When it is not at hydrofoil speed, the planes extend an extra 2m below the bottom of the boat, making it less able to maneuver in shallow waters.

Hydrofoil rules can also apply to diving planes on a submarine, and can provide extra lift while in motion in case ballast tanks are damaged. Note that if a vehicle is designed such that they can be useful for lift, then they also produce drag which will reduce the top speed of the vehicle. Hydrofoils can use most of the other rules for wings, such as variable pitch wings, hardpoints, etc.

Helicopter rotors

Helicopters and other VTOL vehicles are a special case of wings. The rotor provides lift, forward propulsion *and* turn capability. This creates special design considerations.

Controls

The controls for a helicopter must be bought as at least "advanced" quality. This covers the cost for a *two*-bladed rotor. Each *blade* past this is the "advanced" multiple *again*, so a helicopter with twin *three*-bladed rotors would have the "advanced" multiple four times in addition to the base. Non-helicopter VTOL (**V**ertical **T**akeoff **o**r **L**anding) vehicles must be bought at "best" quality (**p.11** & **p.34**).

Lift

In order to hover, a helicopter or VTOL must have a vertical acceleration of at least 10, which counteracts Earth-normal gravity. VTOLs do this through normal power trains and special controls. The power requirements for helicopter and VTOL acceleration are the same as for other vehicles (**p.7**), but final acceleration is doubled for *vertical* lift. Helicopters have an indirect to thin medium power train as for a regular aircraft, but have *additional* mass for the rotor itself. Helicopters use a rotating wing which is both power train, surface treatment and controls rolled into one system. This rotor has a mass like a wing of the same area, stressed to either the maximum acceleration or maximum Turn of the helicopter, whichever is greater. This is designed exactly the same as a regular aircraft wing, i.e. the wing area/vehicle area ratio is the same as the rotor structure mass/vehicle structure mass ratio, and the rotor surface area is doubled to get the area needing to be surfaced (top and bottom of rotor blades).

Example - a 1,000kg helicopter requires 250kw to maintain an acceleration of 10 (hover).

Power in excess of that needed to hover may be applied to the climb rate, as per normal rules. The rotor must have a wing loading sufficient to handle the anticipated climb rate. Any spare power must be split between vertical and horizontal acceleration.

Rotor dimensions

Once you have determined the area of your rotor, you have to figure its dimensions. The rotor tip velocity is the "stall speed" of the vehicle. The top speed of any helicopter cannot exceed 300m/sec minus the rotor tip velocity.

Example - If our 1,000kg helicopter has $4m^2$ of wing area, it has a "stall speed" of $(1{,}000kg^{.5}/4m^2)^{.5}$ x 50 = 140m/sec. This means the rotor tips will be moving at 140m/sec, and the maximum forward speed of the helicopter cannot exceed (300m/sec-140m/sec) = 160m/sec (576kph/354mph).

The minimum length *per blade* of the rotor is based on this "stall speed".

Minimum blade length = "stall speed"/(# of blades$^{.5}$ x 20)

The minimum *blade* width is x.04 the *blade* length. Given these two numbers, you can figure out the best rotor for your helicopter.

Example - To keep costs down, we decide our 1,000kg helicopter only has a two-bladed rotor, so each blade has a length of 140m/sec stall speed/((2 blades)$^{.5}$ x 20) = 4.9m. This is a total rotor width of 9.8m, and with a blade area of $4m^2$, the blades are $4m^2$/9.8m = .41m wide, which is x.08 the blade length, well within allowable limits.

Tail rotors

A helicopter normally has a tail boom with a smaller rotor to provide sideways thrust to counteract the rotation of the main rotor. This is usually at a distance corresponding to the tips of the main rotor, whether a mechanical linkage is used, or whether the thrust is provided by an engine fan and air ducts. You can either design the vehicle to be that long in a standard length, or use a combination of configurations such that the smaller one is not less than x.2 the width of the larger. A helicopter with counter-rotating blades will not require a tail rotor, but will require at least enough blades to have a second rotor with the same number of blades as the first.

Example - A Box_1 configuration helicopter that was 3m wide could have a $Cylinder_1$ or $Cylinder_2$ configuration tail boom to get the length required in a more mass efficient way than having a single vehicle configuration that was normally long enough.

Another trick is to use the Wedge configuration in reverse, having a narrow tail and broad front to represent a tapered tail boom.

Tilt rotors

Vertical takeoff vehicles that can pivot their rotors/propellers forward for horizontal flight must have all blades at the "best" control quality to account for the extra cost of the machinery. In addition, such a vehicle will need wings capable of providing the lift needed when the rotors are providing none. VTOL's that rely on pivoting jet engines do not have this limitation.

X-wing or helicopters with variable geometry blades also fall into this category. An X-wing helicopter is one which can use rotating wings for vertical takeoff, and then lock the rotor into a fixed position like a normal wing, using a conventional power plant for forward thrust, and the now fixed wing for lift. An X-wing helicopter must have an even number of blades, with a width of at least x.2 the blade length.

VTOL notes

Vertical **T**akeoff **o**r **L**anding vehicles are usually configured like conventional aircraft, except they have enough thrust to fly straight up. They take off from a horizontal or vertical tail-down position, and land the same way. As mentioned earlier, VTOL's require "best" level controls to handle the delicate maneuvering required, and unless VTOL vehicles are the norm in a culture, they usually require a specific skill to operate. This control quality multiple is for being a VTOL and is *in addition* to the normal control quality.

Spoilers

These are aerodynamic surfaces placed on a land vehicle to increase traction. They are treated as wings in all respects, except that they may be of any size.

A land vehicle's Turn is dependent on sliding resistance, and sliding resistance is dependent on the downward force of gravity combined with the characteristics of the tires and the ground. If you increase the apparent weight of the vehicle by inverting a wing so that it pushes the vehicle *into* the ground rather than lifting it into the air, you increase the sliding resistance, and the Turn of the vehicle increases. However, this wing surface increases the drag on the vehicle, and adds mass.

Basically, each 1m^2 of spoiler generates 1kg of "push" for each 50 watts of power put into moving it, which subtracts from engine output for determining top speed, and each 10% increase in effective vehicle mass is a +.1 addition to the Turn multiple based on control quality and Tech Level (see Performance). A vehicle can have a maximum spoiler area equal to half its top armor area, and spoilers will cost and mass the same as extra armor on that facing. The maximum push of 1m^2 of spoiler is equal to the adjusted top speed of the vehicle before streamlining is taken into account.

Example - A 1,500kg car with a 200kw engine has an adjusted top speed of 65m/sec (234kph/144mph) before streamlining is taken into account. If the car has 2.5m^2 of spoiler, it can have a maximum push of 65m/sec x 2.5 = 162.5kg, or a little over 10% of vehicle mass, sufficient for a +.1 addition to the Turn multiple. A push of 65kg per m^2 x 2.5m^2 x 50 watts = 8,125 watts, so the adjusted top speed of the car is reduced by subtracting twice this amount from the power available, going from 200kw of power to 183.75kw of power.

Stealth technology

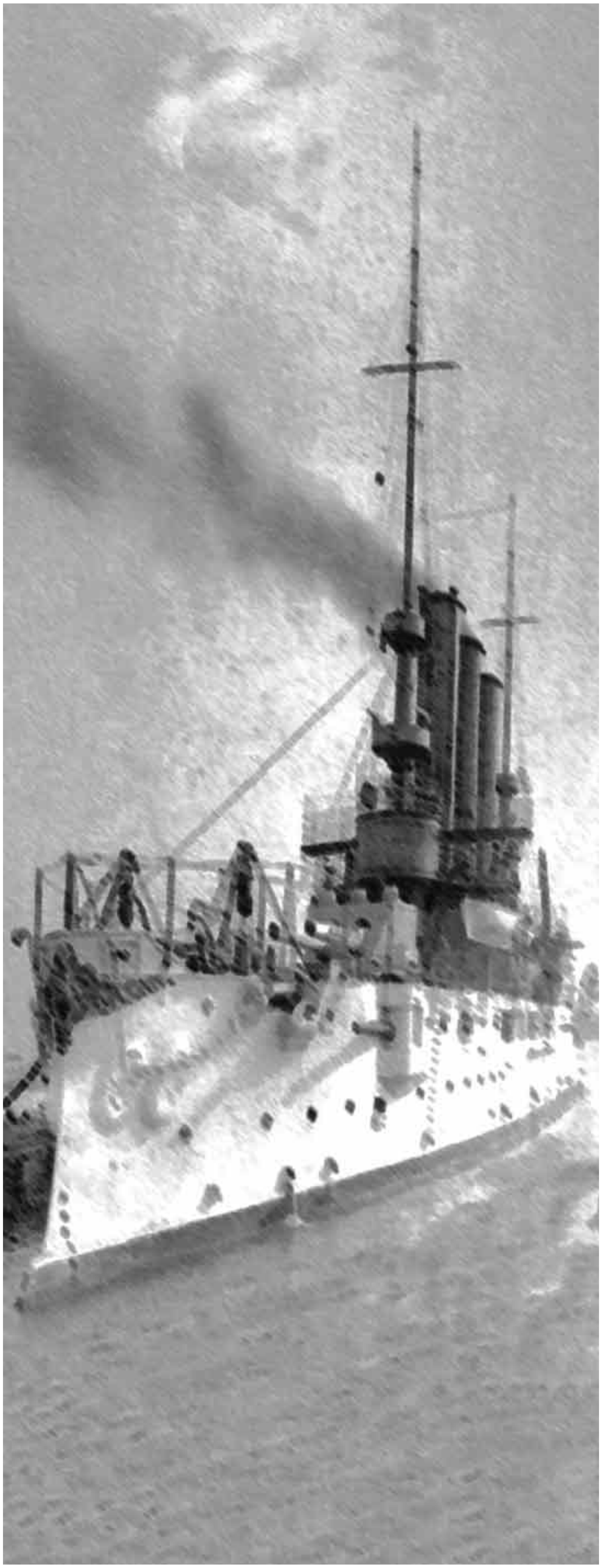
This is any part of vehicle design that makes the vehicle harder to detect with sensors of one or several types. If done as part of the design process, it is substantially more effective than if attempted on an already existing vehicle.

As part of vehicle design, if you apply a x2 cost on *all* the vehicle's surface treatments, you can reduce the size modifier of the vehicle by 1 vs. a *particular* type of sensor (radar, thermal imagers, etc.). You can keep doubling the cost to get protection against multiple sensor types, and keep doubling it to reduce effective size by -2, -3 or more. However, you cannot buy stealth technology vs. a particular type of sensor until the Tech Level *after* the sensor type first appears, and the maximum number of times you can reduce effective vehicle size is the number of Tech Levels past when the sensor *first* appeared, down to a minimum of the (base vehicle size modifier - 4).

Example - A new "stealth" fighter is a TL12 vehicle. Since radar first appeared at TL9, the biggest reduction in apparent vehicle size is -3 (-1 for each TL past TL9). This would make a vehicle that took up 250 hexes (-5 size modifier) look on radar screens like a vehicle that took up 4 hexes (-2 size modifier). Since cost of the surface treatments double for each -1 reduction in size, all the surface treatments of this vehicle cost x8 normal. This includes armor, streamlining, the rotor surface of helicopters, etc.

It is worth noting that claims a particular piece of stealth technology has the "radar signature of a tin can" are invariably made by either the company building it or the military using it, neither of which is really an unbiased source in the matter.

Note that the increase in cost for surface treatments also applies to *anything* attached to the *outside* of the vehicle (hardpoints and what is attached to them, for instance).



Boat hulls

A minimum "keep the water out" hull modification counts as a minor variation in pressure, and is an addition to mass and volume equal to x.05 the structure mass. Normally, a boat has to have armor or structural panels of some type (at least AV1) on all facings except the top, and most large water vessels of any TL will have a solid deck as top armor. This is not capable of absorbing any damage beyond the AV it has, and is just assumed to be watertight.

Does it float?

A vehicle will have a volume based on its configuration, plus that of any turrets or external structures. If the vehicle masses less than 1 ton per cubic meter, it will float. If it masses more than this, it will sink. The percent less than 1 ton per m^3 is the percent of the vehicle that is above the waterline. The depth below the waterline is the "draft" of the vehicle, and would be increased by any hull attachments like hydrofoil. Draft may vary with the load the vehicle is carrying.

Example - A boat with a volume of $100m^3$ and a mass of 40 tons will have 40% of its mass below the waterline.

How many hulls?

A boat can be built with more than one hull, and the hulls do not need to have identical mass, volume or structure. There are certain guidelines you *should* follow, and notes you should make.

1. Make sure the hulls have sufficient volume to perform their designed function. For instance, if the hull contains passenger accommodations, make sure there is sufficient width for the cabins and hallways to get to them.
2. If hulls are separated by a platform, it is considered to have the AV of the lowest hull armor, as appropriate. Increased AV will have mass based on the area of the platform.
3. A between-hull platform can be as thick or thin as desired. If thick enough to put vehicle components *in*, then both top and bottom are surfaces that may need to be armored.
4. If only one of the hulls mounts a ram, it must be the largest hull. All hulls can mount rams, but in a ramming situation, either ram damage is split between the rams, or only one of the rams is effective.
5. Separated hulls are automatically assumed to have a bulkhead between them for purposes of being watertight. Further bulk heads must bought *separately* for each hull.
6. For stability and performance purposes, the length and width of the vehicle are based on the distances from the tips and outside of the hulls that would give the *greatest* dimensions. This does not affect the ability of individual hulls to be highly streamlined.
7. Water vehicles usually have a maximum of three hulls, and vehicles with three hulls are usually symmetrical. Vehicles with two hulls can have hulls of equal size, or have one be larger than the other.
8. If half the hulls of a vehicle would sink due to damage, they will sink, and take the rest of the vehicle with them.

Submarines

A submarine is built as having cargo space that is devoted to water ballast, and a bulkhead to separate it from the occupied parts of the vessel. The mass of the submarine when they are empty should be less than 1 ton per 1m³ of submarine, and equal or more than that when they are full.

Example - A 900 ton submarine with 1,000m³ of internal volume masses less than 1 ton per m³, so it floats. If this 1,000m³ included 100m³ of empty space (ballast tanks), then if they were filled with water at 1 ton per m³, the submarine would mass 1,000 tons when they were full (equal or more than 1 ton per m³), and therefore it would sink.

The vehicle should *also* have cargo space devoted to compressed air storage. This air is used to blow the water out of the ballast tanks when the sub is submerged, allowing it to rise to the surface. The efficiency of compressed air storage is based on the Tech Level.

TL	atmospheres per m³	TL	atmospheres per m³
1	1	9	81
2	4	10	100
3	9	11	121
4	16	12	144
5	25	13	169
6	36	14	196
7	49	15	225
8	64	16	256

Example - A TL10 submarine can hold 100m³ of surface level air pressure in 1m³ of volume. So, if it had 100m³ ballast tanks, each 1m³ of storage would allow the sub to surface once.

Technically, you shouldn't be able to blow out tanks from a depth of greater than 10 meters times the number of atmospheres of pressure you can store, since the water pressure equals or exceeds the air pressure in the tanks. It takes 1,000 watts for 100 seconds to generate +1 atmosphere of pressure in 1m³ (or to pump 100kg (.1m³) of water against 1 atmosphere pressure or a vertical distance of 10m). A power plant that provides compressed air is required to pump these tanks back up once empty, or they can be partially refilled using other storage tanks. Design a compressor or pump as a power plant + generator for mass purposes.

Environment sealing

To seal a vehicle against the outside environment requires x.1 of the vehicle's structure mass and x2 cost, although this can be based on the percentage of mass that needs to be protected from the environment, rather than the entire vehicle. This protects against 1 level of atmospheric change and is a modification to the vehicle surface *in addition* to its normal armor or structural panels.

Example - A vehicle designed for an Earth-normal atmosphere with 1 level of environment sealing is protected from zero atmospheres of pressure through 2 atmospheres of pressure.

A vehicle which is only able to seal against *minor* variations in pressure requires only x.05 of the vehicle's structure mass and x.1 cost. This is sufficient to work in thin atmospheres, keep out toxic environments at the same pressure or make the vehicle watertight/airtight against pressure differences of less than 1 atmosphere.

An environmentally sealed vehicle must pay x.01 of the vehicle's *final* structure cost for *each* human-sized vehicle door or access panel than opens into the sealed area. This covers the extra cost of making the door or panel reliably air-tight. Even so, these doors or hatches are a weak link in the structure of the vehicle and a potential source of leaks.

A vehicle that is watertight in normal conditions is only marginally pressure sealed on its hull, and not pressure sealed anywhere else. A retrofitted watertight vehicle still has to pay x.1 extra for environment sealing. However, a vehicle designed as sealed to begin with is assumed to be watertight as well. That is, an ocean-going ship may be watertight, but not airtight, but a spaceship is both watertight *and* airtight.

As a side note for performance purposes, a pressure hull can withstand maneuvering stresses as though it were a *regular* structure of the same mass, i.e. the square root of the total structure (regular plus pressure hull) over the regular structure alone. So, a pressure hull with a *total* structure mass of 4 times the mass of a 1g structure could withstand 2g's of acceleration stress.

An atmosphere of pressure underwater is about 10m of depth. Each time the number of atmospheres is *doubled*, the structure mass must be paid again, otherwise the vehicle structure risks failure. Exceeding design depth counts as a maintenance interval for the hull, and failure is rolled for each time pressure increases (see **Campaigning**, **p.114**). While it does not *technically* increase the AV of the vehicle surface, each level of this effectively provides an inherent AV of 5 from the more closely space structural elements needed to distribute the pressure.

Example - A submarine rated for a depth of 160m would be withstanding 16 atmospheres. This is 3 doublings over 2 atmospheres, so the environment sealing would be x.4 extra structure mass rather than x.1 (following a 1-2-4-8-16, etc. progression). The submarine would have an inherent armor of 20 from this level of protection plus whatever the normal AV of the vehicle provided.

Am I Doing This Right?

Question #1:

What is the mass and cost of composite AV3 structural panels for a TL11 car that is 4.5 meters long? What would they cost if the car had basic streamlining?

Calculations:

Structure panels at TL11 have an AV of 16 per 10mm, so our panels will be 3/16 the mass of 10mm plating, or 1.9mm thick, with a *cost* like they were 5mm thick (minimum cost for armor, p.45). If the car is a Box_1 configuration it has an area of 2.2 x length^2 = 44.6m^2. Since 10mm of default armor has a mass of 50kg, the body panels have a mass of 3/16 x 44.6m^2 x 50kg = 418kg. Default structure panels cost 125Cr per m^2 that is 10mm thick, so the cost is 8/16 x 44.6m^2 x 125Cr = 2788Cr. If the car had basic streamlining, the cost would be x1.2, or 2788Cr x 1.2 = 3346Cr.

Answers:
Mass = 418kg
Cost for body = 2788Cr
Cost for basic streamlined body = 3346Cr

Question #2:

What would be the cost and mass of a fully articulated suit of lightweight TL12 armor capable of stopping a heavy assault rifle (AV20)?

Calculations:

This would have the mass of 2m^2 of TL12 lightweight armor. Since TL12 armor has a default AV of 37 for 10mm and we need an AV of only 10*, we need 20/37 this amount, which is a mass of 2m^2 x 35kg per 1m^2 of lightweight armor x 10/37 = 20kg. The cost is x2.5 for full articulation and x 2 for lightweight armor, or 2m^2 x 500Cr per 1m^2 x 2 for lightweight armor x 2.5 for articulation x 10/37 = 1,351Cr.

Answers:
Mass = 20kg
Cost = 1,351Cr

***Note** - Since you add a blunt trauma factor to the AV of worn armor, the final armor rating of the would probably be listed as an AV of 10/10 or 16/4 (which adds up to AV20).

Question #3:

If you have a 500kw jet engine in a 5,000kg aircraft, what are its final stall speed and top speed if it has 20m^2 of wings and partial optimum streamlining? If the aircraft has an area (sans wings) of 100m^2 and a structure mass of 1,000kg, how much does the structure of the wings mass?

Calculations:

The base speed of the plane is (500,000w x 5,000kg)$^{.61}$ /5,000kg = 108.1m/sec, x 2 for power train type = 216.2m/sec (778kph/484mph). However, the base speed because of wing drag is (460,000w x 5,000kg)$^{.61}$/5,000kg = 102.7m/sec, x 2 for power train type = 205.4m/sec (740kph/460mph). An air vehicle with partial optimum streamlining will lose 1m/sec per 16m/sec of top speed, so the adjusted top speed is reduced by 12m/sec to 193.4m/sec (696kph/433mph). Stall speed is not affected by streamlining, and is (5,000kg$^{.5}$/20m^2)$^{.5}$ x 50m/sec =94m/sec (338kph/208mph). Since wing area is 20% of the hull area (20m^2 vs. 100m^2), the structure of the wings has 20% of the plane's structure mass, or 200kg.

Answers:
Stall speed: 94m/sec
Adjusted top speed: 156m/sec
Wing structure mass: 200kg

Question #4:

What percentage of extra structure mass is needed for a submarine capable of reaching the deepest portions of Earth's oceans (≈11,000m)? What is the effective AV of the hull of this vessel?

Calculations:

If basic pressure sealing is x.1 structure mass, every 10m of depth is 1 atmosphere of pressure, and structure mass is doubled every time pressure is doubled, then we have to see how many doublings of 10m it takes to reach 11,000m. Ten doublings reaches 10,240 meters, but we need a little more than that, or 11 doublings. Using the 1-2-4-8 progression, 11 doublings of x.1 is x204.8 normal structure mass, and if each one gives an effective AV of 5, then the structure alone is +55AV to the vehicle.

Answers:
Additional structure mass: x204.8 normal structure mass
Additional structural AV: +55

Note - If the pressure hull was a 3.5 meter TL10 sphere stressed to an acceleration and Turn of 1, and loaded mass of the pressure hull was 36 tons, it would have a normal structure mass of about 148kg, and volume (composite *armor*) of .029m^3. With the x204.8 extra for pressure sealing, the total would be 30.5 tons and 6.1m^3 used for pressure sealing alone. However, the extra strength imparted would give the vehicle safety against an acceleration or Turn of up to 14 (the square root of the structure multiple).

7 Accessories

Basics

These are things that may make a vehicle more useful, (immensely so in some cases), but are not usually *required* for it to function in the role of moving from point A to point B.

Access and structure

This covers accessories related to getting people or goods in and out of the vehicle, or accessories related to its internal structural support.

Airlocks

Airlocks take $2m^3$ and 1,000kg per person of capacity. The inner door has the AV of the equivalent vehicle structure, and the outer door has the AV of the vehicle. Vehicles without airlocks must mix or vent the interior air mix with the outside whenever a door is opened.

Airlocks will attempt to conserve the environment within the vehicle to the extent that it is possible at that Tech Level. For instance, the airlock of a spaceship would attempt to put the air inside the airlock into pressure tanks before opening the outer doors. For simplicity's sake, assume that the airlock machinery also holds enough atmosphere in holding tanks to cycle the airlock TL times before needing recharged from other vehicle sources. How efficient and easy to use an airlock is depends on TL. A TL4 airlock might require that 17 bolts be manually unscrewed, while a TL15 airlock simply requires pushing a button and waiting 5 seconds. Assume it takes $(20\text{-}TL)^2$ seconds to fully cycle an airlock against a pressure difference (going from atmosphere to vacuum) and (20-TL) seconds to cycle with a pressure difference (vacuum to atmosphere) or in an emergency if you are not concerned about atmosphere conservation.

Airlocks cost 5,000Cr per $1m^3$, and this provides a seal against any pressure differential the structure of the vehicle can withstand. A simple zero-pressure differential airlock will cost and mass half as much. This would be something like a hostile atmosphere lock, where the air outside is not breathable, but at the same pressure as the inside air. All you need is a set of airtight doors and vents.

Bulkheads

These are interior partitions which have the same degree of sealing as the rest of the vehicle (watertight, pressure seals, etc.). They are usually built to coincide with major structural supports of the vehicle, but you can have as many or few as desired. Each one has a cost, mass and volume of x.01 of the structure cost, mass and volume, and protects 10% of the vehicle's interior volume from a structure or pressure breach elsewhere. The reason a vehicle will have bulkheads is to protect parts of a vehicle from mishaps in the rest. For instance, bulkheads can minimize fire damage, water entry or air loss from a hull breach, containment of prisoners, separation of cargo, and so forth. If a vehicle does not require structure for some reason, bulkheads will be x.001 of the armor cost, mass and volume each, and have an AV of x.05 the side armor of the vehicle.

Example - For an extra x.1 of vehicle structure mass, the entire vehicle interior may be protected, and no structure breach will affect more than 10% of the interior volume of the vehicle. If the vehicle structure was based on a vehicle AV of 6, then the bulkheads would have an AV of 6.

Naturally, bulkheads can't be so numerous that people can't move. A 2 person vehicle with $4m^3$ of interior space will probably only have one bulkhead (at most) in the crew compartment. In this type of case, it is usually pretty obvious how much of the vehicle is protected per bulkhead.

Bulkheads are assumed to have doors of equal strength. In large vehicles, a single bulkhead may represent *many* doors.

Example - An interstellar passenger liner may have 10 “bulkheads”, but the door to each passenger's quarters may also be an airtight seal in case the corridors lose pressure. Since the liner has 10 bulkheads, the internal volume of the vehicle is broken up into 10% increments, which restricts the amount of air lost in the event of a hull breach. It also can restrict movement of hijackers to 10% of the ship, or allow tear gas to be pumped into only 10% of the ship to disrupt them.

Vessels with mass at a premium may decide to only have one bulkhead, to protect the vehicle control section from the rest of the ship. That way, the cockpit can be kept pressurized or secure against intrusion.

Cargo

Cargo bays are any vehicle space that is available for the purpose. The only limits are the size of the cargo bay doors and the height, width and depth of the cargo carried. Powered cargo bay doors have a cycling time equal to the rotation time of a similar mass tank turret, and the mass of a cargo bay door is the area of the door in vehicle armor or structure AV, depending on whether the door is external or internal. External cargo door area cannot be used for other vehicle purposes except possibly heat sinks, which would require opening the cargo bay doors to have any effect.

Example - A 1,000kg cargo bay door will take $(1{,}000)^{.33}$ = 10 seconds to cycle under power, and $(1{,}000)^{.5}$ = 32 seconds to cycle manually. The normal power requirement for the door is (mass x 10/TL) watts.

Cargo cranes

A cargo crane would be counted as a **manipulator arm** with a strength as needed. A winch would be counted as an arm with a length of 1m and an AGL of 0. If used outside a vehicle, the length of the arm could be important, but inside the crane can simply run on tracks on the ceiling (or be a winch on tracks on the ceiling). For simplicity's sake, assume any *dedicated* cargo hold or hangar has a basic crane capable of lifting anything you can fit in the hold or hangar, the quality and sophistication of which will vary with TL.

Cargo rack

A cargo rack can be bought for any vehicle. The mass is (20/TL)kg per square meter of rack, times the acceleration in g's the cargo on the rack can withstand, with an equal cost in Cr. A square meter of cargo rack is sufficient to hold up to 50kg of mass per point of AV the vehicle has. The maximum area of a cargo rack is the upper surface of a vehicle, less any portion that must be clear for visibility.

In addition to the performance penalty from the mass carried, a vehicle is counted as having only basic streamlining if the cargo rack is used for virtually anything, as the carried items disrupt the airflow around the vehicle. The common-sense exception is that a cargo rack on a water vehicle does not disrupt streamlining on the hull, but could conceivably reduce top speed if the boat can go fast enough.

Catapults

Catapults are a vehicle deployment system designed to get a vehicle to a greater departure speed than it could manage on its own. To simplify things as much as possible, figure out the following:

How much "runway" length is available?
How fast does the vehicle need to be going at this point?
What acceleration does this require?

Now figure the mass, volume and cost of the power plant needed to generate this acceleration, and multiply it by 2. This is what you will need for the vehicle catapult. This is for a self-powered catapult (which will require its own fuel supply). If powered by a vehicle power plant, halve the size needed. Note that a catapult will damage any vehicle whose Turn or acceleration (whichever is largest) is less than the acceleration provided by the catapult. The catapulted vehicle will also need a pusher plate or tow hook with a mass based on the vehicle and the acceleration (see **Towing Hitch**, **p.66**).

Example - A 10,000kg jet needs to reach a speed of 70m/sec in a distance of 60m. We have to figure out the launch time to get the acceleration, and this time will be (2 x runway/takeoff speed) = 1.7 seconds. The acceleration needed is (2 x runway distance/time^2) = 41, or just a hair more than of 4g's of acceleration. To give a 10,000kg plane an acceleration of 41 requires a power of about 42,000,000 watts for those 1.7 seconds. If this is a TL10 catapult, it will have a base power output of 100w/kg, and a normal power plant would have an output of 100w x 4 = 400w/kg, and the power plant would mass 105 tons, times 2 is a total catapult mass of 210 tons. Historically, this would be a steam generator and piston assembly, and in **VDS** terms would consume about 5kg of fuel per use.

Docking ports

Spaceships and other vessels may have retractable docking ports that connect to access portals of other ships or space stations. These will mass 100kg per person that can comfortably walk abreast (1m wide x 2m high), per meter of length, and cost 1000Cr per meter of length per person. The minimum length is 1m. Volume is .5m^3 per meter of length per person that can walk abreast. Normally, the heavy stationary space station will have the mass of the docking port, while the ship will simply have an airlock. Docking ports provide minimum anchoring capability, and will not hold a ship against any significant acceleration. Docking ports that provide umbilical support to the docked vehicle cost 100Cr extra per meter of length per service provided (data, power, fluids, gases, etc.). Assume that a full-service umbilical link is an extra 500Cr per meter of length.

Example - A space station has a retractable docking port for passenger ships. It can walk three abreast, and extends up to 10 meters. So, in addition to the mass of the airlock, the retractable parts mass (3 people x 100kg x 10m) = 3000kg and cost 30,000Cr. If it had a full-service umbilical attached it would cost an extra 5,000Cr.

Docking ports on low tech spaceships can have a fractional person movement per turn, and this generally represents a crawl tube instead of a stand-up passageway. Gangways on naval vessels are bought the same way, and their mass includes enough strength to carry a mass equal to full occupancy in passengers in a 1g gravity well.

Drop tanks

This is a use of a vehicle hardpoint for carrying fuel instead of weapons. Drop tanks are external fuel tankage that can (usually) be discarded when empty. Their volume is *external* to the vehicle, and they are *not* protected by armor, although they might be protected by force fields. All regular hardpoint rules apply. The tank itself has a volume equal to the fuel carried, and a mass of the fuel carried x1.1. A drop tank costs 10Cr per kg of empty mass and generally has an AV of half the structure AV or half the vehicle AV, whichever is less.

Example - A drop tank for carrying 200kg of fuel will have a loaded mass of 220kg, an empty mass of 20kg, and a cost of 200Cr.

Water has a mass of about 1,000kg per 1m^3. Gasoline and other hydrocarbons have a mass of about 800kg per 1m^3. Liquid hydrogen has a mass of about 70kg per 1m^3 and liquid oxygen has a mass of about 1,200kg per 1m^3. Drop tanks are assumed to have the same level of streamlining as the vehicle they are mounted on, and if the cost of the vehicle is affected by streamlining, drop tank cost will be modified by the same amount (see p.54).

Firing ports

Firing ports allow weapon fire from inside a vehicle, without exposing the occupants to return fire. Fire out of a firing port is at +3 Difficulty because of the poor visibility and limited aiming ability. A firing port will cost 50Cr and have no appreciable cost or mass. It will be equipped with a small cover, and have a small panel of transparent armor appropriate to the Tech Level. Firing ports generally have a 60° horizontal and vertical arc of fire, and can't target things directly adjacent, above or below them.

Firing ports in a sealed vehicle are x2 cost, and those which can be used in a hostile atmosphere without allowing entry of noxious fumes are x4 cost. Firing ports cannot be used if there is more than a 1 atmosphere pressure difference between the inside and outside of the vehicle. In addition, the vehicle must pay the surcharge for access panels in a sealed environment vehicle (see p.61).

Hangars

Hangars are dedicated vehicle storage space, and are treated as cargo space with a few extra notes. Since vehicles are not designed for efficient storage like cargo crates, the volume required to hangar a vehicle, have access to it and move it in and out of the vehicle is x3 the actual volume of the carried vehicle. In terms of a floor plan, it can be considered a rectangular grid of hexes sufficient to hold the vehicle, plus half again as much for vehicle access/egress space. In addition, the hangar door must be at least 10% larger than the width and depth of the largest carried vehicle, and the rectangular area this represents is a part of the vehicle surface area that can't be used for other purposes except possibly heat sinks. Hangar doors have the same opening and closing times as cargo bay doors.

Hardpoints

Hardpoints are a structural attachment for items carried outside the vehicle, like drop tanks, bombs, missiles, etc. They have a mass of square root of (the carried item mass, times the **VDS** acceleration the carried item or vehicle is capable of withstanding x .05). They have no effective volume, as they are mounted on the outside of the vehicle, and a cost of 10Cr per kg. If a vehicle needs its hardpoints rated, use the mass x g's amount.

Example - A hardpoint for carrying a 100kg missile at a maximum acceleration of 5g's (Turn of 50) would mass $(100\text{kg} \times .05 \times 50)^{.5}$ = 16kg, and be called a "hardpoint 500". It could also hold 200kg bomb against an acceleration of 2.5g's or a 500kg bomb against an acceleration of 1g.

The cost and modifiers for hardpoints are below.

Hardpoint	Cost
Basic	10Cr/kg
Remote detach (missile release, bomb drop)	+5Cr/kg
Fuel/power link to vehicle	+10Cr/kg
Sensor/data link to vehicle	+20Cr/kg

Example - A fighter plane has a hardpoint capable of carrying a 50kg missile programmable by the plane's sensor data, and able to withstand accelerations of 10g by the plane. This has a mass of 25kg. This costs 10Cr/kg for the basic hardpoint, +5Cr/kg since the missile can be released, +20Cr/kg for the sensor link, for a total cost per kg of 35Cr, and a total hardpoint cost of 35Cr x 25kg = 875Cr. This hardpoint would probably also have a power link, in case the missile was replaced by a machinegun pod with electrical firing controls (a missile might have its own on-board power supply). This would cost an extra 250Cr.

Ladders

A generic item still needed for easy access to some vehicle types. A ladder will cost 20Cr per meter of length, and have a mass of 20kg/TL per meter, and a stowed volume of $.01\text{m}^3$ per kilogram. Vehicle mounted handholds or retractable or folding ladders are 100Cr per meter of length, but only take up $.01\text{m}^3$ per 5 kilograms.

Torpedo tubes

Torpedo tubes are basically airlocks for a volume just slightly greater than a torpedo. These will be treated as airlocks, and assume that the total volume is equal to double the volume of the torpedo. For most historical purposes (TL9-12) a torpedo tube and its machinery will be assumed to take up 2m^3. Torpedo tubes can be used by unencumbered people if the tube diameter is at least 50cm. The same rules can apply to missile launch tubes.

Towing hitch

Any sort of arrangement for the long-term towing (or pushing) of another vehicle will need to be mounted solidly to the frame of the towing vehicle. The mass of the towing equipment will be the square root of (mass of the *towed* vehicle, times the maximum acceleration the towing vehicle can safely manage x .02). Since Turn is a lateral acceleration, this will count if it is higher than the Acceleration of the vehicle. Towing hitches are external, and take up no internal volume on the vehicle. A vehicle being towed or pushed *also* requires a hitch, based on its own mass and the maximum acceleration of the towing vehicle. If electrical wiring, hydraulic or other hookups are part of the hitch, they are included in the mass and cost, as is any general structural reinforcement needed to handle the load. A hitch has a cost of 10Cr per kg of mass. Breakaway hitches are also possible. They usually have restrictions on ownership due to their nature. It is identical to a regular hitch, but can be instantly separated by a small explosive charge or other TL-specific means. It has a x5.0 cost but is otherwise the same.

Example - A TL11 car has a towing hitch for a 2,000kg trailer, and the car can manage an acceleration or Turn of 4 while towing. The trailer hitch has a mass of $(2000\text{kg} \times .02 \times 4)^{.5}$ = 12.6kg and costs 126Cr.

If a towed vehicle tows another vehicle in turn, *each* towing hitch will need to be able to handle the stress of half the *total* mass of towed vehicles, and the towed vehicles will require a hitch at each end.

Example - A TL10 locomotive tows 200 cars, each with a mass of 50 tons, at a maximum acceleration (loaded) of .1. Each car coupling will have a mass of $((50{,}000\text{kg} \times 100 \text{ cars}) \times .02 \times .1)^{.5}$ = 100kg, and cost 1,000Cr, times 2, since there is a coupling at each end of the car.

Remember that "towing hitch" is just a term and can also refer to structural reinforcement on a barge so that it can be pushed, modular latches for cargo pods on a space ship or interstage separators on a rocket booster.

Armor and protection

This covers accessories related to the surface treatments of a vehicle.

Force fields

Force fields of the “neat invisible field that stops everything except light and conversations” are not really possible at any pre-TL15 technology. Intense magnetic fields to deflect charged particles are possible at TL's of 13+, however. These are usually part of the basic vehicle design and concept (difficult to retrofit), and consist of a superconducting lattice in the vehicle surface that is charged and provides a very intense magnetic field within a few centimeters of the vehicle surface (x3 armor cost). This will tend to deflect any sort of charged particle or plasma, as well as most metal projectiles. It won't stop them, but it may force a more oblique impact or spread the energy of plasmas or beams over a wider area, often generating X-rays or other radiation as a side effect of this deflection.

You can pump up to 1 megawatt-second of energy into 1m^2 of shielded armor per TL over 12, squared, and the game effect is to increase the AV of any shielded facing by the energy in watt-seconds$^{.33}$ or the normal AV, whichever is less.

Once the armor is charged, it stays charged until a hit on that facing by an attack which would penetrate the shielding effect, at which point the magnetic field is depleted and must be recharged to have further effect.

Magnetic shielding of this level is *extremely* hazardous. Any living thing touching or coming within a few centimeters of the hull of a shielded vehicle will take a lethal damage equal to 1% of the shielding AV (round up), which is not affected by worn armor. The side effects of this much magnetic flux will give an extra Difficulty to all tasks performed by the vehicle equal to 1% of the shielding AV (round up), including firing weapons, using sensors, maneuvering and avoiding detection by sensors. The vehicle will emit a constant electromagnetic crackle that is distinctive and impossible to mask.

Technobabble force fields

We don't have any concrete ideas of how the typical science fiction “force field” might work. We can use electrostatic fields and charged particle energies to figure out how much it would take to deflect certain energy beams, but to absorb or deflect a gamma-ray laser? We have no idea. So, like many other **VDS** concepts, we're going to create a generic technology, and use as many other existing rules with it as possible.

Force fields will work as limiters and dampers, preventing any energy above a certain threshold from entering. At high thresholds, the normal movement of people and slow objects is unimpeded, but might allow a thrown grenade to get through. At low thresholds, light is dimmed, sounds are muted and even the motion of air molecules across the boundary is affected (so it could be a form of space suit!). In game terms, the user can set a DV threshold, and anything with a DV of that amount or more won't get through unless it has a DV high enough to breach the field completely.

A basic force field generator is .1m^3, masses 100kg and costs 10,000Cr. It will protect 1m^2 of area with an AV of TL^2, and consumes TL^3/10 kilowatts of power per second. The area protected can be increased by proportionately increasing the size of the generator, or proportionately decreasing the AV provided (round down). The maximum AV can be increased by increasing the power input and cost proportionately (up to x5). A vehicle can have separate force fields on different facings, each providing different protection.

Example - A TL13 100kg forcefield is mounted on a ground-car with 13m^2 of surface area. It provides a basic AV of 13^2 = 169, divided by 13m^2 = 13. It consumes 16.9 kilowatts of power per second of operation (about 22.5 horsepower).

Option: Spherical force field
For x.5 cost, a forcefield will protect only a spherical volume, which the vehicle must entirely fit inside. This does not affect the power requirements. Use the Sphere vehicle configuration with a length of the longest vehicle dimension to figure the area of this force field (see p.36).

Option: Contoured force field
For x2 cost, a forcefield is indistinguishable from the surface of the vehicle, and follows its every contour with near-perfect accuracy. A person with a total body+equipment mass of 200kg or less has an area of $\approx 2m^2$, and a personal force field has all its AV treated as soak value. A suit of powered armor will usually have an area in the 2-3m^2 range.

Example - A TL15 personal force field with a mass of 5kg (x.05 the default) will protect a human-sized area with an AV of $(TL15^2 \times .05)/2m^2 = 6$, will cost 5,000Cr, and consume 1,125 watts per second of operation. Using the battery rules for power plants (p.15), a 4kg TL15 battery holds 810 watt-hours of power, or 810w x 3600 seconds = 2,916,000 watt-seconds of power. Divided by 1,125 watts per second, this means the battery would power the force field for 2,592 seconds, or about 43 minutes.

Option: Limited force field
For x1 cost but x.5 power consumption, a forcefield will protect only vs. a *particular* type of attack, such as kinetic energy, charged particles, photons, carrier pigeons, etc.

These options allow you to tailor force field use to match a particular game world or technological background. Remember that magical force fields are also possible, and would follow the same rules. Also remember the optional heat dissipation rules. In the case of force fields, either the power source radiates heat normally through heat sinks, or the energy (and heat) is transferred to the force field, which will radiate it like a heat sink would and make the entire force field glow like a beacon on thermal scanners.

Retractable armor
This is geared more for espionage or covert vehicles, and is some form of movable armored panel that protects a vehicle only when needed. This can be for any facing or part of a facing desired. For instance, you could protect a glass windshield with a retractable steel plate, or protect the front seat of a car from the back with a retractable sheet of bulletproof glass. This form of armor *does* take internal vehicle volume, and requires volume equal to twice the armor volume, with a x2 cost multiple. The time to deploy the armored panel is the same as for a complete rotation of a vehicle turret of similar mass (see p.52).

Wheel skirts/tracks
This is secondary armor for the power train of the vehicle. Normally, the power train has its own inherent AV, which is applied vs. any hits on power trains with external components like wheels or tracks. You can get a x3 multiple on power train AV by applying a x1.2 multiple to its mass and cost. This represents armored skirts or other protection for these components, and would be noted on the design simply as "track skirts" or something similarly appropriate. List the *basic* wheel or track AV, but if that location is the initial result of a hit, there is a 50% chance the track or wheel skirt is hit instead, and you apply the increased armor value against the hit.

Example - A TL10 tank with an 800kw power plant will have a default power train mass of 100/TL10 = 10kg per kilowatt, or 8,000kg. This gives a default AV of $(8{,}000kg)^{.33} = 20$. For an extra 1,600kg, the tracks could be given armored skirts to cover many of the exposed parts, and if they were hit, the tracks would be counted as having an AV of 20 x 3 = 60. If however, the power train was hit as a secondary hit (after penetrating the power plant, for instance), then the skirts would not apply.

The multiple on mass and cost can be taken multiple times if desired. Each time after the first multiplies *all* power train components by x3. Wheel or track skirts may not have a greater AV than the sides of the vehicle.

Example - If the tank in the previous example put an additional x1.2 multiple on power train mass and cost, *all* power train components would have an AV of 60, and the track skirts would have an AV of 60 x 3 = 180. If the side armor was an AV of 150, then the tracks would still have an AV of 60, but track skirts would be an AV of 150 instead of 180.

Engines and Fuel

This covers accessories related to the power plant and fuel systems of the vehicle.

Refinery

This is a special purpose area for the purification of fuel (see p.44). The vehicle will either need multiple fuel tanks for the purified and unpurified fuel, or must process it directly from the source and put it into fuel tanks. The rate of purification depends on the quality of the fuel.

Concentration	Rate
Extremely dilute (fission, fusion, antimatter)	x.0001
Dilute	x.001
Average	x.01
Moderately concentrated	x.1
Concentrated	x1.0

Purity	Rate
Very contaminated	x.2
Contaminated	x.4
Average	x.6
Fairly pure	x.8
Almost pure	x1.0
Requires "isotopic separation" (fission, fusion, antimatter)	x.01

Tech Level	Rate
1-2	x.2
3-4	x.4
5-6	x.6
7-8	x.8
9-10	x1.0
11-12	x1.2
13-14	x1.4
15	x1.6

The base refining rate is 100kg of output per hour per 1m^3 of refinery per 100kg of input. The final rate is the actual output per hour per 100kg of input. Refinery plants will consume about 5kw of power per 1m^3 of plant.

A refinery only works for a very limited subset of fuels, determined when it is designed. A plant designed for extracting hydrogen from methane is not going to work for turning crude oil into gasoline, for instance. Likewise, certain refining techniques are only possible at certain TL's and above. For instance, while radioactive elements can be purified at TL8, specific isotopes can't be readily refined until TL9.

Example - You have a TL10 alcohol-powered vehicle, and an on-board still for turning plant matter into alcohol. If you take washed sugar cane and dump it in the hopper, you would say this is moderately concentrated and average cleanliness, so you would get 100kg x .1 x .6 = 6 kilograms of fuel per 100kg of input from a 1m^3 still per hour. Plants without a lot of starch or sugar would only be of average concentration and would generate .6kg per hour.

Refueling probes

These allow refueling while on the move. The probe and associated hardware will cost 10Cr, times the top refueling speed of the vehicle in m/sec (minimum of 1), times the number of kilograms of fuel that can be transferred per second, with a mass of 1kg per 500Cr of cost and volume of 1m^3 per 1000kg. The speed factor only applies for environments that can disturb the process (water, air). In space, assume a cost as for a maximum speed of 100m/sec. The vehicle supplying the fuel has apparatus that is x10 cost, x10 mass and x100 volume. This will allow refueling at any distance up to the longest dimension of the vehicle supplying the fuel, limited by the nature of the environment.

Example - A jet that can be refueled in mid-air at speeds of up to 100m/sec, with up to 30kg of fuel per second, will have a cost of 10Cr x 100m/sec x 30kg/sec = 30,000Cr for the refueling probe, pumps, valves, etc. It will have a mass of 30,000/500 = 60kg, and a internal volume of 60/1000 = .06m^3. The vehicle supplying the fuel has a refueling system that costs 300,000Cr, masses 600kg and takes up 6m^3, not counting the mass, cost and volume of the fuel itself. If the vehicle supplying the fuel was 80m wide, then the refueling could be accomplished anywhere within 80m behind any part of the vehicle.

Snorkel

This is typically a submarine modification that allows air-breathing power plants to work while the submarine is a short distance underwater. The full machinery to operate a snorkel will be counted as generator attached to the power plant (see p.18). The depth it can be used at is TL meters past the tallest point on the sub (e.g. a TL9 sub could have one 9m past the top of the conning tower).

Snorkels may also draw air into the vehicle, and negate the need for atmospheric life support while underwater. The snorkel itself is considered to be a target with a Size Modifier of +0, and has an AV like a vehicle sensor (maximum of one quarter the top armor in this case).

Redundant systems

Almost any vehicle system can have built-in redundancy, but it mainly applies to power plant and power train components. For an extra x.1 of mass and volume, and x.2 of cost, a system can have built-in backups to compensate for damage or malfunction. Each time you buy this system, you can compensate for a +1 impairment to the system in question. Switching to backup systems normally takes a full turn to accomplish (1 second).

Example - A tank with a single-level backup system takes a 2 point impairment to its acceleration and top speed. The built-in redundancy of the power plant (backup cooling pump, redundant fuel lines, reserve oil sump, etc.) mean the actual impairment is only 1 point.

Controls

This covers modifications to any vehicle subsystem which can be used to direct the course of the vehicle.

Cybernetic controls

Any vehicle which can be controlled by the thoughts of the wearer through TL13+ implants or magic will be counted as having an extra control station for the hardware involved.

Extra controls

Vehicles normally only come with one set of controls, for the driver, pilot or whatever. *Extra* sets of controls require x.1 of the power train mass, with a *maximum* mass of 50kg, and a cost like the power train mass. This presumes the same vehicle systems are used as the main controls, just that there is an extra steering wheel, control yoke, etc. Extra controls may be placed anywhere appropriate to the TL of the vehicle, and extra controls require the same internal volume as the regular control station.

Remote controls

Remote controls like an autopilot have the same mass as a set of extra controls. These provide a limited self-maneuvering capability, the sophistication of which depends on TL.

At TL's of 8 or less, it is usually restricted to maintaining a heading, so long as the controls aren't violently disturbed.

Example - Sail north by northwest, or sail at 45° to the wind.

At TL9, course changes can be programmed in for certain times or under certain conditions.

Example - Fly at 5,000m altitude on heading 135 for 76 minutes, and then trigger the bomb release switch.

At TL10, a complete programmed flight path can be managed, but with little ability to handle contingencies.

Example - Take off from known fixed coordinates, fly to coordinates 42.589N, -88.439W, dive to 10,000m altitude, disperse and detonate MIRV's.

At TL11-12, the accuracy is better than TL10, and can handle limited disruptions of its course and still get to roughly the correct destination.

Example - Take off from a moving vehicle, adjust course to take vehicle to the roof of the Iraqi Ministry of Defense and drop rude leaflets, diverting to avoid any ground-based radar emissions detected by at least 10km.

At TL13+, autopilots become good enough to handle sophisticated navigation tasks like getting somewhere on a crowded highway, while a TL12 unit might be able to manage if the road were empty and a TL11 unit would probably forget where the road was and try to go cross-country.

Remotely *piloted* vehicles are another matter. These have to have communications gear on board (p.81), and successfully completing a maneuver depends on whether or not the commands get through. This may require multiply redundant radios operating on different channels. The mass of the remote controls in the plane is the mass of this dedicated communications link.

The maximum skill that a remote operator can manage to use the vehicle with is the communication link's TL/3, minus 2 (round down). This represents the quality of the telemetry data and sophistication of the operator's display, which has a mass equal to an operator's station for that vehicle, plus any overhead for the communications link. The maximum usable skill can be increased by 1 each time you quadruple the mass of the remote operator's station, with a maximum bonus of +4 for 256 times normal mass. Extra control consoles on a *remote* console are the same mass as the base control console, but get the full extra bonus. Remote consoles consume power like active sensors of the same Tech Level.

Example - A large passenger jet has an extra control station mass of 50kg. At TL12, a remote control station also has a mass of 50kg, and lets the pilot operate the plane with a skill of up to TL12/3 - 2 = 2. If the maximum bonus were applied, the pilot would be able to operate the plane with a skill of up to 6, but the remote station would mass 12.8 tons and take up 12.8m^3. For a mass of 100kg more, you could have a copilot and navigator console, and instead of a remotely piloted plane, you could also use it as a training simulator.

Specialized running gear

Vehicles may have certain bits added on to allow use in particular environments. A regular aircraft equipped with pontoon landing gear or skis is an example.

This sort of addition can be defined by the user of the vehicle, and will generally have x.05 of the mass and cost of the vehicle *structure*, and the modifications *substitute* for whatever parts of the power train are not used as a result.

Example - Putting pontoons on a light plane adds mass equal to x.05 of the power train mass, *after* you remove the normal landing gear.

Running gear like skids on the bottom of a grav vehicle or helicopter is subsumed in the normal power train mass. A vehicle can *lose* its default running gear and gain a 5% savings on its structure mass. This will result in some complications when operating the vehicle. For instance, a glider might be equipped with a skid instead of landing gear. This will save some mass, but will increase the difficulty of landing safely.

Stabilizers

This is an enhancement to the power train of the vehicle, designed to provide extra damping so that the passengers or weapons are not jounced around by rough terrain or conditions. The maximum amount of damping a vehicle can have is its TL/3 (round down). Each point of damping masses x.1 of power train mass or .x.001 of vehicle mass, whichever is *larger* and takes up the same volume and cost for a given mass as the power train.

Conditions	Difficulty	Example
Calm	+0	Perfect
Slight disturbance	+2	Light wind
Moderate disturbance	+4	Heavy wind
Severe disturbance	+6	Storm
Extreme disturbance	+8	Hurricane

Example - A 10,000 ton TL11 passenger liner wants to keep passengers from having to hold their china and their dinners down in moderate seas, so they put in the best stabilizers they can (+3, since TL11/3 rounds to 3). The propeller power train for the 20 megawatt power plant (27,000hp) has a mass of 18.2 tons, so *each* +1 of stabilization will mass 1.82 tons. However, x.001 of vehicle mass is 10 tons, so *each* +1 of stabilization actually masses 10 tons, for a total mass of 30 tons.

For land vehicles the increase in Difficulty for a moving attack is the aim penalty for movement or the terrain rating, whichever is *higher*. In normal **CORPS** combat, any bonus from stabilizers also counteracts movement penalties for people firing from the vehicle. For military use, a vehicle will usually have sensors linked to weapons to decrease the Difficulty in addition to stabilizing the entire vehicle.

Environment control

This alters the internal climate of the vehicle in some way. Varying environments require different levels and types of protection.

Basic climate control

This alters the interior temperature over a + or -20°C range, so if the outside temperature were 0°C, temperature inside the vehicle could be increased to 20°C (or dropped to -20°C, if you wanted). Each aspect of temperature change (increase/decrease) is a separate system or has extra mass. The normal mass is 10kg per 1m^3 of protected passenger volume, divided by the TL, and consumes 100w per kg of mass, with a volume of 1m^3 per 1000kg and cost of 10Cr per kg. For larger temperature ranges, the system may be bought multiple times. A spaceship should have a system capable of handling a -80°C through +80°C temperature swing. Climate control mass and volume includes necessary ductwork and controls for the system. And, if you use heat dissipation rules, keeping a vehicle cool in hot temperatures will require heat sinks for the power consumed by the cooling system.

Example - A TL10 arctic runabout has 8m^3 of passenger space, and needs to provide up to a +80°C temperature shift. This is a base mass of (8m^3 x 10kg/m^3)/TL10, times 4 because you want 4 times the normal temperature shift, for a heater mass of 32kg. At 100w/kg, the heater draws 3200w from the power plant.

You can't have a climate control system that you can't rationalize in the context of the technological/magical background the vehicle is constructed in. For instance, you could rationalize a low tech heating system as a brazier and hot coals. A low-tech system that provides minimal airconditioning would be harder, but possible (fans and evaporative cooling). A low-tech system that keeps things really cold via machinery requires adaptation of high-tech principles that probably aren't known yet. The same idea applies to life support and other vehicle enhancements or equipment.

Remember that climate control is what is appropriate for the *users* of the vehicle. Plutonians might need a cooling system of -200°C to survive exploring the hellish (to them) temperatures of Earth.

The table below lists stats for basic climate control units per $1m^3$ of protected volume for *each* aspect of temperature control (heating/cooling).

Climate control	+/-20°C	+/-40°C	+/-60°C	+/-80°C
TL1	10kg/1kw	20kg/2kw	30kg/3kw	40kg/4kw
TL2	5.0kg/500w	10kg/1kw	15kg/1.5kw	20kg/2kw
TL3	3.3kg/330w	6.7kg/670w	10kg/1kw	13kg/1.3kw
TL4	2.5kg/250w	5.0kg/500w	7.5kg/750w	10kg/1kw
TL5	2.0kg/200w	4.0kg/400w	6.0kg/600w	8.0kg/800w
TL6	1.7kg/170w	3.3kg/330w	5.0kg/500w	6.7kg/670w
TL7	1.4kg/140w	2.8kg/280w	4.3kg/430w	5.7kg/570w
TL8	1.3kg/130w	2.5kg/250w	3.8kg/380w	5.0kg/500w
TL9	1.1kg/110w	2.2kg/220w	3.3kg/330w	4.4kg/440w
TL10	1.0kg/100w	2.0kg/200w	3.0kg/300w	4.0kg/400w
TL11	.91kg/91w	1.8kg/180w	2.7kg/270w	3.6kg/360w
TL12	.83kg/83w	1.7kg/170w	2.5kg/250w	3.3kg/330w
TL13	.77kg/77w	1.5kg/150w	2.3kg/230w	3.1kg/310w
TL14	.71kg/71w	1.4kg/140w	2.1kg/210w	2.9kg/290w
TL15	.67kg/67w	1.3kg/130w	2.0kg/200w	2.7kg/270w

Life support

To be effective, this requires a sealed environment surface treatment. Without sealing, the vehicle only provides protection against hostile environments at the same pressure, and then only if the vehicle has at least minimum streamlining (to provide a surface that can be sealed). Life support masses 20kg/TL for each $1m^3$ of volume or person supported, and provides breathable air as long as it has power and fuel. Note that people are assumed to take up $1m^3$ of volume. A ship with an indoor football stadium still only needs $1m^3$ worth of life support if the ship only has one occupant, it's just that the air will be stale and musty in spots.

Note that *life* support is different than *temperature* support. If our lonely spacer wanted to walk around their empty ship without a spacesuit, the *full* volume would need to be temperature supported to a range they could tolerate.

Life support consumes 100w per kg of mass, costs 100Cr per kilogram and has a volume of $.001m^3$ per kilogram ($1m^3$ per ton). In addition, life support usually consumes an amount of fuel (supplies) equal to normal fuel consumed by a normal power plant of the same mass at that Tech Level.

Example - A TL13 hostile environment rover has $4m^3$ of passenger space, so it requires ($4m^3$ x $20kg/m^3$)/TL12 = 6.7kg of life support. This is probably a set of atmosphere sensors and chemical scrubbers to remove impurities. Fuel consumption of a normal 6.7kg power plant is .67kg/hour, so in addition to the electrical power required, the life support will go through (24 hours x .67kg/hour) = 16kg of consumables per day. This will be cylinders of compressed oxygen, new chemical scrubbers, etc.

You can reduce power and consumables to an amount appropriate to the number of occupants. A vehicle with life support for $10m^3$ can support $10m^3$ of volume full of people. If only one person is in the vehicle ($1m^3$), then you can turn the power and supply consumption down to 10% of normal.

Life support	Normal per $1m^3$	Supplies /day	Regen. per $1m^3$
TL1	20kg/2.0kw/2KCr	48kg	40kg/4.0kw/20KCr
TL2	10kg/1.0kw/1KCr	24kg	20kg/2.0kw/10KCr
TL3	6.7kg/670w/670Cr	16kg	13kg/1.3kw/6.7KCr
TL4	5.0kg/500w/500Cr	12kg	10kg/1.0kw/5.0KCr
TL5	4.0kg/400w/400Cr	9.6kg	8.0kg/800w/4.0KCr
TL6	3.3kg/330w/330Cr	8.0kg	6.7kg/670w/3.3KCr
TL7	2.9kg/290w/290Cr	6.9kg	5.7kg/570w/2.9KCr
TL8	2.5kg/250w/250Cr	6.0kg	5.0kg/500w/2.5KCr
TL9	2.2kg/220w/220Cr	5.3kg	4.4kg/440w/2.2KCr
TL10	2.0kg/200w/200Cr	4.8kg	4.0kg/400w/2.0KCr
TL11	1.8kg/180w/180Cr	4.4kg	3.6kg/360w/1.8KCr
TL12	1.7kg/170w/170Cr	4.0kg	3.3kg/330w/1.7KCr
TL13	1.5kg/150w/150Cr	3.7kg	3.1kg/310w/1.5KCr
TL14	1.4kg/140w/140Cr	3.4kg	2.9kg/290w/1.4KCr
TL15	1.3kg/130w/130Cr	3.2kg	2.7kg/270w/1.3KCr

A regenerative life support system recycles its supplies, and is preferred for long-duration missions. It has x2 base mass and volume, and therefore x2 power consumption, but it uses *no* supplies. Regenerative systems cost x10 as much per kg as normal life support. Regenerative life support systems *may* use solar power if sufficient window area is provided, at 10% of the incoming light level. In the habitable zone, normal solar power would be 1kw per $1m^2$ of window space, for an *effective* power of 100w per $1m^2$ of window. This type of system will have a volume of not less than $1m^3$ per $10m^2$ of window, but mass and cost are unaffected.

The "solar power" option for regenerative life support (i.e. plants) is probably the only practical regenerative system available at TL12 or less. So, it will take up a large amount of volume compared to a regular regenerative system ($.33m^3$ vs. $.003m^3$ per person at TL12), but operates on well-known principles rather than being a technobabble "black box" that takes in waste and gives back pure air and water.

Note that an organic food recycling system with plants can be used as part of a life support system, and will produce an amount of "fuel" equal to and *in addition to* the food it produces. These are used up as they are produced and cannot be stored for later need.

Example - A TL12 hydroponic garden producing 7.2kg of food per day would also contribute 7.2kg to any supplies needed by a life support system. That life support system would still require power to operate, but the supplies consumed would be reduced or negated, depending on the load.

Food & water

Almost all Tech Levels have managed to find a way to reduce the bulk of foods for transport, usually by dehydration or other means of concentrating the nutritious parts. So, the minimum mass and volume of food doesn't vary all that much with TL, just the palatability of it. Water requirements for occupants are pretty much fixed by their biology, and how much you need to carry depends on circumstance and TL. If a low-tech sailing ship is going through an area where it rains every other day, you obviously don't need as much water storage as you would if it didn't rain at all. If you have a full life-support system to recycle water, you don't need to carry a surplus unless you want to.

Assume that each 100kg of crew, passengers or biological power plants requires “fuel” per day based on their activity level, half of which can be food, and half water.

Activity level	Fuel required
Low	2kg
Normal	4kg
High	8kg
Very high	12kg

This fuel will have a volume of $1m^3$ per 1,000kg, and cost 2,000Cr per 1,000kg. The default cost means the food is nothing special. Higher cost improves quality, variety and possibly nutrition. Space dedicated to food and water storage may be climate controlled for perishable foods.

At any TL, some of “food storage” can be devoted to “recyclable” food, like a hydroponic garden on a spaceship. It is some means of using the space to turn part of the vehicle's waste back into food. Each $1m^3$ of recyclers will produce .01kg of “fuel” per day, times half the TL squared.

Example - A TL12 space station has a $10m^3$ volume devoted to hydroponic gardening. This will produce $10m^3$ x .01kg x $TL12^2/2$ = 7.2kg of food per day, and cost 20,000Cr. It produces almost enough food for two people to live on, or perhaps to provide homegrown fruit or vegetables at one meal per day for six people. In addition to the food, it also produces the equivalent of 7.2kg of TL12 life support supplies.

Maintenance

Maintenance accessories are useful to keep a vehicle in good working order, or to repair malfunctions or damage.

Spare supplies

A set of tools suitable for performing maintenance on a vehicle will have a mass of the (power plant + power train)/50 and cost 10Cr per kg, with a volume of $1m^3$ per 2,000kg. Ignore the mass of a biologic power plant unless maintenance tools are appropriate for a particular biologic power plant (like curry combs and hoof files for a horse).

Example - A car with a 100kg engine and 200kg power train will have basic tools that mass (100 + 200)/50 = 6.0kg and cost 6kg x 10Cr = 60Cr.

These tools are sufficient for one person to perform normal maintenance on the vehicle, so long as nothing is broken. A complete set of specialized repair tools will mass four times as much, but includes every tool needed to disassemble and reassemble any part of the vehicle that can be taken apart. Normally, maintenance requires spare parts, but you can sometimes get away without them...once. Spare parts for a maintenance interval have the same mass as the tools.

Example - A car might require new filters, motor oil, spark plugs, radiator fluid, axle grease, etc. This is all part of normal maintenance for that type of vehicle.

Parts to actually repair broken components are another matter entirely. “Generic” spare parts have a mass equal to double the maintenance tool mass. If spare parts are necessary, roll 1d10. If the number is equal or less to the units of “generic” parts you have, among them is the part you need, and one unit of spare parts is used up. Otherwise, you're out of luck. However, a unit of spare parts may be bought for a *specific* repair, in which case the roll is *automatically* successful, and that unit of parts is automatically consumed.

Example - If you have one unit of “generic” spare parts and get a flat or a busted radiator hose, you only have a 1 in 10 chance of having a patch kit or spare hose and clamps. If you bought your generic parts as being a spare tire, you *automatically* have a spare tire, but no chance of having parts for any other repair.

Miscellaneous

These are accessories that don't really fit into any of the other categories.

Computers

Computers of a technological nature are possible at TL9+, and can be used for vehicle automation or as an adjunct to certain skills. Computers will have a rating, which is their AWR for purposes of using skills (programs) or analyzing data. A rating 0 computer at TL9 has a mass of 1,000kg. Each TL past 9 divides the mass by 10, and each rating past zero multiplies mass by 8. The maximum rating a computer can have is its TL-8. Computers have a volume of $1m^3$ per 1,000kg, and a cost of 100Cr per kg. Removable or portable computers have half the mass, but cost four times as much. They can be removed from a vehicle to be hooked up to other equipment, or transferred from vehicle to vehicle with little modification required.

TL	Rating 0	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5
9	1,000kg	8,000kg	-	-	-	-
10	100kg	800kg	6400kg	-	-	-
11	10kg	80kg	640kg	5100kg	-	-
12	1kg	8kg	64kg	510kg	4100kg	-
13	.1kg	.8kg	6.4kg	51kg	410kg	3280kg
14	-	.1kg	.6kg	5.1kg	41kg	328kg
15	-	-	.1kg	.5kg	4.1kg	33kg

Computer designed for a specific task	+1 rating
10 computers linked together	+1 rating
100 computers linked together	+1 rating

Acting on its own, a computer can use its inherent AWR to analyze data from sensors, and use any skills (programs) to operate linked vehicle equipment with an AWR or AGL equal to its programs. Since the rating is counted as AWR, programs cannot have a Primary skill of more than the rating. Secondary and Tertiary skills are treated as they would be for a character. All but the most trivial programs have a cost *to develop* of their $(rating+1)^2$ times 10,000Cr. Cost on the open market will vary with the distribution of the program. Secondary and Tertiary programs use their bonus instead of overall rating.

If a computer is expected to do more than one thing at once, it loses a point of rating for each task after the first. The time it takes a computer to process a task depends on its complexity. For most purposes, this is counted as it would for normal task resolution. If a character uses a computer as an "assistant" in some task requiring genuine intelligence (as opposed to brute computing power), the rating of the computer will decrease the Difficulty of the task in question, up to a maximum of half the user's AWR (round down). If a computer is expected to be genuinely intelligent (an AI), use its rating, but subtract 2 to take into account the computational overhead required. An AI can engage in thought and creative processes the same as any character, and will possess a personality and have the same possibilities and liabilities of a human mind. An AI's basic programming is ten times the cost of a regular program, but with this, it is capable of self-learning at x100 a character's rate if access to outside knowledge is available. An AI can have access to up to its AWR cubed in skill points at any one time, but can have virtually any amount in off-line storage that it can swap in and out as needed. This limit does affect the ability of the AI to simultaneously work on problems in different fields.

Example - A bank of 100 TL15 rating 5 computers, each designed for AI work, would have a total rating of 8, and an AI based on them would have an AWR of 6 and be able to have immediate access to up to 216SP worth of AWR-based skills. A character with an AWR of 8 using this computer as an assistant would have a -4 on the Difficulty of whatever task they were trying to accomplish, and the AI would be able to work on the task independently from the researcher.

Using these rules, a humanoid AI robot with usable intelligence (AWR of 3+) is not possible until TL14+.

Manipulators

Manipulators are mechanical arms for doing work outside the vehicle, usually because the environment is too hostile, or because the work is too large to be done manually. In this sense, a backhoe scoop is a manipulator, as is a sampling arm on a deep-sea submersible.

Manipulator arms cost 10Cr per kg. The default AGL of a manipulator is the TL/4 (round nearest), which limits the maximum Primary skill that it can be used with. The STR of the manipulator is based on its mass and the power in watts devoted to moving it. This STR is $((power/length)/10)^{.5}$. The *maximum* length of a manipulator arm is the (Tech Level x mass)/(STR x 10). Conversely, if you know the length you want, its mass is (STR x length x 10)/Tech Level.

Example - A TL10 hydraulic arm with a 20,000 watt power source (27hp) and a length of 5m will have a STR of $((20{,}000\ watts/5m)/10)^{.5}$ = 20. The mass of this arm would be (STR 20 x 5m x 10)/Tech Level 10 = 100kg.

A person using a manipulator arm takes penalties to their skill based on the encumbrance the arm is experiencing. So, while a STR 20 manipulator arm can theoretically lift (STR^2 x 5) = 2,000kg, the operator of the arm would be taking a +10 Difficulty to tasks involving the arm if it is fully loaded.

Also, a manipulator can't effectively move objects that mass more than the vehicle, or which unbalance it due to center of gravity problems.

A manipulator arm can get a +1 to its AGL for each doubling of cost, or take a -1 to AGL for each halving of cost. A manipulator may have submanipulators, which count towards the mass of the main manipulator, but which may have a better AGL. So, you could have a low AGL battering ram with a lockpicking hand at the end if you so choose.

A manipulator arm may be "powered" by a person. Each limb of a person is assumed to have a quarter of total power output for this purpose. An 80kg person has a normal power output of 720w. If they used one arm to move a manipulator, it would be counted as having up to 180 watts of power.

Manipulator arms can be used to generate earthmoving blades (high STR, low AGL), mobile folding bridges (count STR as what it can carry, and length towards how far it can bridge), and a host of other extendible vehicle fittings. A suit of powered armor would use a legged power train, personal armor rules, manipulator rules for the arms, and regular equipment for the electronics. For combat purposes, the maximum level of an AGL-based skill that could be used is the *lowest* AGL of any part of the manipulator.

Retractable items

Some vehicle components are retractable by default, like landing gear on a highly streamlined vehicle. Any vehicle component which is not retractable by default may be made retractable. It probably cannot be used in this state, but it *is* fully protected by vehicle armor. Basically, double the cost of the item, and increase the volume and mass it takes up by x2. This covers the space, cost and mass of the extra equipment required to move the item and lock it into place. If the time to deploy or retract the system is crucial, assume the time in seconds is the cube root of the total item mass in kilograms (like for turrets, **p.52**). This is for "military" items. Civilian technology is more concerned with *not* crushing people who happen to be in the way, so these will take 2 times as long.

A convertible is a vehicle with a percent of the structure mass (say the top armor fraction) being "retractable". Movable car windows are freebies, and not considered any special type of vehicle accessory.

Safety

Safety accessories enhance the security of the vehicle or the safety and survival of the occupants or their possessions.

Component armor

If you want to armor just part of a vehicle, or a particular vehicle component, you can do so. Use the volume of that component, and use its shape to figure its dimensions. If you don't have a shape in mind, assume it is cubical. Then purchase armor for the desired facings to whatever level you want. Unlike regular armor, this *will* take up internal vehicle volume.

The effect of component armor is that its AV will add to the AV of anything protected, *if* that vehicle system is hit.

Note that certain vehicle components cannot be effectively armored, like sensors, which must have an unobstructed view. Tires, wheels, legs and tracks can have armored skirts to protect them (see **p.68**).

To repeat the component volumes for your convenience, most vehicle components have one of three densities. Lightweight systems are those that have a lot of free space around them, like vehicle suspensions (power train). These mass 500kg per $1m^3$. Power plants and other average components are assumed to mass 1,000kg per $1m^3$. This includes the airspace around the component to provide room for maintenance. Components that are tightly packed into a space will have a mass of 2,000kg per $1m^3$, which results in a more compact vehicle, but one which is much harder to perform routine maintenance on.

The visibility of component armor depends on the TL and the vehicle system being armored. Armoring wheels is going to be visible unless you have bullet-proof tire technology, but you can armor the inside of an engine compartment without too much worry it will be seen.

Individual crew or passenger stations in a vehicle may also have armor to protect the occupant. This is usually an option on unarmored vehicles where some protection is desired for key personnel (like a helicopter pilot), from limited arcs (like ground-based fire at the underside of the helicopter). On dedicated combat vehicles, any personal armor is not likely to help much if damage gets through the main vehicle protection.

Armor for a single human passenger will have an area of $2m^2$ if it protects in all arcs except a 60-120° forward visibility arc. A full cocoon would be $3m^2$ if it allows use of controls, or $2m^2$ if it is a tight fit and acts more as a "passenger safe".

The volume of this protection is assumed to be the same volume as the passenger accommodation, and the mass of 2m^2 of various AV's at different TL's is below.

TL	AV3	AV5	AV10	AV15	AV20	AV30
1	300kg	500kg	-	-	-	-
2	150kg	250kg	500kg	-	-	-
3	100kg	170kg	330kg	500kg	-	-
4	60kg	100kg	200kg	300kg	400kg	600kg
5	45kg	70kg	145kg	210kg	290kg	430kg
6	30kg	50kg	100kg	150kg	200kg	300kg
7	25kg	40kg	75kg	115kg	150kg	230kg
8	17kg	30kg	60kg	90kg	120kg	180kg
9	14kg	25kg	50kg	70kg	95kg	140kg
10	12kg	20kg	40kg	60kg	75kg	115kg
11	10kg	16kg	30kg	50kg	65kg	95kg
12	8kg	14kg	25kg	40kg	55kg	80kg
13	7kg	12kg	23kg	35kg	45kg	70kg
14	6kg	10kg	20kg	30kg	40kg	60kg
15	5kg	9kg	18kg	25kg	35kg	55kg

The mass listed is for a composite armor (the default). If the final armor thickness is more than 20cm, then you should probably take the armor volume into account, as it will begin to be a significant part of internal space. If some of the numbers seem a little off to you (except for the *really* low tech ones), consider that a bullet proof vest is about quarter of a square meter (one-eighth the above amounts) and made of lightweight materials (x.7 mass), so a TL11 vest that would stop a .44 Magnum (DV of 10) would mass 3.5kg, close to what it does in the real world.

Disaster system

This is a system to mitigate the effects of the disaster of your choice (within reason). Typically, it is a whole-vehicle fire extinguisher system, but could also be remote controls on the doors to seal off areas of atmosphere leakage, anesthetic gas to stop intruders, and so on.

In general, such a system has a minimum volume of x.001 of vehicle volume, with a mass of 1,000kg per 1m^3 and cost of 10KCr per 1m^3. This gives an effective "skill" of TL/2 vs. the disaster (round up). The skill can be increased by 1 each time the volume of the system is doubled. The disaster will have a Difficulty based on type and severity.

Disaster	Difficulty
Minor, small part of vehicle involved	4
Average, at least two vehicle systems involved	6
Major, several vehicle systems involved	8
Minor hazard type	-1
Average hazard type (fire)	+0
Serious hazard type (intrusion)	+1
Very serious hazard type (biological, radiation)	+3

The system can be set to a certain Difficulty threshold, and won't activate until that threshold is reached. For instance, you don't want your starliner anti-intruder system to gas the entire captain's lounge because two first-class passengers got into a brawl. Similarly, the threshold can have certain responses. A slow pressure leak might send an alert to the bridge, but take no action, while a major breach might automatically close all ship pressure doors without regard as to whether people are on the side that is going to vacuum.

The system rolls its skill vs. the Difficulty immediately and each 10 seconds after a threshold is reached. Automatic success is a routine containment of the hazard. A rolled success means the hazard is contained and no further rolls need to be made. A marginal success means the Difficulty of the hazard is reduced by 1, but continued rolls may be necessary. A roll of 10 means the hazard went undetected or that countermeasures were ineffective and the Difficulty increases by 1.

Note that certain types of disaster systems have certain technological thresholds before you can use them. Automatic water pumps on a ship are impossible if there is no power source to run them.

Escape devices

This is a generic term for some device designed to get a vehicle occupant safely out of the vehicle in the event it is in imminent danger of being destroyed, or protect or mitigate the damage caused by vehicle destruction. Personal armor seldom protects against this type of catastrophe.

Minimal escape device

Some sop thrown to occupant safety that does not actually have much chance of working. Following instructions correctly gives the occupant a skill of the TL/10 (round nearest) vs. the amount of damage they are likely to suffer from the failure of the vehicle. Success means the occupant takes no damage, and failure means they take an overall lethal impairment of +1 per point the roll was missed by. Total destruction of a vehicle is usually counted as a 20 point lethal impairment, with an instant fatality chance based on an abdomen hit. Collisions are treated as falling damage, substituting velocity for height. Minimal escape devices have a cost of 10Cr per occupant protected, and no significant mass or volume.

Example - Remember that your seat cushion can also be used as a floatation device, and to follow the instructions of the flight attendant in the event of a crash.

Basic escape device

A reasonable attempt to provide occupant security. This could be parachutes, airbags and passive restraints, rebreathers, rescue balls or other technologies (including vehicle structure design) that give the occupant a fighting chance at surviving catastrophe. These provide the occupant a skill of TL/3 (round nearest) vs. any accident damage they are likely to suffer, and double this if they have time to make sure the device will protect them, rather than relying on it in a passive sense (like buckling your seat belt when you get in the car, or climbing in the rescue ball *before* your compartment starts depressurizing). Basic escape devices have a cost of 1,000Cr per occupant protected, take up .1m^3 and have no significant mass (but if you want to be detailed, assume 10kg).

Example - Automatically tensioned safety belts combined with an airbag and energy-absorbent structure in a passenger car.

Advanced escape device

A no-expense spared attempt to get an occupant away from a possible injury involving the vehicle. Its use usually involves damage to the vehicle because of the violence of the escape attempt. An ejection seat is a typical example. These measures provide the occupant with a skill of TL/2 (round nearest) vs. the damage, and double this if they have time to activate the device before the damage actually happens. Advanced escape devices have a cost of 100,000Cr per occupant protected, take up .5m^3 and have no significant mass (but if you want to be detailed, assume 50kg).

Example - A rocket boosted ejection seat on a modern fighter plane, that automatically rights the occupant, boosts them to an altitude where the parachute can deploy, and then deploys the parachute.

Note that an escape device only protects vs. the immediate damage of vehicle destruction. It does not protect you from perils of the environment you escape into.

Escape devices should be rationalized within the context of the culture they come from, technology available and vehicle type. Sure, you can mount an advanced escape device on a covered wagon, but you may have a hard time describing exactly what it is that costs 100,000Cr and protects you from damage in case of vehicle destruction. If you can't figure out what it could be, then you can't have it in the vehicle. Advanced escape devices are a lot easier to justify if there is magic around (in which case you would use the “magic Tech Level”).

If an escape device protects the occupant in a passive sense, it has more or less indefinite duration (like a life vest). If the escape device must take active measures to protect the occupant (like life support), the duration of the support is usually no more than (TL^2/10) hours.

If an escape device of any level protects only vs. a *particular* hazard (fire, decompression, smoke, water, collision, tribbles, etc.), double its effective TL for purposes of protecting the occupant.

Emergency lighting

Backup lights in case main power fails are standard for a large vehicle. Their mass and volume is subsumed under that of other systems. Emergency lighting systems are independent of other vehicle power sources except for their recharging, and each area lit is handled by a separate unit. The duration of emergency lights is TL^2 hours, after which they are discharged. For power purposes, assume that it will consume 10w of power per 100m^3 of emergency lighting.

Example - A TL14 ship with 20,000m^3 of staterooms and hallways would have 20,000/100 = 200 emergency lights, each with a power of 10w and a duration of TL14^2 = 196 hours.

Medical kits

Basic first aid kits appropriate for the Tech Level of the vehicle will cost 50Cr each and mass 5kg, and you will need one for each 10 crew or passengers. This simply provides supplies necessary so that anyone using a first aid skill does not take penalties for lack of materials. Generally, this is just an extra cost and does not significantly affect vehicle space or mass. Vehicles with a dedicated medical space do not need medical kits.

Parachutes

Vehicles can have parachutes to either act as extra deceleration, or as a soft landing device (a lot of deceleration). A parachute will act and cost as a reverse sail, providing deceleration instead of acceleration, using a x.2 multiple on final sail mass and cost. Stowed chutes have a volume of $1m^3$ per 1,000kg, and the area of an open chute is generally fixed at what an equivalent mass sail would be at TL4. A parachute is always assumed to operating at maximum power output, and is assumed to be a “normal” power plant (parawings can be “enhanced”). To have a light landing, the deceleration will need to be 8 (treat as a 2m fall). This is about what a personal parachute would provide. For a moderate landing, you need a deceleration of about 4 (treat as a 5m fall). This is suitable for cargo containers. For a hard landing, you need a deceleration of about 2 (treat as a 10m fall). This is suitable for cargo or well-protected people on a water landing. A parachute normally takes 2 seconds to deploy. Chutes that deploy in 1 second cost double, and if the chute can safely deploy at velocities of over 100m/sec, it costs double for each 100m/sec or fraction thereof. The figures below (area, mass, volume) are for 1,000kg loads. Larger or smaller loads are proportionate to this.

Parachute TL	Decel 2 ($32m^2$)	Decel 4 ($125m^2$)	Decel 8 ($500m^2$)
1	1000kg/1.0m^3	-	-
2	250kg/.25m^3	1000kg/1.0m^3	-
3	111kg/.11m^3	444kg/.44m^3	-
4	63kg/.06m^3	250kg/.25m^3	1000kg/1.0m^3
5	40kg/.04m^3	160kg/.16m^3	640kg/.64m^3
6	28kg/.03m^3	111kg/.11m^3	444kg/.44m^3
7	20kg/.02m^3	82kg/.08m^3	327kg/.33m^3
8	16kg/.02m^3	63kg/.06m^3	250kg/.25m^3
9	12kg/.01m^3	49kg/.05m^3	198kg/.20m^3
10	10kg/.01m^3	40kg/.04m^3	160kg/.16m^3
11	8.3kg/.01m^3	33kg/.03m^3	132kg/.13m^3
12	6.9kg/.01m^3	28kg/.03m^3	111kg/.11m^3
13	5.9kg/.01m^3	24kg/.02m^3	95kg/.10m^3
14	5.1kg/.01m^3	20kg/.02m^3	82kg/.08m^3
15	4.4kg/.01m^3	18kg/.02m^3	71kg/.07m^3

If a parachute is used simply as an addition to vehicle deceleration (a drogue chute), the vehicle deceleration and chute deceleration are added together to get the velocity reduction each turn.

Secure storage

A vehicle safe or other secure storage is usually just built as an armored box of the appropriate size. Security measures on the box usually have a maximum Difficulty to bypass of the Tech Level. As a quick approximation for technological systems, the cost of the security system is (Difficulty^2) x 10Cr x size of the volume in m^3 (minimum of $1m^3$ for cost purposes).

Example - The ship's security officer has a weapons closet (a $2m^3$ room), which has an armor value the same as the internal bulkheads. This is a TL14 ship, so it is a Difficulty 14 task to bypass the security system, and the cost of the locker and attendant alarms is $TL14^2$ x 10Cr x $2m^3$ = 3,920Cr. This does not count the cost of the armor on the locker.

Security systems

This is basically whatever your fiendish little minds can come up with. The basic rule to remember is that the more secure it is, the more inconvenient it is. If you try to make it convenient *and* secure, then you run the risk of it being conveniently turned against you. For instance, a high-security voice-print lock could keep *you* out if the computer is disabled by shooting out the microphone. If you set disruptors to vaporize without warning any intruders on the bridge, then *you* will be vaporized without warning if someone hacks into your computer and takes you off the personnel roster. Be warned!

The cost of a security system and the Difficulty of bypassing it are as for secure storage, with a minimum volume of $.1m^3$, since you aren't trying to keep someone out of the vehicle, just out of a very small part (like the ignition circuits of a car). If the security system will actually have some deleterious effect on the trespasser, *then* the volume protected will be a concern.

Example - A security system that locks out the ignition will cost less than one that locks out the ignition and delivers high-voltage shocks to anyone in the driver's seat.

Vestigial fire extinguishers

This a fire-fighting system that is not part of the vehicle design, but which is added in later. These have a mass of 1kg per $1m^3$ which can be protected, divided by the Tech Level, and a cost of 10Cr per kg. They are treated as any other manual fire-fighting system, but they may only be used *once*, and if the fire isn't extinguished by them, it proceeds on its merry way through your vehicle.

Example - A TL10 motorhome with $40m^3$ of protected volume would need to have 40kg/TL10 = 4kg of portable fire extinguishers in order to count as a one-use firefighting system.

Weird-ass stuff

Players are notorious for putting all kinds of non-standard equipment in their character's vehicles, usually some James Bond type of gizmos. If it isn't already in the **VDS** and there is a real-world equivalent, you can usually make a vehicle variant that does what you want for x10 the mass and volume of the mundane item, and x100 its cost. If it is a simple matter of concealing some type of vehicle system (like a retractable gun), then the mass and volume of the system is x2 and the cost is x10.

Example - A character wants their trunk lid to pop open and reveal a traversable rocket launcher. This takes up x2 the volume a normal turret weapon would for whatever level of traverse is needed, and the bodywork and controls are a x10 factor on the cost.

Example - Someone wants a license plate holder that flips around and reveals several different license plates on command, or a transponder chip with a number of valid codes on it. Both will have x10 volume of the normal item (negligible for the transponder), and x100 cost. For the license plate holder, this is because it is probably a hand-made, unique item of machinery. For the transponder, most of the cost is probably the illegal insertion of the transponder codes into the vehicle database that is queried when someone checks it out.

Sensors

Sensors are going to be left as a nebulous category. Each type of sensor will have its own special effects and limitations, types of targets it is especially good at detecting, and those which it cannot see at all. Sensors cover *any* technology used to allow a vehicle to “see” or “be seen” better. In that light, the headlights and turn signals of a car are counted as sensors, and will be designed as such.

A sensor of the appropriate type can be used as a targeting aid for a weapon, decreasing the Difficulty to hit by its rating, or acting on its own with a skill equal to its rating, as in the normal **CORPS** rules. Mass is normal for a fired weapon like a self-guided rocket, but x.25 for a mounted weapon like a cannon. In the latter case, the mass of a sensor used for a weapon's fire control will be at least 10% of the weapon mass to take into account the parts needed for automated aiming. If the sensor/fire control system is “smart”, link it to a computer system running an appropriate program, and use the computer's AWR for making any “intelligence” tasks.

Sensors have a default cost of 10Cr/kg, and take up 1m^3 per 1,000kg if they are able to be maintained or repaired in the vehicle, and 1m^3 per 2,000kg if maintenance requires double the normal time.

Sensor operation

Sensors are treated as having an AWR of 1, which is then used vs. a Difficulty appropriate to the type of target, range and local conditions that favor or hinder the sensor. The *effective* range to a target is based on the sensor's Rating, which will vary. The exact special effects depend on the type of sensor and technology used. Sensors usually either have a readout that is interpreted by a human operator, or an automatic function that performs a sequence of actions when a given condition is met (if incoming rocket detected, activate countermeasures).

The rating of a sensor adjusts the apparent range from the sensor to the target for AWR purposes. A rating 1 sensor will divide the range to the target in meters by 100 to get the base Difficulty (round effective range up), which is then modified by target size and other characteristics. Each point of rating greater than 1 further divides the range by a factor of 10. The rating of a sensor takes into account both its power and sophistication. A higher tech sensor may take less power both because of more efficient electronics, but also because an on-board computer analyzes and enhances the return information for you.

Example - A rating 2 sensor divides actual range by 1,000 to get the base Difficulty. A rating 5 sensor divides actual range by 1,000,000. A rating 5 sensor would treat a range of 1,000km (1,000,000m) as a range of 1m for spotting purposes (Difficulty 3), vs. the sensor's AWR of 1, for a base spotting chance of 70%.

Sensors *do not* apply modifiers for target movement or area viewed. They do apply modifiers for camoflauge or "stealth" coatings, poor visibility (like countermeasures or flying close to the ground), target size, and the "Aptitude" of any skill appropriate to not being seen.

A vehicle sensor takes a +1 Difficulty to any spotting task for *each* range band past an *effective range* of 1m, that is, the Difficulty goes up by +2 per range band instead of +1 per range band. If the effective range to a target is less than .5m, the base Difficulty for spotting is 1, or automatic for targets with no penalty to be seen.

Effective range	1m	2-4m	5-9m	10-16m	17-25m	26-36m	37-49m
Difficulty	3	5	7	9	11	13	15

Example - A rating 1 sensor makes a 100m spotting task like it was a range of 1m, or a base Difficulty of 3. If the range to the target was 120m, the effective range would be 2m, for a Difficulty of 4, +1 more because of the penalty for being past 1m, for a Difficulty of 5.

Example - A missile with a -1 size modifier is fired from a range of 4km at a jet with a rating 2 proximity warning radar. The range of 4,000m is divided down to 4m, for a Difficulty of 5, and dropped back to 4 because of the size of the target. So, the radar immediately uses its AWR of 1 vs. the Difficulty of 4 to spot the missile on the turn it was launched-launched. If it fails, it may try again each second using the the *current* range and target modifiers.

Active sensors

These emit some type of energy, which is usually reflected off the environment (including potential targets), and these reflections are then received and analyzed. The best example of this is radar. Active sensors may cover a wide arc with their total coverage, but you can assume that at any given instant, no more than a 15° arc is actually being illuminated (imagine a rotating radar dish). The disadvantage is that there may be periods of several seconds during which a particular arc is not being scanned.

The mass of a sensor is based on the Tech Level and the rating desired, and is 160kg/(TL-8)^3. Each increase in rating increases volume by a factor of 16. You can see the TL and rating progressions on the table below, which have been rounded to convenient numbers. The number after the sensor rating is the default antenna area.

	Rating(antenna area)					
TL	**1($1m^2$)**	**2($4m^2$)**	**3($9m^2$)**	**4($16m^2$)**	**5($25m^2$)**	**6($36m^2$)**
9	160kg	2.5ton	40ton	650ton	10kton	160kton
10	20kg	300kg	5.0ton	80ton	1.3kton	20kton
11	6.0kg	100kg	1.5ton	25ton	400ton	6.0kton
12	2.5kg	40kg	650kg	10ton	150ton	2.5kton
13	1.2kg	20kg	300kg	5.0ton	80ton	1.3kton
14	.7kg	10kg	160kg	2.5ton	40ton	650ton
15	.5kg	7kg	120kg	2.0ton	30ton	500ton

Remember that sensors with maintenance space are $1m^3$ per 1 metric ton (1000kg) and ones crammed into a space are $1m^3$ per 2 metric tons. Sensors will require a certain area on the vehicle surface for their antennae, and this is a base of (rating of the sensor)^2 in square meters.

This presumably implies that no vehicle sensors are possible below TL9, with the possible exception of headlights or torches (multiply TL9 numbers by 8 for a lower-tech system of polished metal reflectors and oil lamps). Also, a magical Tech Level of 9 would be required for any sort of magic item as a generic vehicle sensor. Otherwise, you would have to rely on a specially made magic object with awareness and an ability to detect different parts of the electromagnetic spectrum.

Active sensors consume power according to the following table:

TL	Power	Plausible technology
9	13.3w/kg	Vacuum tubes
10	10.0w/kg	Transistors and vacuum tubes
11	7.3w/kg	Transistors and integrated circuits
12	5.1w/kg	Integrated circuits
13	3.4w/kg	Optical chips and integrated circuits
14	2.2w/kg	Optical chips and superconducting circuits
15	1.3w/kg	?

Passive sensors use a tenth the power of similarly sized active systems, and cost twice as much.

Example - A TL12 fighter plane has a radar in the nose with a rating of 3. With its displays and readouts, it has a volume of 1.6m^3, and a mass of 1,600kg. At this TL, it consumes 8,160 watts of power when operating.

These sensors were designed in **3G³**, and assume that a +4 sensor in **3G³** has a rating of 1 in **CORPS**, and that a **3G³** weapon sensor is a **CORPS** normal maintenance narrow arc sensor, with targeting only, and with half mass since there is no operator console at all, just a data link to the weapon guidance controls.

Passive sensors

These emit no energy, and thus cannot usually be pinpointed by enemy detection gear, as active sensors might. An automobile radar or laser detector is a typical example. The disadvantage of a passive sensor is that it is totally useless if the target is not emitting or reflecting the energy the sensor is designed to pick up.

Example - A plane with no radar would not be picked up by a passive radar sensor unless it was reflecting radar energy from an outside source. A thermal sensor would not pick up a person who was masked by an insulated chameleon suit.

What you get

The basic active or passive sensor package provides output to a person in the vehicle, or through a remote link, to some other observer. There are options that alter the mass and cost of a sensor system.

Modifiers

Limits and advantages on a sensor will affect its mass and volume.

Detection arc	Mass	Cost	Area
Narrow fixed arc (15°)	x1.0	x1.0	x1.0
Sector scan (60°)	x2.0	x2.0	x2.0
Full directional capability (360°)	x4.0	x4.0	x4.0

Capabilities	Mass	Cost	Area
Weapons targeting only	x.5	x.5	x.5
Target illumination only	x.2	x.2	x.2
Navigation illuminators	x.1	x.1	x.1
Communication facility	x.1	x.1	x.1
Works on natural senses	x.5	x.5	x.1

You can increase the effective TL of a sensor for *resolution purposes only* by doubling the final area multiple per TL of increase desired. For instance, a TL10 sector scan dish could have TL11 resolution if the area of the antenna was x4 instead of x2.

No directional capability

The sensor only works in a fixed arc, a narrow 15° cone that is set when the vehicle is built. A collision avoidance radar would be such a device. This is the base mass, cost and power requirements of a normal system.

Limited directional capability

The sensor works in a fixed 60° arc that is set when the vehicle is built. This has x2 the cost, mass or power modifications.

Full directional capability

The sensor works in a full 360° arc, although there may be limited blind spots based on the structure of the vehicle. This type of sensor takes x4 the normal mass, cost and power requirements of a normal system. In most cases, such a system will make one full sweep or target update per turn. If needed, such a system can be locked into a certain scanning arc to provide more rapid updates of a smaller arc.

Scientific instrumentation

The sensor is designed for scientific analysis of some type, specific to the sensor type. For instance, a radar might be designed to analyze weather data. Scientific instrumentation is x2 sensor mass of a sensor and x10 cost.

Remember that a sensor can be mounted in a turret to change its facing, but it can only detect targets in a given second in its bought detection arc.

Each of the three modifications below is assumed to subsume functions of a smaller sensor. For instance, a sensor which provides target illumination only may also have navigational illumination (a simpler function) at no extra cost or mass.

Targeting only

A sensor which provides only targeting information for weapons is x.5 the mass, cost and power of a normal system. It provides much less detail to the sensor operator, but is sufficient for making firing decisions and transmitting data to smart weapons. Targeting sensors also include such items as a Heads-Up Display (HUD), and in this case, the rating of the sensor counts as a bonus to the targeting skill of the person manning any weapon the sensor is linked with.

Example - A fighter plane equipped with an rating 2 heads-up display (HUD) will provide a 2 point positive modifier to the skill of the pilot when using the plane's weapons that are integrated into the HUD.

Target illumination only

The sensor only radiates energy which must be received by separate passive sensors. This has a mass, cost and power requirement of x.2 the normal amount. The effective rating of the receiver is limited to the rating of the illuminator.

Example - A rating 3 passive sensor is treated as a rating 2 passive sensor if the target illuminator is also rating 2.

On the other hand, if the illuminator is *more* powerful than the passive sensor, the extra +1 Difficulty for range is negated out to the distance the illuminator treats as an effective range of 1m. For most game purposes, human eyes are considered to be a 15° arc passive sensor for light, with a rating of 1.

Works on natural senses

This is a special case where not only is the sensor for target illumination only, the illumination is of a frequency or type that most creatures in the environment have natural receptors for. Light is the most common example. In the case where a person is the AWR component of a sensor, they use their own AWR rating, and would apply the normal person-based AWR modifiers. Assume each point of AWR in target illumination negates 6 points of darkness penalties.

⚠ Any target illumination that uses human vision as the sensor will have a power consumption of around 100w for a rating of 1, and this is multiplied by 10 for each extra point of illumination (e.g. a rating 2 illuminator would consume about 1000w).

⚠ A periscope might fall into the "natural senses" category, and the maximum AWR an observer could use is based on the rating of the periscope.

Example - Vehicle headlights are a target illumination sensor, providing energy so that your eyes can see targets within the active illumination arc. Headlights are usually rating 1 illuminators, so you have a reliable spotting range of around 100m. Total darkness is a +4 on AWR tasks, so rating 1 headlights negate all of it. Narrow beam lights lose one point of bonus per 4 range steps, so at a range of 100m the headlights still negate all of the penalty. If the vehicle had rating 2 searchlights, they would negate all darkness penalties in their arc for just over 1km.

⚠ Remember that this is just a general guide for long-range spotting. At short ranges or for role-playing purposes, uses the regular spotting rules.

Navigational illumination only

The sensors only provide a signal which allows passive sensors of the same type to detect the vehicle easier. This has a mass and cost of x.1 of a normal sensor, and a power requirement of x.1 on this reduced mass. This type of sensor could be running lights, transponders, etc., and automatically broadcast in all directions at no mass or cost penalty.

Communications capability

Vehicle radios are *not* subsumed under larger categories, and must be purchased separately. These have a mass, cost and power requirement of x.1 of a normal sensor, and a power requirement of x.1 of normal for the reduced mass. In general a communicator can handle a number of simultaneous channels over a range of frequencies. Limiting a communicator to a small subset of frequencies *and* channels is *another* x.1 multiple on mass. Like navigational illumination, communications naturally broadcast in all directions at no mass or cost penalty. At higher Tech Levels, more mass is spent on getting better signals with less power, in the form of sophisticated circuits, and special antennas, while at lower Tech Levels, increased range is gotten simply through raw power. You *can* quadruple the mass and area of a radio to get +1 rating from it in a single 15° arc, as would be represented by a parabolic dish or other directional antenna. This mass increase *does not* increase power consumption, but does increase cost, and the rating of the radio is reduced by 3 in any direction other than the one it is aimed at. This can be done up to twice on a communications device. For non-directional use, the antenna area of a communication device can be exchanged for a vertical antenna of the x10 height (i.e. a $.1m^2$ antenna could be a 1m high vertical whip antenna). Antennae shorter than this may reduce communications quality.

Option - Current experience is that higher frequencies are used at higher TL's, because of smaller antenna areas, better rates of information transfer or resolution, etc. To represent this, you may modify antenna area by a multiplier of $x1/(TL/10)^4$. So, a TL12 antenna is about x.5 the area of a TL10 one, and a TL15 antenna about x.2 the area of its TL10 equivalent.

Communications is handled as an AWR check vs. the effective range. The effective rating is the rating of the better of the two radios, plus half the rating (round up) of the worse of the two.

Effective rating	Reliable range	Passable range	Max. range
1	100m	400m	900m
2	1km	4km	9km
3	10km	40km	90km
4	100km	400km	900km
5	1,000km	4,000km	9,000km
6	10,000km	40,000km	90,000km
7	100,000km	400,000km	900,000km
8	1,000,000km	4,000,000km	9,000,000km

Example - A TL11 vehicle radio with a rating of 1 has a mass of .6kg. If communicating with a rating 2 base station, the effective rating is 3, or a division of range of 10,000. So, at 10,000m (10km), the chance is an AWR of 1 vs. a Difficulty of 3 to get a clear signal across. A rating 2 radio in an Apollo capsule talking to a rating 6 dish at NASA would have the same chance at a range of 100,000km (best rating (6) plus half the worst rating (1) for an effective rating of 7).

For purposes of signals to/from a remote control vehicle, reliable communications allows normal use. Passable communications quality is a +2 Difficulty to any control task, and from there to maximum range is a +4 Difficulty.

If there are conditions that block a communications signal, you would treat it exactly like something that blocks a sensor, and the reduced rating will give the communication range through those conditions. Most radio transmissions will either use the radar or longwave numbers for this purpose.

The default communication at this range is understandable voices. The more complex the communications, the shorter the range, and the simpler the communication or the longer it takes to transmit it, the greater the range. For instance, Morse Code would probably be a +1 to the effective rating of a pair of radios as would sending everything ten times to ensure enough of a recognizable signal got through. On the other hand, video or computer data would probably be a -1 to the effective rating. Likewise, these would affect the end cost of the radios in a genre-specific manner. A television would have a radio receiver cost, but the cost, power consumption and size would be dependent on the size of the picture tube you wanted. In general, reduced complexity nets you no gain, since the addition of voice circuits is trivial. Increased complexity of transmitted and received signal is probably x10 cost, mass and power consumption per increase in complexity, with a -1 to the adjusted rating per increase. High quality sound is one level of complexity, and digital data or video pictures is two levels of complexity.

Naturally, both radios need to operate on the same frequency and have compatible communications complexity (a television can receive just sound, but a radio can't receive a TV picture), and historically, certain frequency bands have been allotted for different purposes. So, an aircraft radio is likely to be able to communicate with other aircraft, but not with police cars, which don't interfere with entertainment radio broadcasts, which don't get in the way of satellite TV channels.

Encryption

Historically, communications devices of TL9+ may have built-in encryption to foil eavesdropping on the signal. Encrypted communication devices are x5 cost for basic encryption and x5 cost for each level above this, with a maximum of (TL-8) extra levels. Device-encrypted signals are both hard to intercept *and* hard to decode. Each level of encryption reduces the effective power of the communicator by 1 for purposes of being intercepted by the wrong parties. This could be through frequency hopping, spread-spectrum technology or other means that make it difficult to pick the right signal out of the electromagnetic spectrum. If the communication device is linked to a computer and the encryption is simply a computer program or mathematical algorithm, the cost is only that of the computer and program or at lower TL's, a specialized mechanical encoding device. The limits of this are that it is usually not real-time communications. You record the message, use the computer to encode it, then send it through a regular communications device. The cost of an encryption software program is whatever the market will bear. State-of-the-art software might even be free!

All machine-based encryption requires machines to catch, decode it or decipher it. Basic encryption is a Difficulty to crack of the TL/2 (round up) of the encoding device. Each level above this is +2 to the Difficulty. The time it takes to decrypt someone else's communications is as for other mental tasks. Once the decoding is figured out, a computer can run programs to automatically decrypt what is fed into it, using its rating or rating+1 if designed solely for decryption purposes. Software-based encryption has a base Difficulty of anywhere up to the TL of the software plus the rating of the computer used to do the encrypting. Decoding normal messages that have been transformed by a letter scrambling or substitution algorithm have a DIfficulty based on the skill of the person who created it and how long it took to create.

Example - A TL11 radio transmission with level 2 encryption is intercepted. The base Difficulty of catching the message is 8 (TL/2, plus 2), as is the base Difficulty to decode it. A TL11 transmission of seemingly random Morse Code letters might be easy to pick up, but impossible to decode.

Minimum size

To take into account wiring, switches and other interface-related items, any sensor will have a minimum mass of 1kg for each $1m^3$ of vehicle volume that has structure (blimps only count the gondola, etc.). Vehicles with a volume of less than $1m^3$ do not have to apply this minimum. This minimum mass *does* affect volume and cost, but does not affect power consumption.

Redundancy

A sensor whose function is absolutely necessary for proper operation of the vehicle should have a backup, which will have stats appropriate to its rating. The most common example of this is automotive headlights, which are mounted in pairs so that if one fails while you are speeding down a dark mountain road, you don't suddenly go careening off a cliff. A redundant sensor of the same type and rating as the main sensor *does not* have a minimum size requirement, since they use the same wiring, switches and other features.

Example - A TL11 van with a volume of $14m^3$ will have a minimum headlight + taillight mass of 14kg (rating 1), plus whatever the mass of an extra set of active sensors is.

Protection

Sensors often cannot be protected by armor as heavy as that on the rest of a vehicle. A sensor does automatically get any surface treatment on a vehicle other than armor, so a submarine sonar will be watertight, withstand diving pressures, etc. The AV protecting a sensor will be limited by the type of sensor (periscopes need glass, radar can't be protected by metal, etc.). To generalize this, assume sensor AV is never more than one quarter the AV (round up) of the facing it is mounted on. Even with relatively fragile sensor technologies, this could represent armored louvers, well-protected sensor ports with narrow angles of vulnerability, etc. Players may be able to use skill to aim directly at a vulnerable sensor port, and simply take a greatly increased Difficulty to bypass most of its armor.

Example - A car with an AV of 4 will have headlights with an AV of 1. A tank with a front AV of 300 would have an AV of 75 on the gunner's sights, and while the sight itself might not be that tough, this represents the difficulty of getting a hit near it.

Headlights

Most land vehicles past TL8 will have lights and turn signals. These are considered target illumination and navigational illumination at a rating of 1 (0 at TL8) with a natural illumination source, and the headlights have a fixed 15° arc. Landing lights on aircraft and searchlights are rating 1 or 2 depending on the vehicle. Most of the time the mass required will just be the 1kg per $1m^3$ of vehicle volume, with a power consumption of 100w for rating 1 lights, and 1,000w for rating 2 lights.

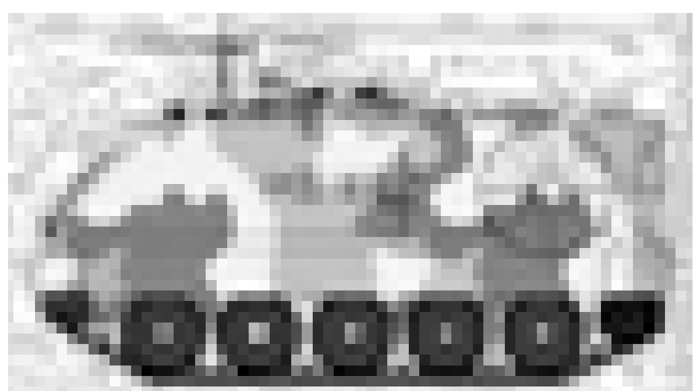
It's worth noting that at TL8, vehicles are unlikely to have headlights with a rating of even 1, due to the mass requirements. For the same mass and volume as TL10 equipment, a TL9 vehicle can have "rating 0" illumination, which in game terms is a 50w narrow beam lighting system that negates 4 points of darkness penalties instead of 6, and drops by 1 point each 4 range steps.

Sensor use

Sensors have an AWR of 1, which determines if they "see" a target and register it on any human-operated display or pass the information on to any computerized processing circuits. If the sensor sees the target, the human operator will see it, and may act on the information provided. Sensors will make one check each turn to spot something. For role-playing purposes, once something is spotted, it is easiest to let it stay spotted until the chances to detect it change for the worse. Likewise, if something isn't spotted in the first three tries, it will probably stay unseen, only checking again when it becomes easier to spot.

Sensors which only illuminate a target for *other* sensors provide a maximum effective rating to calculate range or determine a homing weapon's skill in the absence of other illumination sources.

Example - A laser-guided missile with a skill of 2 will only act with a skill of 1 if the laser illuminator unit only has a rating of 1. A laser illuminator with a rating of 3 would *not* have the missile act at skill 3, but it would be able to punch through 1 point of visual obscurement and still have a rating of 2.



10cm resolution (TL11 thermal telescope at 2.5km)

Typical sensor types

These guidelines are for historically developed sensors, and those which we can postulate, but only make educated guesses on otherwise. One thing to note is that certain types of obscurement affect some sensor types more than others. The table below gives the minimum rating of a particular type of sensor to penetrate a given type of obscurement (say perhaps a 100m thickness or less). If the rating of the sensor is less than this amount, the sensor is *totally* blocked. If equal to or greater than this amount, the number is subtracted from the rating before a detection attempt is made at that range. If there is a "-" for a type of cover, that type of sensor cannot penetrate it at all. Extremely large amounts of a given type of cover will increase its obscuring ability (just because a nucleonic sensor can sense through soil doesn't mean you can scan the inside of a planet).

Sensor	Fog/ mist	Light cl. cover	Hvy cl. cover	Water	Soil	Dust/ smoke	Foliage/ brush
Radar	0	2	4	6	6	0	1
Longwave	0	0	1	2	3	0	0
Lidar	3	-	-	3	-	3	3
Sonar	0	1	2	0	2	0	1
Thermal	1	3	-	3	-	1	1
Nucleonic	0	0	0	1	2	0	0
Optical	2	-	-	2	-	3	2

Example - If heavy cloud cover is a level 4 obscurement for radar, then any radar of rating 3 or less will only give the outline of the cloud cover. If the radar is rating 4, then you can see inside or through the cloud cover, but only from very short range. If your rating was 6, then your effective rating for scanning through the cloud is 2, and so on.

Sensor resolution

How fine a detail a sensor type can resolve depends on the sensor type and the TL.

TL	Resolution	@1km	@10km	@100km	@1000km
9	1cm per 10m	1m	10m	100m	1km
10	1cm per 50m	20cm	2m	20m	200m
11	1cm per 250m	4cm	40cm	4m	40m
12	1cm per 1km	1cm	10cm	1m	10m
13	1cm per 5km	.2cm	2cm	20cm	200cm
14	1cm per 25km	-	.4cm	4cm	40cm
15	1cm per 100km	-	.1cm	1cm	10cm

Resolution is the smallest size a image can be detailed at. Smaller items than this can be *detected*, but are resolved as images of the larger size. Anything that subtracts from the rating of a sensor also subtracts from its TL for resolution purposes. So, TL12 radar penetrating light cloud cover would be counted as TL10 radar for resolution purposes. Increased antenna size can increase the resolution, but not to more than TL+2 past the normal maximum. The following notes cover various normal sensor types. Adjustments to power and antenna area are optional but recommended.

Radar

Generally at TL9+. An active sensor that bounces high-frequency radio waves off targets to determine position, size, velocity and direction of movement. The maximum resolution available is at TL12, and the smallest object that can be resolved at any range is about 5cm.
Advantages - Will penetrate dust, mist and cloud cover.
Disadvantages - The AWR only applies vs. metal and thick targets.
Notes - Normal active sensor power and antenna area.

Longwave

Generally at TL10+. An active sensor using a longer wavelength than normal radar, capable of penetrating obscurement better. The maximum resolution available is at TL10, and the smallest object than can be resolved is about 50m.
Advantages - Will penetrate soil and water much better than normal radar.
Disadvantages - As regular radar, but less ability to resolve targets for identification purposes.
Notes - Normal active sensor power, x10 antenna area.

Lidar

Generally at TL12+. An active sensor that bounces light beams off targets. The maximum resolution available is at TL15, and there is no practical minimum to the size of objects that can be resolved.
Advantages - Better target resolution than radar. Computer image enhancement and manipulation allows some data to be collected from fragmentary or distorted reflections.
Disads - Does not penetrate any visual cover and cannot detect targets which have good light absorption characteristics. Is an active sensor which can be detected.
Notes - Normal active sensor power, x.1 antenna area.

Thermal

Generally at TL11+. A passive sensor that picks up the temperature differences between an object and its background. The maximum resolution available is at TL15, and there is no practical minimum to the size of objects that can be resolved.
Advantages - Can penetrate fog, dust and underbrush. Is passive and provides no information to enemy.
Disads - Does not penetrate any kind of solid object.
Notes - Normal passive sensor power, x.1 antenna area.

Sonar

Generally at TL9+. Available in both active and passive versions. Operates by interpreting reflected or generated sound waves. The maximum resolution available is at TL15, and the smallest object than can be resolved is about 5cm.
Advantages - Penetrates with ease the one medium blocking most other sensor types.
Disads - Since sound travels at a relatively low speed, sonar is unsuited for accurate tracking of high-speed or long range targets.
Notes - Active or passive sensor power, x.2 antenna area.

Nucleonic
Generally at TL12+. A passive sensor that picks up emanations from nuclear power sources, or detects things that are blocking distant radiation sources (like stars). The maximum resolution is available at TL12, and the smallest object that can be resolved at any range is about 10m. Gravitic sensors of any useful type are TL13+. They would have the same resolution as nucleonic sensors, but work on mass differentials.
Advantages - Is completely unaffected by low-density cover like smoke or fog.
Disads - Low resolution, unable to function at all in radiation-free environments.
Notes - Normal passive sensor power, x5 antenna area.

Optical
Generally at TL5+ for manual systems like telescopes, and TL10+ for any system with acquisition and tracking. A passive system that picks up some visual characteristic of the target, usually a difference in brightness as compared to the background, but may be able to distinguish shapes at higher Tech Levels. No minimum limits on resolution.
Advantages - Easy to provide output compatible with human senses.
Disads - Provides only detail, rather than enhancement, since it is blocked by anything that would block normal vision.
Notes - Normal passive sensor power, x.1 antenna area.

Bizarre sensors
We don't have any idea how “magical” or “psionic” sensors would work, so for now you will have to assume that they can detect those types of energies with the same level of detail and range that a conventional sensor of the same TL. So, a magical TL9 **MARAD** (**Ma**gical **R**anging **a**nd **D**etection) would be able to provide blips in a crystal ball, but a TL12 unit might be able to show little icons of the type of blip (dragon, flying broom, etc.), provide friend or foe designation, and read transponder signals for air traffic control use.

Electronic Countermeasures

Or ECM. ECM is an anti-sensor, actively working to defeat other sensors. This would be treated as a “targeting illumination only” type of sensor, and may be active or passive. Active ECM tries to jam an opponent's sensors, while passive sensors (like a stealth coating or chaff) tries to hide from them. The rating of the ECM subtracts from the rating of an opponent's sensors for picking things up. If opposing sensors are dropped to a rating of 0, they can't see you, and any tracking weapons lose their lock-on. There are several important side notes to the use of ECM:

Obviously, your ECM has to be jamming the right type of sensor. A radar jammer won't do much to a optical based system. Decoy flares to stop heat seeking missiles won't stop radar guided ones. ECM can be bought separately vs. each of the listed sensor types (radar, longwave, lidar, sonar, thermal, nucleonic and optical). For instance, the F-117 “stealth” fighter might have passive ECM vs. radar and thermal sensors. The mass for these is represented in the extra body structure and component placement for maximum passive ECM effect.

The size and cost of a *passive* ECM system is multiplied by -(the Size Modifier) of the vehicle. For instance, a stealthy vehicle with a Size Modifier of -4 would have x4 the normal ECM size and mass. Most vehicles with passive ECM are easily spotted as such because they will have an unusual body shape appropriate to deflecting, dispersing or absorbing signals from active sensors, or concealing their own emissions from passive sensors.

If the sensor you are jamming is of a superior TL, your ECM rating is reduced by 2 per TL of difference. On the other hand, if your ECM is of a superior TL, your rating is increased by 1 per TL.

Passive ECM works equally well vs. active and passive sensors. Active ECM is counted as one TL lower vs. appropriate passive sensors. For instance, a radio jammer out in the middle of nowhere is still obvious to a direction finder, even if the jammer is broadcasting a signal that disrupts active communications.

ECM dischargers
A vehicle can mount single-use ECM pods, which dispense flares, radar chaff, flocks of sonar-jamming bats or whatever. These will have a tenth the cost and mass of normal ECM of the same type, but will only provide protection for about 10 seconds, and usually only from a particular 60° arc of fire. Protection from other arcs is halved, rounding down.

Electronics

The amount of useful consumer electronics that can be placed in a vehicle is limited only by your line of credit, and the sophistication by only by the Tech Level. Some examples are below. At the lowest TL, functions are basic, and increase in utility and user-friendliness as TL increases. For generic electronics, assume cost stays the same and mass and volume are halved with each TL past the base.

Communications	Mass	Volume	Power	Cost
TL9 rating 1 transceiver	16kg	.016m^3	20w	160Cr
TL9 rating 2 transceiver	250kg	.25m^3	330w	2,500Cr
TL10 rating 1 transceiver	2kg	.002m^3	2w	20Cr
TL10 rating 2 transceiver	30kg	.03m^3	30w	300Cr
TL10 rating 3 transceiver	500kg	.50m^3	500w	5,000Cr
TL11 rating 1 transceiver	.6kg	.001m^3	.4w	6Cr
TL11 rating 2 transceiver	10kg	.01m^3	7.3w	100Cr
TL11 rating 3 transceiver	150kg	.15m^3	110w	1,500Cr
TL12 rating 1 transceiver	.25kg	.001m^3	.1w	3Cr
TL12 rating 2 transceiver	4kg	.004m^3	2w	40Cr
TL12 rating 3 transceiver	65kg	.065m^3	33w	650Cr
TL12 rating 4 transceiver	1,000kg	1.0m^3	500w	10KCr
TL13 rating 2 transceiver	2kg	.002m^3	.7w	20Cr
TL13 rating 3 transceiver	30kg	.03m^3	10w	300Cr
TL13 rating 4 transceiver	500kg	.50m^3	170w	5,000Cr
TL13 rating 5 transceiver	8,000kg	8.0m^3	2,700w	80KCr
TL14 rating 2 transceiver	1kg	.001m^3	.2w	10Cr
TL14 rating 3 transceiver	16kg	.016m^3	3.5w	160Cr
TL14 rating 4 transceiver	250kg	.25m^3	55w	2,500Cr
TL14 rating 5 transceiver	4,000kg	4.0m^3	880w	40KCr
TL14 rating 6 transceiver	65,000kg	65m^3	14,300w	650KCr
TL15 rating 2 transceiver	.7kg	.001m^3	.1w	7Cr
TL15 rating 3 transceiver	12kg	.012m^3	1.6w	120Cr
TL15 rating 4 transceiver	200kg	.20m^3	26w	2,000Cr
TL15 rating 5 transceiver	3,000kg	3.0m^3	390w	30KCr
TL15 rating 6 transceiver	50,000kg	50m^3	6,500w	500KCr

Remember to take signal complexity into account when trying to figure out effective range for your radios.

Example - A TL12 cellular phone (rating 1) and a cellular base station (rating 3) have a total rating of 4 for communications, for a reasonable range of 100km. However, for high quality voice transmissions, the combined rating is 3, and for sending high-speed data or video the combined rating would be 2.

Example - A TL12 satellite phone (rating 2, but with extra mass and a dish antenna to make it rating 3), and a rating 3 satellite with dish antenna to make it rating 4 will have a total rating of 6 for communications purposes, for reliable communications about to 10,000km, and passably good communications at the geosynchronous satellite's distance of 35,000km.

Starship notes

We know you're going to use this for starships, ship combat and other high-end topics more suited for a dedicated vehicle combat system, so here's a few pointers.

1. If there is some sort of regulation authority for starships, there will probably be a minimum communications and sensor requirement. For passable interplanetary communications with planets and base stations, a Rating 5 transceiver would be the minimum (probably a Rating 4 unit with a directional antenna). For orbital maneuvering, detection and avoidance of debris a Rating 3 sensor with full directional capability and navigational illuminators would be the minimum, and even this is probably low if high-speed interplanetary transits are considered.
2. The front armor of a starship should be appropriate to stop or deflect small debris at the maximum normal speed of the ship (see p.106). This roughly an AV of 30 per g/hour of acceleration you expect to do. For instance, if your ship has an acceleration of 20 (2g's) and a 20 hour fuel endurance, your maximum expected speed would be after 10 hours (since you need the rest of the fuel to decelerate). Ten hours at 2g's is 20g/hours of acceleration, so the front of the ship should have an AV of 20g/hour x AV30 = AV600. This can be from armor, force fields or a combination of the two. For reference, a Rating 3 sensor would pick up a piece of debris that would do this much damage (a sand grain) only a few hundredths of a second before you hit it...
3. Relative movement is much less a concern at potential starship ranges. Ignore ship movement for firer and target modifiers. Substitute the Acceleration/10 (round down) of the firer and tar get for movement and evasion purposes.
4. If you are designing starships for combat, make sure the Range Mod of the weapons corresponds to the detection range of the sensors the ship has. To do otherwise could be fatally embarassing. A realistic estimate would be Rating 5+ sensors for medium-sized vessels and Rating 6+ for capital ships. You'll see that sensor mass can be a major part of a combat starship's payload.

Am I Doing This Right?

Question #1:

How much mass and volume is taken up by a TL14 “technobabble” force field that provides an AV of 800 to the front of a ship that is 80 meters long with a Cylinder$_1$ configuration? How much power does it consume? How much does it cost?

Calculations:

A ship of the listed size will have a total area of: length^2 x .69, and a front area of x.05 of this. The front area is then 80m^2 x .69 x .05 = 220.8m^2 (round to 221m^2).

A basic generator will provide an AV of TL14^2 = 196 to an area of 1m^2 and consume TL14^3/10kw = 274.4kw. We have to increase basic generator size by x221 to cover the front (since it is 221m^2), and increase the basic power consumption by AV800/AV196 = x4.08. Total size is x221 the base amount, and power consumption (and cost) is (221 x 4.08) = x902 the base amount. Since the basic generator is .1m^3, 100kg, TL14^3/10kw of power and 10,000Cr, our final numbers are: 100kg x 221 = 22,100kg, .1m^3 x 221 = 22.1m^3, 274.4kw x 902 = 247.5Mw and 10,000Cr x 902 = 9.02MCr.

Answers:

Mass = 22.1 tons
Volume = 22.1m^3
Power = 247.5Mw
Cost = 9.02MCr

Note - It's pretty expensive no matter how you slice it, but it *is* a self-regenerating energy field that is the equivalent of 1.6 meters of TL14 composite armor. That armor would have a mass of 176.8 tons and cost 1.77MCr. The force field will always be more expensive, but even with the power plant factored in, it will have less mass.

Question #2:

The fishery ship *S.S.Politically Incorrect* has a fish packing plant on board that occupies 50m^3. Assuming it is a TL11 ship that deals with concentrated sea products of average purity, how many kilos of fish can be processed and frozen per hour? How much electricity does the equipment consume?

Calculations:

This would be treated as a refinery (**p.69**). Each 1m^3 of refinery has a base output of 100kg per hour, so 50m^3 would have a base output of 50m^3 x 100kg = 5,000kg per hour. Modifiers on this are x1.2 for the Tech Level and x.6 for the purity, for a total of 5,000kg x 1.2 x .6 = 3,600kg per hour. Power consumption is 50m^3 x 5kw = 250kw.

Answers:

Mass processed per hour = 3,600kg
Power consumption = 250kw

Question #3:

A TL11 tank with a mass of 60 tons and a 1000kw power plant wants stabilizers capable of countering 2 points of terrain penalties. How much will this system mass and cost?

Calculations:

We assume the tank is a tracked vehicle, and the mass of the power train is (100/TL11)kg per kilowatt of power (**p.29**). This is 9.09kg x 1000kw = 9,091kg. Each point of stabilization is the *larger* of x.1 this (909.1kg), or x.001 of total vehicle mass (50kg). So, 2 points of stabilization will mass 1,818kg. Since the power train costs 5Cr/kg, the cost of the system is 1,818kg x 5Cr = 9,090Cr.

Answers:

Mass for +2 stabilizers = 1,818kg
Cost for +2 stabilizers = 9,090Cr

Note - Given the relatively low cost compared to the total cost of a tank, it would probably have the best stabilizers possible at that TL, and use that in combination with targeting sensors to get the best targeting chance possible.

8 Weapons

Pre-designed weapons

The weapons on this list from modern TL's down (TL12 or less) are based on historical weapons where exact references are available. Otherwise, they were designed in **3G³** from the best information found, or as a weapon that combines several known weapons into a representative sample.

These weapons have not been optimized, and anyone with **3G³** can probably design better. For instance, rockets are not designed with booster charges for extra velocity, shaped charge warheads are single rather than tandem, etc.

Keeping with the theme of making it as simple as possible, you can also use a formula to get *approximate* weapon masses for any direct fire weapon in the **CORPS** system. This is *not* a substitute for **3G³**, but rather a means to get quick and dirty numbers for vehicles that you expect to be "disposable" in the course of the campaign (i.e. don't put a lot of effort into it because someone is going to blow it up). This mass in *kilograms* of any *direct fire* weapon is:

$$(9/TL)^4 \times DV^{1.8} \times (\text{Range Mod} + 1)^{.9} \times RoF^{.4} \times 1/Reload^{.1} \times 1/(TL^{.4} \times 100) + DV/TL$$

A few of the terms need elaboration. RoF is Rate of Fire. For most weapons, the **CORPS** rate of fire is used. Light duty autoweapons use a RoF of 4 to take into account that they are usually semi-auto designs with an autofire capability, not a dedicated autofire weapon with a correspondingly heavier mass. Reload is the reloading time of the weapon in seconds. Most archaic or muzzle loading weapons will have a time of 30 seconds or more. Most breech loading weapons, regardless of size, will usually use 1 second for this equation.

Example - If you do the math right, a TL10, DV17 weapon with a Range Mod of 4, an RoF of 4 and a reload time of 1 will have a mass of 4.9kg. These are the stats for an FN-FAL, which actually has an unloaded mass of about 4.2kg. This equation gives passable results for weapons from TL4-15, all the way up to a 16" naval gun.

The mass of ammunition for the weapon is a separate equation. The mass of a single unit of ammunition in kilograms is:

$$DV^{1.8} \times (9/TL)^4 \times (Rmod + 1)^{.5} \times .00015$$

This equation works best for weapons where ammunition matches the range characteristics of the weapon itself. So, for instance, 9mm ammunition will weigh different amounts in this equation, based on the weapon using it. Obviously this isn't correct, but the equation is designed to generate ammunition appropriate for the weapon, *not* match existing ammunition to a new design. It isn't a perfect set of equations, but it covers a broad range of damage and TL's with one brush stroke, and passably well.

Example - You've designed a TL5 pirate ship, and want some generic cannons on it. You decide that they'll have a DV of 50, a Range Mod of 7, an RoF of 1, and a reload time of 45 seconds. After crunching the numbers, you see each one has a mass of 246kg, and an ammunition mass of 5.1kg per shot. With these numbers, you quickly whip together an idea of how many guns she can carry, how many crew are needed to man them and how much ammunition is aboard. It's a lot quicker than designing the weapons up in **3G³**, and if characters manage to board and seize the vessel, *then* you can go through the effort of designing them up right.

Weapon modifiers

Normal weapons have a volume of 1m³ per 1,000kg when you take crew space into account. For unconventional weapons like lasers or siege engines, use the following multiples on the previous formulas.

	Mass	Wpn. volume	Ammo vol.
Siege engines	x1	x2	x2
Conventional	x1	x1	x1
Lasers	x1	x2	x2
Railguns	x1	x1	x2
Particle beams	x1	x2	x3

For indirect fire weapons like rockets, the wide variety of technologies available make even a reasonable equation next to impossible. The best assumption to make is that you can get 20 rockets for the mass of a regular direct fire weapon. These have quadruple the weapon volume, and this is doubled again if the rockets can be fired as a group rather than individually loaded. Guidance or the lack thereof will be abstracted into the Range Mod stat of the weapon, and is a multiplier of x(Range Mod/10 + .1) (round down).

Example - If our pirate ship mounted a brace of rockets instead of one of the cannon, it could get 20 rockets, each with a Range Mod of 5 instead of 7 (Range Mod of 7 x (7/10 + .1)). The cannon massed 246kg, so it took up .25m³. The rockets take up four times this, or 1m³, and if they are on a rack so they can be fired all at once, they take up 2m³.

We know *some* of you are going to try and design combat starships with **VDS**. Assume energy weapons have an *output* of around ($DV^2 \times 10$) watts/shot. Range Mod is 1,000 for 1,000km, 3,000 for 10,000km and 10,000 for 100,000km. A TL13, RoF 1, reload 1/sec., DV1000 weapon with a range of 100,000km has a mass of 823 tons (TL15 version is 439 tons).

Hand-held weapon	Caliber	DV	Initiative mod	Range mod*	Size	TL	Mass	Extra clip	Rate of fire	Clip	AV	Cost	Origin
Hand cannon	12mm	4	+1	-1	7	5	2.1kg	-	1/30	1i	9	70	n/a
Musket	19mm	6	-1	1	19	6	4.7kg	-	1/30	1i	7	90	n/a
Muzzle loading rifle	12mm	10	+0	3	17	7	4.1kg	-	1/30	1i	10	140	n/a
Breech loading rifle	8mm	18	+0	4	15	8	4.1kg	-	1/2	5i	10	340	n/a
Squad autorifle	8mm	19	-1	4	16	9	9.5kg	.7kg	10	20c	8	975	n/a
Squad autorifle	8mm	19	-1	4	18	10	16.3kg	5.8kg	10	200e	8	975	n/a
Squad autorifle	6mm	16	-1	4	16	11	10.0kg	3.1kg	10	200e	6	730	n/a
Squad autorifle	5mm/c	16	-1	5	12	12	7.0kg	1.3kg	10	300c	6	1800	n/a
Squad autorifle	7mm/c	21	-1	5	10	13	7.6kg	2.3kg	10	200c	5	2500	n/a
Squad autorifle	4mm railgun	24	+0	5	9	14	5.5kg	2.1kg	10	50c	4	4400	n/a
Squad autorifle	4mm railgun	27	+0	5	10	15	6.1kg	2.9kg	10	100c	4	5000	n/a

The squad autorifles are capable of being solidly mounted to get +2 Range Mod.

Siege engine	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass	Extra clip	Rate of fire*	Clip	AV	Cost	Origin
Siege crossbow	32mm	11	-1	4	15	5	17.3kg/.35m^3	.3kg	1/35	1i	6	330	n/a
Onager, small	90mm	13	-3	3	-	4	75kg/1.5m^3	.8kg	1/130	1i	8	210	n/a
Onager, medium	140mm	18	-4	0	-	4	115kg/2.3m^3	4.3kg	1/270	1i	9	340	n/a
Sprengal, small	65mm	15	-3	9	-	4	75kg/1.5m^3	2.1kg	1/130	1i	8	270	n/a
Sprengal, medium	55mm	15x4	-3	9	-	4	275kg/5.5m^3	5.0kg	4(1/400)	4i	9	550	n/a
Ballista, small	45mm	13	-2	9	-	4	50kg/1.0m^3	1.4kg	1/70	1i	7	210	n/a
Ballista, medium	75mm	16	-3	10	-	4	85kg/1.7m^3	6.4kg	1/170	1i	8	580	n/a
Trebuchet	250mm	36	-7	0	-	4	2.7t/54m^3	16.4kg	1/1100	1i	11	1200	n/a

*Assumes one person working at 150J per second. Divide by up to 2 people per 100kg (round up) of weapon if extra help is available.

Archaic cannon	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass*	Extra clip	Rate of fire*	Clip	AV	Cost	Origin
Swivel gun	25mm	20	-2	2	16	5	29.1kg/.03m^3	.1kg	1/20	1i	15	205	n/a
(cannister shot)	10mm shot	8(+0)		0									
6pd muzzle loader	93mm	55	-4	7	-	6	400kg/.4m^3	3kg	1/30	1i	20	1400	n/a
(cannister shot)	28mm shot	19(+2)											
12pd muzzle loader	117mm	97	-5	7	-	6	800kg/.8m^3	6kg	1/40	1i	24	3700	n/a
(cannister shot)	38mm shot	30(+2)											
32pd muzzle loader	163mm	148	-5	7	-	6	2000kg/2.0m^3	15kg	1/50	1i	26	6000	n/a
(cannister shot)	51mm shot	40(+2)											
20pd breech load rfl	85mm	90	-4	9	-	7	400kg/.4m^3	10kg	1/12	1i	21	7500	n/a
(shell)		9E											
70pd breech load rfl	150mm	195	-5	9	-	7	3.0t/3.0m^3	37kg	1/20	1i	27	34k	n/a
(shell)		20E											
110pd breech load rfl	180mm	231	-6	16	-	7	4.0t/4.0m^3	60kg	1/20	1i	28	48k	n/a
(shell)		26E											

Note that muzzle loading cannon require either loading from outside a vehicle, or double interior volume to allow retraction of the weapon for reloading.
Rate of fire assumes crew of 2 per 1m^3 of weapon (round up). This can be decreased by a variable amount depending on how much safety you want to sacrifice.

Machineguns	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass/vol.	Extra clip	Rate of fire	Clip	AV	Cost	Origin
13mm machinegun	13mm	36	-2	11	-	9	60kg/.06m^3	20kg	10	200e	10	2500	n/a
15mm machinegun	15mm	42	-3	11	-	9	90kg/.09m^3	35kg	10	200e	12	3300	n/a
8mm rotary gun	8mm	18	-1	3	-	11	120kg/.12m^3	100kg	100	4000e	8	1400	n/a
13mm machinegun	13mm	40	-2	11	-	12	40kg/.04m^3	15kg	20	200e	8	3000	n/a
15mm machinegun	15mm	44	-3	16	-	11	75kg/.08m^3	28kg	10	150e	10	3500	n/a
15mm machinegun	15mm	47	-3	16	-	12	70kg/.07m^3	28kg	10	150e	9	4100	n/a
15mm machinegun	15mm	50	-3	16	-	13	70kg/.07m^3	28kg	10	150e	8	4500	n/a
6mm railgun*	6mm	90	-2	11	-	14	27kg/.03m^3	9.0kg/7Mw	20	2000e	7	19k	n/a
6mm railgun*	6mm	101	-2	11	-	15	26kg/.03m^3	9.0kg/6Mw	20	2000e	6	23k	n/a
5mm particle beam*	5mm	90	-2	18	-	14	30kg/.03m^3	13Mw	10	∞	5	38k	n/a
5mm particle beam*	5mm	103	-2	18	-	15	27kg/.03m^3	10Mw	10	∞	4	49k	n/a

*Requires vehicle power source. Railgun clip mass is for projectiles only.

Cannon	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass/vol.	Extra clip	Rate of fire	Clip	AV	Cost	Origin
20mm autocannon	20mm	57	-3	26	-	11	100kg/.1m^3	20kg	10	50c	11	8000	n/a
25mm autocannon	25mm	67	-4	26	-	11	150kg/.15m^3	40kg	10	50c	12	10.5k	n/a
30mm autocannon	30mm	75	-4	26	-	11	200kg/.2m^3	60kg	10	50c	13	13k	n/a
30mm rotary cannon	30mm	75	-6	26	-	11	1.7t/1.7m^3	1.0t	60	1200e	13	25k	n/a
40mm autocannon (HE)	40mm	5E	-5	26	-	11	700kg/.7m^3	80kg	5	25i	14	23k	n/a
(APFSDS)		96		38									
76mm cannon (HE)	76mm	9E	-5	26	-	9	600kg/.6m^3	12kg	1	1i	24	36k	n/a
(AP)		200		38				12kg					
90mm lt. cannon (HE)	90mm	14E	-4	9	-	11	300kg/.3m^3	5.0kg	1	1i	14	2500	n/a
(HEAT)		480/7E		16				4.0kg					
105mm cannon (HE)	105mm	18E	-6	26	-	11	2.5t/2.5m^3	19kg	1	1i	22	28k	n/a
(APFSDS)		370		52				17kg					
(HEAT)		686/11E		26				22kg					
120mm cannon (HE)	120mm	22E	-6	38	-	11	3.0t/3.0m^3	25kg	1	1i	22	35k	n/a
(APFSDS)		400		52				20kg					
(HEAT)		950/14E		38				25kg					

Range mods assume handheld wpns use handhelp category, and vehicle ones use turreted.

Fire & forget missiles	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass	Extra clip	Rate of fire	Clip	AV	Cost	Origin
AT msl. (skill 0/600m/sec)	80mm	400/6E	-1	-	12	11	9.0kg	5.0kg	1	1i	11	900	n/a
AT msl. (skill 1/650m/sec)	80mm	440/7E	-1	-	12	13	8.0kg	5.0kg	1	1i	8	1200	n/a
AT msl. (skill 2/600m/sec)	90mm	560/9E	-1	-	12	15	9.5kg	7.0kg	1	1i	6	5000	n/a
AA msl. (skill 1/700m/sec)	70mm	330/13E	-1	-	20	11	9.5kg	6.5kg	1	1i	10	1000	n/a
AA msl. (skill 1/850m/sec)	70mm	360/14E	-1	-	20	13	9.5kg	6.5kg	1	1i	8	1000	n/a
AA msl. (skill 2/800m/sec)	70mm	390/15E	-1	-	20	15	8.5kg	6.5kg	1	1i	6	5000	n/a
AT msl. (skill 2/550m/sec)	180mm	1350/22E	-3	-	-	11	75kg/.08m^3	55kg	1	1i	15	15k	n/a
AT msl. (skill 2/850m/sec)	180mm	1500/24E	-3	-	-	13	70kg/.07m^3	55kg	1	1i	12	20k	n/a
AT msl. (skill 3/850m/sec)	200mm	1800/30E	-3	-	-	15	90kg/.09m^3	75kg	1	1i	9	150k	n/a
AA msl. (skill 2/1.1km/sec)	150mm	1000/29E	-3	-	-	11	80kg/.08m^3	65kg	1	1i	15	15k	n/a
AA msl. (skill 2/1.3km/sec)	150mm	1100/31E	-3	-	-	13	80kg/.08m^3	65kg	1	1i	12	15k	n/a
AA msl. (skill 3/1.2km/sec)	150mm	1200/34E	-3	-	-	15	75kg/.08m^3	65kg	1	1i	8	100k	n/a
Torpedo (skill 2/25m/sec)	550mm	200E	-5	-	-	11	1.7t/1.7m^3	1.6t	1	1i	25	400k	n/a
Torpedo (skill 3/25m/sec)	550mm	220E	-5	-	-	13	1.7t/1.7m^3	1.6t	1	1i	20	1.6m	n/a
Torpedo (skill 3/30m/sec)	550mm	240E	-5	-	-	15	1.7t/1.7m^3	1.6t	1	1i	15	2.0m	n/a

Active Sensors*	TL	Mass	Volume	Cost	Power	Antenna	Resolution	@1km	@10km	@100km	@1000km
Rating 1 (range/100)	9	640kg	.64m^3	6.4KCr	8.5kw	1m^2	1cm per 10m	1m	-	-	-
Rating 2 (range/1000)	9	10 ton	10m^3	100KCr	133kw	4m^2		1m	10m	-	-
Rating 2 (range/1000)	10	1.2 ton	1.2m^3	12KCr	12kw	4m^2	1cm per 50m	20cm	2m	-	-
Rating 3 (range/10000)	10	20 ton	20m^3	200KCr	200kw	9m^2		20cm	2m	20m	-
Rating 2 (range/1000)	11	400kg	.40m^3	4.0KCr	2.9kw	4m^2	1cm per 250m	4cm	40cm	-	-
Rating 3 (range/10000)	11	6.0 ton	6.0m^3	60KCr	44kw	9m^2		4cm	40cm	4m	-
Rating 4 (range/100000)	11	100 ton	100m^3	1.0MCr	730kw	16m^2		4cm	40cm	4m	40m
Rating 2 (range/1000)	12	160kg	.16m^3	1.6KCr	.82kw	4m^2	1cm per 1km	1cm	10cm	-	-
Rating 3 (range/10000)	12	2.6 ton	2.6m^3	26KCr	13kw	9m^2		1cm	10cm	1m	-
Rating 4 (range/100000)	12	40 ton	40m^3	400KCr	204kw	16m^2		1cm	10cm	1m	10m
Rating 3 (range/10000)	13	1.2 ton	1.2m^3	12KCr	4.1kw	9m^2	1cm per 5km	<1cm	2cm	20cm	-
Rating 4 (range/100000)	13	20 ton	20m^3	200KCr	68kw	16m^2		<1cm	2cm	20cm	2m
Rating 5 (range/1000000)	13	320 ton	320m^3	3.2MCr	1.1Mw	25m^2		<1cm	2cm	20cm	2m
Rating 3 (range/10000)	14	640kg	.64m^3	6.4KCr	1.4kw	9m^2	1cm per 25km	<1cm	<1cm	4cm	-
Rating 4 (range/100000)	14	10 ton	10m^3	100KCr	22kw	16m^2		<1cm	<1cm	4cm	40cm
Rating 5 (range/1000000)	14	160 ton	160m^3	1.6MCr	352kw	25m^2		<1cm	<1cm	4cm	40cm
Rating 3 (range/10000)	15	480kg	.48m^3	4.8KCr	.62kw	9m^2	1cm per 100km	<1cm	<1cm	1cm	-
Rating 4 (range/100000)	15	8.0 ton	8.0m^3	80KCr	10kw	16m^2		<1cm	<1cm	1cm	10cm
Rating 5 (range/1000000)	15	120 ton	120m^3	1.2MCr	156kw	25m^2		<1cm	<1cm	1cm	10cm

*AWR 1. Assumes a manned sensor, a control console and a 360° field of view, like a ground-based radar installation.

9 Combat

Basics

Now that you have a few vehicles designed, you probably want to know how to disassemble them as fast as technology will allow.

For the most part, vehicle combat is covered by the basic rules in **CORPS**. Speed and size modifiers, weapon Range Class, special weapon vs. armor effects and component damage are all covered. However, there are some special effects to be listed, and a re-iteration of the basics.

Range

Ranges in **CORPS** are measured in meters, and the base Difficulty to hit is equal to the square root of the range in meters, plus 2.

Range(m)	100m	200m	400m	600m	800m	1.0km	1.2km	1.5km	2.0km	3.0km	4.0km	5.0km	7.0km	10.0km
Difficulty	12	17	22	27	31	34	37	41	47	57	66	73	86	102

If you are at all familiar with the **CORPS** system, you will instantly see that these ranges are all but impossible to succeed at. For instance, a skill 6 sniper trying to take a shot at 600 meters will need a weapon with a range mod of 5, a 6x scope, an out of combat bonus and setting and bracing for at least 10 seconds to have a 50% chance of success. And that is at only 600m. Of course, a good sniper would probably have a better weapon and skill, and be able to engage out to 800m in **CORPS**, but it serves to illustrate the difficulty of hitting targets at long range. **CORPS** was not really designed for use at these ranges, so the rules may not work as well as they could.

Range Mod

Range Mod represents the overall accuracy of the weapon system, and subtracts from the Difficulty for range. Vehicle mounted weapons will have *high* Range Mods.

This is double-edged sword, since at closer ranges it becomes more difficult to train the weapon on a moving target. If the target is at a Difficulty for range of the Range Mod or less, all movement penalties are increased by 1. If the Difficulty for range is half the Range Mod or less, they are increased by 2, by 3 at a quarter the Range Mod or less, and so on.

Example - A modern tank cannon has a Range Mod of around 50. If firing at a target 400m away (Difficulty 22), the Range Mod cancels out the Difficulty for range. However, if the target was moving, it would be +1 Difficulty over the normal movement penalty, and if the firer was moving, it would be +1 Difficulty over that movement penalty as well.

Size

Normal penalties and bonuses to hit for vehicle size apply, as per the basic **CORPS** rules. To cover vehicles of odd shapes, use whichever modifier (hexes filled/volume) makes it *easier* to hit the vehicle.

Hexes filled	Volume	Example	Difficulty
1-3	<$4m^3$	Motorcycle	-1
4-15	<$32m^3$	Automobile	-2
16-63	<$250m^3$	Large truck, jet fighter	-3
64-250	<$2,000m^3$	Patrol boat	-4
251-1,000	<$16,000m^3$	Airliner, frigate	-5
1,001-4,000	<$125,000m^3$	Destroyer	-6
4,001-16,000	<$1,000,000m^3$	Cruiser	-7

Example - A vehicle using the "half-cylinder$_1$" configuration and a length of 70m would have a volume of $15,365m^3$, and a "hexes filled" amount of 70m long x 21m wide = $1,470m^2$. The *area* gives a -6 Difficulty to hit, and the *volume* gives a -5, so you use the -6 figure.

Visibility

At lower TL's, vehicle targeting systems are limited by the ability of the crew to see their targets. Simple periscopes and vision slits do not provide the same visibility as the open air, but do provide much greater protection against incoming fire. The designer of a vehicle can pick any number from +1 Difficulty to +4 Difficulty to represent the size of a vehicle's vision ports, if it has any at all. A submarine might have sensors, but no windows for instance. This Difficulty minus 1 is the penalty to any AWR checks made through that vision port. A normal civilian vehicle has +1 Difficulty windows, for a +0 AWR penalty, while a tank with periscopes that are +4 Difficulty to be targeted are +3 Difficulty to see out of. Both sets of "vision ports" have reduced AV compared to the rest of the vehicle, but they are much harder to hit on the tank.

Advanced technology can negate some or all of these vision penalties. For vehicles with any form of optical sensor equipment, one point of vision penalty is negated at TL10 and each 2 TL's past TL10 (round down). So, a TL14+ vehicle with minimal ports for optical sensors would give no vision penalties for the occupants.

A vehicle which *does* have penalties may selectively negate them for some crew members by allowing them to stick their heads out through hatches. This allows a crew member to be targeted directly by weapons and to have their head exposed to area effect attacks, but reduces their vision penalty to +0 or +1 (if they have overhead cover).

Bombing

Bombs are considered indirect fire weapons with a Range Mod of zero, and an "infinite" maximum range (you can drop them from any height). Bombing rules can also be used to simulate extremely long range artillery fire. What you end up with is a guaranteed miss 99% of the time, with a lot of hits somewhere in the vicinity of the target. Since the maximum distance of a miss is the $(\text{Difficulty}/5)^2$, the chart below lists the maximum dispersion distances and distribution of hits. Hit distribution for an area is based on results for aiming at a larger area, as for a vehicle target, rather than amount missed by. That is, if you miss by 144m, all the misses don't cluster as if they were exactly that far off. Rather, all the shots land randomly in a circle with a radius of 144m.

Difficulty of shot	40	60	80	100	120
max dispersion	64m	144m	256m	400m	576m

	out of 1000 shots		
Difficulty vs. skill	**10**	**15**	**20**
in target hex (+0)	10	1	0
in 1 hex radius (-1)	30	3	0
in 2 hex radius (-2)	50	5	0
in 5 hex radius (-3)	70	7	1
in 9 hex radius (-4)	90	9	1
in 18 hex radius (-5)	100	10	1
in 36 hex radius (-6)	300	30	3
in 72 hex radius (-7)	500	50	5

Example - If the final Difficulty of an indirect fire shot was 60 (after taking any Range Mod of the weapon into account), then no matter how badly the "to hit" roll was flubbed, the maximum miss distance would be by 144m. If this were part of an artillery barrage of 1,000 shells, and on average, the Difficulty of the task exceeded skill by 10, then 10 would hit the target hex, and a total of 70 would have landed within 5 hexes of the target location.

As you can see, if the Difficulty is more than 20 points over your adjusted skill, you have a negligible chance of directly targeting anything without a huge barrage of shells.

Proximity fuses

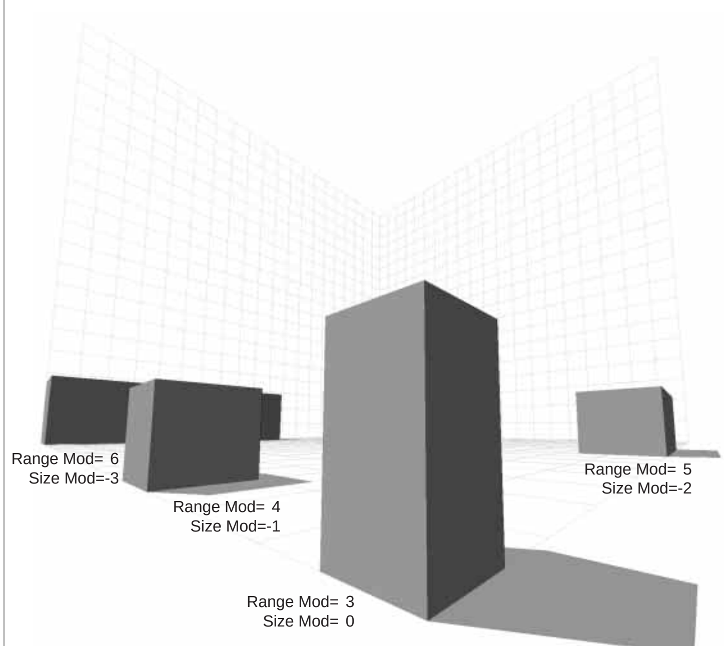
If a weapon has a proximity fuze in **CORPS**, it basically goes off on a near miss. Since miss distance is the amount the roll was failed by, squared, most proximity fuzes are set for a miss by 1, 2 or 3, corresponding to a range of 1m, 4m, or 9m. Presumably the proximity fuze is set for a distance where the weapon payload can have an effect on the target.

Spotting

With large and cumbersome weapons, they can often hold their aim well, or be adjusted minutely between shots to get closer to the target. If a given *stationary* (vehicle not moving) indirect fire weapon has someone who can spot where each shell lands with regards to an equally stationary target, the spotter can make a Difficulty 6 skill roll vs. the applicable heavy weapon skill to call in corrections to aim. If successful, the result is to drop the Difficulty by the TL of the weapon, but not by more than half of its original value. This can be repeated multiple times, but each time after the first the effective TL is halved (round down).

Example - A forward observer at TL11 calls in reports from 3 spotting rounds. The first report allows the "missed by" amount to be dropped by 11, if it was greater than 22. If it were 20, for instance, it would only be dropped to half its original value, or 10. The second report can drop the value by half the Tech Level (round down), or 5, and the third can drop it by a maximum of half of that (round down), or 2.

Once a weapon is sighted in, the exact target settings can be noted, and as long as the weapon is not moved and fires the same ammunition in roughly the same conditions (temperature, wind, humidity, etc.), then it automatically hits somewhere within the radius appropriate to the Difficulty and skill. Strategic emplacements often have key locations targeted in this fashion, allowing for accurate fire at long ranges. Also indirect fire weapons with known, predictable characteristics (like bombs) can sometimes use this rule to represent a skilled bombardier.



Strafing

Strafing is a vehicle variation of Spray Fire from the **CORPS** basic rules. Normally, spray fire takes the recoil into account for figuring the to hit chance, but for a weapon so solidly mounted that recoil is irrelevant, you *can* use the Range Mod of the weapon to reduce the Difficulty of the task. The pattern of fire is along a path in front of the firing vehicle, and the length of the path is based on the spread for spray fire (the pilot can adjust the flight path to put the spread in a smaller distance than the plane is actually flying). If more than one weapon is fired, add the total number of shots together for figuring the chances. If the strafing vehicle is moving at a high rate of speed, use the average of the distance between where it starts and stops strafing *each second* for purposes of determining hits. The final chance to hit represents how well the strafing run targeted the area aimed at. Note that against dense concentrations of targets, you *will* get hits, but they might not be in the area you thought you were aiming at. For instance, if you put an average of 5 bullets per hex, and strafe a multi-hex vehicle like a tank, your chance to hit it reflects whether the stream of fire actually went across the tank, or missed its location altogether.

Example - An aircraft with a several machineguns (total number of shots per second of 40 and Range Mod of 7) is strafing a roadway 200m in front of it, and the aircraft is going at a speed of 100m/sec. The aircraft starts strafing at 200m and stops at 100m, so the *average* distance is 150m. The *minimum* number of hexes the spread can be across is the Difficulty for range (15), minus the Range Mod of the guns (7), for an 8 hex spread which we assume is a line down the road. With 40 bullets fired, this is 5 per hex, for a "skill" of 5, minus the adjusted Difficulty for range (8, after you apply the weapon's Range Mod), for an effective skill of -3. Compared to a Difficulty of 0 for a person, this isn't very good, but remember that this chance applies to *every* target in *every* hex of the pattern (roll a 5 or less on 1d10 for the skill vs. Difficulty in this case). If a vehicle fills multiple hexes, it is targeted multiple times. Also note that this has *not* included any targeting aids available. Spray fire is *unaimed* fire. If the pilot wanted to target a *particular* vehicle, or do a number of controlled bursts vs. several vehicles, then they would have a better chance if they picked them out as deliberate targets.

Blowing things up

Non-vehicle structures like buildings will have an AV based on their construction material, as per the normal **CORPS** rules. To blow one up or structurally weaken it to the point of collapse takes some work. Each time a building takes a number of "hits" equal to its volume/250, it checks for collapse. A "hit" is damage that completely demolishes at least one hex of supporting structure, like a load bearing wall. This could either be an explosive attack, a vehicle impact, several hits from a cannon-sized weapon or at least a hundred bullets or beam hits from lighter weapons. Attacks that destroy more than one hex of wall count the number of hexes destroyed. Deliberate and *successful* demolition attempts count the height of the structure as a maximum of 1 meter. Normally, to collapse a building from damage is a task with a skill of 0 vs. a Difficulty of 5, rolled when the first number of hits is taken. Each time this hit threshold is reached, increase the "skill" used by 1.

Example - A small office building that is 20m x 20m x 10m has a total volume of 4,000m^3, so it requires at least 4,000/250 = 16 hits before it checks for collapse. After three hits by HE shells that demolish 7 hexes each (impact and surrounding hexes), it has taken 21 hits, and checks for collapse with a skill of 0 vs a Difficulty of 5. After two more HE hits, it has taken 35 hits, and checks for collapse with a skill of 1 vs. a Difficulty of 5.

If a structure collapses, the level of destruction is based on the roll. A marginal success means that part (at least 10%) of the building has failed and caved in on itself. Making the roll by 1 means about half the building has collapsed, and making the roll by 2 or more means total or near total collapse of the building. Characters in part of a building that collapses have to spend 1ASP to avoid being crushed in the rubble (whole body lethal DV of 1d10), or 2ASP to avoid being trapped but otherwise unhurt (requires a lifting capacity of 1d10 x 100kg to eventually get free). Characters on upper levels of a tall structure need to spend +1ASP, and may end up trapped on teetering, unsupported walls with no easy way down and a limited time available before their precarious situation deteriorates and makes their descent decision for them.

Advanced Hit Locations

You can use the following tables to determine hit location on vehicles. These are expansions on the tables in the **CORPS** rules.

Hit locations (land vehicle)

Roll	Front	Rear	Side	Top
1	Body	Body	Body	Body
2	Controls	Body	Controls	Controls
3	Controls*	Fuel*	Engine*	Engine*
4	Engine	Cargo*	Window	Body
5	Engine*	Controls	Body	Window
6	Engine*	Window	Accessory	Accessory
7	Window	Body	Fuel*	Cargo*
8	Body	Window	Cargo*	Fuel*
9	Window	Accessory	Controls	Controls
10	Accessory	Body	Body	Body

Hit locations (water vehicle)

Roll	Front	Rear	Side	Top
1	Body	Controls	Body	Body
2	Body	Engine*	Body	Body
3	Cargo*	Body	Cargo*	Cargo*
4	Accessory	Fuel	Body	Window
5	Window	Body[w]	Window	Body[w]
6	Body[w]	Window	Accessory	Accessory
7	Fuel	Accessory	Body[w]	Fuel*
8	Body	Cargo*	Engine*	Engine*
9	Engine*	Body	Body	Controls
10	Controls	Body	Controls	Body

Hit locations (air vehicle)

Roll	Front	Rear	Side	Top
1	Engine*	Controls	Accessory	Body
2	Accessory	Body	Body	Accessory
3	Controls	Cargo*	Window	Window
4	Body	Fuel	Engine*	Engine*
5	Window	Window	Controls	Controls
6	Body	Controls	Cargo*	Fuel*
7	Fuel*	Body	Body	Cargo*
8	Cargo*	Controls	Fuel*	Body
9	Body	Accessory	Controls	Controls
10	Controls	Engine*	Body	Body

Remember that locations marked with an "*" are only hit after the damage penetrates the armor of the vehicle. On a water vehicle, "w" is a waterline hit (underwater attacks are automatically below the waterline). Also, any balloon, blimp or lighter than air vehicle is hit in the gondola or other mechanical bits only on a roll of "1", in which case you roll for location normally. Otherwise the hit is in the gas bag. On armored vehicles, "window" hits include any vehicle part with reduced armor, like sensor ports. Aiming at a *particular* hit location on a vehicle ranges from +1 Difficulty for things like "Body", to +4 Difficulty to hit a small sensor port, and limits on the level of called shot possible apply as for hand-held weapons.

Example - A hit to the top of an airplane results in a roll of 6. This shot will enter a fuel tank, *after* it goes through the armor provided by the surface of the vehicle.

Remember that these hit locations are generic. A hit to a wing is not necessarily a control hit, nor is a fuselage hit necessarily a body hit. If a hit has a particular game effect (such as Controls), it means that the vehicle has been hit *somewhere* that relates to that system. On an aircraft, a control hit could range from a snipped control cable to a hydraulic pump hit to a piece of shrapnel taking out an auxiliary computer. Likewise, a Body hit could have effects ranging from taking out the pilot in the front to blasting apart the toilet in the back.

If necessary, you can roll on one of the tables below for a more specific effect damage will have on a vehicle system. If a specific effect isn't applicable, roll again.

Controls

Roll	Category	Example
1	Acc	Throttle or accelerator
2	Max	Transmission
3	Turn	Steering
4	Dec	Brakes, air brakes
5	Acc, Max	Throttle or accelerator
6	Max, Turn	Tires, tracks
7	Turn, Dec	Rudder, variable pitch prop.
8	Max, Turn, Dec	Control surfaces plus brakes
9	Acc, Max, Dec	Streamlining plus brakes
10	Acc, Max, Turn, Dec	Central control console

Engine

Roll	Category	Example
1	Acc	Fuel delivery problems
2	Acc	Intermittent power delivery
3	Acc	Throttle sticky
4	Max	Excess engine vibration
5	Max	Engine parts grinding on body
6	Max	Cooling system damage
7	Acc, Max	Exhaust system blockage
8	Acc, Max	Damaged ignition system
9	Acc, Max	Drive train damage
10	Acc, Max	Damaged power coupling

Fuel

Roll	Category	Example
1	Max range	Fuel pump leak
2	Max range	Fuel line break
3	Max range	Fuel line break
4	Max range	Fuel tank puncture
5	Max range	Fuel tank puncture
6	Max range	Fuel tank puncture
7	Max range	Fuel tank puncture
8	Max range	Fuel tank puncture
9	Max range	Fuel tank puncture
10	Max range	Fuel tank puncture

Body (passenger)

Roll	Category	Example
1	Crew	Control station
2	Crew	Engine crew station
3	Crew	Crew quarters
4	Crew	Weapon station
5	Passenger	Public area, corridors
6	Passenger	Specialty lab area
7	Passenger	Toilets, showers
8	Passenger	Kitchen, food storage
9	Passenger	Staterooms
10	Passenger	Other passenger quarters

Accessory

Roll	Category	Example
1	Communication	Radio, phone, signal lantern
2	Environmental	Air conditioning, life support
3	Comfort	Pool table, galley, autopilot
4	Targeting	Radar, headlights, weapon
5	Information	Maps, computer
6	Overall safety	Flares, liferafts
7	Individual safety	Escape bubble, life vests
8	Spares & tools	Spare tire, jack
9	External fittings	Cargo rack, mirrors, sensors
10	Personal	Fuzzy dice, good luck charm

Location effects

When a particular vehicle system is hit for damage, it will have specific game effects on the vehicle, depending on the type of system.

As a system takes damage, it incrementally loses performance. When its appropriate stat goes to zero, or it suffers a catastrophic failure, it stops working entirely. If you want to add the extra detail, you can count this as a failed maintenance interval, using the amount the system failed by (minimum of 1) for special effects on that system. That is, in addition to ceasing to work correctly, there may be additional effects. These could be immediate effects, or they could just serve as a guide to what parts need to be replaced to get the vehicle back into working order. See **Other vehicle maintenance**, **p.114**.

Some vehicles will have unique damage effects, which you can improvise or figure out as needed. For instance, a vehicle propelled by oarsmen could lose a great deal of power just by losing a few oarsmen and having their slack oars foul up everyone elses, and might be counted as one or two large power plants for damage purposes. A turn-crank powered vessel would not have this problem, and might be considered several independent units, and the complete loss of one would only reduce performance proportionally, rather than all at once.

Vehicle Toughness

The basic **CORPS** rules assume human scale combat. To reflect the difficulty of harming vehicles and other very large targets, they will have Toughness, a multiplier on *vehicle* subsystem damage (does not apply to *people* in the vehicle). A Size -1 vehicle has a Toughness of 1, and each time vehicle size increases, the Toughness is halved. Toughness is applied *after* vehicle and subsystem armor is taken into account, and you round damage effects down. This can mean that hits can penetrate armor and still have no chance of causing measureable damage. In addition, when a system takes damage, the effect is ignored *if the current penalty to use that system is the same or smaller.* You do, however, continue to check for instant or eventually fatal results from these hits.

Size	Example	Toughness
-1	Motorcycle	x1.00
-2	Automobile	x.50
-3	Large truck, jet fighter	x.25
-4	Patrol boat	x.13
-5	Airliner, frigate	x.06
-6	Destroyer	x.03
-7	Cruiser	x.02
-8	Battleship	x.01

Example - A car has a Size modifier of -2, so damage to it is multiplied by x.5. An airliner has a Size modifier of -5, so damage to it multiplied by x.06.

Example - If the previous airliner had an AV of 6, and was hit for 25 points in the controls, 19 points would get through, and would be multiplied by x.06 to get 19 x .06 = 1.14, or a +1 Difficulty to use the controls. Subsequent hits of this amount or less would *not* make the controls any harder to use, but would still have a chance of causing an eventual or catastrophic control breakdown.

Damage progression

Normally, when a vehicle takes damage, you subtract the AV of the system hit, apply effects, and then apply remaining DV to a system that is adjacent on the appropriate hit location table. This continues until 4 locations have been hit, or no damage remains. In the case of a vehicle with bulkheads, the designer can specify that certain hit locations are separated from others by bulkheads, one per 10% of the vehicle that is so equipped. If a vehicle with multiple systems or homogeneous systems (like fuel) has bulkheads, maximum damage (normally a 10 point impairment) can be divided by the number of bulkheads.

Example - A vehicle is bought with 5 bulkheads (50%). Hits to the fuel system can cause no more than a +2 impairment per fuel system hit. A vehicle with up to 5 power plants could have only 1 destroyed on a power plant hit.

Obviously, a vehicle with 90-100% compartmentalization with bulkheads would be able to apply this effect to *any* hit.

Details and special cases

Use the following notes to cover any questions that might arise on particular vehicle types or combat effects.

Body

The outer surface of the vehicle. This would be the armor of an armored vehicle, or the body panels of a non-armored vehicle. Damage to the body also applies to any surface treatments, like streamlining. Normally the body of the vehicle is not affected by damage (i.e. you can't "break" the structural framework of the vehicle), so *secondary* hits to "Body" simply pass through the structure AV (*and* bulkheads) and go on to hit the next location. In cases where the body involves an important surface treatment (streamlining, pressure hull, etc.), body hits *will* have secondary effects. On a water vehicle hit by above-water weapons, assign one of the Body hit locations to be "waterline". If that location is hit, the vehicle will take on water as well as any other damage effects. Underwater weapons always hit below the waterline, and top attacks always hit above the waterline.

Effects - If the DV of the attack is greater than the AV of the vehicle, the shot penetrates the outer surface of the vehicle. Against most vehicles, it just leaves a hole. However, this hole can in and of itself be a problem. For instance, on a high speed vehicle, you can say that in addition to the hit, the vehicle also automatically takes the effects of a second hit from flying debris (see p.53). On very high speed vehicles, a small break in the surface can result in a portion of the vehicle skin peeling off due to the drag created by the puncture.

If there is a hostile atmosphere outside the vehicle, then the vehicle is no longer air- or watertight. If the vehicle has a positive pressure system (air pressure inside is higher than outside), this isn't a problem as long as you can maintain the pressure difference.

If the surface treatment of a vehicle is punctured by a weapon or other damage, the vehicle will begin to take on water if the hit is below the waterline, or lose air if it is a high-altitude or space vehicle. The normal hole is the size of the weapon, or the blast radius that penetrates the armor of the vehicle. The amount of vehicle *volume* that is affected by a 1 atmosphere differential in a given amount of time is below.

Hole	per second	per minute	per hour
1cm	.0008m^3	.046m^3	2.8m^3
2cm	.003m^3	.18m^3	11m^3
5cm	.02m^3	1.2m^3	69m^3
10cm	.08m^3	4.6m^3	280m^3
20cm	.3m^3	18m^3	1,110m^3
50cm	1.9m^3	115m^3	6,930m^3
1m	7.7m^3	460m^3	27,700m^3
2m	31m^3	1,850m^3	111,000m^3
5m	190m^3	11,500m^3	693,000m^3
10m	770m^3	46,200m^3	2,770,000m^3
20m	3,100m^3	185,000m^3	11,100,000m^3

One atmosphere of difference is about 10m of depth in water, so these numbers would be about right for hits on the bottom of a ship. Hits closer to the waterline would be proportionately less, with a hit near the waterline multiplying these numbers by x.1.

Each atmosphere of pressure difference between the outside and inside of the vehicle will multiply the rate of loss by the (pressure difference+1).

Example - A submarine at a depth of 100m (about 10 atmospheres) would multiply these numbers by 10 (9 atmospheres of difference between inside and outside, plus 1).

The basic game effects are fairly simple for dealing with hostile environments. When an area of a spaceship has been "filled" with vacuum, there is no air to breathe. When a portion of a water vehicle has filled with water, *add* the volume of that area in tons to the ship's mass. If this *total* mass is more than the volume of the ship...it sinks.

Controls

The maneuvering surfaces of the vehicle and the machinery and communications links to operate them. In vehicle system terms, this is usually the power train. On an airplane this includes the wings, tail and landing gear. On a ship it is the rudder, propeller or paddlewheels. On a land vehicle it is the tires, tracks, steering or brakes. On a spaceship it is either the power train part of reaction engines or the jump drive. The controls may sometimes have the same armor as the body (like on aircraft), or be significantly different (tires and tracks), but they almost never have more armor than the body.

Effects - A hit to the controls of the vehicle means any system responsible for the steering and speed control of the vehicle. So, for instance, on an air vehicle a hit might damage both a control surface to affect Turn, and the damage could affect the streamlining of the vehicle, and therefore its Max. Each point of damage that gets through the AV of the controls subtracts from one or more of the affected vehicle stats or is an increase in Difficulty to use the control system.

A hit to the controls does not usually require any special skill roll by the operator of the vehicle unless there is a catastrophic failure of a control system. Hits to special power trains like jump drive will either affect speed in hyperspace, or a penalty to the mass that can be shifted into hyperspace, each point of penalty being a 10% drop in total "jumpable mass".

Engine
The motive power source, whether an ox, sail or fusion plant. In vehicle system terms, this is usually the power plant. If a vehicle has multiple engines, or is by nature separated into discrete units (solar panels, sails, masts, etc.) roll randomly to see which one is hit. Only on vehicles with completely exposed engines can this be an initial hit location. Note that on human-powered vehicles, an “engine hit” is a person or persons.

Effects - Since most power plants don't have a lot of unnecessary parts, anything that gets through the AV of the engine is likely to affect performance. If Acc drops to zero, it means the vehicle can no longer accelerate. If there is a catastrophic failure, the power plant shuts down, regardless of what performance it has left. On power plants supplying electrical power, each point of penalty is a 10% drop in output if the power plant is still working after the hit.

Sails are a special case of vehicle armor, and are never protected by the armor of the vehicle itself. For purposes of impairing a ship's acceleration and top speed, sails are assumed to have an AV equal to that of any other engine, so that small hits and punctures will have little or no effect. Attacks which would be considered to be “armor-piercing” vs. this type of “armor” will have greater effect (like explosions, cutting attacks, etc.). In addition, all sails are assumed to have one “bulkhead” for each $100m^2$ of sail (maximum of 10 “bulkheads”), and performance losses due to damage from a single hit will be limited to whatever fraction of the sails are damaged.

Example - A man o'war completely loses a sail to a volley of chain shot. If this ship had 10 “bulkheads” worth of sails, the maximum effect on performance would be a 10% loss (round up).

For purposes of targeting, just roll a die appropriate to the number of “bulkheads” to see which one was hit. This can make a difference, as adjacent “bulkheads” will be affected by fire in addition to the systems that are normally adjacent.

Window
On civilian vehicles, especially cars, this would be the windshield or other window glass. On military vehicles this is counted as a normal Body hit.

Effects - Any damage getting through the window armor enters a passenger area and may hit an occupant. On a military vehicle or vehicles with a very small window area (like portholes) this would be counted as a Body hit, and any damage that gets through armor would go into a passenger or crew area. The chance of a passenger or crew member being hit is a skill of 0 vs. a Difficulty of 8, -1 Difficulty for each 20% of crew/passenger capacity used.

Accessory
This is any equipment which is not really vital to the continued operation of the vehicle, but which may have a long-term effect on the vehicle. Examples might include a spare tire, ejection seat, radio, sensor, etc. Most of the time, accessories will only get a quarter the AV of the vehicle.

Effects - Accessory equipment seldom survives weapon hits of any kind. Pick a random piece of equipment inside the vehicle and mark it as damaged and inoperable.

Cargo
This is a hit to the cargo compartment of the vehicle. On dedicated cargo vehicles, treat Window hits as Body hits adjacent to a *Cargo* area instead of a *Passenger* area. The Body location closest to the Controls is assumed to be a passenger area in this case, and hits there will check for crew or passenger damage.

Effects - Cargo hits may hit a random item stored in the cargo compartment. The chance of a cargo item being hit is a skill of 0 vs. a Difficulty of 8, -1 Difficulty for each 20% of cargo capacity used. Note that spare parts and tools are almost always stored in the cargo area.

Fuel
This hit is to the fuel supply of the vehicle. If there are multiple fuel tanks, roll randomly to see which one is hit. Some fuel types are flammable (petroleum, wood, coal), some are less so (animal feed), some are dangerous (radioactives) and others are just plain weird (magic).

Effects - Fuel hits either result in loss of fuel, a fuel leak or a fuel explosion. Impairments reduce fuel by 10% of a full load per point of impairment, while “eventually fatal” and “instantly fatal” results are fuel leaks or catastrophic system failure.

Fires

If a vehicle system takes damage from fire, flame or explosion and is made of or contains a flammable material (power plants and fuel), it may ignite and do even more damage. If the system took an eventually fatal result from the attack, it may be considered "on fire". Each 10 turns after this, it makes an attack against *itself* and *each* adjacent vehicle system on the appropriate hit location chart, with a cumulative DV of 1 (adjusted for vehicle size). The system on fire *does not* apply its own AV vs. this attack, but adjacent systems do and also apply any bulkheads to this amount. If these adjacent systems catch fire, they can in turn spread it to *other* adjacent systems until the entire vehicle is involved. If a vehicle system ceases to work as a result of self-inflicted fire damage, the DV of the flames on it drops by 1 each 10 turns, until it goes out. Adjacent systems can continue to take damage until the fire goes out.

If a vehicle has as "disaster system" like fire extinguishers (see **p.76**), they can be used to combat the effects of fire damage. When installed, fire extinguishers are defined as either manual or automatic. Manual ones must be activated...manually, by a crew member or someone else who has access to the extinguisher controls. If it is crew access only, then this has its advantages and disadvantages. The same can be said if *anyone* can activate it.

Automatic systems activate when a certain pre-set damage threshold is reached, and this is made on the assumption that the extinguisher is adjacent to the fire. So, you could set the system at "3", and when the adjusted DV from fire to adjacent systems reached 3, the extinguishers would activate. A setting of "0" would work on any sudden increase in temperature, and would activate more or less the instant the fire was set. The *minimum* threshold for an automatic system is its (9-TL), but not less than 1.

Fire extinguishers work by using their TL as a skill vs. a Difficulty for the fire. Automatic systems are assumed to act at +1 Difficulty, since they are not as intelligently directed to put out the fire.

Fire type	Difficulty
Wood	4
Low-tech oil	7
Greek fire	10
Refined petroleum	13
High-energy propellants	16

Fire extinguishers on automatic get one attempt each 10 seconds, and each attempt after the first is at +1 Difficulty as either the fire spreads despite the extinguishers and/or the extinguishers begin to run out of their working fluid. Extinguishers with a more or less unlimited supply of working fluid (like seawater or vacuum) do not suffer this cumulative penalty.

Example - A TL10 ship has automatic fire extinguishers in the engine room. As soon as a fire starts (DV of 1) the extinguishers get to try to put it out. They have a skill of 10 (their TL) vs. a Difficulty of 14 (13 for refined petroleum and +1 for it being an automatic system), for a 3 or less on 1d10. If this fails, they get another try 10 seconds later vs. a Difficulty of 15, for a 1 in 10 chance of success.

Explosions

If an area of the vehicle in flames is capable of exploding, then this will eventually happen. Any system which uses fuel of an exotic type or better is capable of explosion, or a catastrophic meltdown at least. Lesser fuels will simply burn vigorously. If when the fire affects that system, the roll is a "1", then the system explodes. If there is not some clearly defined amount for the explosion (like ammo storage), then the square root of the system mass in question is treated as the DV of the explosion. If a low energy fuel (enhanced or lower) is capable of exploding, DV is x.5. Dangerous, fission or fusion fuel is DV x 4 and any antimatter or suicidal fuel type is DV x 10 (use *all* that apply). Assume the entire area filled with the exploding material takes full damage, and the explosion drops in effect past its edges. Remember that the Toughness of the vehicle will apply to this damage.

Example - If the fuel bunker of a ship is Size 5,000 (about 5,000 kilograms of fuel), then if it explodes it will do so with a DV of $5000^{.5}$ = 71. If this were low-grade fuel oil, the heated fumes in an enclosed space might still go off, but with a DV of 35 instead of 71.

Ramming

Serious ramming is orders of magnitude beyond the simple manuevering "bumps" in the basic **CORPS** rules. While the DV of a ram might not technically be that high, the sheer momentum of the ramming vehicle can be immense. It is not *armor* that is the main factor, but the strength of the *structure* supporting it. Think of the difference between a car being hit by a motorcycle and being hit by a train...

A ram is handled as an attack based on the velocity of the ramming ship, as for falling or other impact damage. To figure the DV the ramming vehicle inflicts on the target, take the normal DV of the attack (p.93 of **CORPS** rules) and *divide* it by the *ramming* vehicle's Toughness. *This DV is applied to the AV used to calculate the rammed vehicle's structure mass*. The rammed vehicle applies its Toughness to whatever penetrates this. If the DV is greater than the *actual* armor at that location, there is a *major* puncture, otherwise there is just crumpling and denting (if a puncture results, it is x.1 the size). The ramming vehicle takes the impact DV and divides by the *rammed* vehicle's Toughness, and applies it against its own structure AV, or its *actual* front AV if it used a built-in ram to do the damage.

Capital ships were designed with rams into the late 1800's (late TL7).

General targeting

While there is a useful list of weapons in the **Weapons** chapter, some quick and dirty guidelines follow for targeting weapons at long range.

The most important stat for the weapon is its Range Mod. If the Range Mod + user skill - target size is not within 10 points of the Difficulty for range, getting a hit is going to be extremely difficult and/or time consuming. Outside direct fire range, remember that indirect fire can be used.

Typical Range Mods:	Example	Typical DV	RMod
Small arms (TL6)	Flintlock	10	2
Small arms (TL10)	Assault rifle	20	4
Light mounted weapon (TL6)	Swivel gun	20	2
Light mounted weapon (TL10)	Machinegun	40	10
Small cannon (TL6)	6-pdr	60	7
Small cannon (TL10)	30mm	75	25
Medium cannon (TL6)	12-pdr	90	7
Medium cannon (TL10)	90mm	400	40
Large cannon (TL6)	32-pdr	120	7
Large cannon (TL10)	120mm	900	50
Superheavy cannon (TL10)	16“ cannon	800/50E	70
Small siege engine (TL3)	Ballista	16	10
Large siege engine (TL3)	Trebuchet	36	0

Remember that **CORPS** was designed around a human-level scale (it is a *role-playing* game, not a vehicle combat system). As a result, combat rules have been optimized for the lower end of the scale and you will get skewed results out at the far ends of the weapon spectrum.

In **CORPS** terms, vehicles will have a fairly flat hit distribution curve out to a distance corresponding to their Range Mod. Closer than this and hit probability goes down for moving targets due to tracking delays. Maximum practical range is about 20% past this, plus about 4% for each point of target size, adjusted for aiming, sensors and such.

Vehicle stability

How stable a vehicle platform is for shooting depends on what it is moving over and its velocity. Regular velocity modifiers for the firer assume fire is coming from handheld weapons fired by vehicle occupants, not mounted vehicle weapons. To adjust for larger weapons and different terrain, first apply an increased Difficulty to hit based on the terrain the vehicle is moving through. The adjustment to Difficulty is *never* going to make it easier to hit a target. The best it can do is make things the same as firing from perfect conditions.

Terrain	Difficulty
Perfect (paved road, still seas, calm air)	+0
Near-perfect (good road, light seas, average air)	+2
Passable (poor road, moderate seas, light turbulence)	+4
Poor (off-road, storms, moderate turbulence)	+6
Very poor (off-road, hurricane, heavy turbulence)	+8
Ext. poor (barely passable, severe hurricane or turbulence)	+10

The Size of the vehicle *decreases* the Difficulty for all weapons fire from the vehicle, including hand-held weapons. Half the length to width ratio of the vehicle *increases* the Difficulty for water vehicles, since long, narrow vehicles will roll more from side to side. This increase can never be more than the penalty for the terrain itself. Remember that for weapons fired from a vehicle it is usually the movement of the person that is usually important, not the movement of the vehicle they are on. The exception is if the vehicle is maneuvering unpredictably to avoid being hit.

Example - A destroyer with a length to width ratio of 8:1 is using weapons while travelling through light seas. The ocean conditions are a +2 Difficulty to all fire, the ship size is -6 Difficulty, and the length/width ratio is +2 more (since it can't exceed the +2 for sea conditions). The final total is -2 Difficulty, which goes to +0 Difficulty since you can't get a bonus to hit because of size. Normal movement penalties would not apply unless they were greater than +2.

Example - A tank is travelling over moderately rough terrain and firing its main gun. The terrain is a +6 Difficulty to hit, but the size of the tank is a -3, for a total of +3 Difficulty to hit, or movement penalties if they were more than +6. If the tank were engaged in evasive maneuvering at the same time, then you would count the **CORPS** firer evasive movement penalties instead of normal movement. For purposes of *being* hit, you always take the tank's speed into account. A modern tank would probably have stabilizers (**p.71**) and targeting sensors (**p.82**) to offset some of this penalty.

⚠ For starship combat, extremely long ranges and near-light-speed weapons, do not use firer and target velocity modifiers. Instead use the Acceleration/10. For instance, a ship with an acceleration of 30 would be counted as having a movement of 3m/sec for calculating firer and movement penalties.

Am I Doing This Right?

Question #1:

A giant cylindrical space habitat 5km long and 1km in diameter is hit by a meteor that leaves a 10m hole. How long will it take before the atmospheric pressure is 80% of normal?

Calculations:

A cylinder has a volume of $\pi r^2 h$, where in this case r is 500m (.5km) and h is 5,000m (5km). This gives us a volume of about 4 billion cubic meters (3,930,000,000m^3). Dividing this by the 2,770,000m^3 per hour figure for a 10m hole (**p.97**), this means the atmosphere will be completely drained in 1,418 hours (59 days). Since a 20% loss is one-fifth of this, the time to lose 20% of the atmosphere is (59 days/5)=11.8 days.

Answer:

Time = 11.8 days, plenty of time to patch things up.

Question #2:

How many demolition charges will it take to guarantee the destruction of a skyscraper that is 50m x 50m x 100m?

Calculations:

The threshold for checking for collapse is volume/250. To guarantee demolition, this threshold has to be reached 6 times (raises skill to 5 vs. Difficulty of 5, automatic success). The threshold is the building volume, but count the height as 1m since this is a deliberate demolition attempt (blow up the supports on one floor and the rest of the building crumbles). The threshold is then (50m x 50m x 1m) = 2,500/250 = 10. We need to reach this threshold 6 times, so the minimum number of placed charges is 6 x 10 = 60.

Answer:

Number of charges = 60. The size of these charges and skill required to place them will be based on the construction material and accessibility of the major supports.

Question #3:

What is the Difficulty of hitting a speeding tank (15m/sec) at a range of 2km if your vehicle is stationary, your weapon has a Range Mod of 40 and you have a Rating 2 targeting sensor? What if you were moving 15m/sec over off-road conditions? What if the range were 1km instead?

Calculations:

A range of 2km is a Difficulty of 47 (see **p.92**), reduced to 7 by the Range Mod of the weapon, and to 4 because a tank is probably a -3 size modifier. Checking p.61 of the basic **CORPS** rules, a target speed of 15m/sec is +2 Difficulty, raising the total Difficulty to 6. The Rating 2 sensor adds to user skill rather than changing the Difficulty, but in most cases the effect is the same, and we'll use it to drop the Difficulty to 4. If moving 15m/sec, the firer would normally take +4 Difficulty on the shot, but since off-road by itself is a +6 Difficulty, we use that instead and increase the total Difficulty to 10. If the range were 1km, the Difficulty for range would be 0. The movement penalty for the target would be a point higher (+3), countered by the size of the tank (-3), with another -2 Difficulty for the sensor, making the total Difficulty a -2, an automatic hit. If off-road and moving, the only difference is that the firer movement penalty is +5 instead of +4, which is still less than the +6 for being off-road. So, we just add +6 Difficulty to the -2 previously figured, for a total Difficulty of 4.

Answer:

Range of 2km, moving target, stationary firer = Difficulty 4.
Range of 2km, moving target, moving firer = Difficulty 10.
Range of 1km, moving target, stationary firer = Difficulty -2.
Range of 1km, moving target, moving firer = Difficulty 4.

10 Campaigning

Basics

This section covers everything you need to know to integrate a vehicle into your role-playing campaign.

How your vehicle will be used in a **CORPS** campaign is an important aspect of vehicle design and determines how much obnoxious detail you are going to need in putting it together.

While it is a lot of fun putting together detailed designs for exotic vehicles, you need to remember that they are just a prop in a game. Having a good time is the most important thing. If designing the vehicles is fun for you, then by all means do so with whatever level of detail you want. But not all players or GM's care about using the maximum level of detail, or figuring out space utilization down to the last fraction of a cubic meter. So, think about what you want the vehicle to *be* in the campaign and work from there...

Vehicle as setting

The vehicle is a stage for the adventure, large enough that it is a place for things to happen. A spaceship, man o'war, passenger liner or other large vehicle would be an example.

In this case, the level of detail you need is only superficial. As long as the coarse numbers are correct, you don't need to work it out in minute detail.

Things you need	**Why**
Top speed	How long it will take you to get where you are going is usually a concern of passengers.
Structure AV	Because interior bulkheads will have this value and characters may be hiding behind them as cover.
Accommodations	These take up a lot of volume, and their quantity and quality will give a feel for the interior of the vessel (seedy, cramped, open luxurious, etc.). From this you can add stewards, medical staff, etc.and get an idea the total passenger and crew complement.
Power plant size	It may have a required crew to operate it (per shift), and this will let you know how many technical staff the vehicle has.
Dimensions	For some vessels, this will make a difference in how stable it is in rough conditions, which is especially important if you get seasick, for instance.
Bugs	Checking for random vehicle design flaws is especially appropriate for a new design, and can add some life to an adventure.

Other things to do

Using the rules for corridors and quarters, you can draw up simple deck plans for key areas of the vehicle, like the engine room, a sample deck of accommodations or even a ballroom or promenade. Having designed certain aspects of the vehicle, you can incorporate things into the setting that you might not have thought of otherwise, like the chill of areas without environmental controls, the level of pitch and sway on an ocean liner in rough seas, how hard it might be to hide things, or where a certain number of people might meet in secret without drawing attention to their coming and going.

Vehicle as antagonist

This requires a vehicle that is high tech or magically based. The vehicle is an entity capable of independent action, and the characters have to deal with it. A cybertank, intelligent spaceship or magical construct gone amok would be examples of a vehicle antagonist. It may operate with apparent intelligence, or act in an unpredictable or irrational manner. Unless the vehicle contains something that needs to be recovered intact, this is often just an exercise in finding a way to immobilize/destroy it.

Things you need	Why
Performance stats	All aspects of vehicle performance are going to be important, as characters may be pursuing in vehicles of their own.
Armor value	Character decisions will be based on whether or not they can blow it up from a safe distance.
Size	This will affect how easy the vehicle is to hit, and possibly it stability and maneuverability.
Power plant size	The vehicle may have “captive” crew, or robots or simulacrums that can also be used to stop intruders.
Offensive ability	Anything that can be used against characters should be designed in enough detail that you are sure of being correct if a character gets killed as a result of vehicle actions.
Fuel consumption	If this is a concern, characters can predict vehicle actions based on how and when it has to seek new fuel sources.
Bugs	Sometimes a vehicle flaw is the only way characters can exploit an otherwise impregnable design (ala Death Star).

Other things to do

Often such a “plot device” is used as motivation for the characters to do something completely different than hounding the vehicle. Perhaps to kill the Atomic Zombie Tank they have to go on a quest for the “One True Bazooka”, a journey fraught with perils. However, once they have the blessed weapon, zonking the tank is trivial. Since the GM knows the abilities of the characters, making a vehicle too tough for them to take on is pretty easy. However, players are a clever and devious lot, and just may surprise you.

Another thing to do is use the antagonist vehicle as a two-part challenge. The first part is finding a way to get on board, and the second part is using the vehicle as a setting, where the characters *then* try to immobilize or destroy it.

Vehicle as object of adventure

The vehicle is the goal or object of an adventure, something that must be captured, hijacked or stolen, and then gotten away with. This could be a treasure galleon, experimental jet fighter or disguised urban assault vehicle. If the characters don't get to keep the vehicle at the end of the adventure, the detail needed is obviously less. Even if characters do get to keep the vehicle, don't fill out all the details until they succeed (why waste the effort if it might be blown up halfway through the adventure?).

Things you need	Why
Performance stats	All aspects of vehicle performance are going to be important, as characters may be pursued by antagonists.
Armor value	Mainly important if foes see destruction of vehicle as preferable to its theft.
Size	This will affect how easy the vehicle is to hit, and possibly it stability and maneuverability.
Power plant size	Do the characters have the required numbers and knowledge to maintain the vehicle long enough to reach safety?
Offensive ability	Characters may want to use vehicle weapons against any pursuit.
Fuel consumption	Once they have their greedy little mitts on it, they have to keep it powered long enough to get where they are going. Pursuers may know this and be able to ambush the characters.
Bugs	This can always be a complication in getting vehicle to where it is going. The designers of the vehicle may know about and be able to exploit these, but characters probably won't.

Other things to do

It might not be the vehicle itself that is that important, just some facet that is uniquely valuable. If it is a treasure galleon they are after, all they have to do is get the treasure. If on the other hand they need to get the experimental radar off the stolen jet fighter, they probably need to get the whole plane back home. One nice thing about this vehicle use is that characters can't just go in and blow it up. They have to keep the vehicle intact enough to recover what they came to get, *and* keep it intact *after* they gain possession, so they can get it back home in one piece. It can also be a hook to use so characters will go in a particular direction at some later date...“Star Command let you keep the ship, so long as it is at their disposal should they need its unique capabilities someday...and that day has arrived.”

Vehicle as transport

The vehicle is just a means to get from point A to point B, something that is common in the frame of the campaign. An average car or jetliner is an example. Everyone has access to one if they want it. If an adventure involves the vehicle in a critical sense, it is usually by accident.

Things you need	Why
Performance stats	In case you need to outrun, outmaneuver or otherwise get away from something.
Armor value	It probably won't be much, but it *is* protection against attacks.
Size	This will affect how easy the vehicle is to hit, and possibly it stability and maneuverability.
Power plant size	The output of the power plant determines its AV, and is the single component that most determines if the vehicle is functional.
Bugs	Most transport vehicles will be a fairly standard design, and not have serious design flaws. Old or poorly maintained vehicles might get a few to represent aging and wear. In addition, you might apply “damage” to represent things like bald tires, oil leaks, overheating problems, etc.

Other things to do

Generic, everyday vehicles are also the starting point for heavily retrofitted vehicles. An armored limousine starts with the stats of a normal limousine. An aerial command post starts off as a business jet, or the armored car the partisans have used to be a regular truck.

Vehicle as money sink

The vehicle is a custom project that one or more characters are building or having built. At low tech, this will be a one-of-a-kind item hand made by craftsmen, and at high-tech, it will be a one-of-a-kind item built by computer and tested in simulators and require lots of custom expensive hardware.

Things you need	Why
Everything	Because everything has a cost, and characters are paying for it. If they don't buy it explicitly, the vehicle doesn't have it. Anal-retentive detail is encouraged. Hand the rules to the players, and tell them to give you back the design when they are done, complete with step-by-step intermediate calculations for each component.
Bugs	The only thing players don't get to figure out is the quirks and success of the design team. Characters may decide ahead of time how much more or less than the projected cost they are willing to pay, but the GM gets the fun of figuring out any vehicle flaws.

Other things to do

Building this vehicle may have a number of subplots, like trying to find key components, thwarting sabotage attempts, or having to get it back from someone who has stolen it!

Vehicles and roleplaying

Vehicle combat and roleplaying are not mutually exclusive, but you can make them that way if you are not careful. Remember that the characters are the stars of an adventure, and vehicles are just props.

While **CORPS** is a fairly realistic system, characters may want to do larger than life things with vehicles on occasion. What to do?

Clambering around

Climbing around on the outside of a moving vehicle is generally regarded as hazardous to your health. First, anyone trying to do delicate work or work requiring balance or agility will be at a penalty equal to the roughness of the terrain, minus an applicable size modifier and any enhanced stability of the vehicle. If the vehicle is moving fast enough, there will be an additional penalty of the vehicle's target modifier for movement. Movement will normally require an AGL task each phase against this total Difficulty to avoid falling down (or falling off).

Example - A character is chasing a villain across the top of a speeding train. The terrain of “train tracks” is pretty smooth, and we say it is +0 modifier at the moment. The train is moving at 26m/sec (94kph/58mph), which is a target modifier of +3 Difficulty, for a total increased Difficulty of +3. This is less than the character's AGL, so they have no problem maintaining balance, but trying to tackle someone or leap from car to car will be at +3 Difficulty due to the slipstream they have to fight.

Climbing or any other activity that requires traction or handholds will be affected by the surface treatment of the vehicle. Vehicles with no streamlining are at -2 Difficulty to clamber around on, since there are numerous, easily accessible structural members. Each level of streamlining more than this increases Difficulty by 1, so a vehicle with Basic streamlining is at +0, and a vehicle with Optimum streamlining is at +2 Difficulty, since it is smooth and has few projections to hold onto.

Stunts

Are basically any skill-related task you can get away with. How likely you can pull a given stunt off depends on your skill, and the vehicle you are operating. Assuming the average driver has a skill of 1-2 (Familiarity), you can use the general task difficulty table in the basic rules to figure out how hard a specific task is. In general:

Stunt	Difficulty
Parallel parking	(-Size Mod)+1
Bootleg reverse	(-Size Mod)+2
Tip vehicle onto two wheels	(-Size Mod)+5
Properly judge a jump	(-Size Mod)+5

Failing to pull off a stunt can have consequences ranging from inconvenient to fatal (did you overshoot that jump across the chasm, or *undershoot* it?). The GM will have to come up with logical consequences of a failed stunt. For instance, if you try to pop a car onto two wheels to go through a narrow alley, and fail, one of two things is likely. One, you don't get the car onto two wheels and slam into the wall you were trying to avoid, or two, you get the car onto two wheels and then it falls over onto its side halfway down the alley.

In general, the bigger the vehicle, the smaller the variety of stunts available, and the harder they will be to pull off.

Jumps

The maximum distance a vehicle can cover in Earth-normal gravity is its speed in m/sec squared, divided by 10. This presumes a 45° angle ramp, and makes *no* assumptions about what position the vehicle will be in when it lands. Even for a vehicle that is perfectly balanced, the usual result is nose-down, since the nose of the vehicle starts "falling" while the tail of the vehicle is still on the ramp. It is safest to assume that the vertical distance of any jump (usually half the horizontal distance) is counted as a fall for the vehicle. To this DV is added the absolute value of the vehicle's Size Mod (so a car with a -2 Size Mod would add 2 to the DV). This DV is applied vs. the AV of any component or system that has an AV. Tires can burst, engines can have parts knocked loose, windows can pop out and body panels can buckle. In addition, a vehicle usually does not get more than its basic AV from structure vs. a fall (a tank with an AV of 200 is *not* going to be unscathed after falling off a cliff).

Commercial travel

This is handled by the basic **CORPS** rules, but if you have designed a commercial vessel, you can figure out the daily operating expenses in terms of vehicle cost over useful life, cost per day to operate in terms of fuel and crew salaries, and then use this and a reasonable profit margin to figure out exactly how much the vehicle needs to charge per passenger or ton of cargo to be a viable proposition.

Renting a vehicle will usually cost about x.002 of its replacement value per day, plus fuel usage. Normally, the value is the cost to replace it with something of equal quality, so a good condition used car will still rent for new car prices, but a heap will have a rental cost based on the cost of another heap. Vehicles that require a specialized operator will charge the operator's salary x1.5, *plus* the rental cost of the vehicle. A short-term insurance policy to protect the renter from having to pay the replacement cost of the vehicle is another x.001 of replacement cost per day.

Example - Chartering a twin-engine jet with a cost of 2,000,000Cr will cost 2,000,000Cr x .002 = 4,000Cr per day, plus fuel usage. If you need a pilot, and the pilot is paid 25Cr per hour (50KCr/year), then you will be charged 25Cr x 1.5 x 24 hours per day = 900Cr per day for the pilot (even if the pilot isn't flying 24 hours a day, he is exclusively in your employ for the duration of the charter). With the optional insurance rider for 2,000Cr per day, your total cost per day is 6,900Cr, or about 290Cr per hour, *whether you are flying or not*, plus fuel and airstrip fees when you are travelling.

Legal considerations

Governments are quick to see vehicles as a revenue source, and often regulate vehicle design and laws for usage as well. You can reasonably assume that anywhere there are government supported transportation services (paved roads, navigation beacons, etc.) that there will be a yearly tax or usage fee of around x.02 the current value of the vehicle. You can assume that vehicles depreciate about x.8 of their current value per year for tax purposes. This total covers licenses, registration and so forth. Vehicles will be intertwined with laws in ways that are designed to keep them under control and generate the maximum possible amount of revenue. We won't go into this in great detail, but we will cover a number of basic categories:

Taxes

When you buy or sell a commodity like a vehicle, the cost is probably taxed. How much depends on the enlightenment and greed of the local political system. In addition, simple ownership of the vehicle may be taxed on a yearly basis. Taxes may be based on vehicle size and use. The wording of tax laws may affect vehicle design. For instance, a major tax increase for boats over length 'x' will result in a lot of boats slightly shorter than that. Cargo capacity would be increased by making the boats fatter instead of longer (don't laugh, this is a real world example).

Usage fees

Vehicle taxes under a different name. Localities may require permits for vehicles possessed by residents, in the form of city, county, state or regional fees, permits or required safety inspections, including ID numbers prominently displayed for use by law enforcement. Usage fees also include those fees collected by ports for allowing ships to come in and do business, and may indirectly occur if there are monopolies on a given vehicle service, like tugboats, dock workers, etc.

Licensing

In addition, most TL9+ cultures will have a competency-based licensing system of varying effectiveness, requiring a Difficulty 3 test for simple vehicles like cars, 4 for freight-carrying vehicles and 5 for passenger carrying vehicles. At TL11+ these records are computerized and accessible by phone or radio link, and at TL13+ the license check process is probably automated and virtually instantaneous.

Tolls

A more legitimate type of usage fee, based on the maintenance cost of any area the vehicle moves through, like toll roads. Tolls are also used as extortion money by areas that have the force to make them stick. Tolls are usually based on the size or some dimension of the vehicle.

Crimes

Crimes may be distinguished by being committed with a vehicle, on a vehicle or to a vehicle, and these may be separate under the law, or extensions of existing laws. For instance, stealing a vehicle may just be a major theft, or classified as auto theft. Driving under the influence of alcohol may be public drunkenness, or driving under the influence. Hijacking is an example of a purely vehicle-related crime, as is hit-and-run. The penalties for vehicle crimes are likely to be related to the level of calamity if the vehicle were misused. Driving a car while drunk and hitting someone else may be considered a lot less severe than driving an oil tanker onto a reef after having one too many, or driving while drunk in a country where alcohol is a religious taboo.

Vehicle-related crimes are handled as any other infraction in the appropriate subcase of the **CORPS** legal rules. Multiple misdemeanor or a single felony conviction will also usually result in revoking the appropriate vehicle license for several months to a year, or even for life in exceptional cases. These same laws also cover what equipment and capabilities are legal in certain types of vehicle. Sure, you can put a rocket assist pack in a car and make it work, but you'll probably get arrested for some type of public safety violation if a policeman ever looks in your trunk. And if your car has to have routine safety inspections once a year, the mechanic *may* get suspicious about those empty machinegun brackets and ammo feed slots inside your fender wells. Long-term use of an illegal vehicle in commercial traffic lanes requires a lot of planning and support, or government approval of the vehicle with appropriate documentation to back it up.

Space travel

For slower-than-light space travel, how long it takes to get somewhere is mostly a function of how much and how long you can accelerate. Provided you have enough fuel to accelerate to the half-way point, turn around and decelerate the rest of the way, the table below shows how long a round trip takes at a given acceleration. The number below the time is the maximum velocity you reach in *kilometers* per second (kps), and the astronomical body comparison is a rough figure since distance changes with orbital configuration. If you run into it, a 2 millimeter sand grain has a Damage Value of about 175 per 100kps of velocity you have (make sure you have front armor or shields to match!).

	Acceleration				
	1(.1g)	**5(.5g)**	**10(1g)**	**15(1.5g)**	**20(2.0g)**
400,000km	11.1hr	5.0hr	3.5hr	2.9hr	2.5hr
(Earth-Moon)	20kps	45kps	63kps	78kps	90kps
5,000,000km	39.3hr	17.6hr	12.4hr	10.1hr	8.8hr
	71kps	158kps	223kps	273kps	317kps
25,000,000km	3.7 days	39.3hr	27.8hr	22.7hr	19.6hr
	160kps	354kps	500kps	613kps	706kps
100,000,000km	7.3 days	3.3 days	2.3 days	45.4hr	39.3hr
(Earth-Mars)	316kps	713kps	994kps	1230kps	1420kps
150,000,000km	9.0 days	4.0 days	2.8 days	2.3 days	2.0 days
(Earth-Sun)	389kps	864kps	1210kps	1490kps	1730kps
750,000,000km	20 days	9.0 days	6.3 days	5.2 days	4.5 days
(Earth-Jupiter)	864kps	1950kps	2720kps	3370kps	3890kps
1,250,000,000km	26 days	11.6 days	8.2 days	6.7 days	5.8 days
(Earth-Saturn)	1120kps	2510kps	3540kps	4340kps	5010kps
2,750,000,000km	38 days	17 days	12 days	9.9 days	8.6 days
(Earth-Uranus)	1640kps	3670kps	5180kps	6420kps	7430kps
4,500,000,000km	49 days	22 days	16 days	13 days	11 days
(Earth-Neptune)	2120kps	4750kps	6910kps	8430kps	9500kps
6,000,000,000km	57 days	25 days	18 days	15 days	13 days
(Earth-Pluto)	2460kps	5400kps	7780kps	9720kps	11.2kkps

Example - If your ship has an unlimited .5g acceleration and you are making a run equal to the Earth-Mars distance, the trip will take 3.3 days and you will reach a top speed of 713 kilometers per second at the midpoint of the trip.

If you don't have the luxury of unlimited acceleration because of a limited fuel source, you can figure out the trip time by dividing the total distance by the maximum speed you can reach on half your fuel, where speed in kilometers per second equals acceleration times number of seconds, divided by 1000.

Example - After blasting into orbit, your Apollo capsule has a velocity of 2.5kps towards the Moon. The trip will therefore take 400,000km/2.5kps = 160,000 seconds, or about 44.4 hours.

Temperature regimes

Just because a vehicle has life support and environment control doesn't mean it can operate *anywhere*. Realistically, power plants and to some extent power trains have a limited temperature range they can function over. For instance, a regular car engine that relies on a radiator to keep the engine temperature below 100°C will not work for long if the outside temperature is above 100°C.

When you design a vehicle, pick a 100°C temperature range. The vehicle will work passably well over that range, but the GM can make the vehicle cantankerous within 10°C of either end. For instance, a car with a range of -30°C to 70°C will tend to not start in very cold conditions, or be very prone to overheating in very hot conditions. Vehicles that have missed a maintenance interval lose 10°C off both ends of the reliability range, up to 30°C off each end.

Space vehicles tend to get *very* warm on whichever side faces the sun, and *very* cold on the side in the dark. Any dedicated space vehicle will be designed to handle these extremes, and in a habitable zone orbit, can be expected to have an average surface temperature of at least 60°C.

Extra temperature tolerance can be handled by using environmental controls (p.71) to cover a volume of the entire vehicle, not just the crewed areas.

Example - If you want an all-environment rover capable of handling -60°C to 100°C, then you need to get an as much environment control for the crew compartment as is appropriate for their comfort (probably +/-80°C worth), and probably +/-40°C worth for the rest of the vehicle to keep the engine and moving parts happy and well within a 100°C total range of operation. Note that if you turn the "engine block heater" off to conserve power, you will need to warm things back up again to restart the engine. This warm-up (or cool-down) time would be the same as for an external combustion engine (see p.25).

Building a vehicle

Some notes on the design and manufacture of vehicles and vehicle subsystems.

Design

Most vehicles will require some sort of plans or blueprints to guide their construction. A skilled person *can* build some types of vehicle from memory, making minor adjustments as they go along, but this is the exception rather than the rule.

The time and difficulty of designing a vehicle depends on how much original work needs to be done. If you wanted to design a custom car, but were using off-the-shelf components for the power plant, power train and accessories, the time would be a lot less than if you also had to design the engine, suspension, steering and so on.

Generally, vehicle design is broken into separate skill rolls for the following systems as required:

Power plant	Surface treatments
Power train	Accessories
Structure	Weapons

Each new system will have a complexity associated with its construction, and an associated time to build or design. Assuming a complete workshop for the building of a particular component, the following size items will have the listed design and construction times.

Size	m^3	Sample dimensions	Difficulty	Time
10	.1	1.1m x .3m x .3m	4	1 day
20	.2	1.2m x .4m x .4m	5	2 days
30	.3	1.5m x .5m x .4m	6	5 days
40	.4	1.6m x .5m x .5m	7	10 days
50	.5	1.7m x .6m x .5m	8	20 days
70	.7	2.0m x .6m x .6m	9	50 days
100	1.0	2.4m x .7m x .6m	10	100 days

Larger items use a different progression of scale, each x4 Size (round down) adding +1 Difficulty and +100 days to the time. The sample dimensions below would only apply to an unarmored vehicle, and assume a mass of 1,000kg per m^3.

Size	m^3	Sample dimensions	Difficulty	Time
400	4.0	3.1m x 1.2m x1.1m	11	200 days
1,600	16.0	5.0m x 1.8m x 1.8m	12	300 days
6,400	64.0	8.0m x 3.0m x 2.7m	13	400 days
25,000	256	14m x 4.5m x 4.0m	14	500 days
100,000	1,000	30m x 5.8m x 5.7m	15	600 days
400,000	4,000	50m x 9.0m x 8.9m	16	700 days
1,600,000	16,000	80m x 14.2m x 14.1m	17	800 days

Note that Size here refers to the useful Size of the object, which may be significantly different than its physical dimensions. Using the general guide that vehicle components and the space associated with them take up $1m^3$ per 1,000kg, you can get an equivalent Size for items such as surface treatments (except armor), structure, power plants and power trains. For instance, a vehicle that is $10m^3$ with a structure mass of 1,000kg has a structure Size of 100, *not* 1,000, because the *structure itself* is roughly only a tenth the volume. We're counting the volume of the structural elements, not the volume they enclose. Furthermore, the effective Size of a component for design and manufacture purposes is based on its complexity and the number of people working on it.

Modifiers	Size multiplier
Creating plans and blueprints	x.5
Item is largely non-mechanical (structure)	x.5
Item is of normal complexity (power plant)	x1.0
Item is complex (electronics)	x2.0
Item is cutting edge tech	x2.0
Materials partially prepared/assembled	x.3
1 person working on project	x1.0
2 people working on project	x.7
3-4 people working on project	x.5
5-8 people working on project	x.4
9-16 people working on project	x.3
17-32 people working on project	x.2
33-64 people working on project	x.1
65-125 people working on project	x.08
126-250 people working on project	x.06
251-500 people working on project	x.04
501-1000 people working on project	x.03
1000-2000 people working on project	x.02

The "cutting edge" category is seldom used, and would be best applied to research at the cutting edge of technology, or trying to implement advanced and not yet fully understood principles (aka the Mad Scientist's vehicle).

The maximum number of people that can be *effectively* involved in the design or manufacture of a system is the square root of the (*actual* Size/10)(round up). There may be more people actually involved, but this limit represents the number of people at the highest skill level working on the project. Typically there would be double this number of assistants at 1-2 points of skill less, and double this number of flunkies, gophers and support staff with other skills.

Example - A team of 7 people is working on designing a new jet engine (power plant) with a mass of 4,000kg (Size 400). The base Difficulty is 11 (one quadrupling past Size 100), with a base time of 200 days. However, just designing it is a modifier of x.5, and the fact that 7 people are working on it is another x.4, for an adjusted Size of 80, for a design time of around 50 days, with a Difficulty of 9. These 7 engineers might have a dozen assistants, and a few dozen draftsmen, programmers or consultants. If this engine was on the leading edge of technology, using new materials *or* aerospace theory, then the Size would take the x2.0 multiplier, raising it to 160, for a time of around 100 days and a Difficulty of 10. If it was using both new theories *and* materials, you would apply the modifier twice.

Example - Building a 20,000 ton ship hull (structure) would be the same as an object with a Size of 2,000,000. This is a lot of quadruplings past a Size of 100 (about 7). The maximum number of people you could have directly working on the task is the $(\text{Size of } 2{,}000{,}000/10)^{.5}$ = 448, for a Size multiple of x.04, with another x.5 for it being largely non-mechanical. This gives an adjusted Size of 40,000, which is still 4 doublings over Size 100, for +4 Difficulty and +400 days, or a total Difficulty of 14, and a construction time of 500 days.

Remember that these numbers assume you have everything you need close at hand. Building a Size 10 electronic ignition unit might only take a day, provided you have the electronic components already at hand and have already designed component layout. If you don't have these transistors and microchips, then you have to make each of the individual components first (which requires making a number of large and complex machines first).

Once you have the numbers required, you need to make the appropriate skill rolls. This is usually done by the person *overseeing* the design or construction work, and is based on *their* appropriate skills. For some of these really difficult tasks, you want a dedicated professional.

Modifier	Adjust final Difficulty
Complementary skills	-1
Highly competent staff	-1
Average staff	+0
Marginally competent staff	+1
Incompetent staff	+2
Spend x.25 budgeted amount	+2
Spend x.5 budgeted amount	+1
Spend x1.0 budgeted amount	+0
Spend 2-4x budgeted amount	-1
Spend 5-9x budgeted amount	-2

Example - The project manager for our previously estimated ship hull has a skill of 8, vs. a Difficulty of 14. But, this person also has complementary skills and a highly competent staff. This was also a military contract and went 2x overbudget, reducing the final Difficulty to 11.

If success is automatic, the system works and is made on time. If not, then you have to roll. On a failure, you may *claim* the project is still complete, but you have to roll on the appropriate "bug" table once for each point the roll was failed by. On any "graze" result, the system works but is flawed in some way that isn't immediately apparent, resulting in 1 bug of some type, with a -1 on the table roll. ASP may not be used on these skill checks unless all the work is being done by a single person (and that person has ASP to use).

Example - Our hard-pressed project manager has a skill of 8 vs. a Difficulty of 11, for a success chance of 5 or less on 1d10. He rolls the dice of fate, and gets a 7, failing by 2. Not wanting to risk losing future contracts, the hull is delivered to the next phase of the shipyard's construction crew, but with 2 unknown bugs, since the roll was failed by 2.

Bugs

Each particular subsystem of a vehicle can have its own idiosyncrasies. On prototype or one-of-a-kind vehicles, you are pretty much stuck with them. If they were a simple component replacement problem, it would have been found in the design process and fixed. The die result that indicates the presence of a flaw *also* means it has no easy solution. To fix it, you have to rebuild that subsystem from scratch, a costly and time-consuming process. This is what would be done between the prototype of a vehicle and the production models.

Power plant

Bugs in the power plant can affect power output, maintenance or performance under less than ideal conditions. Roll 1d10. If a result does not apply to a particular power plant type, you get by without any defects.

Roll	Effect
1	Power plant needs maintenance twice as often
2	Power plant has x1.2 fuel consumption
3	Power plant has minimum output of 20% of maximum, otherwise it shuts down
4	Power plant is temperature sensitive, has 20°C smaller total operating range than normal
5	Power plant leaks internal fluids, maintenance cost is 2x normal
6	Power plant is bulkier than normal, takes x1.2 normal volume inside vehicle
7	Power plant is overly complex, maintenance takes twice as long
8	Power plant is louder/brighter/hotter/etc. than normal, -1 Difficulty to be spotted
9	Power plant is fragile, x.8 normal AV (round up)
10	Roll twice more

Example - A new automobile engine design rolls a 4 on the bug table. Rather than having an operating range of -30°C to 70°C, it only works from -20°C to 60°C (-4°F to 140°F), and of course is less reliable within 10°C of either end of this range. If it rolled this bug twice, the range would be dropped by 40°C instead of 20°C, and the designer can choose how heat or cold-tolerant the engine is.

Power train

Bugs in the power plant can affect top speed, acceleration, deceleration, turn mode and other factors. Roll 1d10. If a result does not apply to a particular power train type, you get by without any defects.

Roll	Effect
1	Power train needs maintenance twice as often
2	Power train is flawed, turn mode is x.9 (round nearest)
3	Power train is flawed, acceleration is x.9 (round nearest)
4	Power train is flawed, deceleration is x.9 (round nearest)
5	Power train is flawed, top speed is x.9 (round nearest)
6	Power train is subtly flawed, add +1 Difficulty to any handling action which has an adjusted Difficulty of 5 or more.
7	Power train is overstressed, the simultaneous full use of any two of turn mode, acceleration or deceleration counts as a maintenance interval.
8	Power train is bulky, takes up x1.2 normal volume.
9	Power train is balky, +1 Difficulty to any delicate maneuvering tasks.
10	Roll twice more

Example - The drive system of a new tank rolls a 9. The tank can be driven normally without any problem, but trying to drive it through tight spaces, or up narrow loading ramps is at +1 Difficulty.

Structure

Bugs in the structure of the vehicle affect interior volume, noise and comfort. Roll 1d10. If a result does not apply to a particular structure type, you get by without any defects.

Roll	Effect
1	Structure is inefficient, multiply effective internal volume by x.9 (since this is done after the vehicle is built, roll to see what area gets shorted (passenger compartment, cargo, etc.)
2	Structure is noisy, -1 Difficulty to spot vehicle when moving (this can also apply to electrical emissions, etc.).
3	Structure is obtrusive, +1 Difficulty to any action involving moving inside the vehicle (including maintenance).
4	Structure is obtrusive, +1 Difficulty to spot things outside the vehicle (also applies to sensors).
5	Structure is poorly built, requires maintenance twice as often (this includes things like preventing corrosion).
6	Structure is ugly, +1 Difficulty to sell or promote vehicle on esthetic grounds.
7	Structure is vulnerable, x.5AV vs. a particular type of attack, *or* to any attack vs. a specific other subsystem.
8	Structure is non-standard, all collision damage or armor repairs cost x2 normal.
9	Structure is fragile, x.9 to base AV for that Tech Level (round nearest).
10	Roll twice more

Example - The structure of an aircraft rolls a 4 on the bug table. The placement of wings, struts and/or engines creates blind spots for the pilot, for +1 AWR spotting difficulty.

Surface treatment

Bugs in the surface treatment may vary from annoying to deadly, depending on the type of vehicle. Roll 1d10. If a result does not apply to a particular surface treatment, you get by without any defects. If there are multiple surface treatments, bugs are assigned randomly.

Roll	Effect
1	Surface treatment is not 100% effective, or has 1% chance of complete failure each time it is exposed to adverse conditions (pressure hull fails, tail falls off, etc.).
2	Surface treatment is inefficient, has x1.2 normal mass. Since this is found out after the vehicle is constructed, adjust performance figures accordingly.
3	Surface treatment is flawed, requires maintenance twice as often.
4	Surface treatment is expensive, costs x2.0 normal.
5	Surface treatment interacts with some other vehicle system in a detrimental fashion (streamlining causes missile launch gases to choke your jet engine, top acceleration breaks the pressure seal on airlock #2, etc.)
6	Surface treatment has a hidden vulnerability. It either invisibly weakens or automatically fails in certain uncommon conditions (like a hull made from a wood that is tasty to certain uncommon and geographically restricted sea worms, or a door lock that can be easily bypassed)
7	Surface treatment places certain visual limitations on the vehicle (the special heat resistant tiles are only available in hot pink).
8	Surface treatment breaks in inconvenient ways. Any damage that penetrates the surface treatment will automatically reduce a random performance stat by 1 until repaired (minor collisions interfere with steering, streamlining damage increases turbulence, etc.). This is in addition to any other damage done.
9	Surface treatment or part of surface treatment is flammable under certain conditions, or more so than normal. Double the rate at which fire damage against this system increases.
10	Roll twice more

Example - A new car rolls a 3 on the bug table. It turns out the steel used for the body panels corrodes rapidly in salty conditions, and the body requires regular washing and corrosion checks to prevent damage.

Weaponry

Bugs in the weapon systems are usually just annoying, but can result in a vehicle being scrapped if it fails military fitness tests as a result. Roll 1d10. If a result does not apply to any vehicle weapons (or it has none), you get by without any defects.

Roll	Effect
1	Partially blocked weapon arc. All attacks with a particular weapon system are at +1 Difficulty if the weapon suffers a random disaster (in addition to the normal +2 penalty).
2	Weapon system is touchy and fails to work in certain environmental conditions (electrical system shorts out in high humidity, moving parts clog in extreme cold, etc.). Repairs that fix this flaw simply alter the conditions under which it fails (waterproofing causes weapon to overheat in hot conditions, etc.)
3	Weapon design and vehicle space don't work well together. Any time the weapon needs to be repaired, unjammed or maintained, the Difficulty of the task is increased by 2.
4	The weapon system has a hidden flaw. There is a 1% chance that any weapon malfunction is catastrophic, doing the weapon's normal damage to surrounding vehicle components.
5	Weapon system is inconveniently mounted and requires double the time to perform normal maintenance.
6	Weapon system as integrated into the vehicle is difficult to learn how to use. If the operator of the weapon has not spent 2SP learning how to use the weapon in this particular vehicle, they take +1 Difficulty on all weapon-related tasks.
7	Special vehicle-related requirements make using the weapon twice as expensive as normal. Practice to improve weapon skills on this vehicle costs twice as much.
8	Special weapon mounts and installation headaches make the weapon system cost x2.0 the normal amount.
9	Weapon is unwieldy and requires 1 more crew member to operate than originally planned, or requires crew member with special talents.
10	Roll twice more

Example - A new battle tank weapon system rolls a 9 on the bug table. It turns out the cramped quarters mean the weapon loader has to be short and left-handed in order to manage the weapon effectively.

Accessories

Bugs in the accessories are seldom more than annoying. Roll 1d10. If a result does not apply to any vehicle accessories (or it has none), you get by without any defects.

Roll	Effect
1	An accessory has twice the expected power consumption.
2	An accessory requires twice the maintenance expected.
3	An accessory system has a subtle flaw that occasionally causes headaches (the CD player is easy to steal).
4	Two accessories interfere with each other, and one must be deactivated for the other to work properly.
5	Vehicle-based sensors require special training to use. Operator must spend 2SP to learn how to use it on this particular vehicle type or take +1 Difficulty on its use.
6	An accessory is unreliable, and will automatically fail maintenance checks.
7	An accessory has a 10% chance of not working any time it is used. No cause can be found, repairs not possible.
8	An accessory is obtrusive and will either break or cause repeated bruises from people bumping into it.
9	An accessory has a 10% chance of self-activating anytime a performance limit of the vehicle is reached (Acc, Dec, Max, Turn)
10	Roll twice more

Example - A new sub design rolls a 4 on the bug table. It turns out that pressure from the reserve air tanks causes the toilets to work in reverse (violently) if both are used at the same time. Warning lights linked to the system are placed in all toilets to reduce the number of mishaps.

Standardization

Mass produced vehicles have the advantage of standardization, parts from one vehicle interchanging with other vehicles of the same type. The more mass production there is, the more likely that manufacturers will cut costs by using the same components on as many vehicles as possible, like spark plugs, air filters, windshield wipers, tires, etc. This does not make repairs any easier, but it does make it easier to find parts, either by buying them, or scrounging them from other vehicles.

If a vehicle is a prototype or unique, getting parts for repairs and maintenance is another matter. That x100 cost multiplier for prototype vehicle cost? It applies to maintenance and repairs as well, since every single part has to be custom made just for *your* vehicle.

Once a standardized vehicle ceases to be manufactured, whether or not spare parts remain available depends on how popular and durable the vehicle was. As long as society is still functioning, there will be a subset of the population that likes the vehicle enough to keep a small but steady parts supply flowing, although it may be at several times the price of the parts when the vehicle was still made. If the vehicle was very popular, there may be entire businesses devoted just to the spare parts for that vehicle, with competition keeping the price down to normal levels (people are still selling parts for Russian T-34 tanks, even though it has been 50 years since any were made). Once a vehicle is 2 Tech Levels out of manufacture, most of the normal parts sources will have dried up, and collectors or aficiandos will have to scrounge used parts from wrecked vehicles, or make new parts. The former is time consuming, and the latter is expensive. If the parts have to be custom made, maintenance is x100 cost. If there is still enough of a user base to warrant mass production of parts, cost is probably only slightly more than normal.

Modular components

Some vehicles are designed to be retrofitted, by being built from modular components which can be switched out very quickly. For instance, a tank might have all the power plant components bolted together so that they can be lifted out as a unit, allowing for easy replacement. It also means the engine bay can have the minimum possible volume, since maintenance is supposed to be outside the vehicle, not while it is installed. To a lesser extent, an outboard motor on a powerboat is a modular component. It can be unbolted and carried off, repaired or replaced.

Any vehicle component eligible for modularization (usually power plants and some power trains) can be made so for x1.5 the normal cost. The benefit is that with proper facilities, maintenance or repair is at -1 Difficulty, and complete repair or replacement of the system is at -2 Difficulty, which can save a lot of time and effort.

Warranties

A warranty on a vehicle is a goodwill gesture by the seller that the vehicle is of acceptable quality, backed by free repairs for a certain time period based on market pressure and how likely the vehicle is to last until the warranty expires. Usually, this is halfway through the first maintenance interval for the *least* reliable parts. This is a pretty safe bet for the seller. If market pressure is such that a longer warranty is needed, it may be tied to a regular maintenance schedule, or have limits on what is covered (normal wear is *never* covered). For instance, the power plant, power train and surface treatment (rust warranty) may each have a different warranty period. An extended warranty may be available for the vehicle. The cost of this is double the maintenance cost for the total period of the warranty.

Example - A car with a 1,000 hour maintenance interval is assumed (by the manufacturer) to be used at an average speed of 60kph. A thousand hours at this speed is 60,000km, so the manufacturer gives a generous 30,000km full warranty. If the maintenance cost for the vehicle was 100Cr, then a warranty extending to 60,000km would cost an extra 200Cr (double the cost of that maintenance interval). This doesn't pay for maintenance, but is the manufacturer hedging their bets on potential repair costs if the vehicle breaks down. This 200Cr cost could be added to the vehicle price automatically, and the manufacturer might claim the longer warranty as a “standard” feature, making the vehicle sound more attractive.

Markup

The **VDS** cost of a vehicle is usable however you want in your game world. Within the **VDS** framework, it represents the assembly line cost of the vehicle, with no added profit. How many hands the vehicle sees before it gets to you determines the final cost. *In general*, assume the base cost is x1.0, and add +.3 to this for each time it is sold.

Example - A manufacturer sells a 10,000Cr car to a dealer, who sells it to you. It was sold twice, so the end purchaser has to spend 10,000Cr x 1.6 = 16,000Cr.

If parts of the vehicle have to be imported or bought through channels, this same multiple will apply to the cost of that component.

Example - If a TL13 manufacturer imports TL15 fusion reactors for its vehicles, and buys them from a merchant who bought them from a distributor who bought them from the factory, these fusion reactors will have x1.9 cost. When the finished vehicle is sold, it is treated as a unit, and the increased power plant cost is simply part of the purchase price that is bumped up each step down the distribution chain.

Retrofitting

Retrofitting is the art of ripping out old vehicle components and cramming in new ones. For extremely expensive vehicles it is often significantly cheaper than building a new vehicle from scratch, and allows the user to take advantage of incremental technology improvements.

For vehicle subsystems which do not directly affect movement or performance, it is simply a matter of replacing old technology with new, counting it as a vehicle repair for the appropriate size component.

For power plant or power train upgrades, it is a little trickier. The original vehicle frame, power plant and power train were designed with the performance and limits of each other in mind. If you take a land vehicle with a designed top speed of 20m/sec, and then you cram in a power plant that will let it do 40m/sec, something is likely to give, whether the power train, structure, or both.

What happens is that each time you double power plant output, you quarter the maintenance interval for the structure and power train. Maybe you can cram a car engine into an ox cart, but the resulting unholy hybrid isn't going to last very long.

Upgrading the power train is possible, as is the structure. This could be new components or reinforced old ones, and these are major repairs with significant time and cost associated with them.

Getting power plants, power trains and structures from different Tech Levels to work well together is more difficult than normal. Add 1 to the Difficulty of any repair task that involves components of mismatched Tech Levels, for each 2 Tech Levels of difference (round up).

Example - You have a TL10 compact car that you want to make into a tiny terror. At first, you rip out the easily maintained 40kw power plant and replace it with a turbocharged 80kw model that barely fits the engine compartment. It really tears up the road...but...

Since you no longer have the spare room the original engine gave, routine maintenance is now a real chore, and takes twice as long. Also, a tank of fuel doesn't last nearly as long as it used to.

After about a month, the grinding noises from the transmission tell you that that should have been improved as well, and the torque from the engine is tearing loose the engine mounts, calling for some structural improvement too.

Next time, have the engine replacement done by a professional...

Breakdowns

If a power plant fails due to wear or lack of maintenance (or optionally, combat damage), the effects are based on the type of engine and fuel. Roll 1d10 with applicable modifiers.

Power plant	Die mod.	Fuel type	Die mod.
Durable	-2	Crude	-2
Normal	-1	Normal	-1
Enhanced	+0	Enhanced	+0
Exotic	+1	Exotic	+1
Dangerous	+2	Dangerous	+2
Extremely dangerous	+3	Extremely dangerous	+3
Suicidal	+4	Suicidal	+4

Roll	Result
1-	Minor engine failure, repairable by catching up on lost maintenance
2	Minor engine failure, repairable by catching up on lost maintenance
3	Moderate engine failure, requires 2x normal maintenance time and cost to repair
4	Moderate engine failure, requires 2x normal maintenance time and cost to repair
5	Moderate engine failure, requires 3x normal maintenance time and cost to repair
6	Moderate engine failure, requires 3x normal maintenance time and cost to repair
7	Major engine failure, requires 4x normal maintenance time and cost to repair
8	Engine catastrophically fails, is not repairable without full facilities and replacement parts
9	Engine catastrophically fails,damaged beyond repair. Containment for fuel and engine parts is marginal, and leaks of internal engine fluids, components and fuel will fill the area surrounding the power plant.
10+	Engine catastrophically fails, sending engine parts flying and releasing vital engine parts and fuel into the immediate environment. Any containment devices fail. In addition to immediate and long term effects of engine and fuel being spread around the countryside, the engine explodes with a force of its output in $kw^{.5}$. Living power sources just keel over and die.

If you assume a potentially dangerous power plant has safety features to prevent explosions, either assume that 10+ results don't happen or apply -(TL/2) (round down) to the die roll. If used as a combat result, remember that engine performance can be based on a lot of little things. Your engine might have stopped working simply because a few key wires were cut, and this could be easily fixed once you figure out what is wrong. It might also have stopped because some key ball bearings were shot out and the power plant ground itself to bits as a result. You never know.

Other vehicle maintenance

All vehicle systems need maintenance on occasion, and anyone who has ever had a car rust out from under them can tell you. Power plants generally are more obvious about it, though. All non-power plant parts of a vehicle (each type of system) can use maintenance each 1,000 hours of use to keep up a good appearance and efficiency. This can be waxing the finish, emptying the ash trays and replacing the shock absorbers every 50,000km, or whatever seems appropriate for the vehicle in question (scraping off space barnacles).

This maintenance will have a total cost of 1% of normal vehicle cost, and is optional. Failure to do so only has game effects if the GM desires it (and they probably will, so be warned). The tables below cover failed maintenance on other vehicle systems besides the power plant. Subtract 2 for the first missed interval, 1 for the next interval, and all other rolls are only modified as indicated.

Structure & surface

Roll	Result
1-	Cosmetic damage only
2	Cosmetic damage only
3	Cosmetic damage only
4	Intermittent surface treatment failure, may result in minor internal damage in extreme cases
5	Structure is showing its age, -1 to its effective AV . If AV of surface goes to zero, outer surface is riddled with corrosion or rust. If structure AV goes to zero, vehicle falls apart.
6	Structure is showing its age, -1 to its effective AV . If AV of surface goes to zero, outer surface is riddled with corrosion or rust. If structure AV goes to zero, vehicle falls apart.
7	General wear and tear, add 1 to all future rolls on this table unless structure is given complete overhaul, at 4x normal maintenance time and cost
8	Some structure or surface treatment related function takes a permanent +1 Difficulty to use
9	Structure degrades visibly, with partial failure of some function of a surface treatment, if any.
10+	Structure fails next time it is placed under any stress greater than it is under when this roll is made

Controls

Roll	Result
1-	Cosmetic damage only
2	Cosmetic damage only
3	Cosmetic damage only
4	Controls make annoying noises at maximum limits
5	Random worrisome noise somewhere in the control system. Does not go away after maintenance.
6	Controls are worn, all but frequent users operate vehicle at +1 Difficulty.
7	General wear and tear, add 1 to all future rolls on this table unless controls are given complete overhaul, at 4x normal maintenance time and cost
8	Some control related function takes a permanent +1 Difficulty to use, like taking extra Difficulty on a specialized maneuver. This can be fixed at 4x normal maintenance time and cost.
9	The Turn of the vehicle is reduced by 1 until a system overhaul is done, with 4x normal maintenance time and cost.
10+	Controls fail the next time maximum Turn is used. The vehicle becomes uncontrollable and controls lock in the position used when they broke. In addition to other damage caused, controls need major parts replacement.

Accessories

Roll	Result
1-	Cosmetic damage only
2	Cosmetic damage only
3	Cosmetic damage only
4	Very minor parts failure with little real effect, like a broken knob on the radio or burnt out ashtray light.
5	Very minor parts failure with little real effect, like a broken knob on the radio or burnt out ashtray light.
6	One accessory develops a minor problem that somewhat alters vehicle operation, like the ignition makes rude noises through the radio, or high beams don't work anymore.
7	Random malfunctioning accessory decides to start working again. Effect lasts until next maintenance interval.
8	One accessory item develops an annoying flaw that is a permanent +1 Difficulty to use. Can only be fixed by replacement of flawed unit.
9	One accessory has a 1 in 10 chance of failing to work for unknown reasons each time it is turned on.
10+	One accessory inexplicably fails next time it is used. Requires complete replacement with new unit.

Real world power plants

While you can design up virtually any technology using the abstract nature of **VDS**, there are a number of historically known and conceptually likely systems we can give you guidelines for.

Reciprocating external combustion

Also known as a steam engine. Historically dates to TL6. This type of power plant uses steam power to drive pistons, which in turn usually provide rotary motion for driving wheels. Usually they are *durable* power plants designed to burn a particular type of fuel, and require modification to effectively burn any other type. The normal fuels would be wood, coal or oil, *very crude* to *normal* fuels. They can be boosted and tweaked if necessary. With GM permission, boosting may be possible at no extra charge, since you just overstress the boilers by using more or hotter fuel than normal. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/2) x 100/TL

Fractional power is usually available for *all* power plants on a proportional basis during this time (i.e. if 10% of the time has passed, you have 10% of power plant output).

Example - A 10,000kg TL8 steam locomotive will take (10,000kg$^{.5}$/2) x 100/TL8 = 625 seconds (≈11 minutes) to start from a cold stop.

Turbine external combustion

Also known as a steam turbine. Historically dates to TL8, although the principle was known to the Greeks at TL3. This is a more advanced form of steam engine, and uses high pressure steam to drive a turbine, which is usually geared down to provide the desired revolutions for the end use, like the propeller of a ship. It is bought as a *normal* type of power plant, and will use either coal or oil as the fuel. Low tech versions may also use wood, peat or any other combustible material, either *crude* or *normal* fuels. It may be boosted or tweaked like a reciprocating external combustion engine. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/4) x 100/TL

Example - A 10,000kg TL8 steam turbine will take (10,000kg$^{.5}$/4) x 100/TL8 = 313 seconds (≈5.2 minutes) to start from a cold stop.

Available historical figures for the largest external combustion (i.e. steam) engines show that they are both *a lot* heavier than they needed to be *and* heavier than **VDS** would have them (≈1,000kg/hp vs. a **VDS** figure of ≈10kg/hp), and for the same output they consume about 2-3 times the fuel as a **VDS** power plant. Caveat emptor.

Electric motor

Historically dates to TL8. This uses electrical power to generate motive power, and thus requires batteries or some type of generator in order to run. An electric motor is always bought as a *normal* power plant. It may be boosted or tweaked. This type of power plant can be started from a cold stop almost instantly, with only inertia lag to get the parts moving. It can be started in:

time in seconds = (mass in kilograms$^{.5}$/4) x 10/TL

Example - A 10,000kg TL9 electric locomotive will take (10,000kg$^{.5}$/4) x 10/TL9 = 27.8 seconds to wind up to full power from a cold stop.

Fission reactor

Historically dates to TL9. This usually uses the heat generated by fission of radioactive isotopes to heat water, and provide steam for turbines, either to generate electricity or provide motive power. Usually a fission reactor is bought as up to an *extremely dangerous* power plant type, with a self contained source of fuel, also *extremely dangerous*, with the *fission-based* modifier. Due to the normal mass and hazards of dealing with the reactor and fuel, durability is usually bought up as much as possible. This multiplies reactor cost, but if you figure what an accident costs, it may be worth it. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/16) x 1000/TL

Example - A 100,000kg TL10 nuclear reactor will take (100,000kg$^{.5}$/16) x 1000/TL10 = 1,976 seconds (≈33 minutes) to warm up from a shutdown condition.

Fission reactors are usually heavily overengineered, usually enough to contain a worst possible failure event, at least for a little while. Fission plants will not usually blow up on a catastrophic failure, but will cause a lot of damage and release an equivalent amount of energy in the form of radioactive byproducts.

Fission reactors may also be used in reaction engines, and may use virtually any type of liquefiable fuel as reaction mass. This is handled as listed in the **reaction engine** rules (**p.19**).

Fission, fusion and anitmatter reactors come in a variety of styles, which is why they may be bought as *up to* a type. You could build a “durable” reactor, and in fact it would be more efficient in terms of total power generated per unit fuel, but the watts output per kilogram would be significantly less. A conventional nuclear power plant would be bought a normal or durable reactor, plus a year's supply of fuel, shielding for that fuel (see **p.118**), an electrical generator (**p.18**), plus heat sinks (**p.23**), plus crew stations for its size (**p.17**), plus any safety features added (**p.76**). Reactors *do not* have a mandatory minimum size in **VDS**, but you should look very skeptically at any with a mass of less than ((20-TL)^5/TL)kg.

Fusion reactor

Will hopefully date to TL12. The byproducts of the fusion reaction can be used to generate heat, plasma and radiation, which can be harnessed for various purposes. Fusion reactors are considered *extremely dangerous* power plants for output purposes. Deuterium is an *exotic* fuel, but not radioactive. Tritium is a *dangerous* fuel, *and* is radioactive, which makes a difference for fuel storage purposes. Both are *fusion fuels* for fuel consumption purposes. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/16) x 100/TL

Example - A 100,000kg TL12 fusion reactor will take (100,000kg$^{.5}$/16) x 100/TL12 = 165 seconds (≈2.7 minutes) to start from a cold stop.

Fusion reactors also need a *significant* power source to start the fusion reaction. This is generally going to be a source equal to the output of the fusion plant, for half the duration of the startup time. This represents your lasers or electron beams starting the fusion reaction and maintaining magnetic confinement until the reactor itself generates enough power to take over these functions. The raw plasma output of a fusion reactor can be used as a reaction engine, and the fuel consumption increased to increase thrust, either by using *much* more deuterium or tritium, or in combination with another reaction mass like liquid hydrogen. This is handled as listed in the **reaction engine** rules (**p.19**).

Antimatter reactor

Will hopefully date to TL14. Operates like a fission or fusion reactor, generating great quantities of heat through the matter-antimatter annihiliation process. Exactly how this power is harnessed is variable, given the technological advances likely by TL14. Normally, the heat generated by the matter/antimatter reaction would drive some sort of intermediate stage to provide electricity for antigrav plates or some other high-tech system. However, it could also be used directly as a reaction engine by heating up a working fluid to incredible temperatures and venting it through a rocket nozzle. This would be by the same process as a fusion or fission reaction engine. For output purposes antimatter is a *suicidal* power plant using *suicidal* fuel with the *antimatter* modifier on fuel consumption. In real-world terms, this **VDS** is about .0058% efficient. A 100% efficient plant would be a *total* fuel type multiple of about x.000000002. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/25) x 100/TL

Like fusion reactors, they will require an outside power source during this time.

Example - A 100,000kg TL15 antimatter reactor will take (100,000kg$^{.5}$/25) x 100/TL15 = 84 seconds (≈1.4 minutes) to start from a cold stop.

Reciprocating internal combustion

A conventional piston engine or variants, such as the Wankel rotary engine. A fuel mix is burned inside the engine, and the expanding gases push pistons whose motion is, or is converted to rotational motion to drive a propeller, wheels, etc.

Diesel engines are considered durable power plants burning normal fuel. The average automobile engine is a normal power plant burning normal fuel. A high performance sports car uses an enhanced power plant burning normal or enhanced fuel. Race cars are usually exotic power plants burning enhanced fuel, and drag racers usually have dangerous power plants burning exotic fuels. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/final output modifier) x 10/TL

Example - A 200kg TL10 automobile engine will take (200kg$^{.5}$/4) x 10/TL10 = 3.5 seconds to start from a cold stop.

Turbine internal combustion

A jet engine is the typical example, and the technology dates back to TL9. The expanding gases caused by combustion of the fuel drive a sequence of turbine blades, which generates rotary motion. This can be used to drive wheels, propellers or other power trains. It has the advantage of being able to generate extremely high revolutions per minute, and if designed to produce thrust through its exhaust, is capable of powering a vehicle past the speed of sound, something not possible for a propeller-driven craft. They are normally considered *exotic* power plants burning *enhanced* fuel of some type. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/9) x 100/TL

Example - A 1,000kg TL10 jet turbine will take (1,000kg$^{.5}$/9) x 100/TL10 = 35 seconds to start from a cold stop.

Solar power

Direct solar generation of electricity is a TL9 development. The use of solar power to generate heat for other purposes is possible at any TL where polished metal can be acquired in quantity, normally TL2+. Other details are as described in the **Power Plants** section (**p.21**). Solar electric power is available instantaneously upon exposure to a light source, but use as a heat source will have a startup time appropriate to the secondary technology used, i.e. if a solar steam engine, use steam engine startup time, etc.

Solid fuel rocket

As a power plant/power train combination, these date back to TL3, and Chinese black powder rockets. Knowledge of black powder arrived in the West at TL4, and rockets as a weapon at least didn't catch on until TL7. A solid fuel rocket is a combination power plant, power train and fuel supply, which cannot be turned off once ignited. It burns until the fuel is expended. They are typically a *dangerous* type of power plant using an *exotic* fuel, with however much increased thrust you can get with extra fuel consumption. Typically, the duration of the fuel supply is matched to the first maintenance interval, so the rocket burns out right before it would become unreliable. Since rockets have a distressing tendency to blow up, not everyone designs their rockets in this way. Solid fuel rockets usually have full thrust available from the instant of ignition.

Liquid fuel rocket

These date to TL8, or experiments at TL8 leading to practical application at TL9. Liquid fuel rockets are *dangerous* power plants burning *exotic* or *dangerous* fuels at an appalling rate. Their advantage over solid rockets is that they can be throttled, started and stopped with far less trouble. Most liquid fuel rockets use a mix of two *dangerous* fuels (liquid hydrogen and liquid oxygen), although they can use a two part mixture of a *dangerous* fuel and an *enhanced* fuel (liquid oxygen and aviation kerosene), or other noxious substances like nitric acid, hydrazine, concentrated hydrogen peroxide, and so on. This type of power plant can be started from a cold stop in:

time in seconds = (mass in kilograms$^{.5}$/12) x 10/TL

Example - A 2,000kg TL12 liquid fuel rocket booster will take (2,000kg$^{.5}$/12) x 10/TL12 = 3.1 seconds to start from a cold stop.

Typical fuels

The following guidelines should be used if you want to get real-world fuel volumes for your power plants. Otherwise, just use the generic fuel figures.

Wood

Wood, neatly stacked, takes up approximately 1m^3 per 500kg. Counts as a *very crude* fuel, with a cost of 500Cr per 1,000kg. Available at TL1+.

Coal

Coal takes up approximately 1m^3 per 2,000kg. Counts as a *crude* fuel, with a cost of 700Cr per 1,000kg. Historically available at TL6+ in Western cultures, TL4+ in China.

Oil

Oil or other petroleum derivatives take up approximately 1m^3 per 800kg. Counts as a *normal* fuel, with a cost of 1,000Cr per 1,000kg. Historically common at TL8+.

Gas

Compressed gases take up approximately 1m^3 per 50kg. Liquefied hydrogen takes up about 1m^3 per 70kg, oxygen about 1m^3 per 1,200kg and natural gas about 1m^3 per 525kg. Liquefied or compressed gases count as *dangerous* or *exotic* fuels respectively, with a cost of 9KCr or 4KCr per 1,000kg. Compressed gases are available with some work at TL7+, and reliable storage of liquefied gases is available at TL8+.

Batteries

Batteries are usually made from heavy elements at lower TLs, and get less dense at higher TLs. Assume batteries take up (TL)m^3 per 1,000kg. Count as a any of several types of fuel from very *crude* to *dangerous*. *Very crude* batteries are available at TL5+, and theoretical potential goes up one fuel type per TL after 5.

Flywheels

Flywheels require mass to store energy, but at higher TLs, they can be spun to higher velocity and need less mass for the same amount of energy. Flywheels take up (TL/2)m^3 per 1,000kg. The type of fuel a flywheel counts as depends on how fast you are willing to spin it, with associated dangers of catastrophic flywheel failure (count as having the ability to explode). Flywheels are available at TL1+.

Isotopes

Radioactive isotopes of heavy elements are extremely dense. As a fuel, assume they take up .05m^3 per 1,000kg, plus whatever shielding is used. Fission fuels are an *extremely dangerous* fuel type.

Deuterium/tritium

Fusible hydrogen isotopes (as “heavy water”) have a volume of 1m^3 per 1,000kg, and require minimum shielding, if any. Tritium is radioactive and should have an increased mass for its fuel storage. Fusion isotopes are *exotic* fuels.

Antimatter

Antimatter will typically be stored as supercooled anti-sub-atomic particles, with the low density of $1m^3$ per 1,000kg (not that anyone would want 1,000kg of antimatter lying around). Antimatter is a *suicidal* fuel type.

Magic

Any type of magic fuel would follow guidelines for a similar conventional fuel. For instance, magic cards would burn about as well as wood, and be treated as such for storage purposes.

Specialized fuel handling

This does not increase the *volume* of the fuel storage if using the real-world guidelines just listed, but does increase the cost and/or mass of the storage facility. Stable, normal temperature fuels that are not inherently dangerous have zero cost and mass for their fuel tanks, as it is just a specialize cargo area. Other fuels will have to allot extra mass for their fuel tanks, but the volume is the same unless previously noted for that fuel type.

Fuel is	Storage is
Stored at radically different temperatures (requires insulation)	Fuel mass x .5 Fuel cost x 1
Not stable under normal conditions (compressed gases)	Fuel mass x 2 Fuel cost x 1
Dangerous to be in close proximity of (radioactive isotopes)	Fuel mass x 2 Fuel cost x 2

	temp	unstable	prox
Wood	No	No	No
Coal	No	No	No
Petrochemicals	No	No	No
Compressed gas	No	Yes	No
Liquefied gas	Yes	No	No
Deuterium	No	No	No
Uranium, plutonium, tritium	No	No	Yes
Antimatter	Yes	Yes	Yes

Example - Liquefied natural gas takes up $1.9m^3$ per 1,000kg and costs 2KCr per 1,000kg. This is a cryogenic liquid and requires insulation, so the fuel tank has x.5 the mass of the fuel and x1 cost of the fuel. So, the storage tank for 1,000kg of LNG would mass an extra 500kg and costs 2KCr.

Example - Fissionable uranium isotopes are an extremely dangerous fuel that take up $.1m^3$ per 1,000kg, with a cost of 1.6MCr per 1,000kg. A storage bunker for 1,000kg of fission fuel would mass 2,000kg and cost 3.2MCr. Note that this is not just a big lead-lined box, but also includes any machinery needed to safely power up and power down the reactor. While for a car, refueling simply requires taking off the gas cap and pouring more in, refueling a reactor is a little more complicated than just opening the lid...

Vehicle layout

Laying out the floor plan of your vehicle is done on the large hex sheets in the back of the rules. For most human-occupied vehicles (standing room), a floor plan will be about 1 hex per 2 cubic meters. Multiple decks would be handled based on this amount and the dimensions of the vehicle, plus or minus amounts based on special considerations like ballroom ceilings and so forth.

Example - Take a cubical ship 30 meters on a side. It has a volume of 30m x 30m x 30m = $27{,}000m^3$, so it has a floor plan of about 27,000/2 = 13,500 hexes. Since each deck is 30m x 30m = $900m^2$ in size, the ship has $13{,}500m^2/900m^2$ =15 decks. Each deck would be a separate floor plan. Taller decks (say the engine room) would mean less decks, while a race of beings 1m tall would require less headroom and have more decks...

For vehicles that would have multiple decks of different areas, like in a sphere or cylinder, just divide the decks into areas appropriate to your needs. There's no need to get extra-detailed about it.

Individual components take up 1 hex per $2m^3$ of volume, and when you draw it out, the component fills the entire space if it has no maintenance room, and about half the space if it does.

Quarters, galleys, hallways and so on are simply drawn out as for the guidelines for those systems. If multiple things occupy the same volume, like a crawlway *and* machinery, put one in with dotted lines.

The reference section has a number of blank vehicle sheets, and one of them should be suitable for the scale of your vehicle if you want to lay out a floor plan or put in an illustration of some type.

Am I Doing This Right?

Question #1:

How much would it cost to charter a 20MCr airliner for a week, including 250KCr of total salaries (pilot, co-pilot, attendants), assuming you also have to pay an insurance fee to cover possible damage to the plane?

Calculations:

Renting a vehicle is normall x.002 of its replacement value per day, with another x.001 for the insurance, or 20MCr x .003 x 7 days = 420,000Cr. Salaries are 1/52 of a year (1 week), but x1.5 to cover profits or benefits, for 250KCr x 1/52 x 1.5 = 7,212Cr, for a total rental cost of 427,212Cr. Plus fuel and airport charges...

Answers:

Charter cost for a week = 427KCr

Note - If this seems steep, remember that in commerical service this plane would probably seat 200 people paying perhaps 200Cr each, and make at least two flights a day. Over a week that adds up to 560KCr in fares.

Question #2:

You want an extremely custom shuttlecraft built (Size 25,000 of components, perhaps 100-300 tons). Assuming you use off-the-shelf components for half the size (power plant, power train and weapons), and the rest of the components are evenly split between the remaining mass, how difficult are the custom components to design plans for and how long will it take to build, assuming cost is no object?

Calculations:

Half the size of the shuttle is 12,500, and is evenly split between structure, surface treatments and accessories, for a size of 4,167 each. The structure and surface treatments are largely non-mechanical, for a x.5 adjustment to size for design purposes, so they drop to 2,083. The accessories are treated as a group of normal complexity and have no modifier, staying at 4,167. The most people that can work on any one of these subsystems is the square root of their (*actual* size/10). This is $(4,167/10)^{.5}$ = 20, for a size multiplier of x.2. This reduces the effective size of the structure and surface to 416, and the accessories to 833.

The last modifier is a x.5 for developing plans, dropping the structure and surface to size 208, and the accessories to size 416.

Now that we have these numbers, we can check the chart on p.107 and see that design of the structure and surface is in the Size 100 to 400 bracket, for a Difficulty of 10 and 100 days of design time. The accessories are in the next bracket down, for a Difficulty 11 task and 200 days. The project supervisor for each subsystem would have to make a Difficulty 10 or 11 task on the appropriate scientific or technical skill to avoid mishaps. These would be "bugs" in the final design. Since cost is no object, we throw x5 money at the problem and decrease the Difficulty by 2, making the total Difficulty for each subsystem an 8 or 9.

For construction time, all of the subsystems fall into the Size 400 to 1600 bracket, for a Difficulty 11 task and 200 days. The project supervisor for each subsystem would have to make a Difficulty 11 task on the appropriate scientific or technical skill to avoid mishaps. Since cost is no object, we throw x5 money at the problem and decrease the Difficulty by 2, making the total Difficulty for each subsystem a 9.

Answers:

Time/Difficulty in structure design = 100 days, Difficulty 8
Time/Difficulty in surface design = 100 days, Difficulty 8
Time/Difficulty in accessory design = 200 days, Difficulty 9
Time/Difficulty in construction(ea.) = 200 days, Difficulty 9

Note - In game terms you would plop down the salaries of everyone involved for the duration of design and construction (55 man-years worth!), then take the **VDS** cost of the vehicle, multiply by x5, wait 400 days and then take delivery.

FYI - If you designed a house with a 100m^2 floor plan (Size 25,000, 25 tons) and give it a 2g organic structure and AV3 organic surface (wood), it would have a construction time (once plans were made) of less than a week if a dozen people were in the construction crew, assuming partially prepared material like cut lumber, prepared shingles, etc.

Question #3:

With a perfect takeoff ramp, how far could a *perfectly streamlined* (no drag) motorcycle jump with a final velocity of 45m/sec (162kph/101mph)? What DV would be applied to the suspension components when it landed?

Calculations:

Jump distance is $(45\text{m/sec})^2/10$ = 203m. Vertical distance is half the horizontal distance, or 101m. The DV would be as for falling that far, or a DV of 10 or 11. Real-world streamlining and drag would probably halve the jump distance.

Answers:

Distance jumped = 203m
Damage on impact = DV10

TL3: Trireme

The trireme is a sail and human-powered vessel used as a warship in the Mediterranean during the TL3 period. Usually had one or two masts and capable of sailing only with the wind, it also had three levels of rowers on each side (hence the name ***tri***reme). They were not designed for extended voyages and hence could do without many of the amenities a vessel this size would require. Since it would normally beach each night, it needs no quarters or galley, only food and water storage for the longest duration it could expect to go between ports. As part of a military force, it would also have enough space to store the weapons and gear of the rowers. In ship-to-ship actions it would attempt to ram opposing vessels, either to sink, board, ram or disable the rowers. In this case, it would carry a complement of soldiers on the upper deck, since the rowers would be otherwise engaged. The deck could but did not always mount catapults or other TL3 heavy weapons, hurling stones, bolts or incendiary projectiles.

Special effects - This trireme is modeled after the *Olympias*, a full-scale replica built to historic specifications (which were no more than 37m long by 5.6m wide). Power train AV is based on the power train mass *per* oar (170 oars), and while difficult, the trireme can turn in place. The power plant "crew" is the drummer used to synchronize the oarsmen, without whom 85 oars per side would quickly degenerate into chaos. Oars that are damaged are quickly jettisoned to avoid tangling the rest. The weak structure (stressed to a Turn of only 1) reflects the highly stressed nature of the lightweight hull. They also had lots of oar openings near the waterline, and would disintigrate quickly if mishandled in bad weather. The fairly abysmal sail performance figures could be doubled by adding another mast and using better sails, but the rowers will still provide faster and more consistent performance. The ram is mounted just below the waterline, so any hit that punctures the body of another ship is automatically a waterline hit. Assume the area of a ram puncture is 10% of the front area of the rammer (.8m^2 in this case). Ram damage would be calculated using the maneuvering total of each vehicle, as for chase combat in the normal rules, the difference being the DV of the attack. Remember that DV is +2 or -2 for each doubling or halving of mass between attacker and defender.

Campaign notes - This vessel would be the fast cruiser of its day. Even larger vessels were built in the late TL3 period, such as *quadremes* and *quinqueremes*, which had four and five banks of oars, respectively. Any vessel which can disgorge a few hundred armed men on short notice would rightly be feared by coastal villages, and its ability to run against the wind for extended periods gave it a mobility other vessels lacked. It was *the* fastest water vessel of the period. On the other hand, it was terribly expensive to operate, and getting the "engine" started quickly when its components are out pillaging could be a problem.

Specifications:

Configuration: Prism$_2$, partial optimum streamlining

Length:	40.0m	Size modifier:	-4
Width:	4.0m	Toughness:	x.13
Depth:	2.0m		

		Area	Volume	Mass
Design figures:		400.0m^2	320.0m^3	40,000kg
Power plant:	AV0, TL1 biologic (170 rowers@80kg ea.)			
Stats:	122.4kw	-	272.0m^3	13,600kg
Crew(1):		-	1.0m^3	80kg
Power train:	AV3, TL3 Indir. to dense medium, muscle pow.			
Stats:		1.2m^2	2.4m^3	1,224kg
Power plant:	AV4, TL3 normal sails (19m mast, 250m^2 sail)			
Stats:	18.0kw	-	.5m^3	500kg
Crew(3):		-	3.0m^3	240kg
Power train:	AV6, TL3 Indirect to thin medium (sail)			
Stats:		7.2m^2	1.4m^3	720kg
Structure:	AV2, 40 tons, Turn of 1, TL3 organic armor (wood)			
Stats:		-	18.7m^3	9,336kg
Watertight:		-	.9m^3	467kg
Surface:	AV2, 7mm, TL3 organic (wood)			
Stats:		-	-	9,336kg
Ram:		-	-	94kg
Other:				
Officers(2), soldiers(14)		-	16.0m^3	160kg
Stores		-	1.0m^3	1000kg
Subtotals:		8.4m^2	316.9m^3	36,757kg
Spare capacity:		391.6m^2	3.1m^3	3,243kg

Performance:

Base top speed:	20.4m/sec (rowers)	6.3m/sec (sail)
Adjusted:	4.1m/sec (rowers)	2.8m/sec (sail)
(sail w/6m/sec wind)	(15kph/9mph)	(10kph/6mph)
Base acceleration:	1.1 (rowers)	.4 (sail)
Adjusted:	.1 (rowers)	.1 (sail)
Base deceleration:	2	
Adjusted:	1	
Base Turn Mode:	1	
Adjusted:	1	
Draft (mass/vol):	13% (.25m)	

Bugs:

Balky power train, +1 Difficulty to delicate maneuvering

Surface treatment breaks in inconvenient ways (any hull breach interferes with rower performance)

TL5: DiVinci War Wagon

This is based on a DiVinci sketch of a turtle-like wheeled vehicle with multiple cannon ports. We are going to make it practical by adding a magical power plant which is fed off of condemned prisoners, whose screams and wails add to the crushing wheels and smoking cannons. If the full spread of cannons were not enough of a threat, the war wagon can slowly tow an armored sledge full of soldiers, allowing them to approach an enemy and still be protected. In addition, it can also carry up to 8 extra men inside, who can drop through a hatch in the bottom and come up fighting after the war wagon passes over them.

The war wagon's insatiable appetite for human flesh restricts its use to active wartime, or in more oppressive regimes, as a combination execution tool and terror weapon to keep enemies of the state in their place. Warring city-states may have several, since the short range does not keep them from being an excellent defensive weapon.

Special effects - Using the allowed variation, the dimensions of the war wagon are actually a little narrower and a little taller than listed. The fuel consumption of prisoners assumes they have no magical potential. The armor can be sloped if desired, but is not designed as such. The power train is capable of turning the vehicle in place, but has crude quality controls. The suspension rating of 3 allows the war wagon to operate on hard soil, poor roads or city streets. It has a soft terrain rating a point lower and tends to get bogged down in difficult terrain. The bulkheads isolate the power plant, driver and commander, and the weapons and ammunition from each other, and are accessed through iron-bound wooden doors (AV4) that are kept closed in combat. In addition to the cannon firing ports, smaller ports allow spears to be jabbed, or muskets fired through them, and all ports can be closed to prevent return fire into the wagon.

Campaign notes - Due to its slow speed and relatively short range, moving this vehicle a long distance would be a problem, much the same problem as with WWI tanks. Like a WWI tank, it is designed to be proof against infantry weapons, but is not capable of resisting the attacks of artillery. Fortunately, TL5 artillery is not very accurate. As a war wagon is an expensive item, deployment and tactics will take its advantages and vulnerabilities into account. If characters ever have the opportunity to be in one, it will not be a pleasant experience. There is plenty of room to move around, but the ceiling is low and sloped, with heavy wooden beams to scramble through. A set of powered bellows does little to clear the stifling air of choking gunpowder fumes. The suspension is non-existent, and the iron-shod wheels transmit every nuance of the ground directly into the unpadded benches that pass for seats. The dark interior is lit only by small lanterns well away from the powder kegs, and you can barely hear yourself think over the din of clanking wooden cogs and the screams of the damned.

Specifications:

Configuration: Disk, minimum streamlining

Length:	7.0m	Size modifier:	-4
Width:	7.0m	Toughness:	x.06
Depth:	1.8m		

		Area	Volume	Mass
Design figures:		117.6m^2	68.6m^3	20,000kg
Power plant:	AV4, TL5 normal magical (w/radiators)			
Stats:	51.0kw	2.0m^2	.51m^3	510kg
Crew(2, w/seats):		-	2m^3	180kg
Power train:	AV3, TL5 wheeled, +2 terrain rating (to 3)			
Stats:		1.3m^2	2.6m^3	1,275kg
Wheel skirts (AV12):		-	.5m^3	255kg
Fuel:	10 captives@40kg fuel each (7.8 hours fuel)			
Stats:		-	10m^3	800kg
Structure:	AV4, 20 tons, TL5 organic structure (wood)			
Stats:		-	5.9m^3	4,116kg
Bulkheads(3):		-	.18m^3	123kg
Surface:	TL5 composite (iron-faced wood)			
Bottom (AV5):		-	-	1,486kg
Other facings (AV12)		-	-	6,753kg
Minimum streamlining:		-	-	-
Weapons:	6 cannon@176kg ea., DV=50, RMod=7			
Stats:		-	1.06m^3	1,056kg
Crew (12):		-	12.0m^3	960kg
Firing ports:		-	-	-
Ammunition:	180 shots @5.1kg ea.			
Stats:		-	.92m^3	918kg
Crew (w/seats):				
Driver:		-	1.0m^3	90kg
Commander:		-	1.0m^3	90kg
Other:				
Towing hitch:		-	-	15kg
Vestigial fire extinguishers:		-	-	31kg
Eight "marines" (w/seats)		-	8.0m^3	720kg
Storage lockers:		-	4.0m^3	-
Subtotals:		3.3m^2	49.7m^3	19,378kg
Spare capacity:		114.3m^2	18.9m^3	622kg

Performance:

Base top speed:	15.6m/sec (56kph/35mph)
Adjusted:	7.8m/sec (28kph/17mph)
Base acceleration:	1.0
Adjusted:	1.0
Base deceleration:	2.8
Adjusted:	4.1
Base Turn Mode:	7
Adjusted:	4

Bugs:

Power plant leaks internal fluids (bleah!), x2 maintenance cost

Structure is obtrusive, +1 Difficulty moving inside the vehicle

TL7: Armored Frigate (Gloire)

The *Gloire* was a French iron-clad wooden frigate launched in 1859, and makes a nice design piece because it was in the transition between wood and metal hulls and sail and steam power. We also have reasonable historical and construction data for the vessel. Of course, an exact example like this can also point out some inaccuracies in your vehicle design system. We make no apologies in this case (nobody's perfekt), so just let the numbers give you an idea of how much you trust the system.

Special effects - Not every last nook and cranny of the ship has been allotted. For instance, you have to add an infirmary, brig, officer's lounge, spare parts, ventilators, fire fighting system, pumps, etc. The redundancy of its eight boilers is represented by mass and cost of four levels of redundant systems on the steam engine (total of x1.4 normal mass and x1.8 cost). Remember that extra mass for power plant redundancy does not increase normal fuel consumption or power train mass.

Campaign notes - The *Gloire* was the first iron-armored vessel to make an Atlantic crossing, and so was apparently seaworthy. In a Victorian-era campaign, she could be used as an exploration vessel, with plenty of room for storage of scientific specimens and extra supplies. She has a steaming range at cruising speed (14kph) of over 12,000km, enough to go nearly anywhere, as long as there is coal available to get back home (though see note on p.115 about accuracy of this figure). With a total crew of over 500, there is plenty of room for expendable crew to be grabbed by giant squid, a foreign spy or two and plenty of rank and status conflicts.

Specifications:

Configuration: Box_2, partial optimum streamlining

Length:	75.0m	Size modifier:	-6
Width:	15.0m	Toughness:	x.03
Depth:	11.3m		

		Area	Volume	Mass
Design figures:		4,275.0m^2	12,656.3m^3	5,630.0t
Power plant:	AV15, TL7 durable ext. combustion (w/radiators)			
Stats:	2,625kw	38.3m^2	37.5m^3	37.5t
Crew (6):		-	6.0m^3	.5t
Power train:	AV16, TL7 indirect to dense medium (propellor)			
Stats:		3.8m^2	7.5m^3	3.8t
Fuel:	Coal (crude fuel), 25 days			
Stats:		-	332.5m^3	665t
Power plant:	AV10, TL7 normal sails (33m mast x 3, 1600m^2)			
Stats:	627kw	-	3.2m^3	3.2t
Crew (12):		-	12.0m^3	1.0t
Ballast:		-	3.7m^3	7.4t
Power train:	AV28, TL7 Indirect to thin medium (sail)			
Stats:		215.0m^2	43.0m^3	21.5t
Structure:	AV24, 5630 tons, TL5 organic structure (wood)			
Stats:		-	1,282.5m^3	897.8t
Bulkheads (10):		-	128.3m^3	89.8t
Watertight:		-	64.1m^3	44.9t
Surface:	TL5&7 composite (wood with iron facings)			
Top (10mm steel, 150mm wood, AV37)			-	200.1t
Bottom (10mm steel, 150mm wood, AV37)			-	200.1t
Other (115mm steel, 650mm wood, AV278)			-	2,703.5t
Weapons:	36 cannon@3.3t ea., DV=350, RMod=12			
Stats:		-	11.9m^3	118.8t
Crew (216):		-	216.0m^3	17.3t
Ammunition:	1440 shots @56.1kg ea.			
Stats:		-	8.1m^3	80.8t
Accomodations:				
Captain & officers (10):		-	220.0m^3	2.2t
Crew (500):		-	1,000.0m^3	10.0t
Galley:		-	50.0m^3	1.0t
Common:		-	600.0m^3	-
Supplies (100 days):		-	204.0m^3	204.0t
Accessways:		-	680.0m^3	-
Other:				
Additional crew (276)		-	276.0m^3	24.8t
Ship's boats (4):		80m^2	80.0m^3	4.0t
Subtotals:		122.1m^2	5,266.3m^3	5,338.8t
Spare capacity:		4,152.9m^2	7,390.0m^3	291.2t

Performance:

Base top speed:	19.2m/sec (steam)	8.0m/sec (sail)
Adjusted:	5.7m/sec (steam)	4.4m/sec (sail)
(sail w/14m/sec wind)	(20kph/13mph)	(16kph/10mph)
Base acceleration:	.9 (steam)	.2 (sail)
Adjusted:	.1 (steam)	.1 (sail)
Base deceleration:	2	
Adjusted:	1	
Base Turn Mode:	0	
Adjusted:	1	
Draft (mass/vol):	44.5% (5.0m)	

TL9: Messerschmitt Me 262

The Me 262 was the world's first operational turbojet fighter, first deployed in July 1944. Performance exceeded any propellor-driven craft of the day, and was formidably armed for a fighter, with four nose-mounted 30mm cannon. The fact that the tide of war had long turned against Germany, combined with the short operational range of its gas-guzzling turbines, meant the Me 262's superiority made little or no difference in the timing or outcome of the war.

Fitting the design into **VDS** requires some tweaking. We were unable to find the actual figures on the Junkers 109-004B turbojets, or the ammunition load. The power plants have been tweaked to TL10 performance to get a weight savings, and the structure of the plane is made form armor quality materials to further reduce weight. The biggest single weight item is the power train, which in this case is the additions to the structure dedicated to maneuvering surfaces, hydraulic pistons, retractable landing gear and so forth.

Special effects - The wings (5.5m x 1.8m each) add to the total area of the Me 262 for Size modifier purposes. The structure of the vehicle is stressed to a Turn of 35, and wing structure mass is based on this as well. The top speed calculated is based on sea level air pressure. At high altitude the adjusted top speed is 223m/sec (802kph/499mph) if you take into account decreased drag, and 217m/sec (781kph/486mph) if you take into account the extra power required for lift.

Campaign notes - There aren't too many WWII roleplaying campaigns going on, and the Me 262 was a single-seat machine anyway, so a group of characters encountering one are likely to be on the receiving end. Science-fiction campaigns might use it if high-tech characters encounter a pre- or barely atomic-level culture, and it doesn't matter where or when you come from, a quad-mount 30mm cannon will definitely get your attention if the shells are pockmarking or poking holes in your high-tech hull.

Specifications:

Configuration:	Box$_2$, optimum streamlining		
Length:	10.0m	Size modifier:	-3
Width:	1.5m(12.5m wingsp.)	Toughness:	x.25
Depth:	2.0m		

		Area	Volume	Mass
Design figures:		76.0m^2	30.0m^3	7,100kg
Power plant:	AV7, TL9 tweaked exotic x 2 (w/radiators)			
Stats(#1):	425.0kw	2.4m^2	.62m^3	472kg
Stats(#2):	425.0kw	2.4m^2	.62m^3	472kg
Power train:	AV14, TL9 indirect to thin medium			
Stats:		2.8m^2	5.66m^3	2,834kg
Fuel:	Aviation gas (enhanced fuel), 2 hours			
Stats:		-	.49m^3	378kg
Structure:	AV5, lightweight armor (Turn=35)			
Stats:		-	.27m^3	607kg
Wing structure		-	.07m^3	160kg
Surface:	AV3, TL9 lightweight (+20m^2 wings)			
All (AV):		-	-	460kg
Optimum streamlining:		-	-	-
Weapons:	4 cannon@162kg ea., DV=65, RMod=18, RoF=7			
Stats:		-	.74m^3	648kg
Ammunition:	800 shots @1.2kg ea.			
Stats:		-	.72m^3	960kg
Crew (w/seat):				
Pilot:		-	1.0m^3	90kg
Other:				
Rating 1 communicator		1.0m^2	.02m^3	16kg
Basic escape device (parachute)		-	.10m^3	10kg
Life support (air bottle)		-	.01m^3	3kg
Subtotals:		8.6m^2	9.83m^3	7,110kg
Spare capacity:		67.4m^2	20.17m^3	-10kg

Performance:

Base top speed:	130m/sec (469kph/292mph)
Adjusted:	219m/sec (787kph/490mph)
Stall speed (loaded):	103m/sec (369kph/230mph)
Base acceleration:	6.9
Adjusted:	3.5 (max. climb angle=15°, 2.6m↑ per 10m→)
Runway length:	1,500 m
Base deceleration:	3.3
Adjusted:	0.7
Base Turn Mode:	35
Adjusted:	35

Bugs:

Power plant needs maintenance twice as often as normal

TL11: Abrams M1A2

Everybody loves the M1 tank. Except maybe the Iraqis. It's big, it's angular, it's fast and it's got a sexy turbine engine instead of a clunky diesel. And aside from the exact details on the armor, we also have a lot of solid info on it.

The **VDS** figures for the M1A2 are based on multiple Slab configurations, a 7.0m long slab for the body and a pair of 3.0m slabs for the turret, ignoring the bottom and touching sides of the turret pieces. Armor is sloped 50° on the front (x1.56 effective thickness), increasing total vehicle length to 8.1m. Because of the overall thickness of the armor we include it as part of the volume calculations. To keep things manageable, the armor on the turret facings is the same as the vehicle facings, though technically the turret is sloped.

The 120mm cannon and secondary armament we have real world figures for, and they have been used instead of the formula-based ones.

Special effects - The armor is "heavy armor" but is bought as "composite armor" because it includes lightweight technologies to defeat shaped charges. You can reduce the AV on a facing by 9 to give it +30AV vs. shaped charges, for instance, making an AV of 100 into an AV of 91(121), where the AV of 121 applies vs. shaped charges and the 91 vs. everything else. Since we don't know the exact amount, use this proportion as many or as few times as you wish (within reason) to personal taste. The power train has been given 1 level of redundant systems and should be bought as being able to turn in place. There is not room in the next column to list all the accessories the tank has, such as cargo racks, spare parts, food & water stores, smoke dischargers (ECM), etc. The bulkheads (4) of the vehicle separate the crew, engine, fuel and ammunition with AV30 partitions, and the ammunition storage is designed to rupture panels on the outside of the vehicle rather than blowing through the internal bulkhead. The remaining internal volume on the VDS version is largely illusionary and based on inexact representation of the hull and turrent configuration.

Campaign notes - Can it *really* go 73mph? Probably not, but it is said to go *a lot* faster than the 45mph figure quoted as the "official" top speed. The truth? Somewhere in between, we suspect.

The damage of the weapons and toughness of the armor are an example of why **VDS** is not all that great from a purely role-playing standpoint. If you've got weapons that can penetrate the armor, the vehicle is probably cooked. Even if the toughness and bulkheads protect it somewhat, a 700 point hit to a 600 point side armor could still send 100 points into the crew compartment, which is a lot more painful than a 7 point bullet hitting 6 points of body armor. It also brings up the question of gamemaster escalation. If you're riding around in a tank, expect to be shot at with anti-tank weapons...

Specifications:

Configuration:	Slab, basic streamlining			
Length:	8.1m	Size modifier:	-3	
Width:	3.5m	Toughness:	x.25	
Depth:	2.6m			
		Area	**Volume**	**Mass**
Design figures:		103.7m^2	51.6m^3	66,000kg
Power plant:	AV8, TL11 enhanced (w/radiators)			
Stats:	1,125.0kw	4.5m^2	1.6m^3	1,550kg
Power train:	AV66, TL11 tracksw/skirts (terrain rating 4)			
Stats:		12.3m^2	24.5m^3	12,272kg
Redundant sys.x 1		1.2m^2	2.5m^3	1,227kg
Stabilizers (1 pt)		-	2.5m^3	1,227kg
Fuel:	Most liquid hydrocarbons (normal fuel), 4.7 hours			
Stats:		-	1.9m^3	1,460kg
Structure:	None needed due to level of armor			
Environ. sealing, bulkheads(4)		-	.01m^3	165kg
Surface:	TL11 heavy armor			
Front (250mm sloped, AV1210)		-	2.05m^3	10,258kg
Rear (71mm, AV200)		-	.58m^3	2,913kg
R.side (129mm, AV400)		-	1.96m^3	9,819kg
L.side (129mm, AV400)		-	1.96m^3	9,819kg
Top (25mm, AV78)		-	.82m^3	4,130kg
Bottom (40mm, AV124)		-	.96m^3	4,802kg
Basic streamlining:		-	-	-
Weapon:	120mm cannon (DV=946, RMod=38 (HEAT rounds))			
Stats:		-	3.0m^3	3,020kg
Ammunition:	40 shots	-	.92m^3	920kg
Weapon:	12.7mm machinegun (DV=36, RMod=10)			
Stats:		-	.06m^3	60kg
Ammunition:	900 shots	-	.09m^3	90kg
Weapon:	7.62mm machinegun x 2 (DV=19, RMod=4)			
Stats:		-	.04m^3	40kg
Ammunition:	12,000 shots	-	.35m^3	350kg
Crew (w/seats):				
Commander, loader, gunner, driver:			4.0m^3	400kg
Other:				
Climate control, +/-20°C		-	.04m^3	40kg
Maintenance tools		-	.16m^3	326kg
Rating 1 computer		-	.08m^3	80kg
Disaster system(fire suppres.)		-	.06m^3	56kg
Rating 2 thermal sensor		.2m^2	.10m^3	100kg
Rating 2 laser detector		.2m^2	.04m^3	40kg
Rating 2 communicator		2.0m^2	.05m^3	50kg
Subtotals:		20.4m^2	50.3m^3	65,214kg
Spare capacity:		83.3m^2	1.3m^3	786kg

Performance:

Base top speed:	58m/sec (208kph/129mph)
Adjusted:	32m/sec (117kph/73mph)
Base acceleration:	2.6
Adjusted:	2.6
Base deceleration:	2.2
Adjusted:	6.4
Base Turn Mode:	5
Adjusted:	4

TL13: Interstellar freighter

Someone has to haul the cargo. The "long haul" is expensive, but if you have the right goods, profitable. But that profit margin isn't large, and salaries are sometimes cheaper than reaction mass, so big and slow is the way to go.

This freighter is one that would not be as profitable on the main lines, but would make runs to smaller systems with less advanced berthing facilities. Streamlining and heat shielding the entire ship would be prohibitively expensive, so it never actually lands on worlds with significant atmopsphere. It is capable of controlled landing on worlds with no atmosphere and less than .4g gravity. Anyone this vessel trades with usually has at least ground-to-orbit cabability to pick up cargo, but the ship does have a small hangar for an atmospheric shuttlecraft and room to mount a purification plant to extract deuterium from liquid methane or ammonia.

Special effects - On a ship like this, minimum streamlining simply means the hull is capable of being sealed against vacuum. It is still a mess of external girders and conduits. There are eight fusion power plants, each with an adjusted reliability of 100 hours at base purchase price. Adjust to taste. Unless fully loaded, the ship usually runs the jump drive on seven of them, keeping the eighth as a spare in case of failure. Each of the four fusion engines runs on pure deuterium and produces a hair over .1g of thrust with an adjusted reliability of 6.25 hours. Aside from the command crew(3), the ship requires two shifts of power plant crew (10), and cooks/stewards(2) for any paying passengers. Full quarters are for the captain and paying passengers(3). Basic quarters are for the other officers and passengers(6), and bunks for the remainder of the crew(12).

Campaign notes - This freighter is designed for a "hard science" campaign, or is a relic leftover from pre-antigrav and force field days. Everything it does, it does the hard way, with matter for shielding and good old Newtonian reaction mass. If you want to give or sell characters a ship and don't want to worry about them getting too far out of hand, this is a good start. It isn't fast, or tough, but it is big and chunky enough to have some durability, with some extra volume deliberately left for later improvements. You can figure out the cost based on the reliability of components, how out of date they are and other improvements, but fuel cost at full thrust (.4g) is about 5.7MCr *per hour*, but running the power plants during jump transit costs only about 240Cr per hour. Using low thrust to get to the jump point is obviously a major economic concern. Of course, for an Earth-sized planet, a .1g thrust for an hour (1.43MCr) will get you to the .01g jump point in 5 hours, the .001g jump point in 15 hours and the .0001g jump point in just over 2 days. Assuming you have to slow down at the other end, a jump can be made for less than 4MCr. If carrying 4,000 tons of cargo, this comes out to a shipping cost of about 1Cr/kg. Figure 2Cr/kg by the time profit and maintenance is taken care of and you'll get an idea of what goods are profitable to ship this way.

Specifications:

Configuration: Cylinder$_1$, minimum streamlining

Length:	60.0m	Size modifier:	-5
Width:	12.0m	Toughness:	x.06
Depth:	12.0m		

		Area	Volume	Mass
Design figures:		2,484.0m^2	6480.0m^3	7,000.0t
Power plant:	AV82, TL13 ext. dang. x 8(w/radiators for 20%)			
Stats(total):	32.0Mw	728.3m^2	11.8m^3	11.8t
Generators:	25.0Mw	-	61.5m^3	61.5t
Power plant:	AV23, TL13 ext. dang. x 4			
Stats(total):	3.1Mw	77.6m^2	1.1m^3	1.1t
Power train:	AV19, TL13 reaction engine x 4			
Stats(total):		-	7.2m^3	7.2t
Power train:	AV81, TL13 jump drive(23.3Mw, .17pc per hour)			
Stats:		-	538.5m^3	538.5t
Energy pulse pack:		-	19.3m^3	19.3t
Fuel (power pl.):	Deuterium(exotic fuel), 1000 hours			
Stats:		-	6.0m^3	6.0t
Fuel (fus.drive.):	Deuterium(exotic fuel), 6 hours			
Stats:		-	860.0m^3	860.0t
Structure:	AV60, TL13 composite (stressed to acc. of 5)			
Environ. sealing, bulkheads(10)		-	80.5m^3	406.6t
Surface:	TL13 composite armor			
Front (70mm, AV300)		-	-	43.3t
Rear (7mm, AV30)		-	-	4.3t
R.side (7mm, AV30)		-	-	19.9t
L.side (7mm, AV30)		-	-	19.9t
Top (7mm, AV30)		-	-	19.1t
Bottom (7mm, AV30)		-	-	19.1t
Basic streamlining:		-	-	-
Weapon:	Pulse laser x 1 (DV=500, RMod=1000), 2.5Mw/shot			
Stats:		-	8.4m^3	3.0t
Crew :				
Quarters, galley, etc.		-	450.0m^3	4.5t
Other:				
Climate control,regen. life supp.		-	4.2m^3	4.2t
Airlock (2 person) x 2		4.0m^2	8.0m^3	4.0t
Cargo holds(loaded mass)		50.0m^2	4,000.0m^3	4,500.0t
Hangar(loaded mass)		20.0m^2	100.0m^3	50.0t
Maintenance tools		-	6.4m^3	12.8t
Rating 4 computer		-	.4m^3	.4t
Disaster system		-	64.8m^3	64.8t
Rating 5 lidar(15°)		.9m^2	80.0m^3	80.0t
Rating 4 radar(360°)		22.5m^2	20.0m^3	20.0t
Rating 6(3) radio(15°)		35.2m^2	32.0m^3	32.0t
Subtotals:		938.5m^2	6,360.1m^3	6,813.3t
Spare capacity:		1,545.5m^2	119.9m^3	186.7t

Performance:

Top speed:	170 km/sec vs. minor space debris
Base acceleration:	4.0
Adjusted:	4.0
Deceleration:	4.0
Base Turn Mode:	0
Adjusted:	1

TL15:Hypersonic interceptor

Not every planet can afford an expensive space fleet or heavy orbital platforms, but most can use a fast-response fighter capable of reaching anywhere on the planet in an hour or less, and able to engage low orbit or near-space targets. This interceptor uses a fusion plant to run a thermal scramjet, with a limited supply of reaction mass to use to use outside the atmosphere. Like interceptors circa 2000CE, it consists almost entirely of power plant and power train, with pilot, weapons and everything else crammed into the space that remains.

Special effects - The reaction engine power train is attached to the fusion reactors, and is bought as using only 100kg of power plant output, with pure deuterium fuel and somewhat radioactive exhaust. The stubby little wings provide marginal amounts of lift and are mostly for biting atmosphere to make high-g turns. The vehicle has an appallingly high stall speed. This normally isn't a problem for takeoff, as it is vertically deployed and takes off straight up (the backwash is not something you want to be close to). Landings are handled on normal runways and aided with drogue chutes. The front and bottom armor are as much for re-entry protection as from weapons fire. The gravity compensators protect the cockpit volume only, but allow the vehicle to pull 13g accelerations and 20g turns without turning the pilots into mush. They soak up 28.8kw from the battery bank, which also powers all the other electronics except for the pulse laser, which has a dedicated discharge bank (200 shots). Last, this design has *not* been optimized. You should be able to do *much* better on your own...

Campaign notes - This is a fairly scary piece of hardware, but also fragile. In any realistic campaign the gravity compensators would be ripped out and replaced with a remote control interface, as no pilot would really want to fly that fast and that hard. Well, maybe some would...

A 10 second use of the reaction engine would take you from sitting on the ground to 6 kilometers up at Mach 4. Cutting in the main engines would let you cruise at Mach 2.9, getting you anywhere on an Earth-sized planet in 6 hours or less, or you could hold the “rocket” button down for 20 more seconds and be 54 kilometers up at Mach 11. Not anywhere near orbital velocity, but you could coast quite a way before the atmosphere starts dragging you down again.

Specifications:

Configuration: Prism$_1$, optimum streamlining

Length:	15.0m	Size modifier:	-4
Width:	4.5m	Toughness:	x.13
Depth:	2.3m		

		Area	Volume	Mass
Design figures:		135.0m^2	151.9m^3	100,000kg
Power plant:	AV7, TL15 ext. dang. x 2(w/radiators)			
Stats(total):	28.8Mw	28.8m^2	4.0m^3	8,000kg
Energy bank	2000Mw/sec	-	5.3m^3	5,340kg
Battery	200kw/hr	-	.1m^3	99kg
Power train:	AV35, TL15 indirect to thin medium			
Stats:		64.8m^2	115.2m^3	57,600kg
Power train:	AV9, TL15 reaction engine(1,300,000kg thrust)			
Stats:		.7m^2	1.4m^3	720kg
Fuel (power pl.):	Deuterium(exotic fuel), 100 hours			
Stats:		-	.3m^3	300kg
Fuel (fus.drive.):	Deuterium(exotic fuel), 100 seconds			
Stats:		-	1.4m^3	1,400kg
Structure:	AV45, TL15 compos. armor(stressed to turn of 200)			
Stats:		-	1.1m^3	5,329kg
Environ. sealing		-	.1m^3	533kg
Wing structure for 20m^2		-	.2m^3	789kg
Surface:	TL15 composite armor			
Front (35mm, AV200)		-	-	1,895kg
Rear (3.5mm, AV20)		-	-	190kg
Sides (7mm, AV40)		-	-	1,046kg
Top (3.5mm, AV20)		-	-	1,184kg
Bottom (7mm, AV200)		-	-	2,842kg
Wings(3.5mm, AV20)		-	-	351kg
Optimum streamlining:		-	-	-
Weapon:	Pulse laser(DV=500,RMod=300,RoF=5),10Mw/shot			
Stats:		-	9.3m^3	10,281kg
Crew :				
Pilot, weapons officer.		-	2.0m^3	200kg
Other:				
Climate control, life supp.		-	.01m^3	10kg
Gravity compensators (12g)		-	.03m^3	58kg
Hardpoint x 2 (500kg)		-	-	141kg
Rating 6 tactical computer		-	.03m^3	33kg
Rating 4 target radar(15°)		1.6m^2	.5m^3	500kg
Rating 3 radar(360°)		7.2m^2	.5m^3	480kg
Rating 4 radio(360°)		.3m^2	.2m^3	200kg
Subtotals:		103.4m^2	141.7m^3	99,521kg
Spare capacity:		31.6m^2	10.2m^3	479kg

Performance:

Base top speed:	398.0m/sec(1,433kph/891mph)
Adjusted:	955.2m/sec(3,439kph/2,140mph)
Stall speed:	198.8m/sec(716kph/445mph)
Base acceleration:	10.7 (140.7)
Adjusted:	5.4 (135.7)
Runway	3.6km (.15km)
Base deceleration:	2
Adjusted	.4
Base Turn Mode:	200
Adjusted:	200

TL17:Assassin android

This is something you do not want chasing you around, because it is almost impossible to kill, and it does not give up. Ever. If someone wealthy and powerful in a very high tech society wants you dead, this is what they will send. It is programmed with everything known about the target and the target area, and is genuinely intelligent enough to act creatively on this information (within the limits of its programmed skills). These can include impersonations, disguise and other ruses, but normally it relies on nearly infinite patience and waits for you to make a mistake. The first (and usually last) mistake is letting it get line of sight anywhere within about 4 kilometers of you...

Special effects - While **VDS** only officially goes up to TL15, the equations are good out to about TL20. Our lovable terminator is bought as you would handle a suit of light powered armor, a .10m^3 shell around a .10m^3 "body" (total volume of .20m^3), with 2m^2 of surface area for armor purposes. For all practical purposes, it looks like a very hefty (≈200kg) human, say a 6-foot-7 linebacker muscled like Mr. Universe. Irregularities could conceivably be concealed under heavy clothing or as a special effect on the surface treatments. Everything in the android is bought to take the minimum amount of volume, since that is at a premium in this small chassis. Because of the constraints on appearance, armor is bought as taking internal volume.

Campaign notes - This is another scary creation, if only because it is something characters could encounter on the street. The armor value is high enough that any civilian weapon is virtually useless. Most hand-held military weapons, too.

In any sort of urban area this android has a more or less unlimited operating range, as it can recharge its internal battery from any convenient source. And while it will run this battery down in about an hour at full operating power, normal "walking around" power is low enough that it can run for days. And if it runs low, it can always kick in the tiny antimatter plant in its chest, which also makes a nifty self-meltdown device should it be needed.

Its major attributes are STR38, AGL6, AWR5, with optical (low light) sensors for eyes, audio(sonar) sensors for ears and a targeting radar array built into its chest. While it's legged power train only has a rating of 3, practically it can go anywhere a person can walk. And of course, it can fly too. If it is configured to pass as person on normal observation, a weakness will be its thermal signature, which is -3 Difficulty to spot if the reactor is running or the built-in laser is being used, and -2 Difficulty if it is using more than a human level of output for movement. If trying to take it out, the only weak spots are the sensor ports, which would be counted as half AV, but are also +4 Difficulty to hit.

Specifications:

Configuration:	Special, basic streamlining			
Height:	2.0m	Size modifier:	+0	
Width:	1.0m	Toughness:	x1.0	
Depth:	.5m			
		Area	**Volume**	**Mass**
Design figures:		2.000m^2	.2000m^3	400.00kg
Power plant:	AV2, TL17 suicidal (antimatter)			
Stats(total):	57.8kw	.173m^2	.0050m^3	10.00kg
Energy bank	1.00Mw/sec	-	.0016m^3	1.60kg
Battery	33.2kw/hr	-	.0050m^3	10.00kg
Power train:	AV4, TL17 legged, small feet (10.0kw)			
Stats:		.047m^2	.0941m^3	47.06kg
Power train:	AV9, TL17 antigrav (10.0kw)(1000m ceiling)			
Stats:		.018m^2	.0088m^3	17.65kg
Fuel (power pl.):	antimatter(suicidal fuel), 1 month, plus storage			
Stats:		-	.0012m^3	1.20kg
Structure:	AV6, TL17 ex.heavy armor (stressed to turn of 20)			
Stats:		-	.0115m^3	107.01kg
Environ. sealing		-	.0012m^3	10.70kg
Surface:	TL17 ex.heavy armor			
Head (5mm, AV52)		-	.0010m^3	9.30kg
Torso (7mm, AV73)		-	.0042m^3	39.06kg
Arms (4mm, AV42)		-	.0016m^3	14.88kg
Legs (4mm, AV42)		-	.0032m^3	29.76kg
Basic streamlining:		-	-	-
Weapon:	Pulse laser(DV=100,RMod=50,RoF=5),100kw/shot			
Stats:		-	.0202m^3	40.54kg
Other:				
Rating 7 special purpose AI (AWR 5)			.0026m^3	2.60kg
Manipulator arms(.7m,AGL6,STR38)			.0313m^3	31.29kg
Rating 1 opt. sensor(60°)		.012m^2	.0002m^3	.44kg
Rating 1 sonar sens.(360°)		.048m^2	.0004m^3	.88kg
Rating 2 target radar(15°)		.479m^2	.0018m^3	3.51kg
Subtotals:		.777m^2	.1949m^3	377.04kg
Spare capacity:		1.223m^2	.0055m^3	23.40kg

Performance:

Base top speed:	26.6m/sec	(96kph/60mph)
Adjusted:	16.0m/sec	(57kph/36mph)
Flying speed:	29.9m/sec	(108kph/67mph)
Base acceleration:	3.2	
Adjusted:	3.2	
Base deceleration:	6.0	
Adjusted	6.0	
Base Turn Mode:	6	
Adjusted:	6	

Top speed — (power in watts x mass in kg)$^{.61}$/mass in kg

Power	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
1000w	11.2m/s	8.6m/s	6.0m/s	4.6m/s	3.5m/s	2.4m/s	1.9m/s	1.4m/s	1.0m/s	.76m/s	.58m/s	.40m/s	.31m/s
2000w	17.1m/s	13.1m/s	9.1m/s	7.0m/s	5.3m/s	3.7m/s	2.8m/s	2.2m/s	1.5m/s	1.2m/s	.88m/s	.62m/s	.47m/s
5000w	29.9m/s	22.9m/s	16.0m/s	12.2m/s	9.3m/s	6.5m/s	5.0m/s	3.8m/s	2.7m/s	2.0m/s	1.5m/s	1.1m/s	.82m/s
10.0kw	45.7m/s	34.9m/s	24.4m/s	18.6m/s	14.2m/s	9.9m/s	7.6m/s	5.8m/s	4.0m/s	3.1m/s	2.4m/s	1.6m/s	1.3m/s
20.0kw	69.8m/s	53.2m/s	37.2m/s	28.4m/s	21.7m/s	15.2m/s	11.6m/s	8.8m/s	6.2m/s	4.7m/s	3.6m/s	2.5m/s	1.9m/s
50.0kw	122.m/s	93.1m/s	65.1m/s	49.7m/s	37.9m/s	26.5m/s	20.2m/s	15.5m/s	10.8m/s	8.2m/s	6.3m/s	4.4m/s	3.4m/s
100kw	186.m/s	142.m/s	99.4m/s	75.9m/s	57.9m/s	40.5m/s	30.9m/s	23.6m/s	16.5m/s	12.6m/s	9.6m/s	6.7m/s	5.1m/s
200kw	284.m/s	217.m/s	152.m/s	116.m/s	88.4m/s	61.8m/s	47.2m/s	36.0m/s	25.2m/s	19.2m/s	14.7m/s	10.3m/s	7.8m/s
500kw	497.m/s	379.m/s	265.m/s	203.m/s	155.m/s	108.m/s	82.5m/s	62.9m/s	44.0m/s	33.6m/s	25.6m/s	17.9m/s	13.7m/s
1.0Mw	759.m/s	579.m/s	405.m/s	309.m/s	236.m/s	165.m/s	126.m/s	96.1m/s	67.2m/s	51.3m/s	39.1m/s	27.4m/s	20.9m/s
2.0Mw	1158m/s	884.m/s	618.m/s	472.m/s	360.m/s	252.m/s	192.m/s	147.m/s	102.m/s	78.3m/s	59.7m/s	41.8m/s	31.9m/s
5.0Mw	2025m/s	1545m/s	1081m/s	825.m/s	630.m/s	440.m/s	336.m/s	256.m/s	179.m/s	137.m/s	105.m/s	73.1m/s	55.8m/s
10.0Mw	3090m/s	2358m/s	1650m/s	1259m/s	961.m/s	672.m/s	513.m/s	391.m/s	273.m/s	209.m/s	159.m/s	112.m/s	85.1m/s
20.0Mw	4717m/s	3599m/s	2518m/s	1921m/s	1466m/s	1026m/s	783.m/s	597.m/s	417.m/s	319.m/s	243.m/s	170.m/s	130.m/s
50.0Mw	8248m/s	6295m/s	4403m/s	3360m/s	2564m/s	1794m/s	1369m/s	1045m/s	731.m/s	558.m/s	426.m/s	298.m/s	227m/s.

Modifier	Amount	Modifier	Amount
Wheels	x.80	Muscle-powered	x1.0
Tracks	x.60	Tech Level 1-2	x.50
Legs, small feet	x.50	Tech Level 3-4	x.60
Legs, average feet	x.40	Tech Level 5-6	x.70
Legs, large feet	x.30	Tech Level 7-8	x.80
Indirect to dense medium (water)	x.50	Tech Level 9-10	x.90
Indirect to avg. medium (dense gas)	x1.0	Tech Level 11-12	x1.0
Indirect to thin medium (air)	x2.0	Tech Level 13-14	x1.1
Antigrav	x1.0	Tech Level 15	x1.2

How to use this table:
Cross reference the closest figures for the power and mass of your vehicle to get the approximate base top speed in m/sec, then multiply by all appropriate modifiers to get the approximate final speed, less streamlining considerations.

Example - A Tech Level 11 airplane with a loaded mass of 2,000kg and a 250kw power plant would have a speed slightly greater than the 200kw entry, which is 88.4m/sec, times x2.0 for indirect to thin medium (air) for a final approximate top speed of 176.8m/sec.

Acceleration — (power in watts x mass in kg x .1)$^{.5}$/(mass in kg x .5)

Power	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
1000w	2.0	1.4	0.9	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0
2000w	2.8	2.0	1.3	0.9	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0
5000w	4.5	3.2	2.0	1.4	1.0	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0
10kw	6.3	4.5	2.8	2.0	1.4	0.9	0.6	0.4	0.3	0.2	0.1	0.1	0.1
20kw	8.9	6.3	4.0	2.8	2.0	1.3	0.9	0.6	0.4	0.3	0.2	0.1	0.1
50kw	14.1	10.0	6.3	4.5	3.2	2.0	1.4	1.0	0.6	0.4	0.3	0.2	0.1
100kw	20.0	14.1	8.9	6.3	4.5	2.8	2.0	1.4	0.9	0.6	0.4	0.3	0.2
200kw	28.3	20.0	12.6	8.9	6.3	4.0	2.8	2.0	1.3	0.9	0.6	0.4	0.3
500kw	44.7	31.6	20.0	14.1	10.0	6.3	4.5	3.2	2.0	1.4	1.0	0.6	0.4
1.0Mw	63.2	44.7	28.3	20.0	14.1	8.9	6.3	4.5	2.8	2.0	1.4	0.9	0.6
2.0Mw	89.4	63.2	40.0	28.3	20.0	12.6	8.9	6.3	4.0	2.8	2.0	1.3	0.9
5.0Mw	141.4	100.0	63.2	44.7	31.6	20.0	14.1	10.0	6.3	4.5	3.2	2.0	1.4
10Mw	200.0	141.4	89.4	63.2	44.7	28.3	20.0	14.1	8.9	6.3	4.5	2.8	2.0
20Mw	282.8	200.0	126.5	89.4	63.2	40.0	28.3	20.0	12.6	8.9	6.3	4.0	2.8
50Mw	447.2	316.2	200.0	141.4	100.0	63.2	44.7	31.6	20.0	14.1	10.0	6.3	4.5

Modifier	Amount	Modifier	Amount
Transfer to liquid	x.1	Transfer to dense gas	x.7
Transfer to rarefied gas	x.2	Transfer to solid	x1.0
Transfer to gas	x.5	Transfer independent of medium	x1.0

How to use this table:
Cross reference the closest figures for the power and mass of your vehicle to get the approximate base acceleration, then multiply by all appropriate modifiers to get the approximate final speed, less streamlining considerations.

Example - A Tech Level 11 airplane with a loaded mass of 2,000kg and a 250kw power plant would have a speed slightly greater than the 200kw entry, which is 6.3, times x.5 for power transfer to a gas (propellor) for a final approximate acceleration of 3.1.

Deceleration $20/(\text{mass in kg})^{.2}$

Type	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000ton
Default	8.0	6.9	5.8	5.0	4.4	3.6	3.2	2.8	2.3	2.0	1.7	1.4	1.3

Modifier	Amount
Very high contact with environment (tracks)	x2.0
High contact with environment (wide wheels)	x1.5
Average contact with environment (air brakes, wheels)	x1.0
Low contact with environment (narrow wheels)	x.5
Very low contact with environment (boat propellor)	x.3
Friction with solid surface (tires to pavement)	x1.0
Friction with liquid (boat hull)	x2.0
Friction with dense gas	x.5
Friction with gas (air brakes)	x.2
Friction with rarefied gas (upper atmosphere)	x.1

Ground contact (land vehicles only)	Amount
Maximum (wide tracks)	+3
Very good (tracks, race car)	+2
Good (sports car, many wheels)	+1
Average (average land vehicle)	+0
Poor (wagon wheels, bicycles)	-1
Minimal (trains)	-2
None (hovercraft)	-3

How to use this table:
Cross reference the closest figures for the mass of your vehicle to get the approximate base deceleration, then add appropriate modifiers, then multiply appropriate modifiers to get the approximate final deceleration.

Example - A loaded tractor-trailer with a mass of 40 tons would be close to the entry for 50 tons, or 2.8. It has many wheels, so it goes to 3.8, with a x1.0 multiplier for friction with a solid surface, for a final approximate deceleration of 3.8.

Turn mode

Length/ width	Turn Mode	Height/ width	Modifier
≤1:1	7	≤.5:1	+0
≤2:1	6	≤1:1	-1
≤3:1	6	≤2:1	-2
≤4:1	5	≤3:1	-3
≤5:1	5	≤4:1	-4
≤6:1	5	≤5:1	-5
≤7:1	5	≤6:1	-6
≤8:1	5	≤7:1	-7
≤9:1	4	≤8:1	-8
≤10:1	4	≤9:1	-9
≤11:1	4	≤10:1	-10
≤12:1	4	≤11:1	-11
≤13:1	4	≤12:1	-12
≤14:1	4	≤13:1	-13
≤15:1	4	≤14:1	-14

Modifiers

Ground contact	Modifier	Suspension	Modifier	Overall length	Modifier
Maximum (wide tracks)	+3	Rating 0 (race car)	+1	1m	+2
V.good (tracks, race car)	+2	Rating 1 (most cars)	+0	2-4m	+1
Good (sports car)	+1	Rating 2 (trucks)	-1	5-9m	+0
Average (avg. car)	+0	Rating 3 (hvy. duty 4WD)	-2	10-16m	-1
Poor (wagon wheels)	-1	Rating 4(tank, dirt bike)	-3	17-25m	-2
Minimal (trains)	-2	Rating 5 (legged vehicle)	-4	26-36m	-3
None (hovercraft)	-3			37-49m	-4
				50-64m	-5
Control quality	**Modifier**	**Tech Level**	**Modifier**	65-81m	-6
Best	x1.2	1	-.2	82-100m	-7
Advanced	x1.1	2-4	-.1	101-121m	-8
Basic	x1.0	5-8	+.0	122-144m	-9
Crude	x.8	9-12	+.1	145-169m	-10
None	x.6	13-15	+.2	170-196m	-11
				197-225m	-12

How to use this table:
Take the basic Turn Mode from the first two columns, based on your vehicle's length to width ratio. Apply all additive modifiers on the top row. Save the result. Then take the multiplier for control quality, adjust by the Tech Level modifier, and multiply times the saved result. This is the final result. Results of less than 1 are counted as 1.

Example - A TL13 tractor trailer is 20m long by 2.9m wide by 3.0m high. Its base Turn Mode is based on the ≤7:1 number, which is 5. Its height is in the ≤2:1 row, for a -1 modifier. Ground contact is good, for +1, but the suspension rating is another -1, for an adjusted total of 4. It has basic controls, for a x1.0 multiplier, increased by +.2 for it being TL13, to x1.2. The final Turn Mode is 4 x 1.2 = 4.8, rounding to 5.

Ground pressure

Rating	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
+1	≥1.67	≥3.33	≥8.33	≥16.7	≥33.3	≥83.3	≥167.	≥333.	≥833.	≥1,670	≥3,333	≥8,333	≥16,667
+0	≥.500	≥1.00	≥2.50	≥5.00	≥10.0	≥25.0	≥50.0	≥100.	≥250.	≥500.	≥1,000	≥2,500	≥5,000
-1	≥.167	≥.333	≥.833	≥1.67	≥3.33	≥8.33	≥16.7	≥33.3	≥83.3	≥167.	≥333.	≥833.	≥1,670
-2	≥.050	≥.100	≥.250	≥.500	≥1.00	≥2.50	≥5.00	≥10.0	≥25.0	≥50.0	≥100.	≥250.	≥500.
-3	<.050	<.100	<.250	<.500	<1.00	<2.50	<5.00	<10.0	<25.0	<50.0	<100.	<250.	<500.

Ground pressure	Rating
Extremely low (wide tracks, large feet)	+2
Very low (narrow to average tracks)	+1
Low (wide or many tires, average feet)	+0

Ground pressure	Rating
Average (average tires)	-1
High (wagon wheels, bicycles, small feet)	-2
Very high (skates)	-3

How to use this table:
To adjust a land vehicle suspension rating for soft terrain, find the column entry that corresponds to vehicle mass and (length x width). The leftmost column is the adjustment for purposes of bogging down, modified further by the type of power transfer to the ground.

Output per kg

Tech Level	Biologic (Draft animals)	Durable (Diesel, steam)	Normal (Normal car)	Enhanced (Sports car)	Exotic (Race car, jet)	Dangerous (Rocket)	Ext. dangerous (Nuclear)	Suicidal (Antimatter)
1	9w	2w	4w	6w	9w	12w	16w	20w
2	9w	8w	16w	24w	36w	48w	64w	80w
3	9w	18w	36w	54w	81w	108w	144w	180w
4	9w	32w	64w	96w	144w	192w	256w	320w
5	9w	50w	100w	150w	225w	300w	400w	500w
6	9w	72w	144w	216w	324w	432w	576w	720w
7	9w	98w	196w	294w	441w	588w	784w	980w
8	9w	128w	256w	384w	576w	768w	1024w	1280w
9	9w	162w	324w	486w	729w	972w	1296w	1620w
10	9w	200w	400w	600w	900w	1200w	1600w	2000w
11	9w	242w	484w	726w	1089w	1452w	1936w	2420w
12	9w	288w	576w	864w	1296w	1728w	2304w	2880w
13	9w	338w	676w	1014w	1521w	2028w	2704w	3380w
14	9w	396w	792w	1188w	1764w	2352w	3136w	3920w
15	9w	450w	900w	1350w	2025w	2700w	3600w	4500w
Cost per kg	2Cr	6Cr	10Cr	20Cr	40Cr	80Cr	160Cr	320Cr

How to use this table:
Cross reference the Tech Level and type of power plant desired. The result is the output in watts per kilogram of power plant. The base cost per kilogram is listed on the last line. This place on the table can be used as a reference point for effects that alter effective Tech Level like tweaking, or effective power plant type, like boosting.

Example - A TL9 sports car engine (an enhanced power plant) has a base output of 486 watts per kilogram. A 100kg power plant would have an output of 48.6kw and have a cost of 2000Cr.

Maintenance intervals

Power plant	Very crude	Crude	Normal	Fuel type Enhanced	Exotic	Dangerous	Ext. dangerous	Suicidal
Biologic	-	2000hr	1000hr	-	-	-	-	-
Durable	16000hr	8000hr	4000hr	2000hr	1000hr	400hr	240hr	160hr
Normal	4000hr	2000hr	1000hr	500hr	250hr	100hr	60hr	40hr
Enhanced	1000hr	500hr	250hr	125hr	62hr	25hr	15hr	10hr
Exotic	240hr	120hr	60hr	30hr	15hr	6.0hr	3.6hr	2.4hr
Dangerous	60hr	30hr	15hr	7.5hr	3.7hr	1.5hr	54min	36min
Ext. dangerous	16hr	8hr	4hr	2hr	1hr	24min	14min	9.6min
Suicidal	4hr	2hr	1hr	30min	15min	6.0min	3.6min	2.4min

How to use this table:
Cross-reference the type of power plant and the type of fuel used to power it to get the base maintenance interval. This interval may be further modified by the money spent on the power plant (p.13).

Example - A sports car with an enhanced power plant running on normal fuel will have a 500hr maintenance interval.

Fuel consumption

Power plant	Very crude	Crude	Normal	Fuel type Enhanced	Exotic	Dangerous	Ext. dangerous	Suicidal
Biologic	.004kg	.003kg	.002kg	.001kg	-	-	-	-
Durable	.060kg	.042kg	.030kg	.015kg	.0075kg	.003kg	.0018kg	.0012kg
Normal	.200kg	.140kg	.100kg	.050kg	.025kg	.010kg	.006kg	.004kg
Enhanced	.400kg	.280kg	.200kg	.100kg	.050kg	.020kg	.012kg	.008kg
Exotic	.800kg	.560kg	.400kg	.200kg	.100kg	.040kg	.024kg	.016kg
Dangerous	1.30kg	.910kg	.650kg	.325kg	.163kg	.065kg	.039kg	.026kg
Ext. dangerous	2.00kg	1.40kg	1.00kg	.500kg	.250kg	.100kg	.060kg	.040kg
Suicidal	3.00kg	2.10kg	1.50kg	.750kg	.375kg	.150kg	.090kg	.060kg
Modifiers								
Fission	x.0050	x.0050	x.0050	x.0050	x.0050	x.0050	x.0050	x.0050
Fusion	x.0020	x.0020	x.0020	x.0020	x.0020	x.0020	x.0020	x.0020
Antimatter	x.0005	x.0005	x.0005	x.0005	x.0005	x.0005	x.0005	x.0005

How to use this table:
Cross-reference the power plant and fuel type to get the consumption per hour per kilogram of power plant at full power. For the special types listed, the fuel consumption is a multiple on whatever basic type is used.

Example - An enhanced power plant running on normal fuel consumes .2kg of fuel per kilogram of power plant per hour.

Reaction engines 1

Power plant	Very crude	Crude	Normal	Fuel type Enhanced	Exotic	Dangerous	Ext. dangerous	Suicidal
Biologic	3.25	4.64	6.50	13.0	26.0	65.0	108.	163.
Durable	.217	.310	.433	.867	1.73	4.33	7.22	10.8
Normal	.065	.093	.130	.260	.520	1.30	2.17	3.25
Enhanced	.033	.046	.065	.130	.260	0.65	1.08	1.63
Exotic	.016	.023	.033	.065	.130	.325	.542	.813
Dangerous	.010	.014	.020	.040	.080	.200	.333	.500
Ext. dangerous	.007	.009	.013	.026	.052	.130	.217	.325
Suicidal	.004	.006	.009	.017	.035	.087	.144	.217
Modifiers								
Fission	x200	x200	x200	x200	x200	x200	x200	x200
Fusion	x500	x500	x500	x500	x500	x500	x500	x500
Antimatter	x2000	x2000	x2000	x2000	x2000	x2000	x2000	x2000

Reaction engines 2

Tech Level	K	Reliability
1	.017	x.5000
2	.035	x.5000
3	.069	x.5000
4	.139	x.2500
5	.278	x.2500
6	.556	x.2500
7	1.11	x.2500
8	2.22	x.1250
9	4.44	x.1250
10	8.89	x.1250
11	17.8	x.0625
12	34.7	x.0625
13	69.4	x.0625
14	139.	x.0312
15	278.	x.0312
Modifiers		
Fission	x.0050	x100
Fusion	x.0020	x100
Antimatter	x.0005	x100

Fuels

Fuel	Tech Level	Type	Vol./1,000kg	Mass/m^3	Cost/1000kg
Wood	1	V.crude	2.0m^3	500kg	500Cr
Coal	4	Crude	.50m^3	2,000kg	700Cr
Distilled alcohol	5	Crude	1.4m^3	725kg	700Cr
Black powder[1]	5	Exotic	2.0m^3	500kg	4,000Cr
Low-grade oil[2]	7	Crude	1.2m^3	850kg	700Cr
Gasoline	8	Normal	1.3m^3	800kg	1,000Cr
Jet fuel	9	Enhanced	1.3m^3	750kg	2,000Cr
Liquid oxygen[3]	8	Dangerous	.83m^3	1,200kg	2,000Cr
Liquid hydrogen	8	Dangerous	14.3m^3	70kg	2,000Cr
Liquid nat. gas	8	Dangerous	1.9m^3	525kg	2,000Cr
$Uranium_{235}$	9	Fiss., E.dangerous	.05m^3	19,050kg	16MCr
$Plutonium_{239}$	9	Fiss., E.dangerous	.05m^3	19,840kg	16MCr
Deuterium	9	Fusion, Exotic	1.0m^3	1,000kg	40KCr
Tritium	9	Fusion, Exotic	1.0m^3	1,000kg	40KCr
Antiprotons[4]	12	Antim., Suicidal	1.0m^3	1,000kg	36MCr

1.Was actually experimented with as a “horseless carriage” fuel. Unsuccessfully.
2.Includes heavy petroleum oil, vegetable oils and animal-based oils.
3.Technically not a fuel, but will support combustion in anything that can burn.
4.Hypothetical. No form of storage this dense exists at time of publication.

How to use these tables:
The first table is used to figure the I_{sp} of your engine. Take the output for your power plant and multiply it by the number at the intersection between your power plant type and the type of fuel you are using. Save the result. Then take the number for this power plant from the **Fuel Consumption** table and multiply by the “K” result on the second table for the appropriate Tech Level. This is the fuel consumption of the reaction engine at full power, in terms of kilograms of fuel per kilogram of reaction engine, *per second*. This number, times the I_{sp} you saved from the first table, is the thrust of the reaction engine in kilograms. The second number on the second table is the multiplier on power plant reliability.

The modifiers for *pure* fission, fusion and antimatter engines below the first table multiply the figured I_{sp}, and those below the second table multiply the fuel consumption and maintenance interval. For a hybrid nuclear reaction engine, figure the I_{sp} for each part based on its contribution to fuel consumption. Add these I_{sp} figures together and save the result. Then take the fuel consumption of each part (like an extremely dangerous fuel with a fission modifier times its percentage contribution, and a dangerous fuel times its percentage contribution), add them together, then multiply by K to get total fuel consumption per second and by the hybrid I_{sp} to get the total thrust.

Example - A TL9 Dangerous power plant has an output of $TL9^2 \times 12 = 972$ watts per kilogram. If using Dangerous fuel, we would multiply 972 watts by the number on the first table, at the intersection of Dangerous power plant and Dangerous fuel. This is .200, so the I_{sp} of this reaction engine is 194.4. The fuel consumption of this combination is .065kg (from the **Fuel consumption** table), so .065kg times 4.44 (the K for TL9 on the second table) equals .289kg per second per kilogram of reaction engine. A figure of .289kg per second times the I_{sp} of 194.4 gives a thrust of 56.2kg per kilogram of reaction engine. Base maintenance interval for the power plant and fuel combination is 1.5 hours (from the M**aintenance intervals** table), and we see that a TL9 reaction engine has a multiplier of x.125, for a new maintenance interval of .1875 hours, or about 11 minutes.

Example - A TL12 hybrid fission-hydrogen reaction engine is designed around a fuel consumption of 1% fission fuel (Extremely dangerous, Fission) and 99% hydrogen (Dangerous). Output for the fission part is 2,304 watts per kilogram, x.217 from the first table, x200 for fission, for an I_{sp} of 99,994, times .01 for its fraction equals I_{sp} of 999.9. Output for the hydrogen part is 2,304 watts per kilogram (it's still a nuclear engine), x.130 from the first table, for I_{sp} of 299.5, times .99 for its fraction equals I_{sp} of 296.5. Together, the I_{sp} is 1296.4. Fuel consumption of the fission fuel is .06kg, x.005 for fission fuel is .0003kg, times .01 for its fraction is .000003kg. The hydrogen has a base fuel consumption of .1kg, times .99 for its fraction is .099kg. The combined fuel consumption is .099003kg, times the 34.7 on the second table equals a fuel consumption of 3.44kg of fuel per kilogram of reaction engine per second, times the I_{sp} of 1296.4 is 4,460kg of thrust per kilogram.

Sails 1

Tech Level	Durable	Maximum power output Normal	Enhanced	Max. safe wind	x.5 durabil.	x.25 durabil.	x.125 durabil.
1	2w/kg(4w/m^2)	4w/kg(8w/m^2)	6w/kg(12w/m^2)	2m/sec	3m/sec	4m/sec	6m/sec
2	8w/kg(16w/m^2)	16w/kg(32w/m^2)	24w/kg(48w/m^2)	4m/sec	6m/sec	8m/sec	11m/sec
3	18w/kg(36w/m^2)	36w/kg(72w/m^2)	54w/kg(108w/m^2)	6m/sec	8m/sec	12m/sec	17m/sec
4	32w/kg(64w/m^2)	64w/kg(128w/m^2)	96w/kg(192w/m^2)	8m/sec	11m/sec	16m/sec	23m/sec
5	50w/kg(100w/m^2)	100w/kg(200w/m^2)	150w/kg(300w/m^2)	10m/sec	14m/sec	20m/sec	28m/sec
6	72w/kg(144w/m^2)	144w/kg(288w/m^2)	216w/kg(432w/m^2)	12m/sec	17m/sec	24m/sec	34m/sec
7	98w/kg(w196/m^2)	196w/kg(392w/m^2)	294w/kg(588w/m^2)	14m/sec	20m/sec	28m/sec	40m/sec
8	128w/kg(256w/m^2)	256w/kg(512w/m^2)	384w/kg(768w/m^2)	16m/sec	23m/sec	32m/sec	45m/sec
9	162w/kg(324w/m^2)	324w/kg(648w/m^2)	486w/kg(972w/m^2)	18m/sec	25m/sec	36m/sec	51m/sec
10	200w/kg(400w/m^2)	400w/kg(800w/m^2)	600w/kg(1.20kw/m^2)	20m/sec	28m/sec	40m/sec	57m/sec
11	242w/kg(484w/m^2)	484w/kg(968w/m^2)	726w/kg(1,45kw/m^2)	22m/sec	31m/sec	44m/sec	62m/sec
12	288w/kg(576w/m^2)	576w/kg(1.15kw/m^2)	864w/kg(1.73kw/m^2)	24m/sec	34m/sec	48m/sec	68m/sec
13	338w/kg(676w/m^2)	676w/kg(1.35kw/m^2)	1.01kw/kg(2.03w/m^2)	26m/sec	37m/sec	52m/sec	74m/sec
14	392w/kg(784w/m^2)	784w/kg(1.57kw/m^2)	1.18kw/kg(2.35w/m^2)	28m/sec	40m/sec	56m/sec	79m/sec
15	450w/kg(900w/m^2)	900w/kg(1.80kw/m^2)	1.35kw/kg(2.70w/m^2)	30m/sec	42m/sec	60m/sec	85m/sec

How to use this table:
Cross reference the sail type and Tech Level to get the *maximum* output per 1 kilogram of sails, or *maximum* output per square meter (2kg), whichever is more convenient. Also listed is the maximum safe wind velocity for that Tech Level of sails, and the wind velocities that correspond to particular durability modifiers.

Example - A TL5 ship with normal sails will have a maximum output of 100 watts per kilogram of sails, and this is at a wind velocity of 10m/sec, so each 1m/sec of wind velocity generates 10 watts of power from 1kg of sails. Durability for normal sails is 1000 hours between maintenance. If the ship were constantly subjected to 20m/sec winds, the maintenance interval would be x.25, or 250 hours.

Sails 2

Vehicle width	10m^2	20m^2	50m^2	100m^2	Total sail area 200m^2	500m^2	1000m^2	2000m^2	5000m^2	10000m^2
1m	3.3/1.7/1.1	6.7/3.3/2.2	17/8.3/5.6	33/17/11	67/33/22	-	-	-	-	-
2m	1.7/.83/ -	3.3/1.7/1.1	8.3/4.2/2.8	17/8.3/5.6	33/17/11	83/42/28	-	-	-	-
3m	-	-	5.6/2.8/1.9	11/5.6/3.7	22/11/7.4	56/28/19	- /56/37	-	-	-
4m	-	-	4.2/2.1/1.4	8.3/4.2/2.8	17/8.3/5.6	42/21/14	83/42/28	-	-	-
5m	-	-	3.3/1.7/1.1	6.7/3.3/2.2	13/6.7/4.4	33/17/11	67/33/22	-	-	-
6m	-	-	-	5.6/2.8/1.9	11/5.6/3.7	28/14/9.3	56/28/19	- /56/37	-	-
7m	-	-	-	-	9.5/4.7/3.2	24/12/7.9	48/24/16	95/48/32	-	-
8m	-	-	-	-	8.3/4.2/ -	21/10/6.9	42/21/14	83/42/28	- / - /69	-
9m	-	-	-	-	7.4/3.7/ -	19/9.3/6.1	37/19/12	74/37/25	- /93/62	-
10m	-	-	-	-	6.7/3.3/ -	17/8.3/5.6	33/22/11	67/33/22	- /83/56	-
12m	-	-	-	-	5.6/ - / -	14/6.9/4.6	28/14/9.3	56/28/19	- /69/46	- / - /93
15m	-	-	-	-	-	11/5.6/ -	22/11/7.4	44/22/15	- /56/37	- / - /74
20m	-	-	-	-	-	8.3/4.2/2.8	17/8.3/5.6	33/17/11	83/42/28	- /83/56

How to use this table:
Cross reference the sail area and vehicle width to get the minimum mast height in meters for either 1, 2 or 3 masts with a *total* sail area used. The mass of the masts will depend on the height and Tech Level, and the height allowed on a given boat depends on its length. Dashes represent combinations of sail area and vehicle width unlikely to be encountered.

Example - You have a ship with a 6 meter width and 500m^2 of sail area. You see that if using maximum allowed sail width, you would either have one 28m mast, two 14m masts or three 9.3m masts.

Batteries/stored power

Tech Level	V.crude	Crude	Normal	Battery type Enhanced	Exotic	Dangerous	Ext. dangerous	Suicidal
1	.00w/hr	.00w/hr	.00w/hr	.01w/hr	.02w/hr	.04w/hr	.07w/hr	.10w/hr
2	.03w/hr	.05w/hr	.06w/hr	.13w/hr	.26w/hr	.64w/hr	1.1w/hr	1.6w/hr
3	.16w/hr	.23w/hr	.32w/hr	.65w/hr	1.3w/hr	3.2w/hr	5.4w/hr	8.1w/hr
4	.51w/hr	.73w/hr	1.0w/hr	2.0w/hr	4.1w/hr	10.2w/hr	17.1w/hr	25.6w/hr
5	1.3w/hr	1.8w/hr	2.5w/hr	5.0w/hr	10.0w/hr	25.0w/hr	41.7w/hr	62.5w/hr
6	2.6w/hr	3.7w/hr	5.2w/hr	10.4w/hr	20.7w/hr	51.8w/hr	86.4w/hr	130.w/hr
7	4.8w/hr	6.9w/hr	9.6w/hr	19.2w/hr	38.4w/hr	96.0w/hr	160.w/hr	240.w/hr
8	8.2w/hr	11.7w/hr	16.4w/hr	32.8w/hr	65.5w/hr	164.w/hr	273.w/hr	410.w/hr
9	13.1w/hr	18.7w/hr	26.2w/hr	52.5w/hr	105.w/hr	262.w/hr	437.w/hr	656.w/hr
10	20.0w/hr	28.6w/hr	40.0w/hr	80.0w/hr	160.w/hr	400.w/hr	667.w/hr	1000w/hr
11	29.3w/hr	41.2w/hr	58.6w/hr	117.w/hr	234.w/hr	586.w/hr	976.w/hr	1464w/hr
12	41.5w/hr	59.2w/hr	82.9w/hr	166.w/hr	332.w/hr	829.w/hr	1382w/hr	2074w/hr
13	57.1w/hr	81.6w/hr	114.w/hr	228.w/hr	457.w/hr	1142w/hr	1904w/hr	2856w/hr
14	76.8w/hr	110.w/hr	154.w/hr	307.w/hr	615.w/hr	1537w/hr	2561w/hr	3842w/hr
15	101.w/hr	145.w/hr	203.w/hr	405.w/hr	910.w/hr	2025w/hr	3375w/hr	5062w/hr
Cost per kg	.20Cr	.28Cr	.40Cr	.80Cr	1.6Cr	3.6Cr	6.4Cr	10Cr

How to use this table:
Base a battery or other energy storage device on a normal power plant type and a fuel type for the battery. The result is the amount of energy the battery can store in watt-hours per kilogram. This is compared to the output of whatever power plant is used to get the duration power can be supplied for. We aren't even going to begin to imagine what a suicidal TL1 battery is made from...

Example - A TL11 electric vehicle has 500kg of normal batteries, which provide 500kg x 58.6w/hr = 29,300 watt-hours of power. If the vehicle has a 30hp electric motor (22,500w power), then the vehicle can run at full speed for (29,300w/hr)/(22,500w) = 1.3 hours.

Solar power

Tech Level	Output per kg	Output per m^2
1	.20w	2.0w
2	.80w	8.0w
3	1.8w	18.0w
4	3.2w	32.0w
5	5.0w	50.0w
6	7.2w	72.0w
7	9.8w	98.0w
8	12.8w	128.w
9	16.2w	162.w
10	20.0w	200.w
11	24.2w	242.w
12	28.8w	288.w
13	33.8w	338.w
14	39.2w	392.w
15	45.0w	450.w
Cost per kg	50Cr	

Solar sails

Tech Level	Power per km^2	Mass per km^2
1	10w	50,000kg
2	10w	12,500kg
3	10w	5,556kg
4	10w	3,125kg
5	10w	2,000kg
6	10w	1,389kg
7	10w	1,020kg
8	10w	781kg
9	10w	617kg
10	10w	500kg
11	10w	413kg
12	10w	347kg
13	10w	296kg
14	10w	255kg
15	10w	222kg

Energy banks

Tech Level	Low density	High density
1	-	-
2	-	-
3	-	-
4	-	-
5	-	-
6	-	-
7	-	-
8	400w/sec	-
9	800w/sec	-
10	1200w/sec	-
11	1600w/sec	-
12	2000w/sec	-
13	2400w/sec	125,000w/sec
14	2800w/sec	250,000w/sec
15	3200w/sec	375,000w/sec
Cost per kg	100Cr	

How to use these tables:
The first table is for solar power sources, either solar-to-electricity or solar-to-heat applications. Cross-reference the Tech Level of the solar panels with either the output per kilogram or per square meter, as desired. Power output is based on Earth-normal light intensity.

Example - A TL11 solar panel produces 24.2 watts per kilogram, or 242 watts per square meter.

The second table lists the output and mass of solar sails used for motive power on a spacecraft. Power output is constant across Tech Levels and assumes Earth-orbit light intensity, but mass of sails will vary.

Example - A TL14 solar sail will have an output of 10 watts per square kilometer, and mass 222kg per square kilometer.

The last table is for energy storage banks, required for high-intensity, short-duration pulses, like those required for some energy weapons and jump drives. Cross-reference the Tech Level with either low- or high-density storage (whichever is available in your game universe) to get the output in watt-seconds per kilogram of storage bank.

Example - A 100kg pack of TL13 low-desnity storage banks will hold 100kg x 2400w/sec = 240,000w/sec of power, or (240,000w/sec)/(3,600 sec) = 66.7w/hr of power.

Conventional power trains

Tech Level	Wheels(1)	Tracks(4)	Legs, sm. feet(3)	Legs, med. feet(4)	Legs, lg. feet(5)	Indirect to dense	Indirect to avg.	Indirect to thin
1	50.0kg/x.40	100kg/x.30	80.0kg/x.25	100kg/x.20	120kg/x.15	10.0kg/x.25	20.0kg/x.50	30.0kg/x1.0
2	25.0kg/x.40	50.0kg/x.30	40.0kg/x.25	50.0kg/x.20	60.0kg/x.15	5.00kg/x.25	10.0kg/x.50	15.0kg/x1.0
3	16.7kg/x.48	33.3kg/x.36	26.7kg/x.30	33.3kg/x.24	40.0kg/x.18	3.33kg/x.30	6.67kg/x.60	10.0kg/x1.2
4	12.5kg/x.48	25.0kg/x.36	20.0kg/x.30	25.0kg/x.24	30.0kg/x.188	2.50kg/x.30	5.00kg/x.60	7.50kg/x1.2
5	10.0kg/x.56	20.0kg/x.42	16.0kg/x.35	20.0kg/x.28	24.0kg/x.21	2.00kg/x.35	4.00kg/x.70	6.00kg/x1.4
6	8.33kg/x.56	16.7kg/x.42	13.3kg/x.35	16.7kg/x.28	20.0kg/x.21	1.67kg/x.35	3.33kg/x.70	5.00kg/x1.4
7	7.14kg/x.64	14.3kg/x.48	11.4kg/x.40	14.3kg/x.32	17.1kg/x.24	1.43kg/x.40	2.86kg/x.80	4.28kg/x1.6
8	6.25kg/x.64	12.5kg/x.48	10.0kg/x.40	12.5kg/x.32	15.0kg/x.24	1.25kg/x.40	2.50kg/x.80	3.75kg/x1.6
9	5.56kg/x.72	11.1kg/x.54	8.89kg/x.45	11.1kg/x.36	13.3kg/x.27	1.11kg/x.45	2.22kg/x.90	3.33kg/x1.8
10	5.00kg/x.72	10.0kg/x,54	8.00kg/x.45	10.0kg/x.36	12.0kg/x.27	1.00kg/x.45	2.00kg/x.90	3.00kg/x1.8
11	4.55kg/x.80	9.09kg/x.60	7.27kg/x.50	9.09kg/x.40	10.9kg/x.30	.909kg/x.50	1.82kg/x.1.0	2.73kg/x2.0
12	4.17kg/x.80	8.33kg/x.60	6.67kg/x.50	8.33kg/x.40	10.0kg/x.30	.833kg/x.50	1.67kg/x.1.0	2.50kg/x2.0
13	3.85kg/x.88	7.69kg/x.66	6.15kg/x.55	7.69kg/x.44	9.23kg/x.33	.769kg/x.55	1.54kg/x.1.1	2.31kg/x2.2
14	3.57kg/x.88	7.14kg/x.66	5.71kg/x.55	7.14kg/x.44	8.57kg/x.33	.714kg/x.55	1.43kg/x.1.2	2.14kg/x2.2
15	3.33kg/x.96	6.67kg/x.72	5.33kg/x.60	6.67kg/x.48	8.00kg/x.36	.667kg/x.60	1.33kg/x.1.3	2.00kg/x2.4
Cost per kg	5Cr/kg	5Cr/kg	5Cr/kg	5Cr/kg	5Cr/kg	5Cr/kg	5Cr/kg	5Cr/kg
Can pivot in place	7Cr/kg	7Cr/kg	7Cr/kg	7Cr/kg	7Cr/kg	7Cr/kg	7Cr/kg	7Cr/kg

Modifiers	Speed	kg/kw	Cost
Muscle-powered	x1.0	x3.0	x2.0
Terrain rating-2 (min. of 0)	x1.0	x.25	x1.0
Terrain rating-1 (min. of 0)	x1.0	x.50	x1.0
Terrain rating+1 (max. of 5)	x1.0	x1.5	x1.0
Terrain rating+2 (max. of 5)	x1.0	x2.0	x1.0
Terrain rating+3 (max. of 5)	x1.0	x2.5	x1.0

How to use this table:
Cross reference the Tech Level and type of power train desired. The first number is the kilograms of power train required per kilowatt of power plant output used. The second number is the multiplier on vehicle top speed based on the power train and Tech Level. If you have already figured top speed from the Performance tables, don't apply this multiplier again. You can, however, use it to double check against the base speed from that table to see if the figures match. The number after the land-based power trains is the default terrain rating of that type of power train. Use the modifiers table to adjust these figures for special cases. Remember that indirect to thin is used for reaction engines.

Example - A TL7 tracked vehicle with a 250kw power plant will require 14.3kg of power train per kilowatt of power plant output, for a total power train mass of 3,575kg. The vehicle will also have a top speed of x.48 the base maximum speed, not counting any streamlining or other considerations. A power train of 3,575kg will have a cost of 3,575kg x 5Cr = 17,875Cr. If the tracked vehicle can pivot in place instead of doing normal turns, the power train cost is 3,575kg x 7Cr = 25,025Cr.

Antigrav

Tech Level	Grav plates	Altitude	Acceleration
1	30.0kg/x.50	≤1m	x5.0
2	15.0kg/x.50	≤10m	x4.5
3	10.0kg/x.60	≤100m	x4.0
4	7.50kg/x.60	≤1km	x3.5
5	6.00kg/x.70	≤10km	x3.0
6	5.00kg/x.70	≤100km	x2.5
7	4.28kg/x.80	≤1,000km	x2.0
8	3.75kg/x.80	≤10,000km	x1.5
9	3.33kg/x.90	≤100,000km	x1.0
10	3.00kg/x.90	≤1,000,000km	x.50
11	2.73kg/x1.0		
12	2.50kg/x1.0		
13	2.31kg/x1.1		
14	2.14kg/x1.1		
15	2.00kg/x1.2		
Cost per kg	10Cr/kg		
Can pivot in place	12Cr/kg		

Artificial gravity

Artificial gravity	Power per 100m^3	Mass @TL13	Mass @TL14	Mass @TL15
.1g	.100kw	.231kg	.214kg	.200kg
.2g	.400kw	.924kg	.856kg	.800kg
.3g	.900kw	2.08kg	1.93kg	1.80kg
.4g	1.60kw	3.70kg	3.42kg	3.20kg
.5g	2.50kw	5.78kg	5.35kg	5.00kg
.6g	3.60kw	8.32kg	7.70kg	7.20kg
.7g	4.90kw	11.3kg	10.5kg	9.80kg
.8g	6.40kw	14.8kg	13.7kg	12.8kg
.9g	8.10kw	18.7kg	17.3kg	16.2kg
1.0g	10.0kw	23.1kg	21.4kg	20.0kg
1.5g	22.5kw	52.0kg	48.2kg	45.0kg
2.0g	40.0kw	92.4kg	85.6kg	80.0kg
2.5g	62.5kw	144.kg	134.kg	125.kg
3.0g	90.0kw	208.kg	193.kg	180.kg
4.0g	160.kw	370.kg	342.kg	320.kg

How to use this table:
Check the Tech Level to see the power train mass for converting electrical power into antigrav thrust. Actual acceleration potential is modified by the distance to nearest significant gravity source. For installing artifical gravity, each 100m^3 of volume protected will consume the listed power for the gravity desired, and the grav compensators will have the listed mass per100m^3 of volume protected.

Jump drive

Tech Level	Jump core per ton of ship	Power per ton of ship	"Hyperspeed" per 100hr	Starting pulse
1	1,000kg	3.33kw	.1pc	-
2	500kg	3.33kw	.4pc	-
3	333kg	3.33kw	.9pc	-
4	250kg	3.33kw	1.6pc	-
5	200kg	3.33kw	2.5pc	-
6	167kg	3.33kw	3.6pc	-
7	143kg	3.33kw	4.9pc	-
8	125kg	3.33kw	6.4pc	83.3kg
9	111kg	3.33kw	8.1pc	41.7kg
10	100kg	3.33kw	10.0pc	27.8kg
11	90.9kg	3.33kw	12.1pc	20.8kg
12	83.3kg	3.33kw	14.4pc	16.7kg
13	76.9kg	3.33kw	16.9pc	2.76kg
14	71.4kg	3.33kw	19.6pc	1.33kg
15	66.7kg	3.33kw	22.5pc	.889kg
Cost per kg	10Cr/kg			
Can pivot in place	n/a			

Gravity wells

Gravity source	.01g	.001g	.0001g
Ceres	.895kkm	2.83kkm	8.95kkm
Moon	7.00kkm	22.1kkm	70.0kkm
Mars	20.7kkm	65.5kkm	207.kkm
Earth	63.3kkm	200.kkm	633.kkm
Neptune	262.kkm	829.kkm	2.62Mkm
Saturn	616.kkm	1.95Mkm	6.16Mkm
Jupiter	1.13Mkm	3.56Mkm	11.3Mkm
Sol	36.4Mkm	115.Mkm	364.Mkm
Distances	**Sol**		
Earth	150.Mkm		
Mars	227.Mkm		
Jupiter	778.Mkm		
Saturn	1,428Mkm		
Neptune	4,501Mkm		

How to use this table:
Check the Tech Level to see the mass of a jump core per ton of loaded ship mass. The TL also determines the rate at which you cross hyperspace, and if using the energy pulse optional rule, the mass of storage banks per ton of ship is also included. If you decide that a ship has to be in a certain gravity gradient before it can jump, use the right-hand table to figure the distance required in thousands of kilometers (kkm) or millions of kilometers (Mkm).

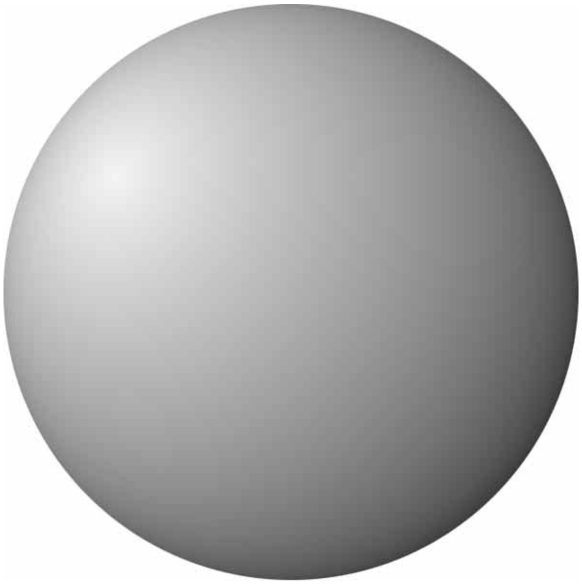
Example - A TL13 ship of 100 tons loaded mass will have a 76.9kg jump core, a storage bank of 2.76kg, and consume 33.3kw of power for the duration of its trip, at a speed of 16.9 parsecs per 100 hours (4.06 parsecs per day).

Hoverskirts

Length x width	Mass 100kg	200kg	500kg	1000kg	2000kg	5000kg	10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
5	800w	3.2kw	20kw	80kw	320kw	2.0Mw	8.0Mw	32Mw	200Mw	800Mw	-	-	-
10	400w	1.6kw	10kw	40kw	160kw	1.0Mw	4.0Mw	16Mw	100Mw	400Mw	1600Mw	-	-
15	267w	1.1kw	6.7kw	27kw	107kw	667kw	2.7Mw	11Mw	67Mw	267Mw	1067Mw	-	-
20	200w	800w	5.0kw	20kw	80kw	500kw	2.0Mw	8.0Mw	50Mw	200Mw	800Mw	-	-
25	160w	640w	4.0kw	16kw	64kw	400kw	1.6Mw	6.4Mw	40Mw	160Mw	640Mw	4000Mw	-
30	133w	533w	3.3kw	13kw	53kw	333kw	1.3Mw	5.3Mw	33Mw	133Mw	533Mw3	3333Mw	-
40	100w	400w	2.5kw	10kw	40kw	250kw	1.0Mw	4.0Mw	25Mw	100Mw	400Mw	2500Mw	-
50	80w	320w	2.0kw	8.0kw	32kw	200kw	800kw	3.2Mw	20Mw	80Mw	320Mw	2000Mw	-
70	57w	229w	1.4kw	5.7kw	23kw	143kw	571kw	2.3Mw	14Mw	71Mw	281Mw	1429Mw	-
100	40w	160w	1.0kw	4.0kw	16kw	100kw	400kw	1.6Mw	10Mw	40Mw	160Mw	1000Mw	4000Mw
150	27w	107w	667w	2.7kw	11kw	67kw	267kw	1.1Mw	6.7Mw	27Mw	107Mw	667Mw	2667Mw
200	20w	80w	500w	2.0kw	8.0kw	50kw	200kw	800kw	5.0Mw	20Mw	80Mw	500Mw	2000Mw
300	13w	53w	333w	1.3kw	5.3kw	33kw	133kw	533kw	3.3Mw	13Mw	53Mw	333Mw	1333Mw
400	10w	40w	250w	1.0kw	4.0kw	25kw	100kw	400kw	2.5Mw	10Mw	40Mw	250Mw	1000Mw
500	8w	32w	200w	800w	3.2kw	20kw	80kw	320kw	2.0Mw	8.0Mw	32Mw	200Mw	800Mw

How to use this table:
Compare the loaded mass of a hovercraft to the bottom area of the vehicle (usually length x width). The intersection of these two items will be the power required to maintain an intact hoverskirt.

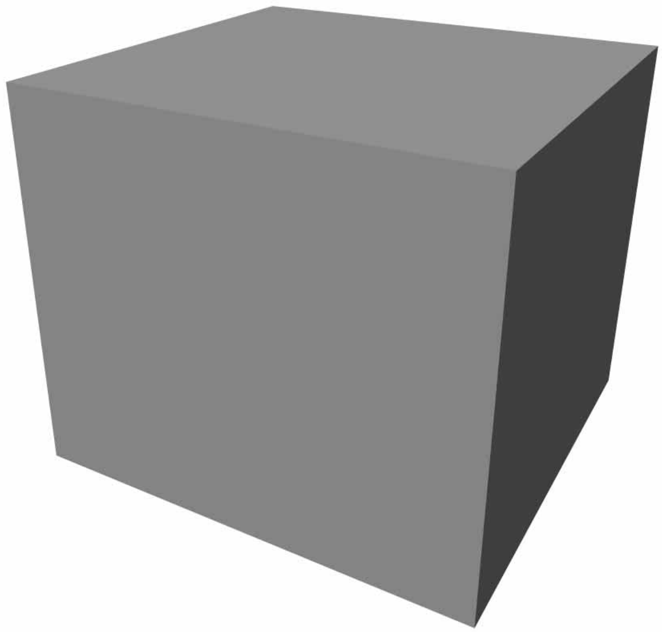
Example - A hovercraft with a loaded mass of 5 tons and a length x width of 20 (bottom area = 20m^2) will require 500kw of power to keep the hoverskirt inflated, or about 667 horsepower.



SPHERE

Area = Length^2 x 3.1
Volume = Length^3 x .52
F:17% R:17% S:16% T:17% B:17%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.065m^3	.775m^2	.50m	.50m	.50m	.132m^2	.132m^2	.124m^2	.132m^2	.132m^2
1.0m	.520m^3	3.10m^2	1.0m	1.0m	1.0m	.527m^2	.527m^2	.496m^2	.527m^2	.527m^2
1.5m	1.76m^3	6.98m^2	1.5m	1.5m	1.5m	1.19m^2	1.19m^2	1.12m^2	1.19m^2	1.19m^2
2.0m	4.16m^3	12.40m^2	2.0m	2.0m	2.0m	2.11m^2	2.11m^2	1.98m^2	2.11m^2	2.11m^2
3.0m	14.04m^3	27.90m^2	3.0m	3.0m	3.0m	4.74m^2	4.74m^2	4.46m^2	4.74m^2	4.74m^2
4.0m	33.28m^3	49.60m^2	4.0m	4.0m	4.0m	8.43m^2	8.43m^2	7.94m^2	8.43m^2	8.43m^2
5.0m	65.00m^3	77.50m^2	5.0m	5.0m	5.0m	13.2m^2	13.2m^2	12.4m^2	13.2m^2	13.2m^2
6.0m	112.3m^3	111.6m^2	6.0m	6.0m	6.0m	19.0m^2	19.0m^2	17.9m^2	19.0m^2	19.0m^2
7.0m	178.4m^3	151.9m^2	7.0m	7.0m	7.0m	25.8m^2	25.8m^2	24.3m^2	25.8m^2	25.8m^2
8.0m	266.2m^3	198.4m^2	8.0m	8.0m	8.0m	33.7m^2	33.7m^2	31.7m^2	33.7m^2	33.7m^2
10m	520.0m^3	310.0m^2	10.0m	10.0m	10.0m	52.7m^2	52.7m^2	49.6m^2	52.7m^2	52.7m^2
12m	898.6m^3	446.4m^2	12.0m	12.0m	12.0m	75.9m^2	75.9m^2	71.4m^2	75.9m^2	75.9m^2
15m	1755.m^3	697.5m^2	15.0m	15.0m	15.0m	118.6m^2	118.6m^2	111.6m^2	118.6m^2	118.6m^2
20m	4160.m^3	1240.m^2	20.0m	20.0m	20.0m	210.8m^2	210.8m^2	198.4m^2	210.8m^2	210.8m^2
25m	8125.m^3	1938.m^2	25.0m	25.0m	25.0m	329.4m^2	329.4m^2	310.0m^2	329.4m^2	329.4m^2
30m	14040m^3	2790.m^2	30.0m	30.0m	30.0m	474.3m^2	474.3m^2	446.4m^2	474.3m^2	474.3m^2
35m	22295m^3	3798.m^2	35.0m	35.0m	35.0m	645.6m^2	645.6m^2	607.6m^2	645.6m^2	645.6m^2
40m	33280m^3	4960.m^2	40.0m	40.0m	40.0m	843.2m^2	843.2m^2	793.6m^2	843.2m^2	843.2m^2
45m	47385m^3	6278.m^2	45.0m	45.0m	45.0m	1067.m^2	1067.m^2	1004.m^2	1067.m^2	1067.m^2
50m	65000m^3	7750.m^2	50.0m	50.0m	50.0m	1318.m^2	1318.m^2	1240.m^2	1318.m^2	1318.m^2
60m	112320m^3	11160m^2	60.0m	60.0m	60.0m	1897.m^2	1897.m^2	1786.m^2	1897.m^2	1897.m^2
70m	178360m^3	15190m^2	70.0m	70.0m	70.0m	2582.m^2	2582.m^2	2430.m^2	2582.m^2	2582.m^2
80m	266240m^3	19840m^2	80.0m	80.0m	80.0m	3373.m^2	3373.m^2	3174.m^2	3373.m^2	3373.m^2
90m	379080m^3	25110m^2	90.0m	90.0m	90.0m	4269.m^2	4269.m^2	4018.m^2	4269.m^2	4269.m^2
100m	520000m^3	31000m^2	100.0m	100.0m	100.0m	5270.m^2	5270.m^2	4960.m^2	5270.m^2	5270.m^2
120m	898560m^3	44640m^2	120.0m	120.0m	120.0m	7589.m^2	7589.m^2	7142.m^2	7589.m^2	7589.m^2
150m	1.76 x 10^{6}m^3	69750m^2	150.0m	150.0m	150.0m	11858m^2	11858m^2	11160m^2	11858m^2	11858m^2
200m	4.16 x 10^{6}m^3	124000m^2	200.0m	200.0m	200.0m	21080m^2	21080m^2	19840m^2	21080m^2	21080m^2
250m	8.13 x 10^{6}m^3	193750m^2	250.0m	250.0m	250.0m	32938m^2	32938m^2	31000m^2	32938m^2	32938m^2
300m	14.0 x 10^{6}m^3	279000m^2	300.0m	300.0m	300.0m	47430m^2	47430m^2	44640m^2	47430m^2	47430m^2
400m	33.3 x 10^{6}m^3	496000m^2	400.0m	400.0m	400.0m	84320m^2	84320m^2	79360m^2	84320m^2	84320m^2
500m	65.0 x 10^{6}m^3	775000m^2	500.0m	500.0m	500.0m	131750m^2	131750m^2	124000m^2	131750m^2	131750m^2
600m	112 x 10^{6}m^3	1.12 x 10^{6}m^2	600.0m	600.0m	600.0m	189720m^2	189720m^2	178560m^2	189720m^2	189720m^2
700m	178 x 10^{6}m^3	1.52 x 10^{6}m^2	700.0m	700.0m	700.0m	258230m^2	258230m^2	243040m^2	258230m^2	258230m^2
800m	266 x 10^{6}m^3	1.98 x 10^{6}m^2	800.0m	800.0m	800.0m	337280m^2	337280m^2	317440m^2	337280m^2	337280m^2
900m	379 x 10^{6}m^3	2.51 x 10^{6}m^2	900.0m	900.0m	900.0m	426870m^2	426870m^2	401760m^2	426870m^2	426870m^2
1000m	520 x 10^{6}m^3	3.10 x 10^{6}m^2	1000.0m	1000.0m	1000.0m	527000m^2	527000m^2	496000m^2	527000m^2	527000m^2



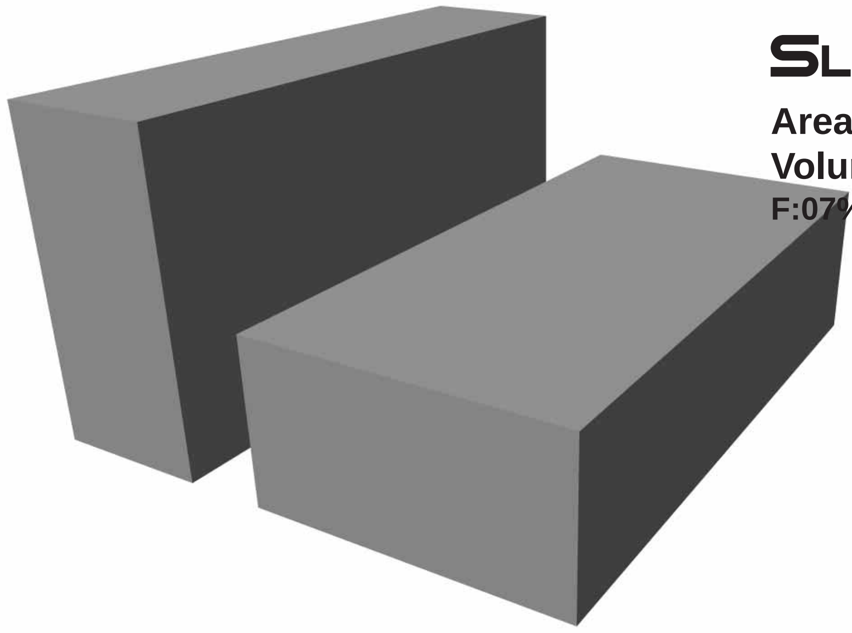
Cube

Area = Length^2 x 6.0

Volume = Length^3 x 1.00

F:17% R:17% S:16% T:17% B:17%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.125m^3	1.50m	.50m	.50m	.50m	.255m^2	.255m^2	.240m^2	.255m^2	.255m^2
1.0m	1.00m^3	6.00m	1.0m	1.0m	1.0m	1.02m^2	1.02m^2	0.96m^2	1.02m^2	1.02m^2
1.5m	3.38m^3	13.50m	1.5m	1.5m	1.5m	2.30m^2	2.30m^2	2.16m^2	2.30m^2	2.30m^2
2.0m	8.00m^3	24.00m	2.0m	2.0m	2.0m	4.08m^2	4.08m^2	3.84m^2	4.08m^2	4.08m^2
3.0m	27.00m^3	54.00m	3.0m	3.0m	3.0m	9.18m^2	9.18m^2	8.64m^2	9.18m^2	9.18m^2
4.0m	64.00m^3	96.00m	4.0m	4.0m	4.0m	16.3m^2	16.3m^2	15.4m^2	16.3m^2	16.3m^2
5.0m	125.0m^3	150.0m	5.0m	5.0m	5.0m	25.5m^2	25.5m^2	24.0m^2	25.5m^2	25.5m^2
6.0m	216.0m^3	216.0m	6.0m	6.0m	6.0m	36.7m^2	36.7m^2	34.6m^2	36.7m^2	36.7m^2
7.0m	343.0m^3	294.0m	7.0m	7.0m	7.0m	50.0m^2	50.0m^2	47.0m^2	50.0m^2	50.0m^2
8.0m	512.0m^3	384.0m	8.0m	8.0m	8.0m	65.3m^2	65.3m^2	61.4m^2	65.3m^2	65.3m^2
10m	1000.m^3	600.0m	10.0m	10.0m	10.0m	102.0m^2	102.0m^2	96.0m^2	102.0m^2	102.0m^2
12m	1728.m^3	864.0m	12.0m	12.0m	12.0m	146.9m^2	146.9m^2	138.2m^2	146.9m^2	146.9m^2
15m	3375.m^3	1350.m	15.0m	15.0m	15.0m	229.5m^2	229.5m^2	216.0m^2	229.5m^2	229.5m^2
20m	8000.m^3	2400.m	20.0m	20.0m	20.0m	408.0m^2	408.0m^2	384.0m^2	408.0m^2	408.0m^2
25m	15625m^3	3750.m	25.0m	25.0m	25.0m	637.5m^2	637.5m^2	600.0m^2	637.5m^2	637.5m^2
30m	27000m^3	5400.m	30.0m	30.0m	30.0m	918.0m^2	918.0m^2	864.0m^2	918.0m^2	918.0m^2
35m	42875m^3	7350.m	35.0m	35.0m	35.0m	1250.m^2	1250.m^2	1176.m^2	1250.m^2	1250.m^2
40m	64000m^3	9600.m	40.0m	40.0m	40.0m	1632.m^2	1632.m^2	1536.m^2	1632.m^2	1632.m^2
45m	91125m^3	12150m	45.0m	45.0m	45.0m	2066.m^2	2066.m^2	1944.m^2	2066.m^2	2066.m^2
50m	125000m^3	15000m	50.0m	50.0m	50.0m	2550.m^2	2550.m^2	2400.m^2	2550.m^2	2550.m^2
60m	216000m^3	21600m	60.0m	60.0m	60.0m	3672.m^2	3672.m^2	3456.m^2	3672.m^2	3672.m^2
70m	343000m^3	29400m	70.0m	70.0m	70.0m	4998.m^2	4998.m^2	4704.m^2	4998.m^2	4998.m^2
80m	512000m^3	38400m	80.0m	80.0m	80.0m	6528.m^2	6528.m^2	6144.m^2	6528.m^2	6528.m^2
90m	729000m^3	48600m	90.0m	90.0m	90.0m	8262.m^2	8262.m^2	7776.m^2	8262.m^2	8262.m^2
100m	1.00 x 10^{6}m^3	60000m	100.0m	100.0m	100.0m	10200m^2	10200m^2	9600.m^2	10200m^2	10200m^2
120m	1.73 x 10^{6}m^3	86400m	120.0m	120.0m	120.0m	14688m^2	14688m^2	13824m^2	14688m^2	14688m^2
150m	3.38 x 10^{6}m^3	135000m	150.0m	150.0m	150.0m	22950m^2	22950m^2	21600m^2	22950m^2	22950m^2
200m	8.00 x 10^{6}m^3	240000m	200.0m	200.0m	200.0m	40800m^2	40800m^2	38400m^2	40800m^2	40800m^2
250m	15.6 x 10^{6}m^3	375000m	250.0m	250.0m	250.0m	63750m^2	63750m^2	60000m^2	63750m^2	63750m^2
300m	27.0 x 10^{6}m^3	540000m	300.0m	300.0m	300.0m	91800m^2	91800m^2	86400m^2	91800m^2	91800m^2
400m	64.0 x 10^{6}m^3	960000m	400.0m	400.0m	400.0m	163200m^2	163200m^2	153600m^2	163200m^2	163200m^2
500m	125 x 10^{6}m^3	1.50 x 10^{6}m^2	500.0m	500.0m	500.0m	255000m^2	255000m^2	240000m^2	255000m^2	255000m^2
600m	216 x 10^{6}m^3	2.16 x 10^{6}m^2	600.0m	600.0m	600.0m	367200m^2	367200m^2	345600m^2	367200m^2	367200m^2
700m	343 x 10^{6}m^3	2.94 x 10^{6}m^2	700.0m	700.0m	700.0m	499800m^2	499800m^2	470400m^2	499800m^2	499800m^2
800m	512 x 10^{6}m^3	3.84 x 10^{6}m^2	800.0m	800.0m	800.0m	652800m^2	652800m^2	614400m^2	652800m^2	652800m^2
900m	729 x 10^{6}m^3	4.86 x 10^{6}m^2	900.0m	900.0m	900.0m	826200m^2	826200m^2	777600m^2	826200m^2	826200m^2
1000m	1000 x 10^{6}m^3	6.00 x 10^{6}m^2	1000.0m	1000.0m	1000.0m	1020000m^2	1020000m^2	960000m^2	1020000m^2	1020000m^2



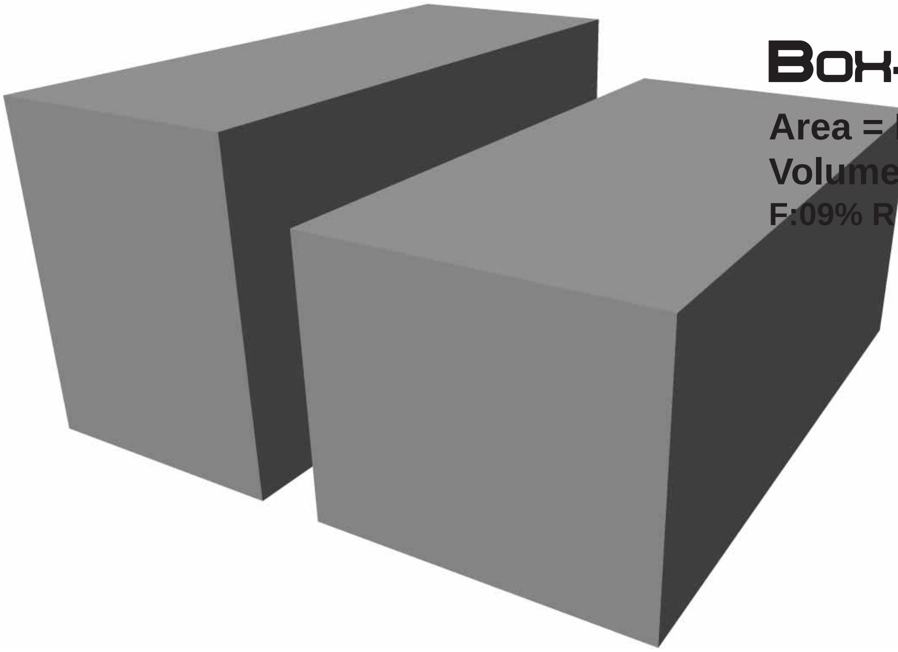
SLAB

Area = Length^2 x 1.75

Volume = Length^3 x .13

F:07% R:07% S:15% T:28% B:28%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.016m^3	.438m^2	.50m	.25m	.13m	.031m^2	.031m^2	.066m^2	.122m^2	.122m^2
1.0m	.130m^3	1.75m^2	1.0m	.50m	.25m	.122m^2	.122m^2	.263m^2	.490m^2	.490m^2
1.5m	.439m^3	3.94m^2	1.5m	.75m	.38m	.276m^2	.276m^2	.591m^2	1.10m^2	1.10m^2
2.0m	1.04m^3	7.00m^2	2.0m	1.0m	.50m	.490m^2	.490m^2	1.05m^2	1.96m^2	1.96m^2
3.0m	3.51m^3	15.80m^2	3.0m	1.5m	.75m	1.10m^2	1.10m^2	2.36m^2	4.41m^2	4.41m^2
4.0m	8.32m^3	28.00m^2	4.0m	2.0m	1.0m	1.96m^2	1.96m^2	4.20m^2	7.84m^2	7.84m^2
5.0m	16.25m^3	43.75m^2	5.0m	2.5m	1.3m	3.06m^2	3.06m^2	6.56m^2	12.3m^2	12.3m^2
6.0m	28.08m^3	63.00m^2	6.0m	3.0m	1.5m	4.41m^2	4.41m^2	9.45m^2	17.6m^2	17.6m^2
7.0m	44.59m^3	85.75m^2	7.0m	3.5m	1.8m	6.00m^2	6.00m^2	12.9m^2	24.0m^2	24.0m^2
8.0m	66.56m^3	112.0m^2	8.0m	4.0m	2.0m	7.84m^2	7.84m^2	16.8m^2	31.4m^2	31.4m^2
10m	130.0m^3	175.0m^2	10.0m	5.0m	2.5m	12.2m^2	12.2m^2	26.3m^2	49.0m^2	49.0m^2
12m	224.6m^3	252.0m^2	12.0m	6.0m	3.0m	17.6m^2	17.6m^2	37.8m^2	70.6m^2	70.6m^2
15m	438.8m^3	393.8m^2	15.0m	7.5m	3.8m	27.6m^2	27.6m^2	59.1m^2	110.2m^2	110.2m^2
20m	1040.m^3	700.0m^2	20.0m	10.0m	5.0m	49.0m^2	49.0m^2	105.0m^2	196.0m^2	196.0m^2
25m	2031.m^3	1094.m^2	25.0m	12.5m	6.3m	76.6m^2	76.6m^2	164.1m^2	306.3m^2	306.3m^2
30m	3510.m^3	1575.m^2	30.0m	15.0m	7.5m	110.3m^2	110.3m^2	236.3m^2	441.0m^2	441.0m^2
35m	5574.m^3	2144.m^2	35.0m	17.5m	8.8m	150.1m^2	150.1m^2	321.6m^2	600.3m^2	600.3m^2
40m	8320.m^3	2800.m^2	40.0m	20.0m	10.0m	196.0m^2	196.0m^2	420.0m^2	784.0m^2	784.0m^2
45m	11846m^3	3544.m^2	45.0m	22.5m	11.3m	248.1m^2	248.1m^2	531.6m^2	992.3m^2	992.3m^2
50m	16250m^3	4375.m^2	50.0m	25.0m	12.5m	306.3m^2	306.3m^2	656.2m^2	1225.m^2	1225.m^2
60m	28080m^3	6300.m^2	60.0m	30.0m	15.0m	441.0m^2	441.0m^2	945.0m^2	1764.m^2	1764.m^2
70m	44590m^3	8575.m^2	70.0m	35.0m	17.5m	600.3m^2	600.3m^2	1286.m^2	2401.m^2	2401.m^2
80m	66560m^3	11200m^2	80.0m	40.0m	20.0m	784.0m^2	784.0m^2	1680.m^2	3136.m^2	3136.m^2
90m	94770m^3	14175m^2	90.0m	45.0m	22.5m	992.3m^2	992.3m^2	2126.m^2	3969.m^2	3969.m^2
100m	130000m^3	17500m^2	100.0m	50.0m	25.0m	1225.m^2	1225.m^2	2625.m^2	4900.m^2	4900.m^2
120m	224640m^3	25200m^2	120.0m	60.0m	30.0m	1764.m^2	1764.m^2	3780.m^2	7056.m^2	7056.m^2
150m	438750m^3	39375m^2	150.0m	75.0m	37.5m	2756.m^2	2756.m^2	5906.m^2	11025m^2	11025m^2
200m	1.04 x 10^{6}m^3	70000m^2	200.0m	100.0m	50.0m	4900.m^2	4900.m^2	10500m^2	19600m^2	19600m^2
250m	2.03 x 10^{6}m^3	109400m^2	250.0m	125.0m	62.5m	7656.m^2	7656.m^2	16406m^2	30625m^2	30625m^2
300m	3.51 x 10^{6}m^3	157500m^2	300.0m	150.0m	75.0m	11025m^2	11025m^2	23625m^2	44100m^2	44100m^2
400m	8.32 x 10^{6}m^3	280000m^2	400.0m	200.0m	100.0m	19600m^2	19600m^2	42000m^2	78400m^2	78400m^2
500m	16.3 x 10^{6}m^3	437500m^2	500.0m	250.0m	125.0m	30625m^2	30625m^2	65625m^2	122500m^2	122500m^2
600m	28.1 x 10^{6}m^3	630000m^2	600.0m	300.0m	150.0m	44100m^2	44100m^2	94500m^2	176400m^2	176400m^2
700m	44.6 x 10^{6}m^3	857500m^2	700.0m	350.0m	175.0m	60025m^2	60025m^2	128625m^2	240100m^2	240100m^2
800m	66.6 x 10^{6}m^3	1.12 x 10^{6}m^2	800.0m	400.0m	200.0m	78400m^2	778400m^2	168000m^2	313600m^2	313600m^2
900m	94.8 x 10^{6}m^3	1.42 x 10^{6}m^2	900.0m	450.0m	225.0m	99225m^2	99225m^2	212625m^2	396900m^2	396900m^2
1000m	130 x 10^{6}m^3	1.75 x 10^{6}m^2	1000.0m	500.0m	250.0m	122500m^2	122500m^2	262500m^2	490000m^2	490000m^2



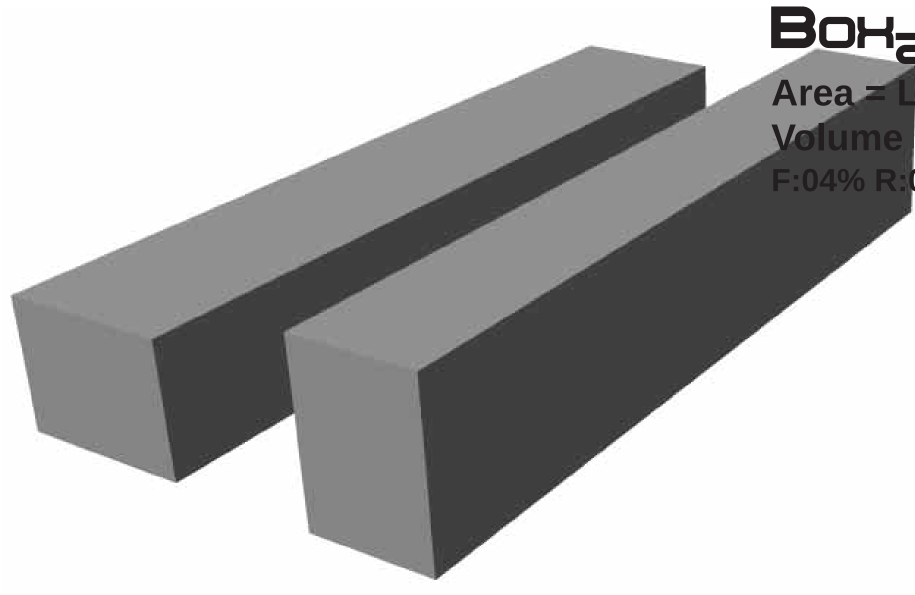
Box1

Area = Length^2 x 2.2

Volume = Length^3 x .20

F:09% R:09% S:19% T:22% B:22%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.025m^3	.550m^2	.50m	.25m	.20m	.050m^2	.050m^2	.104m^2	.121m^2	.121m^2
1.0m	.200m^3	2.20m^2	1.0m	.50m	.40m	.198m^2	.198m^2	.418m^2	.484m^2	.484m^2
1.5m	.675m^3	4.95m^2	1.5m	.75m	.60m	.445m^2	.445m^2	.941m^2	1.09m^2	1.09m^2
2.0m	1.60m^3	8.80m^2	2.0m	1.0m	.80m	.792m^2	.792m^2	1.67m^2	1.94m^2	1.94m^2
3.0m	5.40m^3	19.80m^2	3.0m	1.5m	1.2m	1.78m^2	1.78m^2	3.76m^2	4.36m^2	4.36m^2
4.0m	12.8m^3	35.20m^2	4.0m	2.0m	1.6m	3.17m^2	3.17m^2	6.69m^2	7.74m^2	7.74m^2
5.0m	25.0m^3	55.00m^2	5.0m	2.5m	2.0m	4.95m^2	4.95m^2	10.5m^2	12.1m^2	12.1m^2
6.0m	43.2m^3	79.20m^2	6.0m	3.0m	2.4m	7.13m^2	7.13m^2	15.0m^2	17.4m^2	17.4m^2
7.0m	68.6m^3	107.8m^2	7.0m	3.5m	2.8m	9.70m^2	9.70m^2	20.5m^2	23.7m^2	23.7m^2
8.0m	102.4m^3	140.8m^2	8.0m	4.0m	3.2m	12.7m^2	12.7m^2	26.7m^2	31.0m^2	31.0m^2
10m	200.0m^3	220.0m^2	10.0m	5.0m	4.0m	19.8m^2	19.8m^2	41.8m^2	48.4m^2	48.4m^2
12m	345.6m^3	316.8m^2	12.0m	6.0m	4.8m	28.5m^2	28.5m^2	60.2m^2	69.7m^2	69.7m^2
15m	675.0m^3	495.0m^2	15.0m	7.5m	6.0m	44.6m^2	44.6m^2	94.0m^2	108.9m^2	108.9m^2
20m	1600.m^3	880.0m^2	20.0m	10.0m	8.0m	79.2m^2	79.2m^2	167.2m^2	193.6m^2	193.6m^2
25m	3125.m^3	1375.m^2	25.0m	12.5m	10.0m	123.8m^2	123.8m^2	261.2m^2	302.5m^2	302.5m^2
30m	5400.m^3	1980.m^2	30.0m	15.0m	12.0m	178.2m^2	178.2m^2	376.2m^2	435.6m^2	435.6m^2
35m	8575.m^3	2695.m^2	35.0m	17.5m	14.0m	242.6m^2	242.6m^2	512.0m^2	592.9m^2	592.9m^2
40m	12800m^3	3520.m^2	40.0m	20.0m	16.0m	316.8m^2	316.8m^2	668.8m^2	774.4m^2	774.4m^2
45m	18225m^3	4455.m^2	45.0m	22.5m	18.0m	401.0m^2	401.0m^2	846.4m^2	980.1m^2	980.1m^2
50m	25000m^3	5500.m^2	50.0m	25.0m	20.0m	495.0m^2	495.0m^2	1045.m^2	1210.m^2	1210.m^2
60m	43200m^3	7920.m^2	60.0m	30.0m	24.0m	712.8m^2	712.8m^2	1505.m^2	1742.m^2	1742.m^2
70m	68600m^3	10780m^2	70.0m	35.0m	28.0m	970.2m^2	970.2m^2	2048.m^2	2372.m^2	2372.m^2
80m	102400m^3	14080m^2	80.0m	40.0m	32.0m	1267.m^2	1267.m^2	2675.m^2	3098.m^2	3098.m^2
90m	145800m^3	17820m^2	90.0m	45.0m	36.0m	1604.m^2	1604.m^2	3386.m^2	3920.m^2	3920.m^2
100m	200000m^3	22000m^2	100.0m	50.0m	40.0m	1980.m^2	1980.m^2	4180.m^2	4840.m^2	4840.m^2
120m	345600m^3	31680m^2	120.0m	60.0m	48.0m	2851.m^2	2851.m^2	6019.m^2	6970.m^2	6970.m^2
150m	675000m^3	49500m^2	150.0m	75.0m	60.0m	4455.m^2	4455.m^2	9405.m^2	10890m^2	10890m^2
200m	1.60 x 10^{6}m^3	88000m^2	200.0m	100.0m	80.0m	7920.m^2	7920.m^2	16720m^2	19360m^2	19360m^2
250m	3.13 x 10^{6}m^3	137500m^2	250.0m	125.0m	100.0m	12375m^2	12375m^2	26125m^2	30250m^2	30250m^2
300m	5.40 x 10^{6}m^3	198000m^2	300.0m	150.0m	120.0m	17820m^2	17820m^2	37620m^2	43560m^2	43560m^2
400m	12.8 x 10^{6}m^3	352000m^2	400.0m	200.0m	160.0m	31680m^2	31680m^2	66880m^2	77440m^2	77440m^2
500m	25.0 x 10^{6}m^3	550000m^2	500.0m	250.0m	200.0m	49500m^2	49500m^2	104500m^2	121000m^2	121000m^2
600m	43.2 x 10^{6}m^3	792000m^2	600.0m	300.0m	240.0m	71280m^2	71280m^2	150480m^2	174240m^2	174240m^2
700m	68.6 x 10^{6}m^3	1.08 x 10^{6}m^2	700.0m	350.0m	280.0m	97020m^2	97020m^2	204820m^2	237160m^2	237160m^2
800m	102 x 10^{6}m^3	1.41 x 10^{6}m^2	800.0m	400.0m	320.0m	126720m^2	126720m^2	267520m^2	309760m^2	309760m^2
900m	146 x 10^{6}m^3	1.78 x 10^{6}m^2	900.0m	450.0m	360.0m	160380m^2	160380m^2	338580m^2	392040m^2	392040m^2
1000m	200 x 10^{6}m^3	2.20 x 10^{6}m^2	1000.0m	500.0m	400.0m	198000m^2	198000m^2	418000m^2	484000m^2	484000m^2



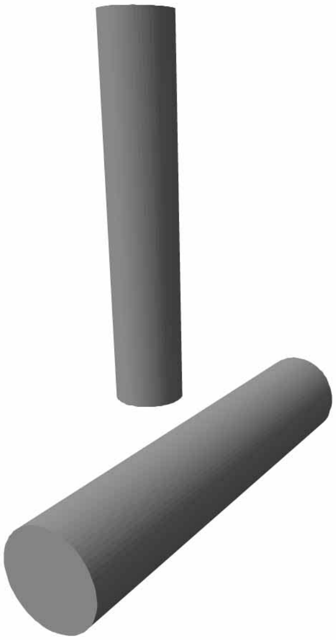
Box$_2$

Area = Length^2 x .76

Volume = Length^3 x .03

F:04% R:04% S:20% T:26% B:26%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.004m^3	.190m^2	.50m	.10m	.08m	.008m^2	.008m^2	.038m^2	.049m^2	.049m^2
1.0m	.030m^3	.760m^2	1.0m	.20m	.15m	.030m^2	.030m^2	.152m^2	.198m^2	.198m^2
1.5m	.101m^3	1.71m^2	1.5m	.30m	.23m	.068m^2	.068m^2	.342m^2	.445m^2	.445m^2
2.0m	.240m^3	3.04m^2	2.0m	.40m	.30m	.122m^2	.122m^2	.608m^2	.790m^2	.790m^2
3.0m	.810m^3	6.84m^2	3.0m	.60m	.45m	.274m^2	.274m^2	1.37m^2	1.78m^2	1.78m^2
4.0m	1.92m^3	12.16m^2	4.0m	.80m	.60m	.486m^2	.486m^2	2.43m^2	3.16m^2	3.16m^2
5.0m	3.75m^3	19.00m^2	5.0m	1.0m	.75m	.760m^2	.760m^2	3.80m^2	4.94m^2	4.94m^2
6.0m	6.48m^3	27.36m^2	6.0m	1.2m	.90m	1.09m^2	1.09m^2	5.47m^2	7.11m^2	7.11m^2
7.0m	10.29m^3	37.24m^2	7.0m	1.4m	1.1m	1.49m^2	1.49m^2	7.45m^2	9.68m^2	9.68m^2
8.0m	15.36m^3	48.64m^2	8.0m	1.6m	1.2m	1.95m^2	1.95m^2	9.73m^2	12.6m^2	12.6m^2
10m	30.00m^3	76.00m^2	10.0m	2.0m	1.5m	3.04m^2	3.04m^2	15.2m^2	19.8m^2	19.8m^2
12m	51.84m^3	109.4m^2	12.0m	2.4m	1.8m	4.38m^2	4.38m^2	21.9m^2	28.5m^2	28.5m^2
15m	101.3m^3	171..0m^2	15.0m	3.0m	2.3m	6.84m^2	6.84m^2	34.2m^2	44.5m^2	44.5m^2
20m	240.0m^3	304.0m^2	20.0m	4.0m	3.0m	12.2m^2	12.2m^2	60.8m^2	79.0m^2	79.0m^2
25m	468.8m^3	475.0m^2	25.0m	5.0m	3.8m	19.0m^2	19.0m^2	95.0m^2	123.5m^2	123.5m^2
30m	810.0m^3	684.0m^2	30.0m	6.0m	4.5m	27.4m^2	27.4m^2	136.8m^2	177.8m^2	177.8m^2
35m	1286.m^3	931.0m^2	35.0m	7.0m	5.3m	37.2m^2	37.2m^2	186.2m^2	242.1m^2	242.1m^2
40m	1920.m^3	1216.m^2	40.0m	8.0m	6.0m	48.6m^2	48.6m^2	243.2m^2	316.2m^2	316.2m^2
45m	2733.m^3	1539.m^2	45.0m	9.0m	6.8m	61.6m^2	61.6m^2	307.8m^2	400.1m^2	400.1m^2
50m	3750.m^3	1900.m^2	50.0m	10.0m	7.5m	76.0m^2	76.0m^2	380.0m^2	494.0m^2	494.0m^2
60m	6480.m^3	2736.m^2	60.0m	12.0m	9.0m	109.4m^2	109.4m^2	547.2m^2	711.4m^2	711.4m^2
70m	10290m^3	3724.m^2	70.0m	14.0m	10.5m	149.0m^2	149.0m^2	744.8m^2	968.2m^2	968.2m^2
80m	15360m^3	4864.m^2	80.0m	16.0m	12.0m	194.6m^2	194.6m^2	972.8m^2	1265.m^2	1265.m^2
90m	21870m^3	6156.m^2	90.0m	18.0m	13.5m	246.2m^2	246.2m^2	1231.m^2	1601.m^2	1601.m^2
100m	30000m^3	7600.m^2	100.0m	20.0m	15.0m	304.0m^2	304.0m^2	1520.m^2	1976.m^2	1976.m^2
120m	51840m^3	10944m^2	120.0m	24.0m	18.0m	437.8m^2	437.8m^2	2189.m^2	2845.m^2	2845.m^2
150m	101250m^3	17100m^2	150.0m	30.0m	22.5m	684.0m^2	684.0m^2	3420.m^2	4446.m^2	4446.m^2
200m	240000m^3	30400m^2	200.0m	40.0m	30.0m	1216.m^2	1216.m^2	6080.m^2	7904.m^2	7904.m^2
250m	468750m^3	47500m^2	250.0m	50.0m	37.5m	1900.m^2	1900.m^2	9500.m^2	12350m^2	12350m^2
300m	810000m^3	68400m^2	300.0m	60.0m	45.0m	2736.m^2	2736.m^2	13680m^2	17784m^2	17784m^2
400m	1.92 x 10^{6}m^3	121600m^2	400.0m	80.0m	60.0m	4864.m^2	4864.m^2	24320m^2	31616m^2	31616m^2
500m	3.75 x 10^{6}m^3	190000m^2	500.0m	100.0m	75.0m	7600.m^2	7600.m^2	38000m^2	49400m^2	49400m^2
600m	6.48 x 10^{6}m^3	273600m^2	600.0m	120.0m	90.0m	10944m^2	10944m^2	54720m^2	71136m^2	71136m^2
700m	10.3 x 10^{6}m^3	372400m^2	700.0m	140.0m	105.0m	14896m^2	14896m^2	74480m^2	96824m^2	96824m^2
800m	15.4 x 10^{6}m^3	486400m^2	800.0m	160.0m	120.0m	19456m^2	19456m^2	97280m^2	126464m^2	126464m^2
900m	21.9 x 10^{6}m^3	615600m^2	900.0m	180.0m	135.0m	24624m^2	24624m^2	123120m^2	160056m^2	160056m^2
1000m	30.0 x 10^{6}m^3	760000m^2	1000.0m	200.0m	150.0m	30400m^2	30400m^2	152000m^2	197600m^2	197600m^2



CYLINDER1

Area = Length^2 x .69

Volume = Length^3 x .03

F:05% R:05% S:23% T:22% B:22%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.004m^3	.173m^2	.50m	.10m	.10m	.009m^2	.009m^2	.040m^2	.038m^2	.038m^2
1.0m	.030m^3	.690m^2	1.0m	.20m	.20m	.035m^2	.035m^2	.159m^2	.152m^2	.152m^2
1.5m	.101m^3	1.55m^2	1.5m	.30m	.30m	.078m^2	.078m^2	.357m^2	.342m^2	.342m^2
2.0m	.240m^3	2.76m^2	2.0m	.40m	.40m	.138m^2	.138m^2	.635m^2	.607m^2	.607m^2
3.0m	.810m^3	6.21m^2	3.0m	.60m	.60m	.311m^2	.311m^2	1.43m^2	1.37m^2	1.37m^2
4.0m	1.92m^3	11.04m^2	4.0m	.80m	.80m	.552m^2	.552m^2	2.54m^2	2.43m^2	2.43m^2
5.0m	3.75m^3	17.25m^2	5.0m	1.0m	1.0m	.863m^2	.863m^2	3.97m^2	3.80m^2	3.80m^2
6.0m	6.48m^3	24.84m^2	6.0m	1.2m	1.2m	1.24m^2	1.24m^2	5.71m^2	5.46m^2	5.46m^2
7.0m	10.29m^3	33.81m^2	7.0m	1.4m	1.4m	1.69m^2	1.69m^2	7.78m^2	7.44m^2	7.44m^2
8.0m	15.36m^3	44.16m^2	8.0m	1.6m	1.6m	2.21m^2	2.21m^2	1.16m^2	9.72m^2	9.72m^2
10m	30.00m^3	69.00m^2	10.0m	2.0m	2.0m	3.45m^2	3.45m^2	15.9m^2	15.2m^2	15.2m^2
12m	51.84m^3	99.36m^2	12.0m	2.4m	2.4m	4.97m^2	4.97m^2	22.9m^2	21.9m^2	21.9m^2
15m	101.3m^3	155.3m^2	15.0m	3.0m	3.0m	7.77m^2	7.77m^2	35.7m^2	34.2m^2	34.2m^2
20m	24.0m^3	276.0m^2	20.0m	4.0m	4.0m	13.8m^2	13.8m^2	63.5m^2	6.72m^2	6.72m^2
25m	468.8m^3	431.3m^2	25.0m	5.0m	5.0m	21.6m^2	21.6m^2	99.1m^2	94.9m^2	94.9m^2
30m	810.0m^3	621.0m^2	30.0m	6.0m	6.0m	31.1m^2	31.1m^2	142.8m^2	136.6m^2	136.6m^2
35m	1286.m^3	845.3m^2	35.0m	7.0m	7.0m	42.3m^2	42.3m^2	194.4m^2	186.0m^2	186.0m^2
40m	1920.m^3	1104.m^2	40.0m	8.0m	8.0m	55.2m^2	55.2m^2	253.9m^2	242.9m^2	242.9m^2
45m	2734.m^3	1397.m^2	45.0m	9.0m	9.0m	69.9m^2	69.9m^2	321.4m^2	307.4m^2	307.4m^2
50m	3750.m^3	1725.m^2	50.0m	10.0m	10.0m	86.3m^2	86.3m^2	396.8m^2	379.5m^2	379.5m^2
60m	6480.m^3	2484.m^2	60.0m	12.0m	12.0m	124.2m^2	124.2m^2	571.3m^2	546.5m^2	546.5m^2
70m	10290m^3	3381.m^2	70.0m	14.0m	14.0m	169.1m^2	169.1m^2	777.6m^2	743.8m^2	743.8m^2
80m	15360m^3	4416.m^2	80.0m	16.0m	16.0m	220.8m^2	202.8m^2	1016.m^2	971.5m^2	971.5m^2
90m	21870m^3	5589.m^2	90.0m	18.0m	18.0m	279.5m^2	279.5m^2	1285.m^2	1230.m^2	1230.m^2
100m	30000m^3	6900.m^2	100.0m	20.0m	20.0m	345.0m^2	345.0m^2	1587.m^2	1518.m^2	1518.m^2
120m	51840m^3	9936.m^2	120.0m	24.0m	24.0m	496.8m^2	496.8m^2	2285.m^2	2186.m^2	2186.m^2
150m	101250m^3	15525m^2	150.0m	30.0m	30.0m	776.3m^2	776.3m^2	3571.m^2	3416.m^2	3416.m^2
200m	240000m^3	27600m^2	200.0m	40.0m	40.0m	1380.m^2	1380.m^2	6348.m^2	6072.m^2	6072.m^2
250m	468750m^3	43125m^2	250.0m	50.0m	50.0m	2156.m^2	2156.m^2	9919.m^2	9488.m^2	9488.m^2
300m	810000m^3	62100m^2	300.0m	60.0m	60.0m	3105.m^2	3105.m^2	14283m^2	13662m^2	13662m^2
400m	1.92 x 10^{6}m^3	110400m^2	400.0m	80.0m	80.0m	5520.m^2	5520.m^2	25392m^2	24288m^2	24288m^2
500m	3.75 x 10^{6}m^3	172500m^2	500.0m	100.0m	100.0m	8625.m^2	8625.m^2	39675m^2	37950m^2	37950m^2
600m	6.48 x 10^{6}m^3	248400m^2	600.0m	120.0m	120.0m	12420m^2	12420m^2	57132m^2	54648m^2	54648m^2
700m	1.3 x 10^{6}m^3	338100m^2	700.0m	140.0m	140.0m	16905m^2	16905m^2	77763m^2	74382m^2	74382m^2
800m	15.4 x 10^{6}m^3	441600m^2	800.0m	160.0m	160.0m	22080m^2	22080m^2	101568m^2	97152m^2	97152m^2
900m	21.9 x 10^{6}m^3	558900m^2	900.0m	180.0m	180.0m	27945m^2	27945m^2	128547m^2	122958m^2	122958m^2
1000m	3.0 x 10^{6}m^3	690000m^2	1000.0m	200.0m	200.0m	34500m^2	34500m^2	158700m^2	151800m^2	151800m^2

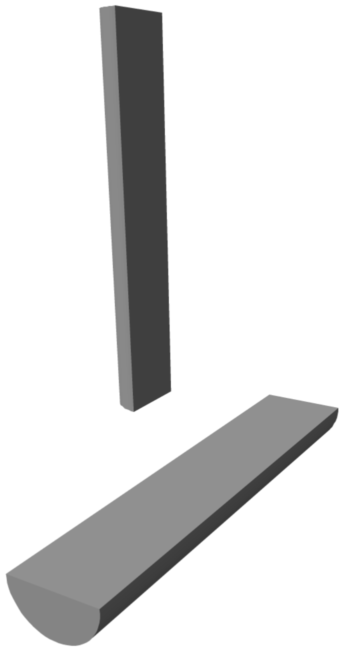
CYLINDER2

Area = Length^2 x .33

Volume = Length^3 x .008

F:03% R:03% S:24% T:23% B:23%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.001m^3	.083m^2	.50m	.05m	.05m	.003m^2	.003m^2	.020m^2	.020m^2	.020m^2
1.0m	.008m^3	.330m^2	1.0m	.10m	.10m	.010m^2	.001m^2	.079m^2	.076m^2	.076m^2
1.5m	.027m^3	.743m^2	1.5m	.15m	.15m	.022m^2	.022m^2	.178m^2	.171m^2	.171m^2
2.0m	.064m^3	1.32m^2	2.0m	.20m	.20m	.040m^2	.040m^2	.317m^2	.304m^2	.304m^2
3.0m	.216m^3	2.97m^2	3.0m	.30m	.30m	.089m^2	.089m^2	.713m^2	.683m^2	.683m^2
4.0m	.512m^3	5.28m^2	4.0m	.40m	.40m	.158m^2	.158m^2	1.27m^2	1.21m^2	1.21m^2
5.0m	1.00m^3	8.25m^2	5.0m	.50m	.50m	.248m^2	.248m^2	1.98m^2	1.90m^2	1.90m^2
6.0m	1.73m^3	11.88m^2	6.0m	.60m	.60m	.356m^2	.356m^2	2.85m^2	2.73m^2	2.73m^2
7.0m	2.74m^3	16.17m^2	7.0m	.70m	.70m	.485m^2	.485m^2	3.88m^2	3.72m^2	3.72m^2
8.0m	4.10m^3	21.12m^2	8.0m	.80m	.80m	.634m^2	.634m^2	5.07m^2	4.86m^2	4.86m^2
10m	8.00m^3	33.00m^2	10.0m	1.0m	1.0m	.990m^2	.990m^2	7.92m^2	7.59m^2	7.59m^2
12m	13.82m^3	47.52m^2	12.0m	1.2m	1.2m	1.43m^2	1.43m^2	11.4m^2	10.9m^2	10.9m^2
15m	27.00m^3	74.25m^2	15.0m	1.5m	1.5m	2.23m^2	2.23m^2	17.8m^2	17.1m^2	17.1m^2
20m	64.00m^3	132.0m^2	20.0m	2.0m	2.0m	3.96m^2	3.96m^2	31.7m^2	30.4m^2	30.4m^2
25m	125.0m^3	206.3m^2	25.0m	2.5m	2.5m	6.19m^2	6.19m^2	49.5m^2	47.4m^2	47.4m^2
30m	216.0m^3	297.0m^2	30.0m	3.0m	3.0m	8.91m^2	8.91m^2	71.3m^2	68.3m^2	68.3m^2
35m	343.0m^3	404.3m^2	35.0m	3.5m	3.5m	12.1m^2	12.1m^2	97.0m^2	93.0m^2	93.0m^2
40m	512.0m^3	528.0m^2	40.0m	4.0m	4.0m	15.8m^2	15.8m^2	126.7m^2	121.4m^2	121.4m^2
45m	729.0m^3	668.3m^2	45.0m	4.5m	4.5m	20.0m^2	20.0m^2	160.4m^2	153.7m^2	153.7m^2
50m	1000.m^3	825.0m^2	50.0m	5.0m	5.0m	24.8m^2	24.8m^2	198.0m^2	189.8m^2	189.8m^2
60m	1728.m^3	1188.m^2	60.0m	6.0m	6.0m	35.6m^2	35.6m^2	285.1m^2	273.2m^2	273.2m^2
70m	2744.m^3	1617.m^2	70.0m	7.0m	7.0m	48.5m^2	48.5m^2	388.1m^2	371.9m^2	371.9m^2
80m	4096.m^3	2112.m^2	80.0m	8.0m	8.0m	63.4m^2	63.4m^2	506.9m^2	485.8m^2	485.8m^2
90m	5832.m^3	2673.m^2	90.0m	9.0m	9.0m	80.2m^2	80.2m^2	641.5m^2	614.8m^2	614.8m^2
100m	8000.m^3	3300.m^2	100.0m	10.0m	10.0m	99.0m^2	99.0m^2	792.0m^2	759.0m^2	759.0m^2
120m	13824m^3	4752.m^2	120.0m	12.0m	12.0m	142.6m^2	142.6m^2	1140.m^2	1093.m^2	1093.m^2
150m	27000m^3	7425.m^2	150.0m	15.0m	15.0m	222.8m^2	222.8m^2	1782.m^2	1708.m^2	1708.m^2
200m	64000m^3	13200m^2	200.0m	20.0m	20.0m	396.0m^2	396.0m^2	3168.m^2	3036.m^2	3036.m^2
250m	125000m^3	20625m^2	250.0m	25.0m	25.0m	618.8m^2	618.8m^2	4950.m^2	4744.m^2	4744.m^2
300m	216000m^3	29700m^2	300.0m	30.0m	30.0m	891.0m^2	891.0m^2	7128.m^2	6831.m^2	6831.m^2
400m	512000m^3	52800m^2	400.0m	40.0m	40.0m	1584.m^2	1584.m^2	12672m^2	12144m^2	12144m^2
500m	1.00 x 10^{6}m^3	82500m^2	500.0m	50.0m	50.0m	2475.m^2	2475.m^2	19800m^2	18975m^2	18975m^2
600m	1.73 x 10^{6}m^3	118800m^2	600.0m	60.0m	60.0m	3564.m^2	3564.m^2	28512m^2	27324m^2	27324m^2
700m	2.74 x 10^{6}m^3	161700m^2	700.0m	70.0m	70.0m	4851.m^2	4851.m^2	38808m^2	37191m^2	37191m^2
800m	4.10 x 10^{6}m^3	211200m^2	800.0m	80.0m	80.0m	6336.m^2	6336.m^2	50688m^2	48576m^2	48576m^2
900m	5.83 x 10^{6}m^3	267300m^2	900.0m	90.0m	90.0m	8019.m^2	8019.m^2	64152m^2	61479m^2	61479m^2
1000m	8.00 x 10^{6}m^3	330000m^2	1000.0m	100.0m	100.0m	9900.m^2	9900.m^2	79200m^2	75900m^2	75900m^2



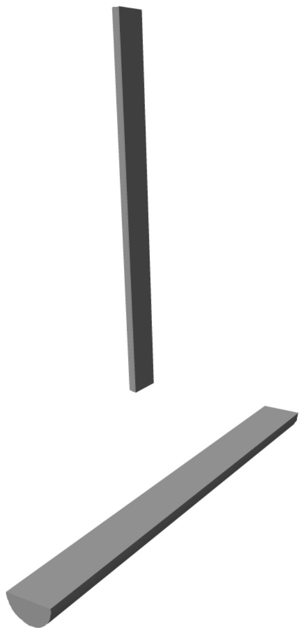
HALF CYLINDER, 1

Area = Length^2 x .55

Volume = Length^3 x .016

F:02% R:02% S:20% T:36% B:20%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.002m^3	.138m^2	.50m	.10m	.05m	.003m^2	.003m^2	.028m^2	.050m^2	.028m^2
1.0m	.016m^3	.550m^2	1.0m	.20m	.10m	.011m^2	.011m^2	.110m^2	.198m^2	.110m^2
1.5m	.054m^3	1.24m^2	1.5m	.30m	.15m	.025m^2	.025m^2	.248m^2	.446m^2	.248m^2
2.0m	.128m^3	2.20m^2	2.0m	.40m	.20m	.044m^2	.044m^2	.440m^2	.792m^2	.440m^2
3.0m	.432m^3	4.95m^2	3.0m	.60m	.30m	.099m^2	.099m^2	.990m^2	1.78m^2	.990m^2
4.0m	1.02m^3	8.80m^2	4.0m	.80m	.40m	.176m^2	.176m^2	1.76m^2	3.17m^2	1.76m^2
5.0m	2.00m^3	13.8m^2	5.0m	1.0m	.50m	.275m^2	.275m^2	2.75m^2	4.95m^2	2.75m^2
6.0m	3.46m^3	19.8m^2	6.0m	1.2m	.60m	.396m^2	.396m^2	3.96m^2	7.13m^2	3.96m^2
7.0m	5.49m^3	27.0m^2	7.0m	1.4m	.70m	.539m^2	.539m^2	5.39m^2	9.70m^2	5.39m^2
8.0m	8.19m^3	35.2m^2	8.0m	1.6m	.80m	.704m^2	.704m^2	7.04m^2	12.7m^2	7.04m^2
10m	16.0m^3	55.0m^2	10.0m	2.0m	1.0m	1.10m^2	1.10m^2	11.0m^2	19.8m^2	11.0m^2
12m	27.6m^3	79.2m^2	12.0m	2.4m	1.2m	1.58m^2	1.58m^2	15.8m^2	28.5m^2	15.8m^2
15m	54.0m^3	123.8m^2	15.0m	3.0m	1.5m	2.48m^2	2.48m^2	24.8m^2	44.6m^2	24.8m^2
20m	128.0m^3	220.0m^2	20.0m	4.0m	2.0m	4.40m^2	4.40m^2	44.0m^2	79.2m^2	44.0m^2
25m	250.0m^3	343.8m^2	25.0m	5.0m	2.5m	6.88m^2	6.88m^2	68.8m^2	123.8m^2	68.8m^2
30m	432.0m^3	495.0m^2	30.0m	6.0m	3.0m	9.90m^2	9.90m^2	99.0m^2	178.2m^2	99.0m^2
35m	686.0m^3	673.8m^2	35.0m	7.0m	3.5m	13.5m^2	13.5m^2	134.8m^2	242.6m^2	134.8m^2
40m	1024.m^3	880.0m^2	40.0m	8.0m	4.0m	17.6m^2	17.6m^2	176.0m^2	316.8m^2	176.0m^2
45m	1458.m^3	1114.m^2	45.0m	9.0m	4.5m	22.3m^2	22.3m^2	222.8m^2	401.0m^2	222.8m^2
50m	2000.m^3	1375.m^2	50.0m	10.0m	5.0m	27.5m^2	27.5m^2	275.0m^2	495.0m^2	275.0m^2
60m	3456.m^3	1980.m^2	60.0m	12.0m	6.0m	39.6m^2	39.6m^2	396.0m^2	712.8m^2	396.0m^2
70m	5488.m^3	2695.m^2	70.0m	14.0m	7.0m	53.9m^2	53.9m^2	539.0m^2	970.2m^2	539.0m^2
80m	8192.m^3	3520.m^2	80.0m	16.0m	8.0m	70.4m^2	70.4m^2	704.0m^2	1267.m^2	704.0m^2
90m	11664m^3	4455.m^2	90.0m	18.0m	9.0m	89.1m^2	89.1m^2	891.0m^2	1604.m^2	891.0m^2
100m	16000m^3	5500.m^2	100.0m	20.0m	10.0m	110.0m^2	110.0m^2	1100.m^2	1980.m^2	1100.m^2
120m	27648m^3	7920.m^2	120.0m	24.0m	12.0m	158.4m^2	158.4m^2	1584.m^2	2851.m^2	1584.m^2
150m	54000m^3	12375m^2	150.0m	30.0m	15.0m	247.5m^2	247.5m^2	2475.m^2	4455.m^2	2475.m^2
200m	128000m^3	22000m^2	200.0m	40.0m	20.0m	440.0m^2	440.0m^2	4400.m^2	7920.m^2	4400.m^2
250m	250000m^3	34375m^2	250.0m	50.0m	25.0m	687.5m^2	687.5m^2	6875.m^2	12375m^2	6875.m^2
300m	432000m^3	49500m^2	300.0m	60.0m	30.0m	990.0m^2	990.0m^2	9900.m^2	17820m^2	9900.m^2
400m	1.02 x 10^{6}m^3	88000m^2	400.0m	80.0m	40.0m	1760.m^2	1760.m^2	17600m^2	31680m^2	17600m^2
500m	2.00 x 10^{6}m^3	137500m^2	500.0m	100.0m	50.0m	2750.m^2	2750.m^2	27500m^2	49500m^2	27500m^2
600m	3.46 x 10^{6}m^3	198000m^2	600.0m	120.0m	60.0m	3960.m^2	3960.m^2	39600m^2	71280m^2	39600m^2
700m	5.49 x 10^{6}m^3	269500m^2	700.0m	140.0m	70.0m	5390.m^2	5390.m^2	53900m^2	97020m^2	53900m^2
800m	8.19 x 10^{6}m^3	352000m^2	800.0m	160.0m	80.0m	7040.m^2	7040.m^2	70400m^2	126720m^2	70400m^2
900m	11.7 x 10^{6}m^3	445500m^2	900.0m	180.0m	90.0m	8910.m^2	8910.m^2	89100m^2	160380m^2	89100m^2
1000m	16.0 x 10^{6}m^3	550000m^2	1000.0m	200.0m	100.0m	11000m^2	11000m^2	110000m^2	198000m^2	110000m^2



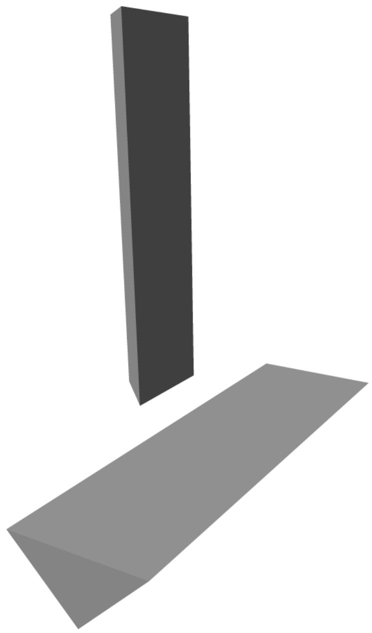
HALF CYLINDER2

Area = Length^2 x .27

Volume = Length^3 x .004

F:01% R:01% S:20% T:36% B:20%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.0005m^3	.068m^2	.50m	.05m	.03m	.000m^2	.000m^2	.014m^2	.026m^2	.014m^2
1.0m	.004m^3	.270m^2	1.0m	.10m	.05m	.003m^2	.003m^2	.054m^2	.103m^2	.054m^2
1.5m	.014m^3	.608m^2	1.5m	.15m	.08m	.006m^2	.006m^2	.122m^2	.231m^2	.122m^2
2.0m	.032m^3	1.08m^2	2.0m	.20m	.10m	.011m^2	.011m^2	.216m^2	.4104m^2	.216m^2
3.0m	.108m^3	2.43m^2	3.0m	.30m	.15m	.024m^2	.024m^2	.486m^2	.9234m^2	.486m^2
4.0m	.256m^3	4.32m^2	4.0m	.40m	.20m	.043m^2	.043m^2	.864m^2	1.64m^2	.864m^2
5.0m	.500m^3	6.75m^2	5.0m	.50m	.25m	.068m^2	.068m^2	1.35m^2	2.57m^2	1.35m^2
6.0m	.864m^3	9.72m^2	6.0m	.60m	.30m	.097m^2	.097m^2	1.94m^2	3.69m^2	1.94m^2
7.0m	1.37m^3	13.2m^2	7.0m	.70m	.35m	.132m^2	.132m^2	2.65m^2	5.03m^2	2.65m^2
8.0m	2.05m^3	17.3m^2	8.0m	.80m	.40m	.173m^2	.173m^2	3.46m^2	6.57m^2	3.46m^2
10m	4.00m^3	27.0m^2	10.0m	1.0m	.50m	.270m^2	.270m^2	5.40m^2	10.3m^2	5.40m^2
12m	6.91m^3	38.9m^2	12.0m	1.2m	.60m	.389m^2	.389m^2	7.78m^2	14.8m^2	7.78m^2
15m	13.5m^3	60.8m^2	15.0m	1.5m	.75m	.608m^2	.608m^2	12.2m^2	23.1m^2	12.2m^2
20m	32.0m^3	108.0m^2	20.0m	2.0m	1.0m	1.08m^2	1.08m^2	21.6m^2	41.0m^2	21.6m^2
25m	62.5m^3	168.8m^2	25.0m	2.5m	1.3m	1.69m^2	1.69m^2	33.8m^2	64.1m^2	33.8m^2
30m	108.0m^3	243.0m^2	30.0m	3.0m	1.5m	2.43m^2	2.43m^2	48.6m^2	92.3m^2	48.6m^2
35m	171.5m^3	330.8m^2	35.0m	3.5m	1.8m	3.31m^2	3.31m^2	66.2m^2	125.7m^2	66.2m^2
40m	256.0m^3	432.0m^2	40.0m	4.0m	2.0m	4.32m^2	4.32m^2	86.4m^2	164.1m^2	86.4m^2
45m	364.5m^3	546.8m^2	45.0m	4.5m	2.3m	5.47m^2	5.47m^2	109.4m^2	207.8m^2	109.4m^2
50m	500m^3	675.0m^2	50.0m	5.0m	2.5m	6.75m^2	6.75m^2	135.0m^2	256.5m^2	135.0m^2
60m	864m^3	972.0m^2	60.0m	6.0m	3.0m	9.72m^2	9.72m^2	194.4m^2	369.4m^2	194.4m^2
70m	1372m^3	1323.m^2	70.0m	7.0m	3.5m	13.2m^2	13.2m^2	264.6m^2	502.7m^2	264.6m^2
80m	2048m^3	1728.m^2	80.0m	8.0m	4.0m	17.3m^2	17.3m^2	345.6m^2	656.6m^2	345.6m^2
90m	2916m^3	2187.m^2	90.0m	9.0m	4.5m	21.9m^2	21.9m^2	437.4m^2	831.1m^2	437.4m^2
100m	4000m^3	2700.m^2	100.0m	10.0m	5.0m	27.0m^2	27.0m^2	540.0m^2	1026.m^2	540.0m^2
120m	6912m^3	3888.m^2	120.0m	12.0m	6.0m	38.9m^2	38.9m^2	777.6m^2	1477.m^2	777.6m^2
150m	13500m^3	6075.m^2	150.0m	15.0m	7.5m	60.8m^2	60.8m^2	1215.m^2	2309.m^2	1215.m^2
200m	32000m^3	10800m^2	200.0m	20.0m	10.0m	108.0m^2	108.0m^2	2160.m^2	4104.m^2	2160.m^2
250m	62500m^3	16875m^2	250.0m	25.0m	12.5m	168.8m^2	168.8m^2	3375.m^2	6413.m^2	3375.m^2
300m	108000m^3	24300m^2	300.0m	30.0m	15.0m	243.0m^2	243.0m^2	4860.m^2	9234.m^2	4860.m^2
400m	256000m^3	43200m^2	400.0m	40.0m	20.0m	432.0m^2	432.0m^2	8640.m^2	16416m^2	8640.m^2
500m	500000m^3	67500m^2	500.0m	50.0m	25.0m	675.0m^2	675.0m^2	13500m^2	25650m^2	13500m^2
600m	864000m^3	97200m^2	600.0m	60.0m	30.0m	972.0m^2	972.0m^2	19440m^2	36936m^2	19440m^2
700m	1.37 x 10^{6}m^3	132300m^2	700.0m	70.0m	35.0m	1323.m^2	1323.m^2	26460m^2	50274m^2	26460m^2
800m	2.05 x 10^{6}m^3	172800m^2	800.0m	80.0m	40.0m	1728.m^2	1728.m^2	34560m^2	65664m^2	34560m^2
900m	2.92 x 10^{6}m^3	218700m^2	900.0m	90.0m	45.0m	2187.m^2	2187.m^2	43740m^2	83106m^2	43740m^2
1000m	4.00 x 10^{6}m^3	270000m^2	1000.0m	100.0m	50.0m	2700.m^2	2700.m^2	54000m^2	102600m^2	54000m^2



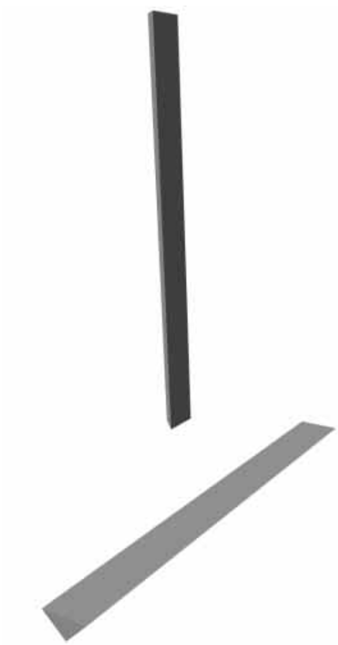
Prism$_1$

Area = Length^2 x .60

Volume = Length^3 x .045

F:08% R:08% S:11% T:50% B:12%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.006m^3	.150m^2	.05m	.15m	.08m	.012m^2	.012m^2	.017m^2	.075m^2	.018m^2
1.0m	.045m^3	.600m^2	1.0m	.30m	.15m	.048m^2	.048m^2	.066m^2	.300m^2	.072m^2
1.5m	.151m^3	1.35m^2	1.5m	.45m	.23m	.108m^2	.108m^2	.149m^2	.675m^2	.162m^2
2.0m	.360m^3	2.40m^2	2.0m	.60m	.30m	.192m^2	.192m^2	.264m^2	1.20m^2	.288m^2
3.0m	1.22m^3	5.40m^2	3.0m	.90m	.45m	.432m^2	.432m^2	.594m^2	2.70m^2	.648m^2
4.0m	2.88m^3	9.60m^2	4.0m	1.2m	.60m	.768m^2	.768m^2	1.06m^2	4.80m^2	1.15m^2
5.0m	5.63m^3	15.0m^2	5.0m	1.5m	.75m	1.20m^2	1.20m^2	1.65m^2	7.50m^2	1.80m^2
6.0m	9.72m^3	21.6m^2	6.0m	1.8m	.90m	1.73m^2	1.72m^2	2.38m^2	10.8m^2	2.59m^2
7.0m	15.4m^3	29.4m^2	7.0m	2.1m	1.1m	2.35m^2	2.35m^2	3.23m^2	14.7m^2	3.53m^2
8.0m	23.0m^3	38.4m^2	8.0m	2.4m	1.2m	3.07m^2	3.07m^2	4.22m^2	19.2m^2	4.61m^2
10m	45.0m^3	60.0m^2	10.0m	3.0m	1.5m	4.80m^2	4.80m^2	6.60m^2	30.0m^2	7.20m^2
12m	77.8m^3	86.4m^2	12.0m	3.6m	1.8m	6.91m^2	6.91m^2	9.50m^2	43.2m^2	10.4m^2
15m	151.9m^3	135.0m^2	15.0m	4.5m	2.3m	10.8m^2	10.8m^2	14.9m^2	67.5m^2	16.2m^2
20m	360.0m^3	240.0m^2	20.0m	6.0m	3.0m	19.2m^2	19.2m^2	26.4m^2	120.0m^2	28.8m^2
25m	703.1m^3	375.0m^2	25.0m	7.5m	3.8m	30.0m^2	30.0m^2	41.3m^2	187.5m^2	45.0m^2
30m	1215.m^3	540.0m^2	30.0m	9.0m	4.5m	43.2m^2	43.2m^2	59.4m^2	270.0m^2	64.8m^2
35m	1929.m^3	735.0m^2	35.0m	10.5m	5.3m	58.8m^2	58.8m^2	80.9m^2	367.5m^2	88.2m^2
40m	2880.m^3	960.0m^2	40.0m	12.0m	6.0m	76.8m^2	76.8m^2	105.6m^2	480.0m^2	115.2m^2
45m	4101.m^3	1215.m^2	45.0m	13.5m	6.8m	97.2m^2	97.2m^2	133.7m^2	607.5m^2	145.8m^2
50m	5625.m^3	1500.m^2	50.0m	15.0m	7.5m	120.0m^2	120.0m^2	165.0m^2	750.0m^2	180.0m^2
60m	9720.m^3	2160.m^2	60.0m	18.0m	9.0m	172.8m^2	172.8m^2	237.6m^2	1080.m^2	259.2m^2
70m	15435m^3	2940.m^2	70.0m	21.0m	10.5m	235.2m^2	235.2m^2	323.4m^2	1470.m^2	352.8m^2
80m	23040m^3	3840.m^2	80.0m	24.0m	12.0m	307.2m^2	307.2m^2	422.4m^2	1920.m^2	460.8m^2
90m	32805m^3	4860.m^2	90.0m	27.0m	13.5m	388.8m^2	388.8m^2	534.6m^2	2430.m^2	583.2m^2
100m	45000m^3	6000.m^2	100.0m	30.0m	15.0m	480.0m^2	480.0m^2	660.0m^2	3000.m^2	720.0m^2
120m	77760m^3	8640.m^2	120.0m	36.0m	18.0m	691.2m^2	691.2m^2	950.4m^2	4320.m^2	1037.m^2
150m	151875m^3	13500m^2	150.0m	45.0m	22.5m	1080.m^2	1080.m^2	1485.m^2	6750.m^2	1620.m^2
200m	360000m^3	24000m^2	200.0m	60.0m	30.0m	1920.m^2	1920.m^2	2640.m^2	12000m^2	2880.m^2
250m	703125m^3	37500m^2	250.0m	75.0m	37.5m	3000.m^2	3000.m^2	4125.m^2	18750m^2	4500.m^2
300m	1.22 x 10^{6}m^3	54000m^2	300.0m	90.0m	45.0m	4320.m^2	4320.m^2	5940.m^2	27000m^2	6480.m^2
400m	2.88 x 10^{6}m^3	96000m^2	400.0m	120.0m	60.0m	7680.m^2	7680.m^2	10560m^2	48000m^2	11520m^2
500m	5.63 x 10^{6}m^3	150000m^2	500.0m	150.0m	75.0m	12000m^2	12000m^2	16500m^2	75000m^2	18000m^2
600m	9.72 x 10^{6}m^3	216000m^2	600.0m	180.0m	90.0m	17280m^2	17280m^2	23760m^2	108000m^2	25920m^2
700m	15.4 x 10^{6}m^3	294000m^2	700.0m	210.0m	105.0m	23520m^2	23520m^2	32340m^2	147000m^2	35280m^2
800m	23.0 x 10^{6}m^3	384000m^2	800.0m	240.0m	120.0m	30720m^2	30720m^2	42240m^2	192000m^2	46080m^2
900m	32.8 x 10^{6}m^3	486000m^2	900.0m	270.0m	135.0m	38880m^2	38880m^2	53460m^2	243000m^2	58320m^2
1000m	45.0 x 10^{6}m^3	600000m^2	1000.0m	300.0m	150.0m	48000m^2	48000m^2	66000m^2	300000m^2	72000m^2



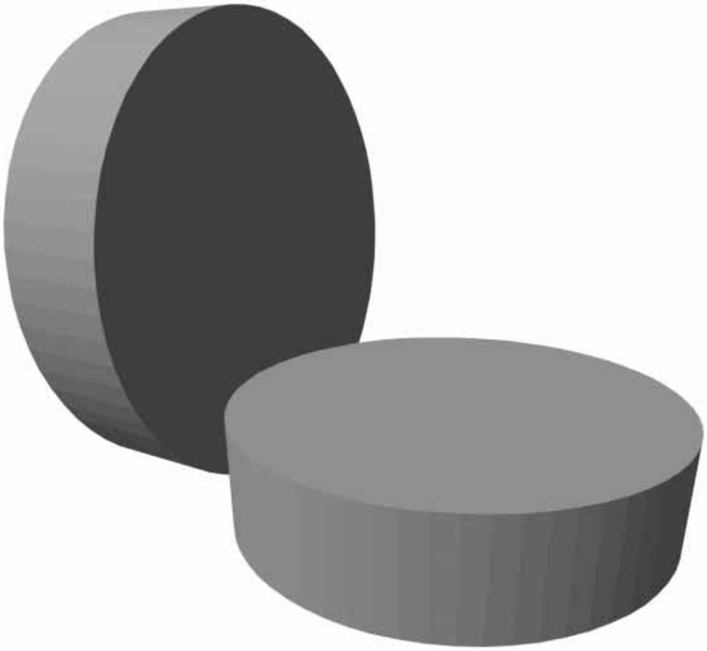
PRISM2

Area = Length^2 x .25

Volume = Length^3 x .005

F:02% R:02% S:18% T:40% B:20%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.0006m^3	.063m^2	.50m	.05m	.03m	.001m^2	.001m^2	.011m^2	.025m^2	.013m^2
1.0m	.005m^3	.250m^2	1.0m	.10m	.05m	.005m^2	.005m^2	.045m^2	.100m^2	.050m^2
1.5m	.017m^3	.563m^2	1.5m	.15m	.08m	.011m^2	.011m^2	.101m^2	.225m^2	.113m^2
2.0m	.040m^3	1.00m^2	2.0m	.20m	.10m	.020m^2	.020m^2	.180m^2	.400m^2	.200m^2
3.0m	.135m^3	2.25m^2	3.0m	.30m	.15m	.045m^2	.045m^2	.405m^2	.900m^2	.450m^2
4.0m	.320m^3	4.00m^2	4.0m	.40m	.20m	.080m^2	.080m^2	.720m^2	1.60m^2	.800m^2
5.0m	.625m^3	6.25m^2	5.0m	.50m	.25m	.125m^2	.125m^2	1.13m^2	2.50m^2	1.25m^2
6.0m	1.08m^3	9.00m^2	6.0m	.60m	.30m	.180m^2	.180m^2	1.62m^2	3.60m^2	1.80m^2
7.0m	1.72m^3	12.3m^2	7.0m	.70m	.35m	.245m^2	.245m^2	2.21m^2	4.90m^2	2.45m^2
8.0m	2.56m^3	16.0m^2	8.0m	.80m	.40m	.320m^2	.320m^2	2.88m^2	6.40m^2	3.20m^2
10m	5.00m^3	25.0m^2	10.0m	1.0m	.50m	.500m^2	.500m^2	4.50m^2	10.0m^2	5.00m^2
12m	8.64m^3	36.0m^2	12.0m	1.2m	.60m	.720m^2	.720m^2	6.48m^2	14.4m^2	7.20m^2
15m	16.88m^3	56.3m^2	15.0m	1.5m	.75m	1.13m^2	1.13m^2	10.1m^2	22.5m^2	11.3m^2
20m	40.00m^3	100.0m^2	20.0m	2.0m	1.0m	2.00m^2	2.00m^2	18.00m^2	40.0m^2	20.0m^2
25m	78.13m^3	156.3m^2	25.0m	2.5m	1.3m	3.13m^2	3.13m^2	28.1m^2	62.5m^2	31.3m^2
30m	135.0m^3	225.0m^2	30.0m	3.0m	1.5m	4.50m^2	4.50m^2	40.5m^2	90.0m^2	45.0m^2
35m	214.4m^3	306.3m^2	35.0m	3.5m	1.8m	6.13m^2	6.13m^2	55.1m^2	122.5m^2	61.3m^2
40m	320.0m^3	400.0m^2	40.0m	4.0m	2.0m	8.00m^2	8.00m^2	72.00m^2	160.0m^2	80.0m^2
45m	455.6m^3	506.3m^2	45.0m	4.5m	2.3m	10.1m^2	10.1m^2	91.13m^2	202.5m^2	101.3m^2
50m	625.0m^3	625.0m^2	50.0m	5.0m	2.5m	12.5m^2	12.5m^2	112.5m^2	250.0m^2	125.0m^2
60m	1080.m^3	900.0m^2	60.0m	6.0m	3.0m	18.0m^2	18.0m^2	162.0m^2	360.0m^2	180.0m^2
70m	1715.m^3	1225.m^2	70.0m	7.0m	3.5m	24.5m^2	24.5m^2	220.5m^2	490.0m^2	245.0m^2
80m	2560.m^3	1600.m^2	80.0m	8.0m	4.0m	32.0m^2	32.0m^2	288.0m^2	640.0m^2	320.0m^2
90m	3645.m^3	2025.m^2	90.0m	9.0m	4.5m	40.5m^2	40.5m^2	364.5m^2	810.0m^2	405.0m^2
100m	5000.m^3	2500.m^2	100.0m	10.0m	5.0m	50.0m^2	50.0m^2	450.0m^2	1000.m^2	500.0m^2
120m	8640.m^3	3600.m^2	120.0m	12.0m	6.0m	72.0m^2	72.0m^2	648.0m^2	1440.m^2	720.0m^2
150m	16875m^3	5625.m^2	150.0m	15.0m	7.5m	112.5m^2	112.5m^2	1013.m^2	2250.m^2	1125.m^2
200m	40000m^3	10000m^2	200.0m	20.0m	10.0m	200.0m^2	200.0m^2	1800.m^2	4000.m^2	2000.m^2
250m	78125m^3	15625m^2	250.0m	25.0m	12.5m	312.5m^2	312.5m^2	2813.m^2	6250.m^2	3125.m^2
300m	135000m^3	22500m^2	300.0m	30.0m	15.0m	450.0m^2	450.0m^2	4050.m^2	9000.m^2	4500.m^2
400m	320000m^3	40000m^2	400.0m	40.0m	20.0m	800.0m^2	800.0m^2	7200.m^2	16000m^2	8000.m^2
500m	625000m^3	62500m^2	500.0m	50.0m	25.0m	1250.m^2	1250.m^2	11250m^2	25000m^2	12500m^2
600m	1.08 x 10^{6}m^3	90000m^2	600.0m	60.0m	30.0m	1800.m^2	1800.m^2	16200m^2	36000m^2	18000m^2
700m	1.72 x 10^{6}m^3	122500m^2	700.0m	70.0m	35.0m	2450.m^2	2450.m^2	22050m^2	49000m^2	24500m^2
800m	2.56 x 10^{6}m^3	160000m^2	800.0m	80.0m	40.0m	3200.m^2	3200.m^2	28800m^2	64000m^2	32000m^2
900m	3.65 x 10^{6}m^3	202500m^2	900.0m	90.0m	45.0m	4050.m^2	4050.m^2	36450m^2	81000m^2	40500m^2
1000m	5.00 x 10^{6}m^3	250000m^2	1000.0m	100.0m	50.0m	5000.m^2	5000.m^2	45000m^2	100000m^2	50000m^2



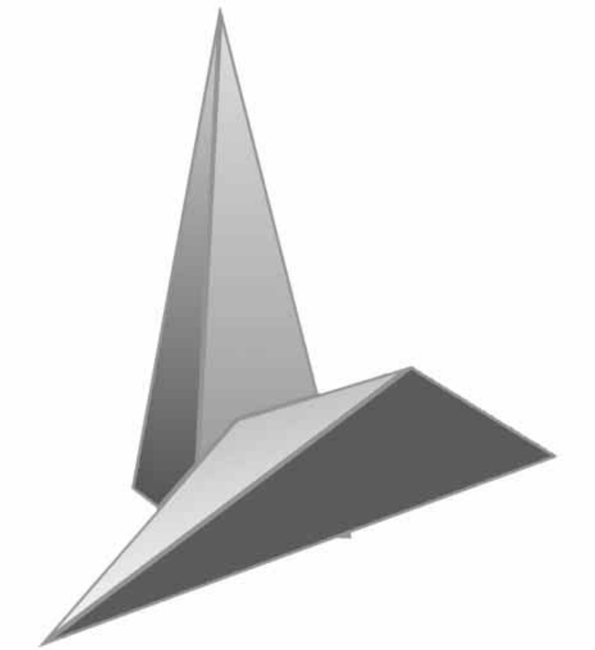
DISK

Area = Length^2 x 2.4

Volume = Length^3 x .20

F:09% R:09% S:08% T:33% B:33%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.025m^3	.600m^2	.50m	.50m	.13m	.054m^2	.054m^2	.048m^2	.198m^2	.198m^2
1.0m	.200m^3	2.40m^2	1.0m	1.0m	.25m	.216m^2	.216m^2	.192m^2	.792m^2	.792m^2
1.5m	.675m^3	5.40m^2	1.5m	1.5m	.38m	.486m^2	.486m^2	.432m^2	1.78m^2	1.78m^2
2.0m	1.60m^3	9.60m^2	2.0m	2.0m	.50m	.864m^2	.864m^2	.768m^2	3.17m^2	3.17m^2
3.0m	5.40m^3	21.6m^2	3.0m	3.0m	.75m	1.94m^2	1.94m^2	1.73m^2	7.13m^2	7.13m^2
4.0m	12.8m^3	38.4m^2	4.0m	4.0m	1.00m	3.46m^2	3.46m^2	3.07m^2	12.7m^2	12.7m^2
5.0m	25.0m^3	60.0m^2	5.0m	5.0m	1.25m	5.40m^2	5.40m^2	4.80m^2	19.8m^2	19.8m^2
6.0m	43.2m^3	86.4m^2	6.0m	6.0m	1.50m	7.78m^2	7.78m^2	6.91m^2	28.5m^2	28.5m^2
7.0m	68.6m^3	117.6m^2	7.0m	7.0m	1.75m	10.6m^2	10.6m^2	9.41m^2	38.8m^2	38.8m^2
8.0m	102.4m^3	153.6m^2	8.0m	8.0m	2.00m	13.8m^2	13.8m^2	12.3m^2	50.7m^2	50.7m^2
10m	200.0m^3	240.0m^2	10.0m	10.0m	2.50m	21.6m^2	21.6m^2	19.2m^2	79.2m^2	79.2m^2
12m	345.6m^3	345.6m^2	12.0m	12.0m	3.00m	31.1m^2	31.1m^2	27.7m^2	114.0m^2	114.0m^2
15m	675.0m^3	540.0m^2	15.0m	15.0m	3.75m	48.6m^2	48.6m^2	43.2m^2	178.2m^2	178.2m^2
20m	1600.m^3	960.0m^2	20.0m	20.0m	5.00m	86.4m^2	86.4m^2	76.8m^2	316.8m^2	316.8m^2
25m	3125.m^3	1500.m^2	25.0m	25.0m	6.25m	135.0m^2	135.0m^2	120.0m^2	495.0m^2	495.0m^2
30m	5400.m^3	2160.m^2	30.0m	30.0m	7.50m	194.4m^2	194.4m^2	172.8m^2	712.8m^2	712.8m^2
35m	8575.m^3	2940.m^2	35.0m	35.0m	8.75m	264.6m^2	264.6m^2	235.2m^2	970.2m^2	970.2m^2
40m	12800m^3	3840.m^2	40.0m	40.0m	10.0m	345.6m^2	345.6m^2	307.2m^2	1267.m^2	1267.m^2
45m	18225m^3	4860.m^2	45.0m	45.0m	11.3m	437.4m^2	437.4m^2	388.8m^2	1604.m^2	1604.m^2
50m	25000m^3	6000.m^2	50.0m	50.0m	12.5m	540.0m^2	540.0m^2	480.0m^2	1980.m^2	1980.m^2
60m	43200m^3	8640.m^2	60.0m	60.0m	15.0m	777.6m^2	777.6m^2	691.2m^2	2851.m^2	2851.m^2
70m	68600m^3	11760m^2	70.0m	70.0m	17.5m	1058.m^2	1058.m^2	940.8m^2	3881.m^2	3881.m^2
80m	102400m^3	15360m^2	80.0m	80.0m	20.0m	1382.m^2	1382.m^2	1229.m^2	5069.m^2	5069.m^2
90m	145800m^3	19440m^2	90.0m	90.0m	22.5m	1750.m^2	1750.m^2	1555.m^2	6415.m^2	6415.m^2
100m	200000m^3	24000m^2	100.0m	100.0m	25.0m	2160.m^2	2160.m^2	1920.m^2	7920.m^2	7920.m^2
120m	345600m^3	34560m^2	120.0m	120.0m	30.0m	3110.m^2	3110.m^2	2765.m^2	11405m^2	11405m^2
150m	675000m^3	54000m^2	150.0m	150.0m	37.5m	4860.m^2	4860m^2	4320.m^2	17820m^2	17820m^2
200m	1.60 x 10^{6}m^3	96000m^2	200.0m	200.0m	50.0m	8640.m^2	8640m^2	7680m^2	31680m^2	31680m^2
250m	3.13 x 10^{6}m^3	150000m^2	250.0m	250.0m	62.5m	13500m^2	13500m^2	12000m^2	49500m^2	49500m^2
300m	5.40 x 10^{6}m^3	216000m^2	300.0m	300.0m	75.0m	19440m^2	19440m^2	17280m^2	71280m^2	71280m^2
400m	12.8 x 10^{6}m^3	384000m^2	400.0m	400.0m	100.0m	34560m^2	34560m^2	30720m^2	126720m^2	126720m^2
500m	25.0 x 10^{6}m^3	600000m^2	500.0m	500.0m	125.0m	54000m^2	54000m^2	48000m^2	198000m^2	198000m^2
600m	43.2 x 10^{6}m^3	864000m^2	600.0m	600.0m	150.0m	77760m^2	77760m^2	69120m^2	285120m^2	285120m^2
700m	68.6 x 10^{6}m^3	1.12 x 10^{6}m^2	700.0m	700.0m	175.0m	105840m^2	105840m^2	94080m^2	388080m^2	388080m^2
800m	102 x 10^{6}m^3	1.54 x 10^{6}m^2	800.0m	800.0m	200.0m	138240m^2	138240m^2	122880m^2	506880m^2	506880m^2
900m	146 x 10^{6}m^3	1.94 x 10^{6}m^2	900.0m	900.0m	225.0m	174960m^2	174960m^2	155520m^2	641520m^2	641520m^2
1000m	200 x 10^{6}m^3	2.40 x 10^{6}m^2	1000.0m	1000.0m	250.0m	216000m^2	216000m^2	192000m^2	792000m^2	792000m^2



WEDGE

Area = Length^2 x .75
Volume = Length^3 x .03
F:18% R:12% S:17% T:18% B:18%

Length	Volume	Area	Length	Width	Depth	Front area	Rear area	Side area (ea.)	Top area	Bottom area
.50m	.004m^3	.188m^2	.50m	.30m	.15m	.034m^2	.023m^2	.032m^2	.034m^2	.034m^2
1.0m	.030m^3	.750m^2	1.0m	.60m	.30m	.135m^2	.090m^2	.128m^2	.135m^2	.135m^2
1.5m	.101m^3	1.69m^2	1.5m	.90m	.45m	.304m^2	.203m^2	.287m^2	.304m^2	.34m^2
2.0m	.240m^3	3.00m^2	2.0m	1.2m	.60m	.540m^2	.360m^2	.510m^2	.540m^2	.540m^2
3.0m	.810m^3	6.75m^2	3.0m	1.8m	.90m	1.22m^2	.810m^2	1.15m^2	1.22m^2	1.22m^2
4.0m	1.92m^3	12.0m^2	4.0m	2.4m	1.2m	2.16m^2	1.44m^2	2.04m^2	2.16m^2	2.16m^2
5.0m	3.75m^3	18.8m^2	5.0m	3.0m	1.5m	3.38m^2	2.25m^2	3.19m^2	3.38m^2	3.38m^2
6.0m	6.48m^3	27.0m^2	6.0m	3.6m	1.8m	4.86m^2	3.24m^2	4.59m^2	4.86m^2	4.86m^2
7.0m	10.3m^3	36.8m^2	7.0m	4.2m	2.1m	6.62m^2	4.41m^2	6.25m^2	6.62m^2	6.62m^2
8.0m	15.4m^3	48.0m^2	8.0m	4.8m	2.4m	8.64m^2	5.76m^2	8.16m^2	8.64m^2	8.64m^2
10m	30.0m^3	75.0m^2	10.0m	6.0m	3.0m	13.5m^2	9.00m^2	12.8m^2	13.5m^2	13.5m^2
12m	51.8m^3	108.0m^2	12.0m	7.2m	3.6m	19.4m^2	13.0m^2	18.4m^2	19.4m^2	19.4m^2
15m	101.3m^3	168.8m^2	15.0m	9.0m	4.5m	30.4m^2	20.3m^2	28.7m^2	30.4m^2	30.4m^2
20m	240.0m^3	300.0m^2	20.0m	12.0m	6.0m	54.0m^2	36.0m^2	51.0m^2	54.0m^2	54.0m^2
25m	468.8m^3	468.8m^2	25.0m	15.0m	7.5m	84.4m^2	56.3m^2	79.7m^2	84.4m^2	84.4m^2
30m	810.0m^3	675.0m^2	30.0m	18.0m	9.0m	121.5m^2	81.0m^2	114.8m^2	121.5m^2	121.5m^2
35m	1286.m^3	918.8m^2	35.0m	21.0m	10.5m	165.4m^2	110.3m^2	156.2m^2	165.4m^2	165.4m^2
40m	1920.m^3	1200.m^2	40.0m	24.0m	12.0m	216.0m^2	144.0m^2	204.0m^2	216.0m^2	216.0m^2
45m	2734.m^3	1519.m^2	45.0m	27.0m	13.5m	273.4m^2	182.3m^2	258.2m^2	273.4m^2	273.4m^2
50m	3750.m^3	1875.m^2	50.0m	30.0m	15.0m	337.5m^2	225.0m^2	318.8m^2	337.5m^2	337.5m^2
60m	6480.m^3	2700.m^2	60.0m	36.0m	18.0m	486.0m^2	324.0m^2	459.0m^2	486.0m^2	486.0m^2
70m	10290m^3	3675.m^2	70.0m	42.0m	21.0m	661.5m^2	441.0m^2	624.8m^2	661.5m^2	661.5m^2
80m	15360m^3	4800.m^2	80.0m	48.0m	24.0m	864.0m^2	576.0m^2	816.0m^2	864.0m^2	864.0m^2
90m	21870m^3	6075.m^2	90.0m	54.0m	27.0m	1094.m^2	729.0m^2	1033.m^2	1094.m^2	1094.m^2
100m	30000m^3	7500.m^2	100.0m	60.0m	30.0m	1350.m^2	900.0m^2	1275.m^2	1350.m^2	1350.m^2
120m	51840m^3	10800m^2	120.0m	72.0m	36.0m	1944.m^2	1296.m^2	1836.m^2	1944.m^2	1944.m^2
150m	101250m^3	16875m^2	150.0m	90.0m	45.0m	3038.m^2	2025.m^2	2869.m^2	3038.m^2	3038.m^2
200m	240000m^3	30000m^2	200.0m	120.0m	60.0m	5400.m^2	3600.m^2	5100.m^2	5400.m^2	5400.m^2
250m	468750m^3	46875m^2	250.0m	150.0m	75.0m	8438.m^2	5625.m^2	7969.m^2	8438.m^2	8438.m^2
300m	810000m^3	67500m^2	300.0m	180.0m	90.0m	12150m^2	8100.m^2	11475m^2	12150m^2	12150m^2
400m	1.92 x 10^{6}m^3	120000m^2	400.0m	240.0m	120.0m	21600m^2	14400m^2	20400m^2	21600m^2	21600m^2
500m	3.75 x 10^{6}m^3	187500m^2	500.0m	300.0m	150.0m	33750m^2	22500m^2	31875m^2	33750m^2	33750m^2
600m	6.48 x 10^{6}m^3	270000m^2	600.0m	360.0m	180.0m	48600m^2	32400m^2	45900m^2	48600m^2	48600m^2
700m	10.3 x 10^{6}m^3	367500m^2	700.0m	420.0m	210.0m	66150m^2	44100m^2	62475m^2	66150m^2	66150m^2
800m	15.4 x 10^{6}m^3	480000m^2	800.0m	480.0m	240.0m	86400m^2	57600m^2	81600m^2	86400m^2	86400m^2
900m	21.9 x 10^{6}m^3	607500m^2	900.0m	540.0m	270.0m	109350m^2	72900m^2	103275m^2	109350m^2	109350m^2
1000m	30.0 x 10^{6}m^3	750000m^2	1000.0m	600.0m	300.0m	135000m^2	90000m^2	127500m^2	135000m^2	135000m^2

Structure AV

Stat	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
1	.10	.14	.22	.32	.44	.71	1.0	1.4	2.2	3.2	4.5	7.1	10.0
2	.14	.20	.32	.44	.63	1.0	1.4	2.0	3.2	4.5	6.3	10.0	14.1
3	.17	.24	.39	.55	.78	1.2	1.7	2.5	3.9	5.5	7.7	12.2	17.3
4	.20	.28	.44	.63	.89	1.4	2.0	2.8	4.5	6.3	8.9	14.1	20.0
5	.22	.32	.50	.71	1.0	1.6	2.2	3.2	5.0	7.1	10.0	15.8	22.3
6	.24	.35	.55	.78	1.1	1.7	2.4	3.5	5.5	7.7	11.0	17.3	24.5
7	.26	.37	.59	.84	1.2	1.9	2.6	3.7	5.9	8.4	11.8	18.7	26.5
8	.28	.40	.63	.89	1.3	2.0	2.8	4.0	6.3	8.9	12.6	20.0	28.3
9	.30	.42	.67	.95	1.3	2.1	3.0	4.2	6.7	9.5	13.4	21.2	30.0
10	.32	.45	.71	1.0	1.4	2.2	3.2	4.5	7.1	10.0	14.1	22.4	31.7
12	.35	.49	.77	1.1	1.5	2.5	3.5	4.9	7.7	11.0	15.5	24.5	34.6
15	.39	.55	.87	1.2	1.7	2.7	3.9	5.5	8.7	12.2	17.3	27.4	38.7
20	.44	.63	1.0	1.4	2.0	3.2	4.5	6.3	10.0	14.1	20.0	31.6	44.7
30	.55	.78	1.2	1.7	2.5	3.9	5.5	7.7	12.2	17.3	24.5	38.7	54.7
40	.63	.89	1.4	2.0	2.8	4.5	6.3	8.9	14.1	20.0	28.3	44.7	63.2
50	.71	1.0	1.6	2.2	3.2	5.0	7.1	10.0	15.8	22.4	31.6	50.0	70.7

How to use this table:
Cross reference the closest figures for the mass and higher of either Turn, Acceleration or Deceleration of the vehicle. The result is the Armor Value used to calculate structure mass. Note that for all vehicles except balloons and blimps, the value rounds up, and for land vehicles, the minimum value would be the suspension rating+1.

Example - A 20 ton cargo truck with an Acceleration of 3, Turn of 4 and Deceleration of 3 would have a structure based on an AV of 2.8, rounding up to 3.

Structure materials

Tech Level	Organic*	Light	Mass/volume per point of AV per 10m^2 Composite	Heavy	Ex.heavy	Transparent
1	350.0kg/.5000m^3	350.0kg/.1500m^3	500.0kg/.1000m^3	600.0kg/.0800m^3	650.0kg/.0700m^3	700.0kg/.3000m^3
2	350.0kg/.5000m^3	350.0kg/.1500m^3	500.0kg/.1000m^3	600.0kg/.0800m^3	650.0kg/.0700m^3	700.0kg/.3000m^3
3	175.0kg/.2500m^3	175.0kg/.0750m^3	250.0kg/.0500m^3	300.0kg/.0400m^3	325.0kg/.0350m^3	350.0kg/.1500m^3
4	125.0kg/.1667m^3	125.0kg/.0500m^3	166.7kg/.0333m^3	200.0kg/.0267m^3	216.7kg/.0233m^3	233.3kg/.1000m^3
5	87.50kg/.1250m^3	87.50kg/.0375m^3	125.0kg/.0250m^3	150.0kg/.0200m^3	162.5kg/.0175m^3	175.0kg/.0750m^3
6	70.00kg/.1000m^3	70.00kg/.0300m^3	100.0kg/.0200m^3	120.0kg/.0160m^3	130.0kg/.0140m^3	140.0kg/.0600m^3
7	50.00kg/.0715m^3	50.00kg/.0215m^3	71.43kg/.0143m^3	85.72kg/.0114m^3	92.86kg/.0100m^3	100.0kg/.0429m^3
8	38.90kg/.0556m^3	38.90kg/.0167m^3	55.56kg/.0111m^3	66.67kg/.0089m^3	72.22kg/.0078m^3	77.78kg/.0333m^3
9	31.82kg/.0455m^3	31.82kg/.0136m^3	45.45kg/.0091m^3	54.54kg/.0072m^3	59.09kg/.0064m^3	63.64kg/.0272m^3
10	26.92kg/.0385m^3	26.92kg/.0116m^3	38.46kg/.0077m^3	46.15kg/.0062m^3	50.00kg/.0054m^3	53.84kg/.0233m^3
11	21.88kg/.0315m^3	21.88kg/.0094m^3	31.25kg/.0063m^3	37.50kg/.0050m^3	40.63kg/.0043m^3	43.75kg/.0188m^3
12	18.42kg/.0265m^3	18.42kg/.0079m^3	26.32kg/.0053m^3	31.58kg/.0042m^3	34.22kg/.0037m^3	36.84kg/.0159m^3
13	15.91kg/.0225m^3	15.91kg/.0067m^3	22.73kg/.0045m^3	27.27kg/.0036m^3	29.55kg/.0032m^3	31.82kg/.0135m^3
14	14.00kg/.0200m^3	14.00kg/.0060m^3	20.00kg/.0040m^3	24.00kg/.0032m^3	26.00kg/.0028m^3	28.00kg/.0120m^3
15	12.07kg/.0170m^3	12.07kg/.0051m^3	17.24kg/.0034m^3	20.69kg/.0027m^3	22.41kg/.0024m^3	24.14kg/.0102m^3
Cost per m^3	5,000Cr	66,670Cr	50,000Cr	125,000Cr	178,570Cr	66,670Cr

How to use this table:
Cross reference the Tech Level with the structure material used to get the mass and volume per point of AV, per 10m^2 of vehicle surface area. Multiply this by the AV from the previous table and the area of the vehicle in multiples of 10m^2 to get total structure mass and volume. Unless weird sceince is used, Organic structures top out at TL5. Note that the cost listed is per *cubic meter* (m^3), not *square meter* (m^2). This compares to the numbers on p.38 by figuring out how many composite equivalents there would be per m^3. For instance, Organic structures are x5.0 thickness and x.5 cost of Composite for *the same AV*, but since they are x5.0 as thick and x.5 cost, for *the same volume* they are much cheaper. If you use *armor* materials for your structure, use the table in the Surface Treatments section and multiply the cost by x4.

Example - The previous 20 ton cargo truck is 12m long in the Box$_2$ configuration, for a total area of 109.4m^2. This is 10.94 multiples of 10m^3, and the truck required a structure AV of 3. So, if using TL10 composite materials, the structure has a mass of 10.94 x 38.46kg x AV3 = 1,262kg, and a volume of 10.94 x .0077m^3 x AV3 = .253m^3. At 50,000Cr per 1m^3, this is a cost of 50,000Cr x .253m^3 =12,650Cr.

Seating & accommodations

Seating(ea)	Mass	Volume	Cost	Quarters(ea)	Mass	Volume	Cost	Other	Mass	Volume	Cost
None	-	-	-	Bunks	20kg	2m^3	100Cr	Toilet or shower	40kg	2m^3	200Cr
Substandard	10kg	-	50Cr	Minimum	100kg	10m^3	1,000Cr	Galley (4 meal/hr)	40kg	2m^3	200Cr
Basic	20kg	-	200Cr	Basic	200kg	20m^3	2,000Cr	Sick bay	100kg	10m^3	5,000Cr
Luxury	40kg	-	800Cr	Full	400kg	40m^3	4,000Cr				

Armor materials

Tech Level	Organic*	Light	Composite	Heavy	Ex.heavy	Transparent
			Mass/volume per point of AV per 10m^2			
1	350.0kg/.5000m^3	350.0kg/.1500m^3	500.0kg/.1000m^3	600.0kg/.0800m^3	650.0kg/.0700m^3	700.0kg/.3000m
2	175.0kg/.2500m^3	175.0kg/.0750m^3	250.0kg/.0500m^3	300.0kg/.0400m^3	325.0kg/.0350m^3	350.0kg/.1500m
3	116.7kg/.1667m^3	116.7kg/.0500m^3	166.7kg/.0333m^3	200.0kg/.0267m^3	216.7kg/.0233m^3	233.3kg/.1000m
4	70.00kg/.1000m^3	70.00kg/.0300m^3	100.0kg/.0200m^3	120.0kg/.0160m^3	130.0kg/.0140m^3	140.0kg/.0600m
5	50.00kg/.0715m^3	50.00kg/.0215m^3	71.42kg/.0143m^3	85.70kg/.0114m^3	216.7kg/.0100m^3	100.0kg/.0429m
6	35.00kg/.0500m^3	35.00kg/.0150m^3	50.00kg/.0100m^3	60.00kg/.0080m^3	65.00kg/.0070m^3	70.00kg/.0300m
7	26.92kg/.0389m^3	26.92kg/.0167m^3	38.46kg/.0077m^3	46.15kg/.0062m^3	50.00kg/.0054m^3	53.84kg/.0233m
8	20.59kg/.0294m^3	20.59kg/.0088m^3	29.41kg/.0059m^3	35.29kg/.0047m^3	38.23kg/.0041m^3	41.17kg/.0176m
9	15.97kg/.0238m^3	15.97kg/.0071m^3	23.81kg/.0048m^3	28.57kg/.0038m^3	30.95kg/.0033m^3	33.33kg/.0143m
10	13.46kg/.0192m^3	13.46kg/.0058m^3	19.23kg/.0038m^3	23.07kg/.0031m^3	25.00kg/.0027m^3	26.92kg/.0115m
11	11.29kg/.0161m^3	11.29kg/.0048m^3	16.13kg/.0032m^3	19.36kg/.0026m^3	20.96kg/.0023m^3	22.58kg/.0097m
12	9.457kg/.0135m^3	9.457kg/.0041m^3	13.51kg/.0027m^3	16.21kg/.0022m^3	17.56kg/.0019m^3	18.91kg/.0081m
13	8.141kg/.0116m^3	8.141kg/.0035m^3	11.63kg/.0023m^3	13.96kg/.0019m^3	15.12kg/.0016m^3	16.28kg/.0070m
14	7.000kg/.0100m^3	7.000kg/.0030m^3	10.00kg/.0020m^3	12.00kg/.0016m^3	13.00kg/.0014m^3	14.00kg/.0060m
15	6.140kg/.0088m^3	6.140kg/.0026m^3	8.772kg/.0018m^3	10.53kg/.0014m^3	11.40kg/.0012m^3	12.28kg/.0053m
Cost per m^3	5,000Cr	66,670Cr	50,000Cr	125,000Cr	178,570Cr	66,670Cr
Special purpose	x3.0	x3.0	x3.0	x3.0	x3.0	x3.0
Hardened x1	x2.0	x2.0	x2.0	x2.0	x2.0	x2.0
Hardened x2	x4.0	x4.0	x4.0	x4.0	x4.0	x4.0

How to use this table:
Cross reference the Tech Level with the armor material used to get the mass and volume per point of AV, per 10m^2 of vehicle surface area. Multiply this by the AV you want for a particular facing and the area of the vehicle in multiples of 10m^2 to get total armor mass and volume. Unless weird sceince is used, Organic structures top out at TL5. Volume is also not normally applied to armor, but in the case that these materials are used as internal structure, their volume is provided. Note that the cost listed is per *cubic meter* (m^3), not *square meter* (m^2). This compares to the numbers on p.48 by figuring out how many composite equivalents there would be per m^3. For instance, Organic structures are x5.0 thickness and x.5 cost of Composite for *the same AV*, but since they are x5.0 as thick and x.5 cost, for *the same volume* they are much cheaper. If you use *structure* materials for your armor, use the table in the Surface Treatments section and multiply the cost by x.25.

Example - A TL12 armored car is designed as a Box_1 configuration with a length of 7.0m. This gives it a total area of 53.90m^2, or 5.39 units of 10m^2. If the entire armored car can stop DV18 assault rifle bullets and uses lightweight armor, the mass of the armor will be 5.39 x AV18 x 9.457kg = 917.5kg. Since we have the volume figure, we can use that to figure the cost, or 5.39 x AV18 x .0135m^3 x 66,670Cr = 87,322Cr.

Body armor

Tech Level	Organic*	Light	Composite	Heavy	Ex.heavy	Transparent
			Head/Torso/Extremities(thickness)			
1	7.00/21.0/42.0(50mm)	7.00/21.0/42.0(15mm)	10.0/30.0/60.0(10mm)	12.0/36.0/72.0(8.0mm)	13.0/39.0/78.0(7.0mm)	14.0/42.0/84.0(30mm)
2	3.50/10.5/21.0(25mm)	3.50/10.5/21.0(7.5mm)	5.00/15.0/30.0(5.0mm)	6.00/18.0/36.0(4.0mm)	6.50/19.5/39.0(3.5mm)	7.00/21.0/42.0(15mm)
3	2.33/7.00/14.0(17mm)	2.33/7.00/14.0(5.0mm)	3.33/10.0/20.0(3.3mm)	4.00/12.0/24.0(2.7mm)	4.33/13.0/26.0(2.3mm)	4.66/14.0/28.0(10mm)
4	1.40/4.20/8.40(10mm)	1.40/4.20/8.40(3.0mm)	2.00/6.00/12.0(2.0mm)	2.40/7.20/14.4(1.6mm)	2.60/7.80/15.6(1.4mm)	2.80/8.40/16.8(6.0mm)
5	1.00/3.00/6.00(7.2mm)	1.00/3.00/6.00(2.1mm)	1.43/4.29/8.57(1.4mm)	1.72/5.15/10.3(1.1mm)	1.86/5.58/11.5(1.0mm)	2.00/6.00/12.0(4.3mm)
6	.700/2.10/4.20(5.0mm)	.700/2.10/4.20(1.5mm)	1.00/3.00/6.00(1.0mm)	1.20/3.60/7.20(.80mm)	1.30/3.90/7.80(.70mm)	1.40/4.20/8.40(3.0mm)
7	.538/1.62/3.23(3.8mm)	.538/1.62/3.23(1.2mm)	.769/2.31/4.62(.77mm)	.923/1.77/5.54(.62mm)	1.00/3.00/6.00(.54mm)	1.08/3.23/6.46(2.3mm)
8	.412/1.24/2.47(2.9mm)	.412/1.24/2.47(.88mm)	.589/1.76/3.53(.59mm)	.707/2.12/4.24(.47mm)	.766/2.30/4.59(.41mm)	.825/2.47/4.95(1.8mm)
9	.333/1.00/2.00(2.4mm)	.333/1.00/2.00(.71mm)	.476/1.43/2.86(.48mm)	.571/1.71/3.43(.38mm)	.619/1.86/3.71(.33mm)	.666/2.00/4.00(1.4mm)
10	.269/.807/1.62(1.9mm)	.269/.807/1.62(.58mm)	.385/1.15/2.31(.39mm)	.462/1.39/2.77(.31mm)	.500/1.50/3.00(.27mm)	.539/1.62/3.23(1.2mm)
11	.226/.677/1.35(1.6mm)	.226/.677/1.35(.48mm)	.323/.968/1.94(.32mm)	.388/1.16/2.33(.26mm)	.420/1.26/2.52(.23mm)	.452/1.36/2.71(.97mm)
12	.189/.568/1.14(1.4mm)	.189/.568/1.14(.41mm)	.270/.811/1.62(.27mm)	.324/.972/1.94(.22mm)	.351/1.05/2.11(.19mm)	.378/1.13/2.27(.81mm)
13	.163/.488/.977(1.2mm)	.163/.488/.977(.35mm)	.233/.698/1.40(.23mm)	.280/.840/1.68(.19mm)	.303/.910/1.82(.16mm)	.327/.980/1.96(.70mm)
14	.140/.420/.840(1.0mm)	.140/.420/.840(.30mm)	.200/.600/1.20(.20mm)	.240/.720/1.40(.16mm)	.260/.780/1.56(.14mm)	.280/.840/1.68(.60mm)
15	.123/.368/.737(.88mm)	.123/.368/.737(.26mm)	.175/.526/1.05(.18mm)	.210/.630/1.26(.14mm)	.227/.683/1.37(.12mm)	.245/.735/1.47(.53mm)
Cost, head	1.2Cr x thickness	16Cr x thickness	12Cr x thickness	30Cr x thickness	43Cr x thickness	16Cr x thickness
Cost, torso	3.3Cr x thickness	44Cr x thickness	33Cr x thickness	83Cr x thickness	118 x thickness	44Cr x thickness
Cost, extremities	9.2Cr x thickness	123Cr x thickness	92Cr x thickness	230Cr x thickness	329 x thickness	123Cr x thickness

How to use this table:
Cross reference the Tech Level with the armor type to get the mass *per point of AV per body area*, followed by the thickness in mm for that AV. Head includes head and neck, and extremities includes arms, hands, legs and feet. Cost is the cost for a given thickness in mm of that type of armor. How the AV is split between soak and blunt trauma values depends on the armor type. Again, remember that most organic materials top out at TL5 and that maximum thickness should be 10mm for anything muscle-powered, and 40mm for any powered armor. The normal concealability threshold for flexible armor (under full clothing) is 5mm thickness for torso and 2mm for extremities.

Example - A lightweight TL11 torso armor will have a mass of .677kg per point of AV, so 5 points of armor would mass .677kg x 5 = 3.39kg, and if it were flexible, like a bulletproof vest, it would have a final AV of 5/5. Cost would be 44Cr x AV5 = 220Cr.

Streamlining

Streamlining	Thin (upper atmosphere)	Normal (sea level air)	Dense gas	V.dense gas	Liquid immersion	Gas-liquid interface
None(x1.0)	11m/sec	6m/sec	3m/sec	2m/sec	1.4m/sec	1.2m/sec
Minimum(x1.0)	16m/sec	8m/sec	4m/sec	3m/sec	2m/sec	1.4m/sec
Basic(x1.2)	23m/sec	11m/sec	6m/sec	4m/sec	3m/sec	2m/sec
Partial opt.(x1.5)	32m/sec	16m/sec	8m/sec	6m/sec	4m/sec	3m/sec
Optimum(x2.0)	45m/sec	23m/sec	11m/sec	8m/sec	6m/sec	4m/sec

How to use this table:
Cross reference the most appropriate type of atmosphere or medium the vehicle travels through with the type of streamlining it has. The result is the multiple at which it loses 1m/sec from its designed top speed due to drag effects. Round drag effects down. The number in parentheses after the streamlining type is the multiple on surface armor cost caused by the streamlining considerations.

Example - A powerboat with a designed top speed of 23m/sec has partial optimum streamlining. Cross-referencing the gas-liquid interface column with partial optimum streamlining gives 3m/sec. Since the boat had a designed top speed of 23m/sec, drag effects are 23/3 = 7.66, rounding down to 7, for an adjusted top speed of 23-7=16m/sec.

Wings 1

Power	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
1000w	100m^2	200m^2	500m^2	1000m^2	2000m^2	5000m^2	10000m^2	20000m^2	50000m^2	1 x10^{5}m^2	2 x10^{5}m^2	5 x10^{5}m^2	1 x10^{6}m^2
2000w	50m^2	100m^2	250m^2	500m^2	1000m^2	2500m^2	5000m^2	10000m^2	25000m^2	50000m^2	1 x10^{5}m^2	2.5 x10^{5}m^2	5 x10^{5}m^2
5000w	20m^2	40m^2	100m^2	200m^2	400m^2	1000m^2	2000m^2	4000m^2	10000m^2	20000m^2	40000m^2	1 x10^{5}m^2	2 x10^{5}m^2
10.0kw	10m^2	20m^2	50m^2	100m^2	200m^2	500m^2	1000m^2	2000m^2	5000m^2	10000m^2	20000m^2	50000m^2	1 x10^{5}m^2
20.0kw	5.0m^2	10m^2	25m^2	50m^2	100m^2	250m^2	500m^2	1000m^2	2500m^2	5000m^2	10000m^2	25000m^2	50000m^2
50.0kw	2.0m^2	4.0m^2	10m^2	20m^2	40m^2	100m^2	200m^2	400m^2	1000m^2	2000m^2	4000m^2	10000m^2	20000m^2
100kw	1.0m^2	2.0m^2	5.0m^2	10m^2	20m^2	50m^2	100m^2	200m^2	500m^2	1000m^2	2000m^2	5000m^2	10000m^2
200kw	.50m^2	1.0m^2	2.5m^2	5.0m^2	10m^2	25m^2	50m^2	100m^2	250m^2	500m^2	1000m^2	2500m^2	5000m^2
500kw	.20m^2	.40m^2	1.0m^2	2.0m^2	4.0m^2	10m^2	20m^2	40m^2	100m^2	200m^2	400m^2	1000m^2	2000m^2
1.0Mw	.10m^2	.20m^2	.50m^2	1.0m^2	2.0m^2	5.0m^2	10m^2	20m^2	50m^2	100m^2	200m^2	500m^2	1000m^2
2.0Mw	.05m^2	.10m^2	.25m^2	.50m^2	1.0m^2	2.5m^2	5.0m^2	10m^2	25m^2	50m^2	100m^2	250m^2	500m^2
5.0Mw	.02m^2	.04m^2	.10m^2	.20m^2	.40m^2	1.0m^2	2.0m^2	4.0m^2	10m^2	20m^2	40m^2	100m^2	200m^2
10Mw	.01m^2	.02m^2	.05m^2	.10m^2	.20m^2	.50m^2	1.0m^2	2.0m^2	5.0m^2	10m^2	20m^2	50m^2	100m^2
20Mw	-	.01m^2	.03m^2	.05m^2	.10m^2	.25m^2	.50m^2	1.0m^2	2.5m^2	5.0m^2	10m^2	25m^2	50m^2
50Mw	-	-	.01m^2	.02m^2	.04m^2	.10m^2	.20m^2	.40m^2	1.0m^2	2.0m^2	4.0m^2	10m^2	20m^2
100Mw	-	-	-	.01m^2	.02m^2	.05m^2	.10m^2	.20m^2	.50m^2	1.0m^2	2.0m^2	5.0m^2	10m^2

Modifier	Power	Modifier	Power
Vacuum	x.∞	Normal atmosphere	x1.0
Extremely thin atmosphere	x5.0	Thick atmosphere	x.70
Thin atmosphere	x2.0	Liquid atmosphere (water)	x.10

How to use this table:
Cross-reference the power plant output and mass of an aircraft to get the wing area required for level flight. Adjust power according to the atmosphere type as needed.

Wings 2

Wing area	100kg	200kg	500kg	1000kg	2000kg	5000kg	Mass 10 ton	20 ton	50 ton	100 ton	200 ton	500 ton	1000 ton
10m^2	50.0m/s	59.5m/s	74.8m/s	88.9m/s	105.m/s	133.m/s	158.m/s	188.m/s	236.m/s	281.m/s	334.m/s	420.m/s	500.m/s
20m^2	35.4m/s	42.0m/s	52.9m/s	62.9m/s	74.8m/s	94.0m/s	112.m/s	133.m/s	167.m/s	199.m/s	236.m/s	297.m/s	354.m/s
30m^2	28.9m/s	34.3m/s	43.2m/s	51.3m/s	61.0m/s	76.8m/s	91.3m/s	109.m/s	137.m/s	162.m/s	193.m/s	243.m/s	289.m/s
40m^2	25.0m/s	29.7m/s	37.4m/s	44.5m/s	52.9m/s	66.5m/s	79.1m/s	94.0m/s	118.m/s	141.m/s	167.m/s	210.m/s	250.m/s
50m^2	22.4m/s	26.6m/s	33.4m/s	39.8m/s	47.3m/s	59.5m/s	70.7m/s	84.1m/s	106.m/s	126.m/s	150.m/s	188.0m/s	224.m/s
60m^2	20.4m/s	24.3m/s	30.5m/s	36.3m/s	43.2m/s	54.3m/s	64.5m/s	76.8m/s	96.5m/s	115.m/s	137.m/s	172.m/s	204.m/s
80m^2	17.7m/s	21.0m/s	26.4m/s	31.4m/s	37.4m/s	47.0m/s	55.9m/s	66.5m/s	83.6m/s	99.4m/s	118.m/s	149.m/s	177.m/s
100m^2	15.8m/s	18.8m/s	23.6m/s	28.1m/s	33.4m/s	42.0m/s	50.0m/s	59.5m/s	74.8m/s	88.9m/s	106.m/s	133.m/s	158.m/s
120m^2	14.4m/s	17.2m/s	21.6m/s	25.7m/s	30.5m/s	38.4m/s	45.6m/s	54.3m/s	68.3m/s	81.2m/s	96.5m/s	121.m/s	144.m/s
150m^2	12.9m/s	15.4m/s	19.3m/s	23.0m/s	27.3m/s	34.3m/s	40.8m/s	48.5m/s	61.0m/s	72.6m/s	86.3m/s	109.m/s	129.m/s
200m^2	11.2m/s	13.3m/s	16.7m/s	19.9m/s	23.6m/s	29.7m/s	35.4m/s	42.0m/s	52.9m/s	62.9m/s	74.8m/s	94.0m/s	112.m/s
300m^2	9.1m/s	10.9m/s	13.7m/s	16.2m/s	19.3m/s	24.3m/s	28.9m/s	34.3m/s	43.2m/s	51.3m/s	61.0m/s	76.8m/s	91.3m/s
400m^2	7.9m/s	9.4m/s	11.8m/s	14.1m/s	16.7m/s	21.0m/s	25.0m/s	29.7m/s	37.4m/s	44.5m/s	52.9m/s	66.5m/s	79.1m/s

How to use this table:
Cross-reference the airplane mass and the wing area to get the stall or takeoff speed in normal atmosphere. Divide wing area by the power modifier for other atmosphere types.

Access & structure

Accessory	Mass	Volume	Cost	Notes
Airlock(per person)	1,000kg	$2m^3$	10,000Cr	Outside has surface AV, inside has structure AV
Bulkheads(ea.)	x.01 structure	x.01 structure	x.01 structure	Has an AV equal to structure AV
Cargo hold	-	-	-	Any available vehicle space
Cargo rack	$(20/TL)kg/m^2$	-	$(20/TL)Cr/m^2$	Mass is x acceleration in g's. Load is $50kg/m_2$ per point of top AV
Catapults	-	-	-	See p.64
Docking port (per pers.)	100kg/m	$.5m^3/m$	1,000Cr/m	Add 100Cr/m for umbilical support (500Cr/m for full support)
Drop tanks	x1.1 fuel(full)	-	10Cr/kg(empty)	AV of half structure or surface AV, whichever is lower
Firing ports(ea)	-	-	50Cr	Sealed vehicle ports are x2 cost, hostil atmosphere are x4 cost
Hangars	-	x3 carried vehicle	-	Requires floor plan of x1.5 vehicle area
Hardpoints	$(\text{item x .05 x Acc.})^{.5}$	-	10Cr/kg	See p.66
Ladders	(20/TL)kg/m	$.01m^3/kg$	20Cr/m	Folding ladders are x5 cost, x.2 volume
Torpedo tube(ea.)	1,000kg	$2m^3$	10,000Cr	Handles most historical TL9-12 torpedos
Towing hitch	$(\text{Towed x .05 x Acc.})^{.5}$	-	10Cr/kg	See p.66

Surface treatments

Accessory	Mass	Volume	Cost	Notes
Magnetic force field	-	-	x3 armor cost	See p.67
T-babble force field	100kg	$.1m^3$	10,000Cr	See p.67
Retractable armor	armor mass	x2 armor vol.	x2 armor cost	See p.68
Wheel/track skirts	x1.2 power train	-	x1.2 power train	Gives x3 power train AV. See p.68

Engines & fuel

Accessory	Mass	Volume	Cost	Notes
Refinery	100kg	$1m^3$	1,000Cr	Consumes 5kw per m^3
Refueling probe	1kg/500Cr	$1m^3/1{,}000kg$	10Cr x spd x kg	Vehicle supplying fuel has x10 cost, x10 mass and x100 volume
Snorkel	(25/TL x kw)kg	$1m^3/1{,}000kg$	5Cr/kg	Operates at up to TL meters below surface
Redundant sys.(ea)	x.1 system	x.1 system	x.2 cost	Will negate 1 point of system impairment

Controls

Accessory	Mass	Volume	Cost	Notes
Extra controls	x.1 power tr.	x.1 power tr.	x.1 power tr.	Maximum mass of 50kg
Remote controls	x.1 power tr.	x.1 power tr.	x.1 power tr.	Max. skill of (TL/3)-2(d), +1 skill per x4 mass, maximum of +4
Special running gear	x.05 structure	-	x.05 structure	Substitutes for something, like floats instead of wheels
Stabilizers(per pt.)	x.1 power tr.	x.1 power tr.	x.1 power tr.	Or x.001 vehicle mass, whichever is larger

Environment control

Accessory	Mass	Volume	Cost	Notes
Climate control(per m^3)	(10/TL)kg	$1m^3/1{,}000kg$	10Cr/kg	Provides either a +20°C *or* -20°C shift. requires 100w/kg
Normal life supp.(per m^3)	(20/TL)kg	$1m^3/1{,}000kg$	100Cr/kg	Consumes supplies as a normal power plant, requires 100w/kg
Regen. life supp.(per m^3)	(40/TL)kg	$1m^3/1{,}000kg$	1,000Cr/kg	Requires 100w/kg, consumes no supplies
Food/water(100kg crew)	4kg	$1m^3/1{,}000kg$	2Cr/kg	Includes food & water for normal activity level of 100kg of crew

Maintenance

Accessory	Mass	Volume	Cost	Notes
Maintenance tools	(pow. pl.&tr.)/50kg	$1m^3/2{,}000kg$	10Cr/kg	Good for all normal maintenance
Maintenance parts	x1 maint. tools	$1m^3/2{,}000kg$	10Cr/kg	Consumed once per vehicle maintenance
Repair tools	x4 maint. tools	$1m^3/2{,}000kg$	10Cr/kg	Good for any vehicle repair
Repair parts	x2 maint. tools	$1m^3/2{,}000kg$	10Cr/kg	Gives 1 in 10 chance of right parts for random repair task

Miscellaneous

Accessory	Mass	Volume	Cost	Notes
Computers	-	-	-	see p.74
Manipulator arms	-	-	-	see p.74
Retractable items	-	-	-	see p.75

Safety

Accessory	Mass	Volume	Cost	Notes
Component armor	-	-	-	see p.75
Disaster system	$1{,}000kg/m^3$	x.001 vehicle	$10KCr/m^3$	Effective skill of TL/2(u) vs. disaster type
Basic escape sys.(ea)	10kg	$.1m^3$	1,000Cr	Effective skill of TL/3(n) vs. accident damage
Adv. escape sys.(ea)	50kg	$.5m^3$	100KCr	Effective skill of TL/2(n) vs. accident damage
Emergency lights	-	-	-	Standard equipment, duration of TL^2 hours
Medical kit(per 10 crew)	5kg	-	50Cr	Basic first aid supplies

Sensors

Tech Level	1(1m²)(1km)	2(4m²)(10km)	3(9m²)(100km)	4(16m²)(1,000km)	5(25m²)(10,000km)	6(36m²)(100,000km)
	Rating(antenna area)(useful range)					
9	160kg/2.1kw	2.5 ton/33.3kw	40 ton/532kw	650 ton/8.6Mw	10 kton/133Mw	160 kton/2,100Mw
10	20kg/200w	300kg/3.0kw	5.0 ton/50.0kw	80 ton/800kw	1.3 kton/13Mw	20 kton/200Mw
11	6.0kg/44w	100kg/730w	1.5 ton/11.0kw	25 ton/183kw	400 ton/2.9Mw	6.0 kton/44Mw
12	2.5kg/13w	40kg/204w	650kg/3.3kw	10 ton/51.0kw	150 ton/765kw	2.5 kton/13Mw
13	1.2kg/4.1w	20kg/68w	300kg/1.0kw	5.0 ton/17.0kw	80 ton/272kw	1.3 kton/4.4Mw
14	.70kg/1.5w	10kg/22w	160kg/352w	2.5 ton/5.5kw	40 ton/88.0kw	650 ton/1.4Mw
15	.50kg/.65w	7.0kg/9.1w	120kg/156w	2.0 ton/2.6kw	30 ton/39.0kw	500 ton650kw

Modifiers	Mass	Cost	Ant. area
Narrow fixed arc(15°)	x1.0	x1.0	x1.0
Sector scan(60°)	x2.0	x2.0	x2.0
Full directional(360°)	x4.0	x4.0	x4.0
Wpn. targeting only	x.50	x.50	x.50
Target illum. only	x.20	x.20	x.20
Navig. illum.(360°)	x.10	x.10	x.10
Communications(360°)	x.10	x.10	x.10
Natural senses	x.50	x.10	x.10
Scientific instruments	x2.0	x10.0	x1.0
Types			
Passive sensor(x.1 power)		x2.0	x1.0
Radar(active)	-	-	x1.0
Longwave(active)	-	-	x10.0
Lidar(active)	-	-	x.10
Thermal(passive)	-	-	x.10
Sonar(active or passive)	-	-	x.20
Nucleonic(passive)	-	-	x5.0
Optical(passive)	-	-	x.10
Optional TL modifier	-	-	$x1/(TL/10)^4$

Cost	10Cr/kg
Volume	$1m^3$/1000kg

Sensor	Fog	L.cloud	H.cloud	Water	Soil	Smoke	Foliage
Radar	0	2	4	6	6	0	1
Longwave	0	0	1	2	3	0	0
Lidar	3	-	-	3	-	3	3
Sonar	0	1	2	0	2	0	1
Thermal	1	3	-	3	-	1	1
Nucleonic	0	0	0	1	2	0	0
Optical	2	-	-	2	-	3	2

	Comm 1						
Comm 2	1	2	3	4	5	6	7
1	1km	10km	100km	1,000km	10,000km	100,000km	1.0Mkm
2	-	10km	100km	1,000km	10,000km	100,000km	1.0Mkm
3	-	-	1,000km	10,000km	100,000km	1.0Mkm	10Mkm
4	-	-	-	10,000km	100,000km	1.0Mkm	10Mkm
5	-	-	-	-	1.0Mkm	10Mkm	100Mkm
6	-	-	-	-	-	10Mkm	100Mkm
7	-	-	-	-	-	-	1.0Bkm

How to use this table:
Cross reference the Tech Level and the rating of the sensor you want, based on the desired useful range. The result is the base mass of that sensor and the power required to operate it. Modifiers on the mass will also apply to the power consumption. The subtable on the middle right gives the reduction in rating a sensor type takes if going through a given type of obscurement. If rating is reduced to zero or below, the sensor is blocked. If more than one modifier applies, use only the largest one, with the exception of scientific instrumentation, which is always counted if it applies. The table on the lower right gives the reliable communication range between communications gear of the given ratings. Passable communications are possible at x4 this range, and maximum range is about x9 this range.

Example - A Rating 3 TL11 airborne radar set will have a base mass of 1.5 tons and consume 11.0kw of power. If it had a forward-looking 60° arc, it would mass 3.0 tons and consume 22.0kw of power. If it were flying through light cloud cover, its rating would be dropped to 1, and if flying through heavy cloud cover, the radar would be useless. The size of the radar antenna (or area on the surface of the vehicle devoted to the antenna) is either $18m^2$(2.4m diameter) or $12.3m^2$(2.0m diameter) depending onwhether or not you use the optional antenna area rule. In either case, the radar cost is 30KCr and it takes up $3m^3$ of internal volume.

Weapons 1

Hand-held weapon	Caliber	DV	Initiative mod	Range mod*	Size	TL	Mass	Extra clip	Rate of fire	Clip	AV	Cost
Hand cannon	12mm	4	+1	-1	7	5	2.1kg	-	1/30	1i	9	70
Musket	19mm	6	-1	1	19	6	4.7kg	-	1/30	1i	7	90
Muzzle loading rifle	12mm	10	+0	3	17	7	4.1kg	-	1/30	1i	10	140
Breech loading rifle	8mm	18	+0	4	15	8	4.1kg	-	1/2	5i	10	340
Squad autorifle	8mm	19	-1	4	16	9	9.5kg	.7kg	10	20c	8	975
Squad autorifle	8mm	19	-1	4	18	10	16.3kg	5.8kg	10	200e	8	975
Squad autorifle	6mm	16	-1	4	16	11	10.0kg	3.1kg	10	200e	6	730
Squad autorifle	5mm/c	16	-1	5	12	12	7.0kg	1.3kg	10	300c	6	1800
Squad autorifle	7mm/c	21	-1	5	10	13	7.6kg	2.3kg	10	200c	5	2500
Squad autorifle	4mm railgun	24	+0	5	9	14	5.5kg	2.1kg	10	50c	4	4400
Squad autorifle	4mm railgun	27	+0	5	10	15	6.1kg	2.9kg	10	100c	4	5000

The squad autorifles are capable of being solidly mounted to get +2 Range Mod.

Siege engine	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass	Extra clip	Rate of fire*	Clip	AV	Cost
Siege crossbow	32mm	11	-1	4	15	5	17.3kg/.35m^3	.3kg	1/35	1i	6	330
Onager, small	90mm	13	-3	3	-	4	75kg/1.5m^3	.8kg	1/130	1i	8	210
Onager, medium	140mm	18	-4	0	-	4	115kg/2.3m^3	4.3kg	1/270	1i	9	340
Sprengal, small	65mm	15	-3	9	-	4	75kg/1.5m^3	2.1kg	1/130	1i	8	270
Sprengal, medium	55mm	15x4	-3	9	-	4	275kg/5.5m^3	5.0kg	4(1/400)	4i	9	550
Ballista, small	45mm	13	-2	9	-	4	50kg/1.0m^3	1.4kg	1/70	1i	7	210
Ballista, medium	75mm	16	-3	10	-	4	85kg/1.7m^3	6.4kg	1/170	1i	8	580
Trebuchet	250mm	36	-7	0	-	4	2.7t/54m^3	16.4kg	1/1100	1i	11	1200

*Assumes one person working at 150J per second. Divide by up to 2 people per 100kg (round up) of weapon if extra help is available.

Archaic cannon	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass*	Extra clip	Rate of fire*	Clip	AV	Cost
Swivel gun	25mm	20	-2	2	16	5	29.1kg/.03m^3	.1kg	1/20	1i	15	205
(cannister shot)	10mm shot	8(+0)		0								
6pd muzzle loader	93mm	55	-4	7	-	6	400kg/.4m^3	3kg	1/30	1i	20	1400
(cannister shot)	28mm shot	19(+2)										
12pd muzzle loader	117mm	97	-5	7	-	6	800kg/.8m^3	6kg	1/40	1i	24	3700
(cannister shot)	38mm shot	30(+2)										
32pd muzzle loader	163mm	148	-5	7	-	6	2000kg/2.0m^3	15kg	1/50	1i	26	6000
(cannister shot)	51mm shot	40(+2)										
20pd breech load rfl	85mm	90	-4	9	-	7	400kg/.4m^3	10kg	1/12	1i	21	7500
(shell)		9E										
70pd breech load rfl	150mm	195	-5	9	-	7	3.0t/3.0m^3	37kg	1/20	1i	27	34k
(shell)		20E										
110pd breech load rfl	180mm	231	-6	16	-	7	4.0t/4.0m^3	60kg	1/20	1i	28	48k
(shell)		26E										

Note that muzzle loading cannon require either loading from outside a vehicle, or double interior volume to allow retraction of the weapon for reloading.
Rate of fire assumes crew of 2 per 1m^3 of weapon (round up). This can be decreased by a variable amount depending on how much safety you want to sacrifice.

Machineguns	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass/vol.	Extra clip	Rate of fire	Clip	AV	Cost
13mm machinegun	13mm	36	-2	11	-	9	60kg/.06m^3	20kg	10	200e	10	2500
15mm machinegun	15mm	42	-3	11	-	9	90kg/.09m^3	35kg	10	200e	12	3300
8mm rotary gun	8mm	18	-1	3	-	11	120kg/.12m^3	100kg	100	4000e	8	1400
13mm machinegun	13mm	40	-2	11	-	12	40kg/.04m^3	15kg	20	200e	8	3000
15mm machinegun	15mm	44	-3	16	-	11	75kg/.08m^3	28kg	10	150e	10	3500
15mm machinegun	15mm	47	-3	16	-	12	70kg/.07m^3	28kg	10	150e	9	4100
15mm machinegun	15mm	50	-3	16	-	13	70kg/.07m^3	28kg	10	150e	8	4500
6mm railgun*	6mm	90	-2	11	-	14	27kg/.03m^3	9.0kg/7Mw	20	2000e	7	19k
6mm railgun*	6mm	101	-2	11	-	15	26kg/.03m^3	9.0kg/6Mw	20	2000e	6	23k
5mm particle beam*	5mm	90	-2	18	-	14	30kg/.03m^3	13Mw	10	∞	5	38k
5mm particle beam*	5mm	103	-2	18	-	15	27kg/.03m^3	10Mw	10	∞	4	49k

*Requires vehicle power source. Railgun clip mass is for projectiles only.

Weapons 2

Cannon	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass/vol.	Extra clip	Rate of fire	Clip	AV	Cost
20mm autocannon	20mm	57	-3	26	-	11	100kg/.1m^3	20kg	10	50c	11	8000
25mm autocannon	25mm	67	-4	26	-	11	150kg/.15m^3	40kg	10	50c	12	10.5k
30mm autocannon	30mm	75	-4	26	-	11	200kg/.2m^3	60kg	10	50c	13	13k
30mm rotary cannon	30mm	75	-6	26	-	11	1.7t/1.7m^3	1.0t	60	1200e	13	25k
40mm autocannon (HE)	40mm	5E	-5	26	-	11	700kg/.7m^3	80kg	5	25i	14	23k
(APFSDS)		96		38								
76mm cannon (HE)	76mm	9E	-5	26	-	9	600kg/.6m^3	12kg	1	1i	24	36k
(AP)		200		38				12kg				
90mm lt. cannon (HE)	90mm	14E	-4	9	-	11	300kg/.3m^3	5.0kg	1	1i	14	2500
(HEAT)		480/7E		16				4.0kg				
105mm cannon (HE)	105mm	18E	-6	26	-	11	2.5t/2.5m^3	19kg	1	1i	22	28k
(APFSDS)		370		52				17kg				
(HEAT)		686/11E		26				22kg				
120mm cannon (HE)	120mm	22E	-6	38	-	11	3.0t/3.0m^3	25kg	1	1i	22	35k
(APFSDS)		400		52				20kg				
(HEAT)		950/14E		38				25kg				

Range mods assume handheld wpns use handhelp category, and vehicle ones use turreted.

Fire & forget missiles	Caliber	DV	Initiative mod	Range mod	Size	TL	Mass	Extra clip	Rate of fire	Clip	AV	Cost
AT msl. (skill 0/600m/sec)	80mm	400/6E	-1	-	12	11	9.0kg	5.0kg	1	1i	11	900
AT msl. (skill 1/650m/sec)	80mm	440/7E	-1	-	12	13	8.0kg	5.0kg	1	1i	8	1200
AT msl. (skill 2/600m/sec)	90mm	560/9E	-1	-	12	15	9.5kg	7.0kg	1	1i	6	5000
AA msl. (skill 1/700m/sec)	70mm	330/13E	-1	-	20	11	9.5kg	6.5kg	1	1i	10	1000
AA msl. (skill 1/850m/sec)	70mm	360/14E	-1	-	20	13	9.5kg	6.5kg	1	1i	8	1000
AA msl. (skill 2/800m/sec)	70mm	390/15E	-1	-	20	15	8.5kg	6.5kg	1	1i	6	5000
AT msl. (skill 2/550m/sec)	180mm	1350/22E	-3	-	-	11	75kg/.08m^3	55kg	1	1i	15	15k
AT msl. (skill 2/850m/sec)	180mm	1500/24E	-3	-	-	13	70kg/.07m^3	55kg	1	1i	12	20k
AT msl. (skill 3/850m/sec)	200mm	1800/30E	-3	-	-	15	90kg/.09m^3	75kg	1	1i	9	150k
AA msl. (skill 2/1.1km/sec)	150mm	1000/29E	-3	-	-	11	80kg/.08m^3	65kg	1	1i	15	15k
AA msl. (skill 2/1.3km/sec)	150mm	1100/31E	-3	-	-	13	80kg/.08m^3	65kg	1	1i	12	15k
AA msl. (skill 3/1.2km/sec)	150mm	1200/34E	-3	-	-	15	75kg/.08m^3	65kg	1	1i	8	100k
Torpedo (skill 2/25m/sec)	550mm	200E	-5	-	-	11	1.7t/1.7m^3	1.6t	1	1i	25	400k
Torpedo (skill 3/25m/sec)	550mm	220E	-5	-	-	13	1.7t/1.7m^3	1.6t	1	1i	20	1.6m
Torpedo (skill 3/30m/sec)	550mm	240E	-5	-	-	15	1.7t/1.7m^3	1.6t	1	1i	15	2.0m

Active Sensors*	TL	Mass	Volume	Cost	Power	Antenna	Resolution	@1km	@10km	@100km	@1000km
Rating 1 (range/100)	9	640kg	.64m^3	6.4KCr	8.5kw	1m^2	1cm per 10m	1m	-	-	-
Rating 2 (range/1000)	9	10 ton	10m^3	100KCr	133kw	4m^2		1m	10m	-	-
Rating 2 (range/1000)	10	1.2 ton	1.2m^3	12KCr	12kw	4m^2	1cm per 50m	20cm	2m	-	-
Rating 3 (range/10000)	10	20 ton	20m^3	200KCr	200kw	9m^2		20cm	2m	20m	-
Rating 2 (range/1000)	11	400kg	.40m^3	4.0KCr	2.9kw	4m^2	1cm per 250m	4cm	40cm	-	-
Rating 3 (range/10000)	11	6.0 ton	6.0m^3	60KCr	44kw	9m^2		4cm	40cm	4m	-
Rating 4 (range/100000)	11	100 ton	100m^3	1.0MCr	730kw	16m^2		4cm	40cm	4m	40m
Rating 2 (range/1000)	12	160kg	.16m^3	1.6KCr	.82kw	4m^2	1cm per 1km	1cm	10cm	-	-
Rating 3 (range/10000)	12	2.6 ton	2.6m^3	26KCr	13kw	9m^2		1cm	10cm	1m	-
Rating 4 (range/100000)	12	40 ton	40m^3	400KCr	204kw	16m^2		1cm	10cm	1m	10m
Rating 3 (range/10000)	13	1.2 ton	1.2m^3	12KCr	4.1kw	9m^2	1cm per 5km	<1cm	2cm	20cm	-
Rating 4 (range/100000)	13	20 ton	20m^3	200KCr	68kw	16m^2		<1cm	2cm	20cm	2m
Rating 5 (range/1000000)	13	320 ton	320m^3	3.2MCr	1.1Mw	25m^2		<1cm	2cm	20cm	2m
Rating 3 (range/10000)	14	640kg	.64m^3	6.4KCr	1.4kw	9m^2	1cm per 25km	<1cm	<1cm	4cm	-
Rating 4 (range/100000)	14	10 ton	10m^3	100KCr	22kw	16m^2		<1cm	<1cm	4cm	40cm
Rating 5 (range/1000000)	14	160 ton	160m^3	1.6MCr	352kw	25m^2		<1cm	<1cm	4cm	40cm
Rating 3 (range/10000)	15	480kg	.48m^3	4.8KCr	.62kw	9m^2	1cm per 100km	<1cm	<1cm	1cm	-
Rating 4 (range/100000)	15	8.0 ton	8.0m^3	80KCr	10kw	16m^2		<1cm	<1cm	1cm	10cm
Rating 5 (range/1000000)	15	120 ton	120m^3	1.2MCr	156kw	25m^2		<1cm	<1cm	1cm	10cm

*AWR 1. Assumes a manned sensor, a control console and a 360° field of view, like a ground-based radar installation.

Velocity Conversions

Velocity	Metric	Imperial	Nautical	per 5 sec	per 10 sec	per 30 sec	per minute	per 2 min	per 5 min
1m/sec	3.6kph	2.2mph	1.9kt	5m	10m	30m	60m	120m	300m
2m/sec	7.2kph	4.5mph	3.9kt	10m	20m	60m	120m	240m	600m
3m/sec	10.8kph	6.7mph	5.8kt	15m	30m	90m	180m	360m	900m
4m/sec	14.4kph	8.9mph	7.8kt	20m	40m	120m	240m	480m	1,200m
5m/sec	18.0kph	11.2mph	9.7kt	25m	50m	150m	300m	600m	1,500m
6m/sec	21.6kph	13.4mph	11.7kt	30m	60m	180m	360m	720m	1,800m
7m/sec	25.2kph	15.7mph	13.6kt	35m	70m	210m	420m	840m	2,100m
8m/sec	28.8kph	17.9mph	15.6kt	40m	80m	240m	480m	960m	2,400m
9m/sec	32.4kph	20.1mph	17.5kt	45m	90m	270m	540m	1,080m	2,700m
10m/sec	36.0kph	22.4mph	19.4kt	50m	100m	300m	600m	1,200m	3,000m
12m/sec	43.2kph	26.8mph	23.3kt	60m	120m	360m	720m	1,440m	3,600m
14m/sec	50.4kph	31.3mph	27.2kt	70m	140m	420m	840m	1,680m	4,200m
16m/sec	57.6kph	35.8mph	31.1kt	80m	160m	480m	960m	1,920m	4,800m
18m/sec	64.8kph	40.3mph	35.0kt	90m	180m	540m	1080m	2,160m	5,400m
20m/sec	72.0kph	44.7mph	38.9kt	100m	200m	600m	1200m	2,400m	6,000m
22m/sec	79.2kph	49.2mph	42.8kt	110m	220m	660m	1320m	2,640m	6,600m
24m/sec	86.4kph	53.7mph	46.7kt	120m	240m	720m	1440m	2,880m	7,200m
26m/sec	93.6kph	58.2mph	50.5kt	130m	260m	780m	1560m	3,120m	7,800m
28m/sec	101kph	62.6mph	54.4kt	140m	280m	840m	1680m	3,260m	8,400m
30m/sec	108kph	67.1mph	58.3kt	150m	300m	900m	1800m	3,600m	9,000m
32m/sec	115kph	71.6mph	62.2kt	160m	320m	960m	1920m	3,840m	9,600m
34m/sec	122kph	76.1mph	66.1kt	170m	340m	1020m	2040m	4,080m	10.2km
36m/sec	130kph	80.5mph	70.0kt	180m	360m	1080m	2160m	4,320m	10.8km
38m/sec	137kph	85.0mph	73.9kt	190m	380m	1140m	2280m	4,560m	11.4km
40m/sec	144kph	89.5mph	77.8kt	200m	400m	1200m	2400m	4,800m	12.0km
42m/sec	151kph	93.9mph	81.6kt	210m	420m	1260m	2520m	5,040m	12.6km
44m/sec	158kph	98.4mph	85.5kt	220m	440m	1320m	2640m	5,280m	13.2km
46m/sec	166kph	103mph	89.4kt	230m	460m	1380m	2760m	5,520m	13.8km
48m/sec	173kph	107mph	93.3kt	240m	480m	1440m	2880m	5,760m	14.4km
50m/sec	180kph	112mph	97.2kt	250m	500m	1500m	3000m	6,000m	15.0km
52m/sec	187kph	116mph	101kt	260m	520m	1560m	3120m	6,240m	15.6km
54m/sec	194kph	121mph	105kt	270m	540m	1620m	3240m	6,480m	16.2km
56m/sec	202kph	125mph	109kt	280m	560m	1680m	3360m	6,720m	16.8km
58m/sec	209kph	130mph	113kt	290m	580m	1740m	3480m	6,960m	17.4km
60m/sec	216kph	134mph	117kt	300m	600m	1800m	3600m	7,200m	18.0km
62m/sec	223kph	139mph	121kt	310m	620m	1860m	3720m	7,440m	18.6km
64m/sec	230kph	143mph	124kt	320m	640m	1920m	3840m	7,680m	19.2km
66m/sec	238kph	148mph	128kt	330m	660m	1980m	3960m	7,920m	19.8km
68m/sec	245kph	152mph	132kt	340m	680m	2040m	4080m	8,160m	20.4km
70m/sec	252kph	157mph	136kt	350m	700m	2100m	4200m	8,400m	21.0km
72m/sec	259kph	161mph	140kt	360m	720m	2160m	4320m	8,640m	21.6km
74m/sec	266kph	166mph	144kt	370m	740m	2220m	4440m	8,880m	22.2km
76m/sec	274kph	170mph	148kt	380m	760m	2280m	4560m	9,120m	22.8km
78m/sec	281kph	174mph	152kt	390m	780m	2340m	4680m	9,360m	23.4km
82m/sec	295kph	183mph	159kt	410m	820m	2460m	4920m	9,840m	24.6km
86m/sec	310kph	192mph	167kt	430m	860m	2580m	5160m	10.3km	25.8km
88m/sec	317kph	197mph	171kt	440m	880m	2640m	5280m	10.6km	26.4km
92m/sec	331kph	206mph	179kt	460m	920m	2760m	5520m	11.0km	27.6km
96m/sec	346kph	215mph	187kt	480m	960m	2880m	5760m	11.5km	28.8km
100m/sec	360kph	224mph	194kt	500m	1000m	3000m	6000m	12.0km	30.0km
110m/sec	396kph	246mph	214kt	550m	1100m	3300m	6600m	13.2km	33.0km
120m/sec	432kph	268mph	233kt	600m	1200m	3600m	7200m	14.4km	36.0km
130m/sec	468kph	291mph	253kt	650m	1300m	3900m	7800m	15.6km	39.0km
140m/sec	504kph	313mph	272kt	700m	1400m	4200m	8400m	16.8km	42.0km
150m/sec	540kph	336mph	292kt	750m	1500m	4500m	9000m	18.0km	45.0km
160m/sec	576kph	358mph	311kt	800m	1600m	4800m	9600m	19.2km	48.0km
170m/sec	612kph	380mph	330kt	850m	1700m	5100m	10.2km	20.4km	51.0km
180m/sec	648kph	403mph	350kt	900m	1800m	5400m	10.8km	21.6km	54.0km
190m/sec	684kph	425mph	369kt	950m	1900m	5700m	11.4km	22.8km	57.0km
200m/sec	720kph	447mph	389kt	1000m	2000m	6000m	12.0km	24.0km	60.0km
220m/sec	792kph	492mph	428kt	1100m	2200m	6600m	13.2km	26.4km	66.0km
240m/sec	864kph	537mph	467kt	1200m	2400m	7200m	14.4km	28.8km	72.0km
260m/sec	936kph	582mph	505kt	1300m	2600m	7800m	15.6km	31.2km	78.0km
280m/sec	1008kph	626mph	544kt	1400m	2800m	8400m	16.8km	33.6km	84.0km
300m/sec	1080kph	671mph	583kt	1500m	3000m	9000m	18.0km	36.0km	90.0km
350m/sec	1260kph	783mph	680kt	1750m	3500m	10.5km	21.0km	42.0km	105.km
400m/sec	1440kph	895mph	778kt	2000m	4000m	12.0km	24.0km	48.0km	120.km
450m/sec	1620kph	1007mph	875kt	2250m	4500m	13.5km	27.0km	54.0km	135.km
500m/sec	1800kph	1118mph	972kt	2500m	5000m	15.0km	30.0km	60.0km	150.km

How to use this table:
Cross-reference the vehicle's velocity in m/sec with the distance or unit of measurement desired.

Vehicle name:

Configuration (Material type)	TL	Area.	L x W x D		Mass	Volume	Cost
		m^3	m		kg	m^3	Cr
		m^3	m		kg	m^3	Cr

Power Plant	TL	Type.	Durability	Power	Mass	Volume	Cost
			hr	kw	kg	m^3	Cr
			hr	kw	kg	m^3	Cr
			hr	kw	kg	m^3	Cr
			hr	kw	kg	m^3	Cr

Fuel		Type.	Durability		Mass	Volume	Cost
			x		kg	m^3	Cr
			x		kg	m^3	Cr
			x		kg	m^3	Cr
			x		kg	m^3	Cr

Power Train	TL	Type.	Top Speed	Power	Mass	Volume	Cost
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr

Seating & Accomodations	TL	Type.	Quantity	Power	Mass	Volume	Cost
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr

Armor	TL	Type.	Facing	Power	Mass	Volume	Cost
			Front( )		kg		Cr
			Rear( )		kg		Cr
			R.Side( )		kg		Cr
			L.Side( )		kg		Cr
			Top( )		kg		Cr
			Bottom( )		kg		Cr

Other Surface Treatments	TL	Type.	Modifier	Power	Mass	Volume	Cost
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr

Accessories	TL	Type.	Quantity	Power	Mass	Volume	Cost
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr
			x	kw	kg	m^3	Cr

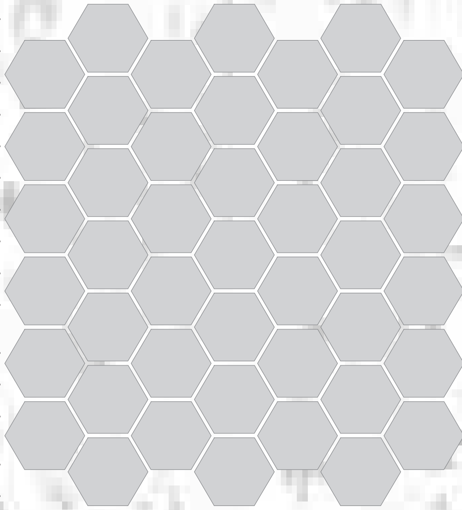
Totals:	Power	Mass	Volume	Cost
	kw	kg	m^3	Cr

VEHICLE : ____________________

FRONT : ____
REAR : ____
R.SIDE : ____
L.SIDE : ____
TOP : ____
BOTTOM : ____
WINDOWS : ____
SENSORS : ____
CONTROLS: ____
ENGINE : ____

MAX : ____
ACC/DEC : ____
TURN : ____

PASS. : ____
CARGO : ____
RANGE : ____
FUEL : ____ SIZE MODIFIER : ____ TOUGHNESS : ____



SPECIAL FEATURES

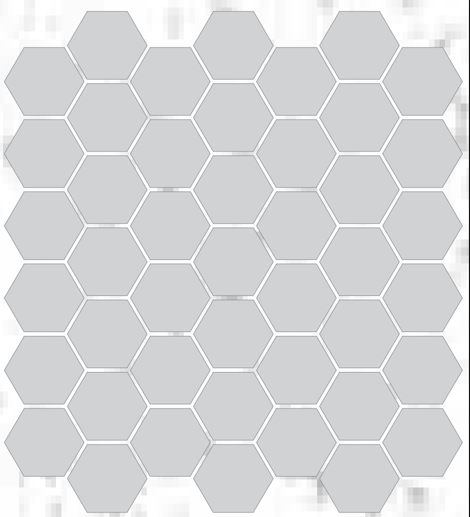
ACCESSORIES AND EQUIPMENT

VEHICLE : ____________________

FRONT : ____
REAR : ____
R.SIDE : ____
L.SIDE : ____
TOP : ____
BOTTOM : ____
WINDOWS : ____
SENSORS : ____
CONTROLS: ____
ENGINE : ____

MAX : ____
ACC/DEC : ____
TURN : ____

PASS. : ____
CARGO : ____
RANGE : ____
FUEL : ____ SIZE MODIFIER : ____ TOUGHNESS : ____



SPECIAL FEATURES

ACCESSORIES AND EQUIPMENT

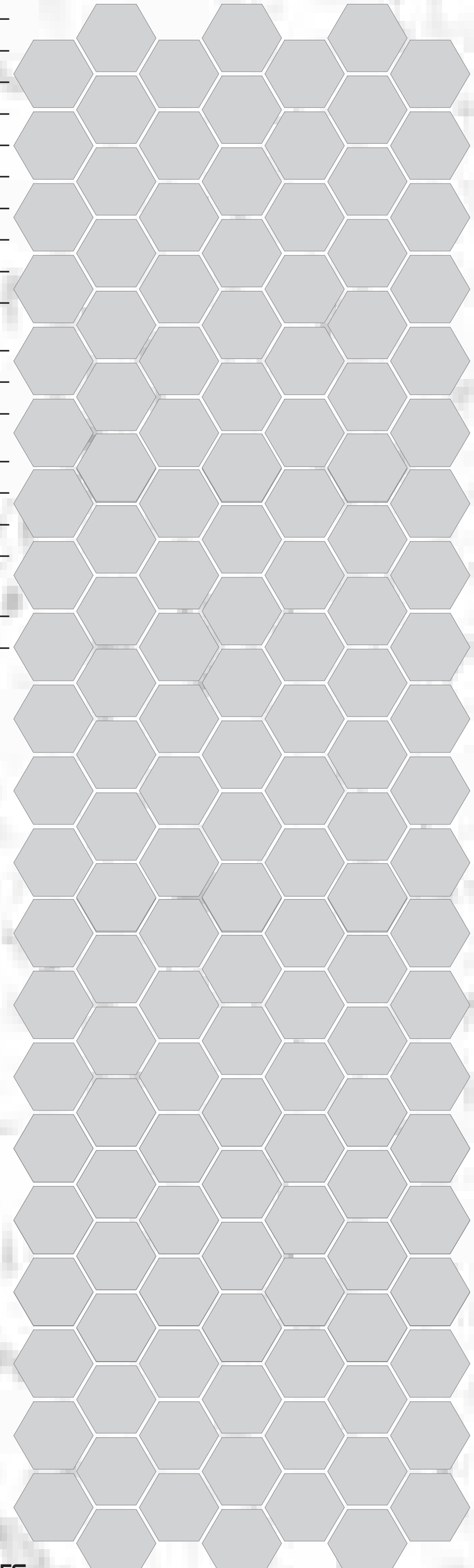
VEHICLE : ____________________

FRONT : ____
REAR : ____
R.SIDE : ____
L.SIDE : ____
TOP : ____
BOTTOM : ____
WINDOWS : ____
SENSORS : ____
CONTROLS: ____
ENGINE : ____

MAX : ____
ACC/DEC : ____
TURN : ____

PASS. : ____
CARGO : ____
RANGE : ____
FUEL : ____

SIZE MOD.: ____
TOUGHN. : ____



SPECIAL FEATURES

ACCESSORIES AND EQUIPMENT

Vehicle :

Front :
Rear :
R.Side :
L.Side :
Top :
Bottom :
Windows :
Sensors :
Controls:
Engine 1 :
Engine 2 :
Engine 3 :
Engine 4 :
Pwr.Trn 1:
Pwr.Trn 2:
Struct. :

Max :
Acc/Dec :
Stall :
Turn :

Pass. :
Cargo 1 :
Cargo 2 :
Hangar 1:
Hangar 2:
Range :
Fuel 1 :
Fuel 2 :
Fuel 3 :
Fuel 4 :

Size Mod:
Toughn. :

Special Features

Accessories and Equipment

Notes

VEHICLE DESIGN 1.0

- YOU CAN NEVER HAVE TOO BIG AN ENGINE
- YOU CAN NEVER HAVE TOO MUCH ARMOR
- YOU CAN NEVER HAVE TOO MANY WEAPONS

CORPS VDS does for vehicles what 3G³ did for weapons: Provide a comprehensive design tool that can be plugged into any roleplaying system. Covers everything from rowboats to starships, past, present, future and then some. If you can imagine it, you can build it. Whether you can afford it is another matter entirely...

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