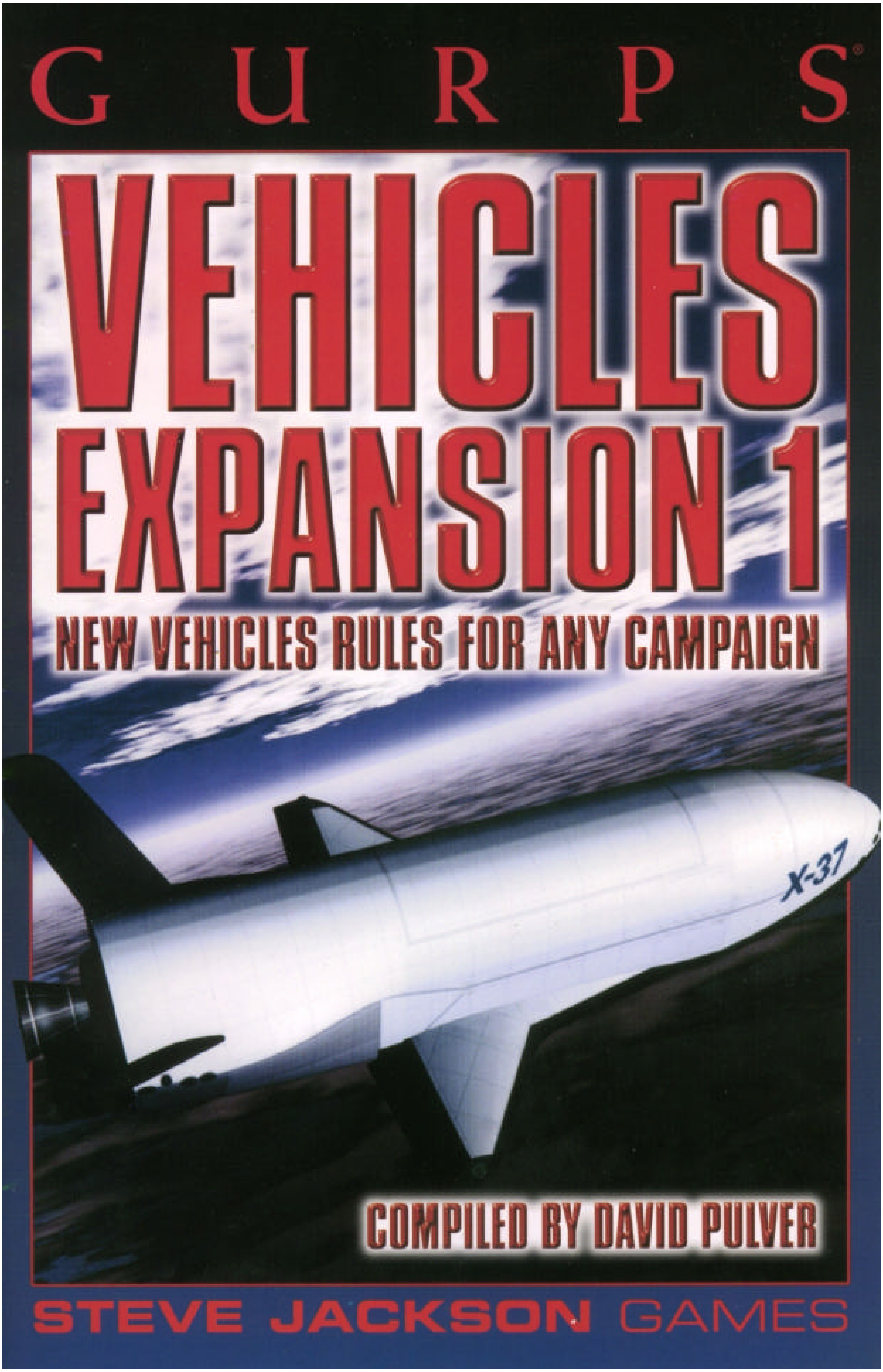

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VEHICLES
EXPANSION 1
NEW VEHICLES RULES FOR ANY CAMPAIGN
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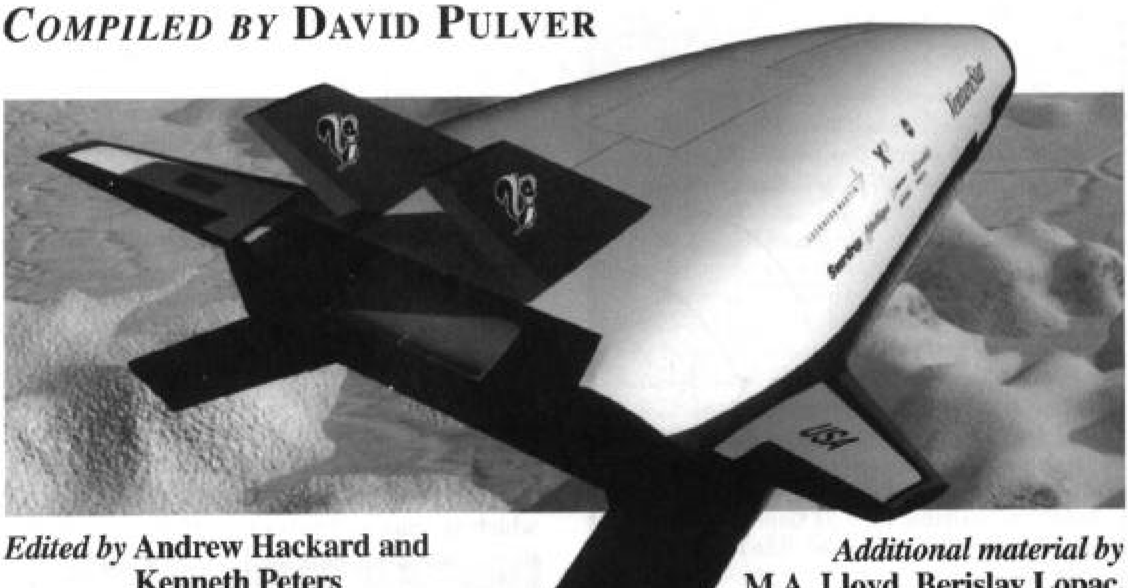
GURPS

VEHICLES 1 EXPANSION

COMPILED BY DAVID PULVER



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STEVE JACKSON GAMES

INTRODUCTION

About GURPS

Steve Jackson Games is committed to full support of the *GURPS* system. Our address is SJ Games, Box 18957, Austin, TX 78760. Please include a self-addressed, stamped envelope (SASE) any time you write us! Resources include:

Pyramid (www.sjgames.com/pyramid/). Our online magazine includes new *GURPS* rules and articles. It also covers *Dungeons and Dragons, Traveller, World of Darkness, Call of Cthulhu,* and many more top games - and other Steve Jackson Games releases like *In Nomine, INWO, Car Wars, Toon, Ogre Miniatures,* and more. *Pyramid* subscribers also have access to playtest files online!

New supplements and adventures. GURPS continues to grow, and we'll be happy to let you know what's new. A current catalog is available for an SASE. Or check out our website (below).

Errata. Everyone makes mistakes, including us - but we do our best to fix our errors. Up-to-date errata sheets for all *GURPS* releases, including this book, are available from SJ Games; be sure to include an SASE. Or download them from the Web see below.

Gamer input. We value your comments, for new products as well as updated printings of existing titles!

Internet. Visit us on the World Wide Web at www.sjgames.com for an online catalog, errata, updates, Q&A, and much more. *GURPS* has its own Usenet group, too: rec.games.frp.gurps.

GURPSnet. This e-mail list hosts much of the online discussion of *GURPS. To* join, e-mail majordomo@io.com with "subscribe GURPSnet-L" in the body, or point your web browser to gurpsnet.sjgames.com.

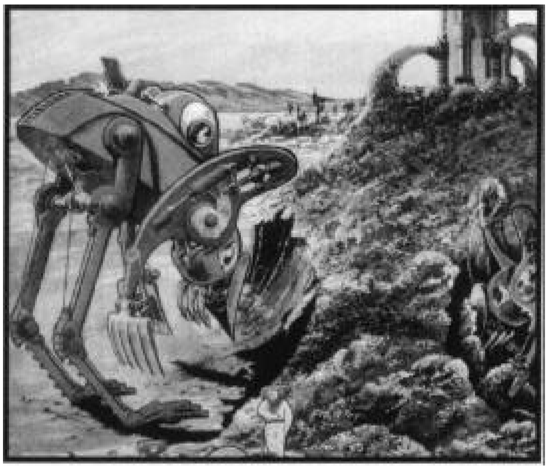
Page References

Rules and statistics in this book are specifically for the *GURPS Basic Set, Third Edition.* Any page reference that begins with a B refers to the *GURPS Basic Set - e.g.,* p. B 102 means p. 102 of the *GURPS Basic Set, Third Edition.* Page references that begin with Cl indicate *GURPS Compendium I.* Other references are CW for *GURPS Cyberworld, HT* for *GURPS High-Tech,* and VE for *GURPS Vehicles, Second Edition.* For a full list of abbreviations, see p. CI181 or the web list at

This supplement to *GURPS Vehicles, Second Edition* provides additional design options, components, and performance rules for creating and operating vehicles.

GURPS Vehicles Expansion 1 focuses on new features, subassemblies, and components that can be used to create more specialized vehi cle designs, or offer alternative byways to existing technology paths. A second purpose of this book is to enhance *GURPS Vehicles'* ability to pass a reality check. To this end, some rules are marked as "extra detail." These optional expansions of existing *GURPS Vehicles* rules provide added realism at the expense of greater complexity or more detailed calculation.

GURPS Vehicles Expansion 1 would not have been possible without the substantial contributions of M.A. Lloyd. A vociferous playtester and tireless advocate of system realism, M.A. Lloyd created a vast array of supplementary material for *GURPS Vehicles,* a good chunk of which appears in this book. Additional contributions came from Berislav Lopac (expanded sailing rules), Shawn Fisher, Anthony Jackson, Phil Masters, Kenneth Peters, William H. Stoddard, and others too numerous to mention.



About the Compiler

David L. Pulver is a writer, game designer, and editor who lives in Victoria, British Columbia. He is the author of numerous roleplaying games and supplements, including *GURPS Vehicles* and *Transhuman Space.*

DESIGN OPTIONS 1

This chapter describes alternative approach es to vehicle technology and design, including options for creating subassemblies, body IPAtures, structures, and armor that expan rules in Chapter 1 of *GURPS Vehicles*.

SUPERSCIENCE

GURPS Space and ***GURPS Ultra-Tech 2*** divided technological developments into those that seemed reasonably plausible ("hard sci ence") and those that postulate changes in the physical laws as we know them today (called "superscience").

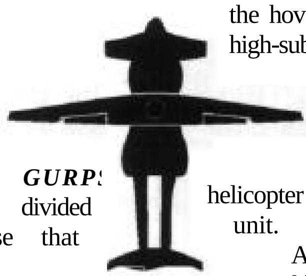
Superscience devices are assigned TLs, but these should be considered arbitrary, and the GM should feel free to change them if it suits the campaign. For example, it can be interesting to add a single newly discovered superscience technology. such as hyperdrive or cosmic power, to a modern society (TL6-8) and explore the ramifications.

SUPERSCIENCE IN GURPS VEHICLES

The following technologies from ***GURPS Vehicles*** are examples of superscience: reactionless thrusters, stardrives, parachronic conveyers, contragravity genera tors, gravity communicators, FTL communicators, mul-tiscanners and gravscanners, psionic technology, tele-port projectors, screen generators, artificial gravity units, gravity webs, grav compensators, cosmic power plant, force field grids, gravitic guns, paralysis beams, fusion beam, gravity beam, disintegrator, and displacer.

These technologies have sound operating princi-ples, but their amazing performance qualifies them as superscience: TL9 and TL10 fusion rocket, all power cells, radiation shielding, neutrino communicators, MHD tunnels, neutrino-homing guidance, X-ray laser, and graser. More realistic alternatives to some of these technologies are described in this book.

Canard Rotor Wing (CRW, TL8)



This wing subassembly design combines the hover efficiency of a helicopter with the high-subsonic cruise speed of a fixed wing aircraft. It consists of a small forward wing (canard), a large but narrow top-mounted wing that can also spin like a helicopter rotor, and a rear twin-boom tail unit.

A CRW is treated as a wing sub-assembly (p. VE8), except that the combi-nation of wings (both wings, tail, and canard) is treated as a single subassembly, rather than a pair of wings. No components can be built into its wings. The vehicle may have up to Very Good streamlining.

Structures: The total wing volume (p. VE17) should not exceed 0.15 x body volume, and will be nothing but empty space; as usual for standard wings, multiply area by 1.5. On the *Vehicle Structure Table (p.* VE19) use the *Wings or Rotors* row for weight and cost multipliers. Treat as a wing for calculation of hit points.

Propulsion Systems: A vehicle with a CRW must be given a reaction rotor drivetrain (p. 12) and a reaction engine (p. VE35 or p. 11), usually a turbojet or turbofan. The engine must be mounted in the body; the combination allows aerial vehicle propulsion.

Performance: A vehicle with a CRW has both helicopter-mode and airplane-mode performance characteristics. Use the figures for the reaction rotor drivetrain (p. 12) to determine helicopter mode statistics and the performance of the jet engine and wing to determine airplane-mode statistics.

The vehicle can change into heli-copter mode at any speed below 300 mph, or into airplane mode at any speed over the aircraft's stall speed. This takes one second, during which time it is treat ed as being in the previous mode. It may not accelerate, decelerate, or maneuver during this time. In helicopter mode, the vehicle may not exceed 300 mph, regardless of streamlining.

Massive Motive Subassemblies (TL1)

Some vehicles have extremely large tracks or wheels for their size, such as monster trucks or Ogre cybertanks. Standard, heavy, and off-road wheels and tracks, skitracks, or halftracks can have any amount of waste space added. Typically this can be simplified to a straight multiplier of the subassembly's base volume (p. VE17); a multiplier of 2 for hostile environment wheels or 4 or more for monster trucks is appropriate.

Body Features

These include streamlining, articulation, and other options - see *Body Features*, p. VE 10.

Motive Body Features

These body features affect the vehicle's mobility on the ground.

Articulation (TL5)

This is an option for any vehicle with tracks, halftracks, or wheel motive subassemblies (pp. VE6-7). The vehicle body is jointed in the middle to allow a smaller turning area and improve performance over rough ground. This feature is common on very large vehicles: giant mobile exploration bases, huge cyber tanks, and so on. It can also model some train carriages. The vehicle may also (GM's option) be able to turn corners that would otherwise be impossible for a vehicle of its size. When determining body volume, multiply by 1.1 to account for the space lost. Ground Stability Rating (gSR) is improved by 1. There is no other cost or weight increase.

Wheelform Propulsion (Late TL6)

A vehicle with this option is shaped like a giant wheel. The body does not rotate, but is surrounded by a rotating tire or tread that propels the vehicle. Fictional wheelform vehicles tend to be well-armored, menacing fighting machines built to terrorize opponents. Real world vehicles tend to be light-weight motorcycle variants.

A wheelform vehicle requires a "wheelform drivetrain" (with the same TL, weight, volume, and cost as a tracked drivetrain, p. VE31) housed in the vehicle's body. A wheelform vehicle can not have any other subassemblies unless they can attach to its sides, such as a side-mounted turret or pod.

A wheelform vehicle moves on the ground. The ground speed, gAccel, gDecel, gMR, and gSR are calculated as if it were a vehicle with one off-road wheel and all-wheel drive, but its ground pressure is calculated as if it were tracked, only using one-fifth of its body area to find contact area. At the GM's discretion any wheel option (p. VE21) with the exception of all-wheel steering can be applied to a wheelform system.

A wheelform vehicle that crashes head-on into anything does +1 per die crushing damage. It can perform an Overrun (p. VE158) even if its Size Modifier is only 1 greater than its target (provided it inflicts twice the damage it suffers) and does +1 per die of damage when overrunning. A wheelform propulsion system is disabled only if the vehicle body is disabled, but for tire damage and hit points, use one-fifth of the body hit points.

Underbelly Skids (TL0)

A vehicle with no underside subassemblies may be designed to use the entire underside as a skid. No skid subassembly is required, but the vehicle must have an underside DR 5 or more and may not have an extra-light or super-light

The vehicle's ground performance is as per skids, except that the contact area for determining ground pressure is body surface area/20. There is no extra cost or weight for this option. It is particularly common on lifting-body aerospace craft. They give -1 penalty to gSR and (like small wheels) have no off-road performance.

Hydrodynamic and Supercavitating Hulls

These are additional options for the hydrodynamic hull body feature on pp. VE10-11:

Spherical Pressure Hull (TL5)

This special hull shape gives a vehicle extreme pressure resistance, and is mostly used by deep sea research and salvage craft. It gives a body volume multiplier (see p. VE16) of 1.9, and can't be combined with any streamlining or hydrodynamic lines. However, accommodations and other components may be placed within spherical pressure hulls inside a larger hull with any level of hydrodynamic lines or streamlining, or inside an unstreamlined submersible hull. If an outer hull has submarine lines, than an internal spherical hull can be no larger than 10% of the volume of the outer hull.

Extra Detail – Submarine Lines

Although listed as TL7, ordinary submarine lines (p. VEll) are realistically available at TL6, though not widely used (since many TL6 subs are optimized for surface cruising).

Advanced Submarine Lines (TL7)

This shape is optimized for swift underwater travel. Advanced Submarine Lines, sometimes known as an "albacore hull," were first seen on the USS Albacore in 1953.

These are mostly used by nuclear submarines, giving a body volume multiplier (see p. VE16) of 1.3 and a divisor when calculating Submerged Hydrodynamic Drag (see p. VE132) of Ls = 20. For all other purposes, they are treated exactly as Submarine Lines.

Supercavitating Hull (TL8)

Cavitation is the formation of vapor-filled bubbles in a fluid caused by changes in the speed of objects moving rapidly through it. Originally a nuisance for aquatic craft when produced inadvertently by screw propellers, cavitation can also be used advantageously.

Supercavitating hulls use careful hull design to promote the smooth formation of a single vapor-filled cavity, a giant bubble, surrounding most of a vehicle. Creating a supercavity requires moving at high speed, but once the supercavity bubble forms, most of the hull is no longer in contact with water. Drag is significantly reduced, allowing the vessel to accelerate to even higher speeds, or to sustain its speed with less effort.

The supercavitating hull option can be added to a vehicle with Mediocre or better hydrodynamics or any type of submarine lines. It includes changes in the design of the bow - vessels with supercavitating lines tend to be elongated, with wedge, conic, or paraboloid noses and adds bow- or strut-mounted control surfaces which project out of the bubble, allowing the vessel to maneuver while supercavitating.

Propulsion systems usable while the vehicle is supercavitating must be able to function with most of the vehicle in a trace atmosphere of water vapor. This rules out most conventional aquatic propulsion systems. Instead, the vessel usually uses underwater rockets (p. 10) or vortex combustion jets (p. 10); if superscience technologies exist, it can also use reactionless thrusters (p. VE38) or grav-rams (p. 11).

Vehicle Structural Options

These are further options for vehicle structures (pp. VE18-20). See the Additions to Vehicle Structure Table (see p. 6) for their cost and weight modifiers.

Ultra-Heavy Frame Strength (TL1)

This is available for vehicles that are essentially blocks of armor with components embedded inside, such as Ogre-era cybertanks. Most vehicles with this option will be unmanned, with a robotic structure.

Extra Detail – Structural Weight and Cost

Realistically, a vehicle's need for structural support scales with the greater of size or surface area. Instead of using structural area to determine a vehicle's structural weight and cost, use the higher of structural area or structural volume (the sum of body and subassembly volume, excluding masts, open mounts, and gasbags). This gives more realistic structural weight values for large vehicles, and is used in **Transhuman Space.**

If the vehicle has a crew, it must have a total volume at least 50 times the volume of all space and components devoted to crew and passengers (e.g., crew stations, seats, quarters, habitat modules, access space, etc.). DR must also be at least 100 x TL (minimum DR 100).

When calculating vehicle hit points (p. VE20), an ultra-heavy frame multiplies HP by 8. For purposes of calculating crush depth (p. 30) the frame multiplier is 8.

Multi-Section (TL5)

Vehicles can be designed to break down into modules for easy transport. The volume and weight of each individual module is the vehicle's volume (excluding cargo space, access space, and half the volume of crew stations or seats) and empty weight divided by the number of modules it breaks down into.

Disassembly or assembly time is 0.01 man-hours times the number of modules times the vehicle's Size Modifier (minimum 1). If total volume is less than 100 cf, a mechanic's toolkit is required to assembly the vehicle. Otherwise an actual machine shop or vehicle assembly yard is needed. A Mechanic skill roll at +2 is required to assemble or disassemble the vehicle properly.

Failure means the time was wasted, but another attempt may be made; critical failure means a vital part is damaged.

Additions to Vehicle Structure Table

Feature	Weight	Cost
Frame Strength		
Ultra-Heavy	x3	x10
Special Structure and Other Modifiers		
Multi-Section	x1.1	x4
Supercavitating Hull	x1.05	x5
Wheelform	x1.2	x1.2

See the *Vehicle Structure Table (p.* VE19) for an explanation. These multipliers are cumulative with the multipliers on that table.

Extra Detail – HT Scores and Winged Vehicles

In some winged vehicles the body is actually fairly small compared to the wing. This includes many flying wing and blended wing-body designs.

If the sum of all wing hit points exceeds the hit points of the body, they may be used instead of the body when calculating the vehicle's HT statistic.

Spin Gravity

Space is a zero-G environment, but most humans (and probably other planet-born races) are physically and mentally accustomed to life in a gravity field. If superscience technology cannot create artificial gravity (p. VE78), the only way to produce real gravity is with mass. To produce Earth-equivalent gravity, a space vessel requires an Earth-like mass, which is not very practical. Instead, vessels accelerate or spin to simulate gravity.

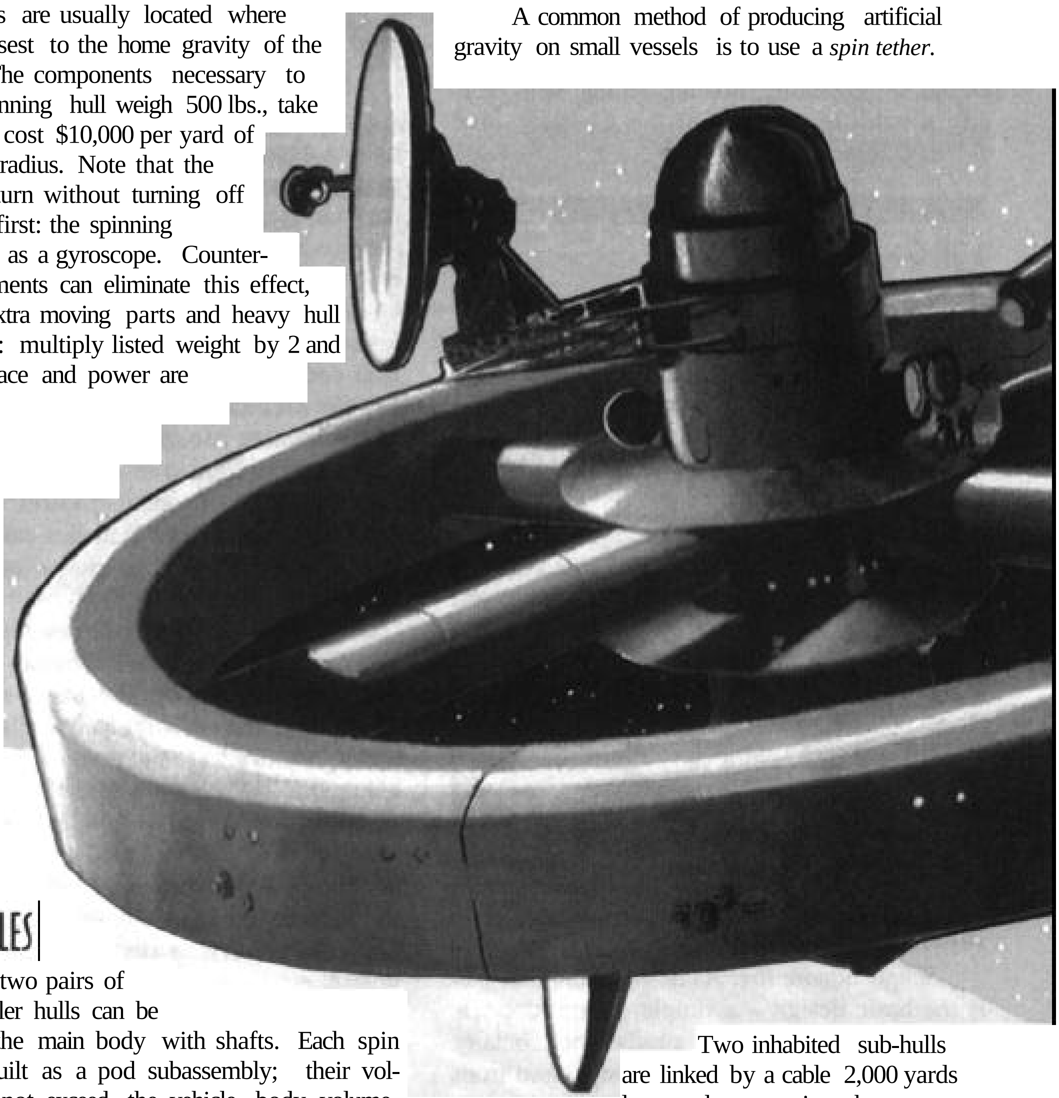
A spacecraft under acceleration will produce effective gravity equal to its sAccel rating. However, unless reactionless thrusters or equivalent technology exists, spacecraft are usually unable to sustain such high accelerations for more than a few hours. The alternative is *spin gravity.*

Spin gravity simulates gravity through centrifugal force. However, the spin cannot be too fast, or it induces motion sickness and structural stress. Spin can be provided in various ways - see below. Gravity depends on the *spin radius,* which varies depending on the mechanism used. At a tolerable spin rate, the *maximum* simulated gravity (G) equals spin radius (in feet) divided by 300; gravity can be reduced by using a slower rotation rate. A spin radius of triple this (maximum G = radius/1,000) is usual for large space stations, to ensure that no one experiences motion sickness. As a general rule, any vehicle or pod with a super-light or extra-light frame cannot safely withstand spin gravity of over 0.001 G.

Spin gravity does not behave quite like real gravity. Move in the direction of spin, and gravity increases; move in the reverse direction, and gravity drops. Individuals unused to spin gravity are at -2 DX. Double this when jumping, throwing, or using low-speed missile weapons like bows; halve it in an extremely large spin-gravity habitat (10 times the minimum tolerable radius for the desired gravity). Each week, a HT roll should be made to adapt to this environment and eliminate the penalties. Those with the G-Experience advantage (p. C125) halve all penalties; those with the Motion Sickness disadvantage (p. CI82) double all penalties and get no HT roll to adapt.

Spinning Hull

A vehicle body (generally shaped like a torus, sphere, or cylinder) can be spun via external assistance for a space station, or by thrusters or reaction engines for a spacecraft. An outer spinning hull may surround a stationary inner hull. A spin-gravity section should have a spin radius of at least 100 yards (300') per G. To contain this, a vehicle needs to be designed with a body volume of at least [8 *x* spin radius (in yards) cubed] cf if unstreamlined, or [1,000 *x* spin radius (in yards) cubed] cf if streamlined. Going partway to the center of rotation reduces gravity proportionally; living quarters are usually located where gravity is closest to the home gravity of the occupants. The components necessary to support a spinning hull weigh 500 lbs., take up 25 cf, and cost $10,000 per yard of spin-section radius. Note that the ship cannot turn without turning off spin gravity first: the spinning segment acts as a gyroscope. Counter-rotating segments can eliminate this effect, but require extra moving parts and heavy hull reinforcement: multiply listed weight by 2 and cost by 5. Space and power are unchanged.



Spin Capsules

One or two pairs of second, smaller hulls can be attached to the main body with shafts. Each spin capsule is built as a pod subassembly; their volume should not exceed the vehicle body volume, and each should have the same volume and approximately the same weight of components, armor, and surface features as the other(s). Each capsule requires a spin arm, the pylon (and machinery) that supports it. Select the spin radius (in feet) and calculate weight and cost of spin arms as follows:

Spin Arm weight =

Spin Radius (in feet) x **Spin Capsule volume** x T. T is 0.06 at TL8, 0.04 at TL9, 0.03 at TL10, 0.02 at TL 11, and 0.015 at TL 12+.

After determining weight, figure cost as:

Spin arm cost = Spin Arm weight x

A spacecraft cannot change facing without canceling spin first, because the spinning segment acts as a gyroscope. If a spacecraft uses spin capsules, a second pair of counter-rotating capsules negates this effect.

Spin Tethers

A common method of producing artificial gravity on small vessels is to use a *spin tether.*

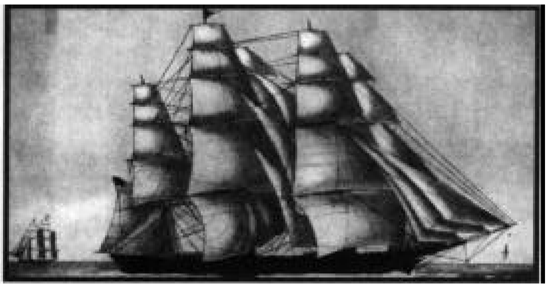
Two inhabited sub-hulls are linked by a cable 2,000 yards long and spun using the spacecraft's (subsumed) reaction control thrusters. To design a vessel with a spin tether, build it as two distinct vehicles, which must be of approximately equal mass (within 5% of loaded weight of each other). The tether itself masses 0.005 lbs. x T per lb. of loaded mass of both vehicles (excluding the tether), where T is as per Spin Arm Weight for spin arms, above. The tether costs $10 per pound of loaded mass. If sufficient cargo space is available, the tether can be retracted. A retracted tether requires 1 cf per 50 lbs. of weight. A spacecraft using spin tethers must retract them and cancel its spin before accelerating or changing facing.

Propulsion and Lift Systems 2

This chapter offers new components and rules for sails, jet engines, space drives, and other means of propelling, floating, lifting, or levitating a vehicle, expanding on Chapter 2 of *GURPS Vehicles.*

Sails – Historical and Contemporary Rigs

The three types of rig described on p. VE30 - square, fore-and-aft, and full rig - represent broad generalizations of possible sail arrangements. Each can be divided into multiple historical and contemporary variations with specific advantages and disadvantages.



Square Rigs

Simple Square Rig: As its name implies, this is the basic design - a simple square piece of cloth hanging from a pole attached horizontally to the mast. It was the primary design used from the Stone Age to the late Middle Ages, although the lugsail challenged its dominance as early as the Roman period.

Spinnaker: This is not a rig, but a large sail which is raised instead of a jib. It greatly enhances the speed when sailing downwind or with wind to the quarters, but is incapable of sailing even with wind abeam. It can be used either with gaff or Bermuda rig on ships with up to two masts, and the numbers in the table include the main sail(s) and a spinnaker.

Asymmetric Spinnaker: A modern variant of the spinnaker, somewhat smaller but designed to enhance a vessel's downwind performance. Also called a "chute."

Fore-and-Aft Rigs

Lugsail: This square sail has been cut to give it a more trapezoidal shape and hung on a slanted pole. Lugsails were the first fore-and-aft rig, placed to one side of the mast and moved from one side to the other to catch wind blowing from the side instead of astern. This significantly lowered the minimum upwind angle.

Lateen: This triangular sail suspended from a slender diagonal yard dates from at least the first century, when it was in use both in the Indian Ocean and by small boats in the Mediterranean. Around 800 A.D., Byzantine and Italian sailors learned to rig ships with it, and it soon became the most popular sail in the Mediterranean. Lateen statistics can also represent Middle-Eastern dhow rigs, except they cannot sail with wind on the bow.

Sprit: A trapezoidal sail developed from the lateen rig. Sprit sails were common in the North Atlantic in the 16th century and in south Asia to the present. The rig is not practical for sails over a few hundred sf, because of the tensions required to support the yard. Subtract 1 from HT for each 100 sf of sail.

Crab Claw: Also called the *proa* or Pacific lateen, this is the traditional Polynesian rig. The sail is three-cornered, filling the space between two convex curving spars meeting at a point, with the free edge concave. Changing tack requires moving the sail to the opposite side of the mast relative to the wind, but Polynesian boats sometimes do this by rotating the sail and using the other end of the ship as the bow.

Gaffsail: A gaffsail is a TL4 development of the sprit sail. The increasingly heavy yard is replaced with a spar along the top of the sail with a jaw to firmly grip the mast. It is still in use today on coastal boats like cats and some schooners, and as part of a full rig.

Bermuda: The most common sail in use today, the Bermuda is the classic triangular sail employed on recreational and regatta sailboats. It is rarely applied by itself (although early 20th-century windjammers had four to six masts with a single Bermuda sail each, with no jibs), and is usually combined with a jib or spinnaker, as shown on the *Expanded Sails Table.*

Except for a sharper upwind sailing angle and simpler rigging, the Bermuda is effectively identical to the gaffsail.

Jib: This triangular sail is attached to a wire that goes from the top of the mast to the prow. It is usually used as an auxiliary sail with either gaff or Bermuda sails (see the *Expanded Sails Table);* its main advantage is that it increases the sail area without adding more masts. It can be used on its own: a jib-only rig; with no other sails, is popular among sailing enthusiasts.

Junk: Developed in the Far East, this rig is the classic sailing design used by Chinese junks and many other Asian sailing vessels. It has one or more masts, each with a single sail of a distinctive "ribbed" design. It is particularly easy to sail (+2 to control rolls).

Full Rigs

As described on p. VE30, a full rig consists of both triangular (i.e., fore-and-aft) and square sails, which gives it the benefit of both It can be applied only on ships with two or more masts. Like all other rigs it developed significantly through history:

Barquentine Rig: This is a full rig which combines fore-and-aft (late TL4: lateen; TL5+: Bermuda or gaff) sails with an equal or smaller number of square sails - usually with square sails on the fore mast and fore-and-aft sails on the other masts. Two area modifiers are given on the table. For a Barquentine rig with an equal number of square and fore-and-aft sails (e.g., two masts, each with different sails) use the higher area modifier; the lower one applies in all other cases.

Standard Full Rig: This type of rig consists of square sails on all masts, with jibs as triangular sails and usually a gaffsail on the aft mast. TL4 full rigs lack jibs and gaffsails; full-rigged ships of that era have lateen sails instead of square on up to half the masts.

Extended Full Rig: This is actually a standard full rig with its sail area enlarged by adding sails wherever possible - usually on poles extending from both ends of the regular yardarms. This type of rig was used by 19thcentury clipper ships which carried tea and spice from the Far East to England, when speed was more important than any other factor - including the ship's stability and the safety of the crew.

The following table shows the effect that rig choice will have on a sailing vessel. Two primary elements influenced by the choice of rig are the area of sails and the minimum angle of sailing upwind.

Expanded Sails Table

Sail/Rig	TL	MUA	Area
Square			
Simple square	1	85°	0.8
Spinnaker	5	105°	1.2
Asymmetric	6	70°	1.1
Fore-and-Aft			
Lugsail	2	40°	0.7
Lateen	2	35°	0.7
Crab Claw	3	25°	0.8
Sprit	3	30°	0.6
Junk	3	20°	0.75
Gaffsail	4	30°	0.6
Bermuda	5	25°	0.6
Lug sail and jib	4	35°	0.8
Gaff and jib	4	25°	0.8
Jib only	4	20°	0.3
Bermuda and jib	5	20°	0.8
Full			
Barquentine	late 4	45°	0.9/0.8
Full (standard)	4	60°	1
Full (extended)	5	75°	1.2

TL: The historical tech level at which the rig originally appeared. Various rigs can appear at different tech levels, depending on the setting.

MUA (Minimum Upwind Angle): This new statistic is the minimum angle between the ship's prow and the wind which still allows it to sail. Use tacking to sail closer to the wind's direction. See *Water Performance: Wind and Sails (pp.* 29-30).

.Area: Area modifier used to determine the sail area of a ship. Use the formula on p. VE31 and then multiply it by the modifier in this table. This replaces the blanket 0.8 modifier for fore and-aft or square rigs.

Weight, cost, and *motive thrust* are determined as per p. VE31.

Historical Rigs

Historically, specific combination of masts and sailing rigs were given individual names: Sloop (TL3): This is one of the most common single-masted riggings since the Middle Ages, and includes a single fore-and-aft sail, often (but not always) with a jib. To design a sloop, use lug, lateen, gaff, gaff and jib, Bermuda, Bermuda and jib, or spinnaker rig. *Cutter* (TL4): Similar to sloop, this design has one mast with two to five jibs, connected to the *bowsprit,* a pole that extends over the boat's prow. Although the great racing yachts built before WWII used cutter rigging, multiple jibs don't improve performance significantly - in game terms, treat them as if there were a single jib. Use gaff and jib, Bermuda and jib, or spinnaker rig.

Extra Detail – TL Rigging Modifiers

Improvements in sailing technology can also affect the ship's performance, primarily concerning two factors: upwind angle and sail efficiency, which determines how well the sails catch the wind. To use these optional modifiers, consult the following table:

TL Rigging Modifiers Table

TL	*MUA modifier*	*Efficiency Modifier*
0-4	-	x0.8
5-6	-5°	x1
7+	-10°	x1.25

MUA Modifier: Apply it to the MUA of the rigging (e.g. a TL7 Bermuda rigging with jibs has a MUA of only 10°).

Efficiency Modifier: Multiply this number by the motive thrust of sails (according to the formula on p. VE30) to get the actual thrust.

Mizzen-masted (TL4-5): These are ships with two masts, one of which - the one abaft - is significantly shorter, never exceeding 2/3 of the main mast's height. There are two common mizzen-masted ships, the ketch and yawl, both similar in game terms. Use gaff, gaff and jib, Bermuda, Bermuda and jib, or spinnaker rig.

Schooner (TL4): A schooner consists of two or more masts with fore-and-aft sails, sometimes without jibs. American windjammers (large sail ing ships with up to six masts which were designed to compete with the new steam ships) used this rigging because of its low crew require ment. Use lug, lateen, gaff, gaff and jib, Bermuda, or Bermuda and jib rig.

Topsail schooner (TL5): This design adds a few square sails to the schooner's fore mast. Use Barquentine rig for two masts, and gaff, gaff and jib, Bermuda, or Bermuda and jib rig for vessels with three or more masts.

Barque (TL4): This is an "almost-full" rig, with square sails on all the masts except the mizzen, which has fore-and-aft sails. Barques always have more than two masts, since a two-masted barque is actually a brigantine (see below). Use full rig.

Barquentine (TL4): Another hybrid design, Barquentine has square sails on the fore mast, and fore-and-aft on the rest. A two-masted Barquentine is called a brigantine. Use Barquentine rig.

Full-rigged ship (TL4): Ship with square sails on all masts, including a few fore-and-aft sails ON and gaffs, with Bermudas on later designs) for improved maneuverability. Use full rig.

Brig and Brigantine (TL4): These two designs are actually the full-rigged and Barquentine rigging, respectively, but with only two masts. Since many small to medium sized ships in the Age of Sail had only two masts, those types of rigging were very common. Use full rig for brig and Barquentine rig for brigantine.

Underwater Conventional Rockets

A rocket engine (p. VE36), fusion air-ram (p. VE36), or fission air-ram (p. 11) can be built to operate while submerged. The high drag of water makes underwater rocketry of limited utility until supercavitation hulls (see p. 5) are developed. After supercavitation is introduced, underwater rockets may become as common as aquatic propellers on special ized, high-speed watercraft.

In order to function underwater, rocket and air-ram engines must have *underwater nozzles.* For rockets, cost and weight are the same; for air-rams, double weight and volume (which will double cost). An underwater nozzle halves thrust due to the back pressure underwater, since it must do more work to push the fluid out of the nozzle. The thrust is also halved in air or space, as the underwater-optimized nozzle area ratio is too small to allow proper expansion of the exhaust.

At TL8+, *adaptive nozzles* are available. Treat as underwater nozzles, except that they alter configuration for air or water: add +20% to cost and allow full thrust in air and space.

Vortex Combustor Ramjets

These are specialized underwater engines burning a metal dust, usually aluminum, using the surrounding water as both oxidizer and reac tion mass. They can be used only for water or underwater propulsion. When used with super-cavitating lines, they can function in a supercavi-ty, since their intakes can be designed to extend beyond the air bubble.

Design Tip – Outboard Motors

These should be built as a screw pro-peller plus a power plant in a pod attached to the rear of the body. The effect will be cor rect: less volume required in the body (as no access space is required for power or propul-sion systems in pods) at some slight increase in body weight (due to the area of the pod).

Vortex Combustor Ramjet Table

TL	Type	Weight	Fuel
8	Vortex CR	0.0375 x thrust	0.22 MD
9+	Vortex CR	0.025 x thrust	0.16 MD

Location: The engine must be placed in the body, a wing, pod or legs.

Weight: This is per pound of motive thrust.

Fuel: The fuel consumption in gallons per hour of metallic dust. This is 18.4 lbs. and $2 per gallon; it does not catch fire.

Volume: The volume is weight/50

cf. *Cost:* The cost is weight *x $100.*

REACTION ENGINES - JETS

All jet engines (see p. VE35) work by pulling in the surrounding air, heating it, and expelling it to produce thrust. They only work in atmospheres of greater than "trace" density. The following additional types of jet engine may be available:

Light Turbofan (TL7): These are lighter weight high-performance engines usually used in small aircraft or cruise missiles. Above 4,000 lbs. thrust (TL7) or 2,000 lbs. thrust (TL8), a normal turbofan is more efficient.

Electric Turbofans (TL8): These turbofans use electric power to heat the air. They are much less efficient than ducted fans, but do not have a 600-mph speed limit.

Fission Air-Rams (TL8): These use a fission reactor to operate a turbofan that sucks in air, heating it and expelling it for thrust. They operate for 2 years on an internal nuclear fuel supply. The exhaust from a fission air-ram is slightly radioactive, enough to prevent their use in today's environmental climate. They have been seriously considered for operation on worlds such as Mars, and there were historical proposals to build an unshielded version to be employed in nuclear-armed cruise missiles.

Laser Turbofans (TL8): These are turbofans powered directly by beamed power (p. VE87). The beam from the remote transmitter heats the air in the turbofan directly, so no separate beam power receiver is required.

Fusion Ram-Rockets (TL10): These fusion air-rams can reconfigure to operate as fusion torch engines in vacuum. In this mode they require reaction mass (0.2 gallons water/hour per pound of thrust).

Super Turbofans (TL9): These are turbofans built with TL9+ materials technology (like hyperfans, p. VE35), but designed to burn conventional hydrocarbon fuels.

Grav-Rams (TL11): This superscience jet propulsion system sucks in and accelerates air by dropping it down a tractor beam-scale gravity gradient. A grav-ram also works in water, sucking in water and expelling it to provide 5 times as much aquatic motive thrust. Grav-rams are available only if tractor beams or gravitic guns exist.

Jet Engine Table

TL	Type	Weight (lbs.)	Cost	Fuel	Power
7	Light Turbofan	0.25 x thrust	$150	0.03J	none
8+	Light Turbofan	0.125 x thrust	$150	0.015J	none
8+	Electric Turbofans	(0.3 x thrust) + 120	$50	none	2.8 kW
8	Laser Turbofans	(0.7 x thrust) + 500	$50	none	4 kW
9+	Laser Turbofan	(0.46 x thrust) + 440	$50	none	2.5 kW
8	Fission Air-Ram	(0.15 x thrust) + 1,100	$100	none	2 year
9+	Fission Air-Ram	(0.11 x thrust) + 1,040	$50	none	2 year
9+	Super Turbofan	(0.08 x thrust) + 40	$50	0.01J	none
10+	Fusion Ram-Rocket	(0.06 x thrust) + 60	$100	0.02W	2.5 year
11+	Grav-Ram	(0.063 X thrust) + 17.5	$10	none	0.125 kW

Location: The engine may be placed in a body, superstructure, pod, or leg.

Weight: The table shows the weight of the propulsion system based on motive thrust (lbs.).

Volume: To find volume, divide weight by 50.

Cost: To find the cost of the propulsion system, multiply weight by the number shown for cost.

Fuel: This is the fuel requirement in gallons per hour per pound of thrust.

Power: The power requirement per pound of thrust, if any; a "year" entry means that an integral reactor powers it for the listed time period between refueling. Laser turbofan power must be provided by beamed power.

All turbofans and the fission air-ram have a jet engine limit of 2,000 mph (p.

Tip Jet Rotor System (TL6)

This system may be used with any helicopter rotor (p. VE8) instead of a helicopter drivetrain. A tip jet rotor pumps a mixture of fuel and compressed air through hollow tubes in the rotor blades to small burner chambers on the rotor tips, where their combustion generates thrust that turns the rotor. Select a motive power for the system, in kW; this determines the helicopter performance (as per *Helicopter Drivetrain,* p. VE34). The tip jet rotor system replaces the helicopter drivetrain and its power plant.

Tip Jet Rotor System Table

Tl	*Weight*		*Cost*	*Fuel*
	less than 5	*5 kW or more*		
6	5.75 x kW	(1.75 x kW)+20	$70	0.16J
7+	4.25 x kW	(1.25 x kW)+15	$150	0.13J

Weight (in lbs.), cost, and fuel (GPH) are per kW of motive power.

Reaction Rotor Drivetrain (TL7)

This allows a reaction engine to be used in place of a rotating drivetrain. A diverter valve permits the vehicle operator to direct the exhaust gas produced by the engine through the nozzle to produce thrust or through a turbine to produce drivetrain power. It is most common on canard rotor wing (p. 3) or other stopped-rotor helicopters, allowing the same engine to produce both aircraft-mode thrust and helicopter-mode rotor power. Treat it as a TTR helicopter drivetrain when determining lift, motive thrust, and performance.

A reaction rotor drivetrain weighs 1.5 lbs. per kW of motive power at TL7, half that at TL8+. Volume is weight/50 cf, cost is weight x $50. The drivetrain requires a reaction engine with at least 5 lbs. thrust per kW of motive power. The drivetrain is often capable of using only a portion of the reaction engine's potential motive power. There is no need to design the drivetrain to be capable of using the entire power of the reaction engine.

Magnus Effect Lift (TL7)

A Magnus effect drivetrain generates lift by deflecting a flow of air moving over a rotating surface - the same effect that provides lift to a spinning ball or seed pod. The most practical application is usually a rotating spherical or cylindrical gasbag (thus combining Magnus lift with that of lifting gas), although a rotating pod or superstructure design is also possible, effectively replacing wings with a rotating cylinder.

A vehicle cannot use Magnus effect lift if it already has wings or rotors, but can combine it with other forms of aerostatic lift (p. VE40).

Determine the surface area of the rotating surface; this may require estimating the expected volume of components. Then install a Magnus effect drivetrain capable of producing 0.75 kW per sf of rotation area. It weighs 1.5 lbs. per kW at TL7, 0.7 lbs. per kW at TL8+. Volume is weight/50 cf. Cost is weight x $20. It goes in the body.

Like a wing, a Magnus rotor generates lift only while moving through the air. Its stall speed is 1.5 mph *x* [(Lwt-Static Lift)/(rotation area)] squared. The static lift can come from lifting gas, contragravity, etc.

Gyroscopic Stabilization

Many satellites and spacecraft use gyroscopes to stabilize themselves and change their orientation without the use of thrusters. This is purchased as *full stabilization (p.* VE45) using the weight and volume for the entire vehicle rather than a weapon. (This will have to be estimated: leave enough weight for the projected final vehicle weight; excess weight can be used for later upgrades.) The vehicle needs a way to track stellar positions in order to orient itself: any telescope, low-light TV, or PESA capable of magnification 1 or greater is suitable.

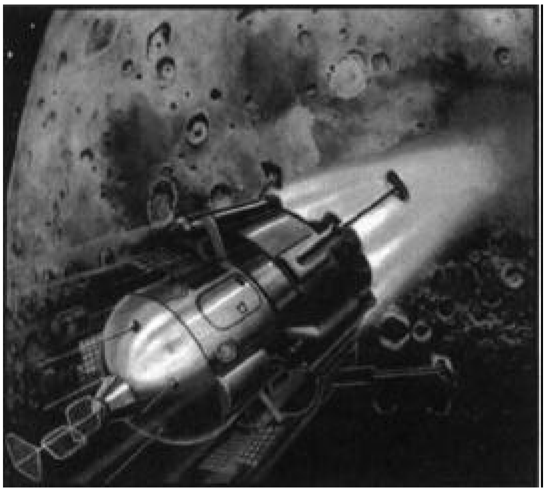
Space Drives

These reaction drives produce thrust through a variety of means, from beams of radiation to nuclear micro-explosions.

Explosive Pulse Drive (TL6): It uses a rapid-fire gun to inject explosives into a hemispherical thrust chamber, where they detonate, pushing the drive forward. Fuel consumption is in pounds per hour per pound of thrust, stored as ammunition at 150 lbs./cf and costing $2/lb. In the event of an ammo explosion (p. VE186), Id lbs. of pellets detonate for 6d exp. damage per lb. This drive is inefficient, but offers a "hard science" option for Victorian-era spacefarers who have somehow managed to get into orbit in the first place.

Slow Ion Drive (TL7): The slow ion drive converts reaction mass to ions (charged atoms or molecules) and electrically accelerates them for thrust. The ion drive listed here is a lower-power design than the examples on p. VE36, of the sort likely to be used in late TL7 and early TL8 spacecraft. The fuel is cryogenically stored argon, at 4.7 lbs. and $4 per pound. It does not catch on **fire.**

Fission Fragment Thruster (TL8): This drive produces thrust by magnetically focusing



charged nuclei emitted by a fission source, typically the decay of a radioactive isotope. The exhaust is a relatively harmless jet of heavy ions, but the drive itself is radioactive, and is unshield ed in the direction of the exhaust. Thrust is very low, but fuel efficiency is excellent, making it a workable alternative to a conventional electric ion drive. A radioactive isotope that decays natu rally by spontaneous fission may be used, or fis sion can be induced in slightly more stable iso topes. Induced fission systems operate for up to 8,000 hours before becoming useless. Natural isotopes lose half their thrust every year whether used or not, but never quite decay to zero thrust. Replacement fuel is 2% of the thruster weight and costs $5,000 per pound.

Mass Driver Engine (TL8): This uses an electromagnetic-coil-gun-propelled bucket chain to launch reaction mass. Fuel consumption is in pounds per hour per pound of thrust. Any mass will work, but safety regulations may require liquids or dust to avoid creating hazardous artificial meteor streams. One application of mass driver engines is to install them on asteroids: the asteroid's own rock can be mined, and some convert ed into reaction mass for propulsion.

Nuclear Pulse Drive (late TL8) *and Fusion Pulse Drive* (TL9): These are crosses between an explosive pulse drive and an inertial nuclear reac tor. Small nuclear explosions (equivalent to about a ton of TNT) generate a plasma, which is expelled to produce thrust. The nuclear pulse drive uses beams of neutrons or antiprotons to trigger fission in fissionable fuel pellets. The fusion pulse drive uses a ring of powerful lasers or ion beams to compress and heat pellets of fusion fuels, with higher fuel efficiency but less thrust. Fuel consumption is in pounds of nuclear pellets per hour. Pellets occupy 0.02 cf per pound, weigh a few ounces each, are only slight ly radioactive, and cannot be made to explode outside the engine. They include a quantity of inert reaction mass to form the plasma. Cost is $12.5/lb. at TL8, $1.25/lb. at TL9, and $0.25/lb. at TL 10+.

Fusion Ramscoops (TL9): One of the difficulties with interstellar flight using reaction drives is that accelerating to a decent fraction of light-speed requires an incredible amount of fuel. Fusion ramscoops get around this by not carry ing any! Interstellar space is not empty; there are stray atoms of hydrogen and other elements floating about. The drive uses a huge magnetic field to scoop up this interstellar hydrogen, which is used as fuel for a fusion drive (p. VE36, included with the ramscoop), heated, and then expelled for thrust. Unfortunately, the fusion reactions required are trickier than those used in an ordinary fusion reactor or drive, and the area of space for about 100-200 parsecs around our solar system is unusually low in interstellar hydrogen (probably due to an old supernova explosion), which makes local use of ramscoops impractical (1% or so thrust). However, parts of the galaxy are especially rich in interstellar gas (nebulae, the galactic center, etc.) and in these conditions, ramscoops would be much more use ful. Two examples are provided: a somewhat realistic design and a far higher-performance Super Bussard Ramscoop intended to simulate the optimistic drives common in 1970s-era sci ence fiction, before the limitations of ramscoop technology were appreciated.

Conversion Drives (TL12): These drives convert fuel directly to propulsive energy with very high or total efficiency. Since they do not actually violate the law of conservation of ener gy, conversion thrusters are slightly more reason able than reactionless thrusters. By adjusting the type of fuel used (and perhaps the amount, since conversion need not be 100% efficient) the feel of many different advanced science fiction space drives can be captured, such as photon or "impulse" drives; the TL12-13 drives are exam ples of this. Likewise, the exhaust of a conver sion drive may range from harmless light or neu trinos to ravening beams of gamma rays or gravi ty waves.

The tabular designs assume conversion drives are not developed until just before total conversion reactors (TL14) appear. However, superscience conversion drives may appear as early as TL9, representing a variety of highly efficient but fuel-using drives common to science fiction. Just use the statistics of reactionless thrusters (p. VE38), but replace the power consumption with a fuel consumption of at least 0.00012M per pound of thrust.

Space Drives Table

TL	Type	Weight	Fuel	Power	Cost
6	Explosive Pulse	(0.06 x thrust) + 50	25X	0	$25
8+	Slow Ion Drive	(1,000 x thrust) + 5	0.085A	80	$50
8+	Fission Fragment	(1,400 x thrust) + 200	0	0	$100
8	Mass Driver Engine	(60 x thrust) + 60	5M	20	$100
9	Mass Driver Engine	(40 x thrust) + 40	5M	20	$50
10+	Mass Driver Engine	(30 x thrust) + 30	5M	20	$25
8	Nuclear Pulse Drive	(0.04 x thrust) + 6,000	0.35N	0	$100
9+	Nuclear Pulse Drive	(0.04 x thrust) + 6,000	0.35N	0	$50
9+	Fusion Pulse Drive	(1 x thrust) + 100	0.12N	0	$50
9	Fusion Ramscoop	(300,000 x thrust) + 200,000	0	0	$200
10	Fusion Ramscoop	(30,000 x thrust) + 20,000	0	0	$200
10	Super Bussard Ramscoop	0.615 x thrust	0	0	$400
12	Partial Conversion Drive	(0.01 x thrust) + 2,000	0.00024M	0	$50
13	Partial Conversion Drive	0.04 x thrust	0.00024M	0	$400
14	Total Conversion Drive '	0.001 x thrust	0.00012M	0	$375

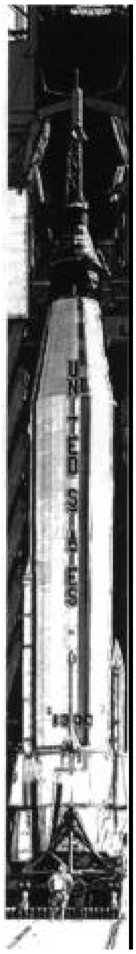
Weight depends on the desired thrust (in pounds) of the drive. *Volume* is weight divided by 50.

Cost is weight multiplied by the value in this column.

Power is thrust multiplied by this column.

Fuel is in gallons per hour per pound of thrust. Fuel types are abbreviated as follows: H is gallons of liquid hydrogen, W is water, A is argon. Exception: fuel for conversion drives, mass drivers, and pulse drives are measured in pounds per hour per pound of thrust: X is pounds of explosive pulse units, N is pounds of nuclear pellets (fission or fusion fuel), and M is pounds of any mass.

Vectored thrust is unavailable for explosive pulse, nuclear pulse, fusion pulse, and all ramscoop designs.



Spacecraft Sails

The lightsail (p. VE30) is only one of several types of "sail" that can be used by a spacecraft. Other types include radioisotope sails, magsails, and plasma sails. None require any subassemblies, and all are useful only for space propulsion.

Radioisotope Sails (TL6)

This concept originated in the early years of space flight and nuclear power, but it might be useful for a civilization that has colonized a radioactives-rich asteroid belt. A thin layer of radioactive isotope material is spread on one side of a giant foil sail that is thick enough to provide a degree of radiation shielding. As the isotope layer decays, radioactive particles escape in the unshielded direction, producing thrust. Radioisotope sails have the same planetary approach limits and furling times as lightsails (p. VE31).

Various isotopes are possible with different half-lives. Divide thrust by the chosen half-life (e.g., if the half-life is 14 years, then divide by 14). As the isotope decays, thrust is reduced, so halve it again every half-life. Thus, an isotope with a 14-year half life has 1/14 thrust, reduced to 1/28 after 14 years, 1/56 after 28 years, and so on. Unprotected individuals on the emitting side of the sail are exposed to some radiation, but since the isotopes used are designed to emit particles that can be stopped by a thin foil, any radiation shielding (PF 2+) will provide full protection.

For each pound of thrust, radioisotope sails weigh 5,400 lbs., cost $3,000,000, and take up 0.0167 square miles. Assume radiation exposure for anyone on the wrong side of the sail is a number of rads/second equal to thrust in pounds divided by square of distance in yards.

Laser-Boosted Lightsails (TL7)

The lightsails on p. VE31 can be pushed by a laser. Divide the output of the laser in kJ by 700,000 to get the pounds of thrust; RoF 1+ is required. Divide thrust by 4 at 1/2D range. Multi-gigawatt lasers are required to propel any but the tiniest space probes.

Microwave Sails (TL8)

Sails designed to be pushed by microwave beams rather than lasers may be perforated, reducing their weight. They have 1/10 the weight and

1/5 the cost of standard lightsails of the same area (p. VE31), but generate only 1/10 the thrust from sunlight or lasers. However, microwave beams are completely reflected and hence produce normal thrusts (1 lb. per 700,000 kJ). See *Beamed Power*, p. VE87, for microwave transmitters.

Magnetic Sails (TL8)

A magsail is a giant loop of superconducting wire carrying a current that generates a magnetic field miles across. The field interacts with the outflowing charged particles of the solar wind to produce thrust. Magsails require light, high current superconductors to be practical, but offer performance advantages over lightsails.

To design a magsail, select its nominal thrust (in lbs.). Find the 3/4 power of thrust (or cube thrust and find the square root twice) and multiply by 3,400 to get weight (in lbs.), by 600,000 to get energy requirement in kWs, and by 0.71 to get radius (in miles, when powered). An unpowered sail can be reeled in and stored in a volume of weight/50 cf. A magsail costs $100 per pound.

Nominal thrust assumes the sail is 1 AU from the sun or a sunlike star. Since the solar wind varies somewhat with distance and dramatically with solar weather, thrust in the inner solar system ranges from 0.005 to 75 times nominal thrust, though it averages out to nominal thrust over an interplanetary voyage. Performance is also limited by the velocity of the solar wind: the craft may not travel outward faster than the solar wind, typically not exceeding 250 miles per second.

Within a few planetary diameters of a world with a strong magnetic field, a magsail may thrust against the world's magnetosphere. This is risky and requires a Piloting (Magsail) roll each hour (or fraction thereof) of maneuver; failure will disable the sail or (on a critical failure) destroy it. However, a successful maneuver can produce high accelerations - in our solar system, about 3 times nominal thrust near Mercury, 20 times near Earth or the smaller gas giants, and 200 times in and around Jupiter. This does require power (since without the solar wind's kinetic energy, energy changes come from the sail current): 30 kW per pound of actual thrust.

The outer edge of a solar system is the heliopause, where the solar wind collides with the interstellar medium. Beyond the heliopause, in interstellar space, a magsail acts as a brake, interacting with the interstellar medium (hydrogen atoms and other interstellar gas). This is a useful method of slowing sublight starships without consuming reaction mass, and so such vessels often carry magsails which they energize only when it is necessary to decelerate. The time required to magsail-brake from near-light speeds to solar wind velocities is 0.0078 years *x* (Lwt./magsail nominal thrust) x [9.1 - cube root (1/initial speed)], where *Lwt.* is the vehicle's loaded weight, c is the speed of light, and *initial speed* is the current speed of the vessel expressed as fraction of light speed. For example, if the vessel is travelling at 80% of the speed of the light, then current speed is 0.8. Peak deceleration in G is: 372 *x* (thrust/Lwt.) *x* (initial speed/c) to the 4/3 power.

Plasma Sails (TL9)

This system is also referred to as "mini-magnetosphere plasma propulsion." A plasma sail generates a magnetic field, then injects hydrogen plasma (ionized gas) to inflate it into a huge bubble around the vessel. This "mini-magnetosphere" acts as a giant sail, catching the solar wind's charged particles and accelerating the vessel to a maximum practical speed of 150 miles per second. The plasma bubble "leaks" a tiny amount of hydrogen as it operates, and thus has a low fuel requirement. A craft under plasma sail is enveloped in a wispy blue-white nebula of ionized gas that leaves a short, comet-like trail.

At TL9, a plasma sail is 400 lbs., 8 cf, $200,000, 50 kW, and requires 1.66 GPH of hydrogen (H) fuel per pound of thrust. Maximum thrust is 20 lbs. thrust. At TL10+, halve weight, volume, and cost; maximum thrust is 40 lbs. thrust.

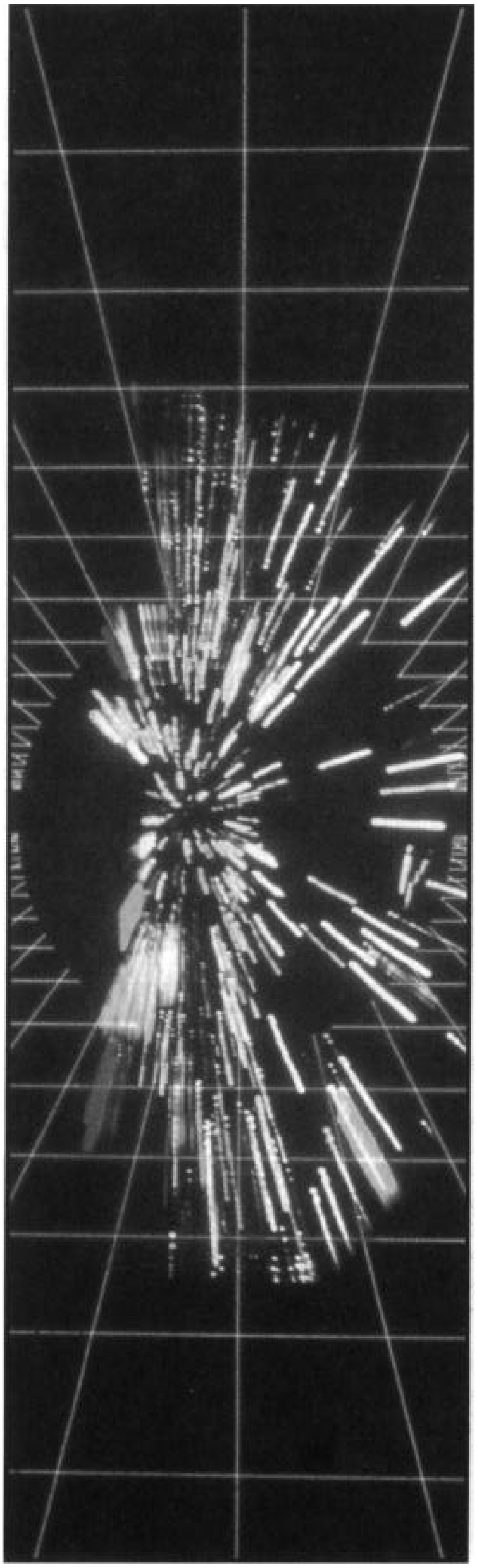
STARGATES

A stargate is an artificial wormhole or jump point. Spacecraft passing through it are instantly translated to another stargate at a distant point. "Hard science" stargate designs tend to involve spinning rings of hyperdense matter with the mass of the Earth, which is obviously difficult to achieve. Assume superscience stargate designs are the same TL as stardrives, though optionally they may be a higher or lower TL. Some examples:

Artificial Wormhole : This is simply an artificial construct that enables a jump drive (see p. VE39) to function. A typical superscience design is 200 million lbs., 100,000. cf, and $10 billion, all multiplied by the radius of the wormhole in yards that any vessels using it must pass through. Unless pocket wormholes seem like a good idea, assume any hole smaller than 5 yards radius collapses, or requires as much energy as one 5 yards in diameter. The artificial wormhole must normally be coupled to a second wormhole on the other end. This generally requires that both be built in the same location, then moved apart, usually through normal space, to the desired location. It is up to the GM whether this process can involve FTL travel. An artificial wormhole generally requires no power to maintain, but a lot of energy (say, kWs equal to 3,600 times mass) to form in the first place. It may need to be built far from the gravity well of a large celestial body such as a planet or star.

Artificial Jump Gate : This is built as an artificial-wormhole, but add a jump drive capable of shunting a given mass (at least 500 tons) through the portal. The jump drive can expend the energy to send through any ship without a jump drive of its own.

Hypergate : This stargate allows a vessel to enter hyperspace at lower energy cost. Build it as a hyperdrive (p. VE39) of 10,000 x normal weight, volume, and cost, but a constant power requirement of 360,000 kW per ton of hypershunt rating. It opens a "door" into hyperspace up to 0.5 times (square root of hypershunt rating) yards in diameter. While the gate is powered, it is open, and hyperdrive-equipped starships can enter hyperspace through it without paying the very high normal energy cost to do so, although they must still expend the power required to stay in hyperspace. No door is needed on the other end, since it normally costs no energy to leave hyperspace. However, the GM could rule instead that any vessel entering hyperspace through a hypergate must emerge through an open hypergate in the destination system, or be trapped in hyperspace.



OTHER COMPONENTS 3

This chapter describes other equipment that can be installed in a vehicle. It expands upon the components detailed in chapters 4 through 8 of *GURPS Vehicles.*

INSTRUMENTS AND ELECTRONICS

This section covers a wide variety of gadgets and options for communication, navigation, jamming, and other purposes. Items so classed can be located in the body, or superstructures, pods, turrets, arms, wings, open mounts, legs,

COMMUNICATIONS

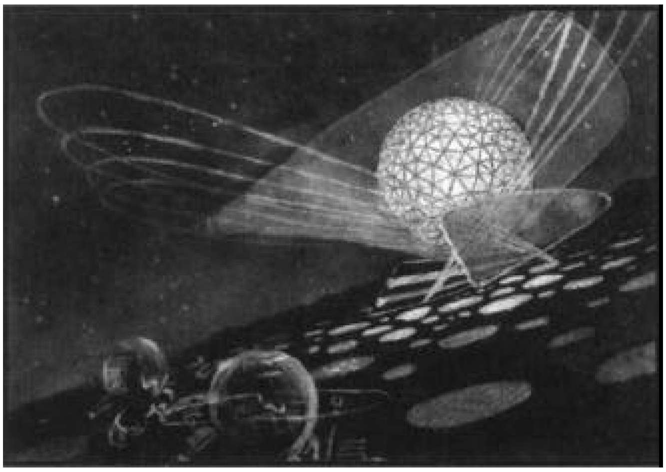
If one communicator is transmit ting to another communicator with a *different* range, the actual maximum range is the square root of (transmit ting communicator range x receiving communicator range). A communica tor's transmitting and receiving range are normally identical, unless the communicator has the options Sensitive or Very Sensitive (increases receive range only) or Receive Only (no trans mit range).

Underwater Communications

Ordinary radio waves cannot penetrate water to any useful depth. Submarines can be equipped to receive VLF radio signals, but they cannot transmit radio in these wavelengths; only fixed stations and specially equipped large aircraft can transmit VLF. Likewise, subs can only be equipped to receive ELF signals, and extending or retracting the antenna for this purpose actually takes around 30 minutes (not 30 seconds) on contemporary subs. However, several additional specialized systems are available:

Sonar Communicator (TL6): This is an option for communicators (p. VE46). A sonar communicator uses sonar pulses fort underwater communication between two vessels with compatible equipment. It can only be combined with the Sensitive, Very Sensitive, Receive-Only, and Tight Beam options, and may not be Long, Very Long, or Extreme range. Multiply weight, cost, and power by 10; divide range by 10. Messages can be voice, text, or datalink, and may use scramblers.

Communications Buoy/Trailing Wire Antenna (late TL6): This is a buoy or wire several hundred yards in length, trailed behind a sub merged submarine, which floats to the surface and acts as an antenna, allowing the sub to receive - and, optionally, transmit - regular (not VLF/ELF) radio messages. The system weighs 5,000 lbs., occupies 100 cf., and costs $250,000.



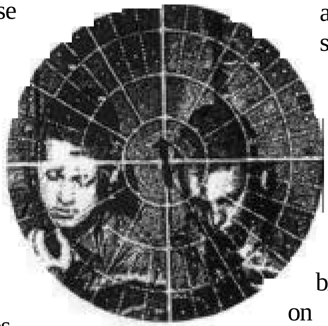
Message Buoy (TL6+): These should be designed as small vehicles with a floatation hull, radio, and battery with enough armor to survive at their launch depth. Many are launched from decoy dischargers, and should range in size from 0.5 to 5 cf. A typical TL7 example has a spheri cal 0.5 cf medium, expensive frame with a sealed floatation hull coated with DR 6 expensive metal and equipped with a medium-range scrambled radio powered by a 72 kWs lead-acid battery. It is 31 lbs. and costs $2,019. It has a crush depth of 384 yards.

Blue-Green Lasers (TL8+): This option (p. VE123) can also be applied to laser communicators, laser rangefinders, ladars, and AESAs for the standard +20% cost and one-half range. (More realistically, blue-green lasers should have one-tenth their range underwater while other lasers have only 1/100th their normal range.)

Underwater Navigation Systems

Sonar IFF (TL7): Submersibles may use a sonar-based (rather then radio-based) identification system. These are treated as standard IFF or transponder systems but have a range equal to a medium-range sonar communicator of the same TL.

Sonar Positioning System (TL7): Sub marines may also have a Sonar Positioning System, which is similar to GPS (often useless underwater, as radio signals from the satellites cannot reach a sub), but uses active sonar transponders, fixed to the sea bottom at known locations, instead of satellites. Single units are sometimes used to mark important locations, but they are more frequently encountered where sev eral transponders are planted across a wide "field." Submarines within their own active sonar range can triangulate their position with GPSstandard accuracy. This is most often used in sci entific or salvage work where positioning is critical. At TL7, the transmitters are 1 cf, 50 lbs., and $2,000; a receiver is 0.2 cf, 10 lbs., and $6,000. Halve all these values at TL8. and divide them by 4 at TL9.



Electronic Warfare

Sonar Detector (TL6): A very sensitive system that detects active sonar transmissions (at up to four times active sonar range) and provides a rough bearing (±30°) and range (±50%) to the source. It has five times the volume, weight, and cost of a radar detector of the same TL. It can either be an add-on to an existing sonar array, or have its own dedicated array, and can be tied to the vessel's computer to permit transmission profiling. Note that a nor mal passive sonar can still detect an active sonar at up to twice the active sonar's range, without any modifications being necessary.

Aircraft Decoy Discharger (TL7): A lightweight discharger that is only usable by an aircraft flying at 50 yards or higher altitude. Treat as an ordinary decoy discharger (p. VE60) except it can only be loaded with chaff or flares. The discharger is 2 lbs., 0.1 cf, and $50 at TL7+. Reloads are 1 lb., 0.05 cf, and $2 at TL7+.

Electro-Optical Missile Jammer (Late TL7): Wire-guided missiles (p. VE114) are not infrared-homing, but the firer's guidance system tracks the missile by monitoring infrared emis sions from a flare on its tail and sending correc tions if the missile departs from the direct line of flight to the target. (At higher TLs, other forms of radiation may be used, but the principle is the same.) An electro-optical missile jammer is a directed emitter that sends out similar signals (infrared at TL7-8) to the missile tail flare, modulated to confuse the tracker and lead it to send false course corrections to the missile. The jammer must be installed with a specified facing. To function, the system must be pointed in the direction that a wire-guided missile or missiles are coming from (an Aim maneuver). Range is 4,000 yards (to the missile controller); one try is allowed each turn, effective against all wire-guid ed missiles in a 15°-wide arc heading toward the vehicle. It confuses a wire-guided missile on a roll of 8 or less on 3d. Modifiers: +2 if missile is an early-TL7 model, no effect if missile is higher TL than jammer; +1 per full TL that the jammer exceeds TL of missile. A confused missile crash es. An EO missile jammer weighs 40 lbs., takes up 0.8 cf, and costs $100,000. It requires negligi ble power. Weight and cost halves at TL8, and again at TL9+.

Underwater Acoustic EW Analogs: Almost all electronic warfare equipment has an underwater acoustic/sonar analog. However, acoustic systems are bulky and power-hungry. Unless otherwise noted, active devices, which broadcast or rebroadcast sound, have 10 times the volume, weight, power consumption, and cost of radio-frequency devices intended for use in atmosphere. Passive devices (detec tors, reflectors, etc.) are not a lot bigger, but if they are mounted externally on the vehicle, they weigh twice as much (built to cope with being pulled through water).

Laser Optics Detector (TL8): This device flashes laser light across a 15° arc in the direction it is facing, and looks for specific signal returns (glint) that indicate an optical lens. It displays that information on a HUD or another readout, showing the bearing and range of the optics it has detected (and giving a +4 bonus to other sensors to locate whatever vehicle or person is carrying them). It can spot telescopes, LLTV, PESA, and the optics of any sort of laser device (weapons, ladars, rangefinders, etc.). It can detect up to two systems per turn, starting with the nearest unde tected one; ignore previously detected systems. It provides the range and bearing of the system. A system is detected on a roll of detector TL+4 or less. However, TL8+ optics normally have non reflective coatings that prevent them from being detected by lower-TL detectors and reduce the chance of equal or higher TL systems to detector TL-3. (Such systems can be retrofitted on TL7 optics for $100.) Optics are also normally provided with lens caps, covers, or shutters; a portable or vehicular system can always avoid detection by sealing the cap or shutter, but this will, of course, prevent its use. A laser optical detector has the same weight, volume, and power requirement as a laser rangefinder of equivalent range (p. VE59), but five times cost. An operating laser optical detector can itself be detected by a laser detector (see p. VE59). It can be used with a Transmission Profiling program (p. VE63) to identify specific optics. A Gunner program (p. VE63) can attack targets whose optics a laser optical detector has just detected, utilizing the detector instead of other sensors.

Proximity Fuse Jammer (TL8): This device sends out short-range radar jamming signals specifically designed to prematurely trigger the proximity fuses in HEPF ammunition (see p. VE191). if proximity-fused ammunition is targeted on or fired through its jamming area, the system will detonate the rounds 50 yards from the jammer - hopefully outside immediate blast range. The jammer works on a roll of 12 or less on 3d against a warhead of the same TL, and on a 14 or less against a warhead of lower TL. It is useless against a warhead of a higher TL. It is often used in conjunction with a line of sight sensor (such as a radar) and set to turn on automatically when incoming indirect fire is detected. It is deliberately short-ranged, to prevent antiradiation missiles (p. VE193) from homing in on it; they can only home in on a proximity fuse jammer if they begin tracking within 100 yards of it. A proximity fuse jammer weighs 40 lbs., takes up 0.8 cf, costs $40,000, and requires 1 kW power. Halve weight and cost at TL9, and again at TL 10+.

Extra Detail – Area Jammers

These jammers (see p. VE59) project a signal that interferes with radio and radar transmissions, drowning them out in static noise. The "5 times jam rating" area of effect given for area jammers is a simplification that understates the capabilities of a larger jamming system. Instead, to get jamming radius, refer to the *Range to Scan Table (p.* VE52). Find a Scan equal to three times the jammer rating, then read the corresponding range as a radius in miles. In space, jamming radius is 10 times the atmospheric range.

Miscellaneous Equipment

These are various items that can be installed in a vehicle. They all count as "miscellaneous equipment" for purposes of hit location rolls.

Craft Shops

In addition to the Armoury, Electronics, Engineering, and Mechanical workshops (see p. VE66), other specialized workshops can be installed for specific crafts. Blacksmithing, Carpentry, and Sewing workshops are common aboard TL4-6 ships, for example. A workshop can also represent such things as a photographic darkroom or an artist's studio.

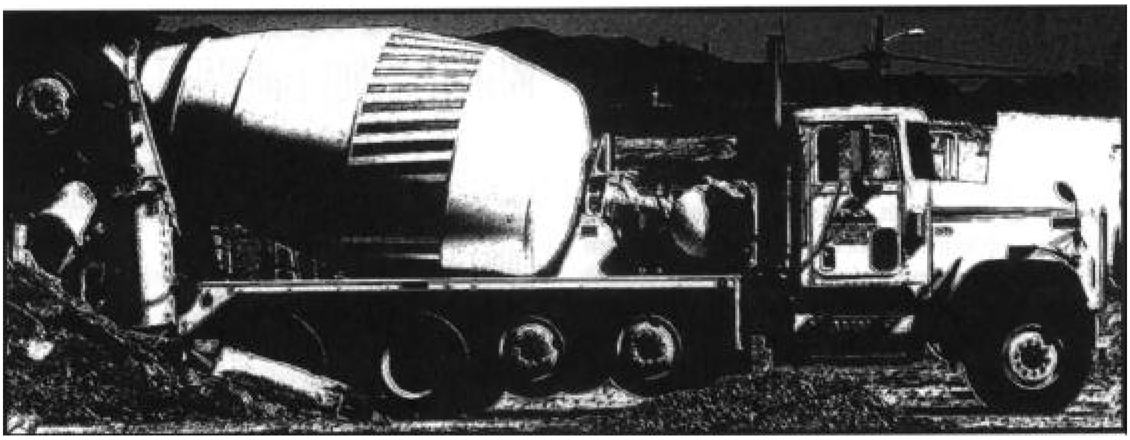
Use the statistics for workshops or mini-workshops, including skill bonuses or penalties. Volumes remain the same for any workspace, but the other statistics assume a job that requires a lot of heavy equipment. For arts and crafts that use lighter tool kits (photography or sewing, for example) divide the weights by up to 10 and costs by up to 4.

Tire Inflation System (TL6)

This system is common on military vehicles. It includes the necessary pumps, hoses, and other equipment to inflate (or deflate) the vehicle's tires. Using this system takes an action in combat. Continuous pressure feed into the tire can keep them from going flat until they reach 0 hit points, at which point the tires are too damaged to maintain air pressure. Until this point no Control rolls are necessary when the tires take damage. The tires can be deflated from inside the vehicle (takes 3 seconds), giving the driver a +1 bonus while driving in Open, Broken, or Quagmire conditions. A tire inflation system has a weight, volume, and cost equal to 10% of that of the wheeled drivetrain. It requires an atmosphere (or supply of compressed air) to function.

Heavy Equipment

These items are common on assault, construction, and infrastructure maintenance vehicles. Corvus (TL2): A four-foot wide boarding gangway, attached by a pivot to a ship. It is held upright by a slightly shorter mast and tackle arrangement. The far end is equipped with a single "beak" of metal. When two ships engage, the crew positions the corvus with the pivot and lets loose the line holding it upright; it swings down and plants the beak in the other ship's deck.



Soldiers then cross the boarding gangway and engage the troops on the other ship directly. Select a length for the corvus (from 8' to 40'); the weight is 48 lbs. per foot of length. The cost is $40 per foot of length. Dropping the corvus in combat is an action taking 1 second.

Cement Mixer Drum (TL6): This is a large rotating drum that keeps cement liquid as it is transported from a plant to a construction site for pouring. It uses engine-powered rotating fins inside the drum to mix the concrete, and includes a hydraulic system to tip the contents. The mixer drum weighs 80 lbs., takes up 1.25 cf, costs $40, and requires 0.2 kW power per cf of cement-carrying capacity. A load of cement weighs an additional 180-200 lbs. per cf. The system will also require 0.5 gallons of water per cf of cement capacity; a tank should be provided.

Drill (TL6): A drill rig suitable for drilling wells or core samples. Drills (augers) are often found on mining or combat engineering vehicles to make bore holes for tamped explosive charges; see p. HT26 for effects of tamped charges. Drilling rate is 30 yards/hour in earth or ice, half that for soft rock, 1/4 for hard rock. Decide on the maximum depth it can drill. Weight is 50 lbs. + 6 lbs./yard of depth; volume is weight/50 cf; cost is $500 + $50/yard. It requires 5 kW power. Weight, volume, and cost are halved at TL7 and again at TL8+.

Harvesting Equipment (TL5): This is used to harvest and process field crops. The category includes reapers, combines, threshers, hay balers, corn pickers and shellers, and potato harvesters. Select a capacity in acres/hour. Weight is 800 lbs. x capacity, volume is weight/50, cost is $5/lb., and the power requirement is 15 kW x capacity. Unless it is acceptable to leave the harvest in the field (e.g., hay bales) the vehicle will either need cargo space or a companion vehicle with open cargo space to pour it into. Harvested volumes run from 5-100 cf per acre. The vehicle is normally limited to 10 mph or less when using the equipment. Many types of harvesting equipment incorporate sharp blades: treat any frontal collision as doing cutting rather than crushing damage. Weight, volume, and cost are halved at TL6 and again at TL7+.

Mower (TL5): This is used to cut grass or hay. Select a capacity in acres/hour. Weight is 200 lbs. x capacity, volume is weight/50 cf, cost is $5/lb. of weight, and the power requirement is 2 kW x capacity. As with harvesting equipment, running someone over will inflict cutting damage. Weight, volume, and cost are halved at TL6 and again at TL7+.

Powered Tillage Equipment (TL5): This represents mechanical gear used to break up ground for cultivation - plows, harrows, power tillers, hoes, etc. Decide on its capacity in acres/hour. Weight is 400 lbs. x capacity, volume is weight/50, cost is $5/lb. and power is 10 kW x capacity. Statistics are averages: tools designed for light-duty work (e.g., in light soils) has 1/4 the weight and power, heavy-duty equipment (e.g., for opening newly cleared forest) needs 4 times the weight and power, while extra-heavy-duty tillage equipment that can cut stone or paved surfaces is 10 times the weight and power. Weight, volume, and cost are halved at TL6 and again at TL7+.

Field Generators

These generate force fields surrounding a vehicle. Except for the magnetic shield, all are "superscience" technology.

Magnetic Shielding (TL8): This generates a magnetic field that deflects charged particle radiation. Multiply the statistics by the square root of the radiation protection factor (PF) desired. For simplicity, assume normal space radiation, e.g. from solar flares, is all charged particles. Other radiation sources are usually mixed; assume maximum PF is 10. Magnetic shields add +1 to PD for each tenfold increase in PF versus charged particle or antiparticle beams, half that against flamers or fusion beams; however, a vehicle's total PD can't exceed 8.

Sonic Screen (TL10): This generates a field that blocks sound waves. It defeats sound detection or sonar and provides DR 15 against sonic attacks (+3 to HT rolls vs. stunning).

Annihilation Damper (TL12): Analogous to a nuclear damper, but more focused in effect, this generates a field that suppresses matter/antimatter reactions, disabling antimatter power plants, drives, and warheads and negating any advantage of antiparticle beams over p-beams. At the GM's option, this may also disable total conversion technology. The antimatter still exists, and when it is no longer within the damper field the antiparticles react normally. An annihilation damper also allows storage of antimatter in ordinary fuel tanks, normally as liquid antihydrogen at up to 250 grams/gallon of tank. The required damper field volume is 0.2 cf per gallon of tank. Note it is virtually impossible to clean all the antimatter off something. A layer of antiatoms will remain on the surface, some will have migrated into the structure, etc. Assume anything that has ever been in physical contact with antimatter explodes if brought out of the field, doing 6d x 2 explosive damage per pound of weight.

Cloaking Field (TL12): The vehicle (and anyone else in the field) can disappear! This sensor-damping field combines the effect of intruder chameleon, radical emissions cloaking, and radical stealth (p. VE92). It is not cumulative with these surface features.

Stasis Web (TL15): This generates a bubble of time running slower than the rest of the universe (the surface is a perfectly elastic, perfectly rigid mirror). It can be set to last anywhere from 5 minutes to billions of years as observed by the rest of the universe, while only microseconds pass within the bubble. Objects in stasis are unable to do anything. Treat a stasis field as if it were an indestructible solid object; no physical force will affect the contents of an operating stasis web.

Field Generator Table

TL	Type	*Weight*	*Cost*	*Power*
8	Magnetic Shielding	0.15	$15	0.01 kWs
10	Sonic Screen	0.0006	$0.75	0.002
12	Annihilation Damper	0.004	$15	0.01
13	Cloaking Field	1	$1,000	1
15	Stasis Web	4	$400	3,000 kWs

Field generator weight, cost, and power are per cubic foot of field volume. Generator volume is weight/50 cf. Fields will be spherical, rather than conforming to the vehicle volume; most vehicles will comfortably fit in a sphere of 20 times the volume of the vehicle. Estimate a spherical volume if the vehicle's volume is unknown, or select a large enough radius to fit the vehicle's longest dimension (which can be determined from volume by its Size modifier, p. VE26): the volume of a sphere is (4[PI]/3) x the radius cubed. Magnetic shielding and stasis web power is actually the energy required to activate the field (in kWs rather than kW), not an ongoing power requirement. It must be paid each time the field is turned on.

Crew and Passengers

This section expands on the rules and systems described in Chapter 6 of *GURPS Vehicles*.

Crew Stations and Seats

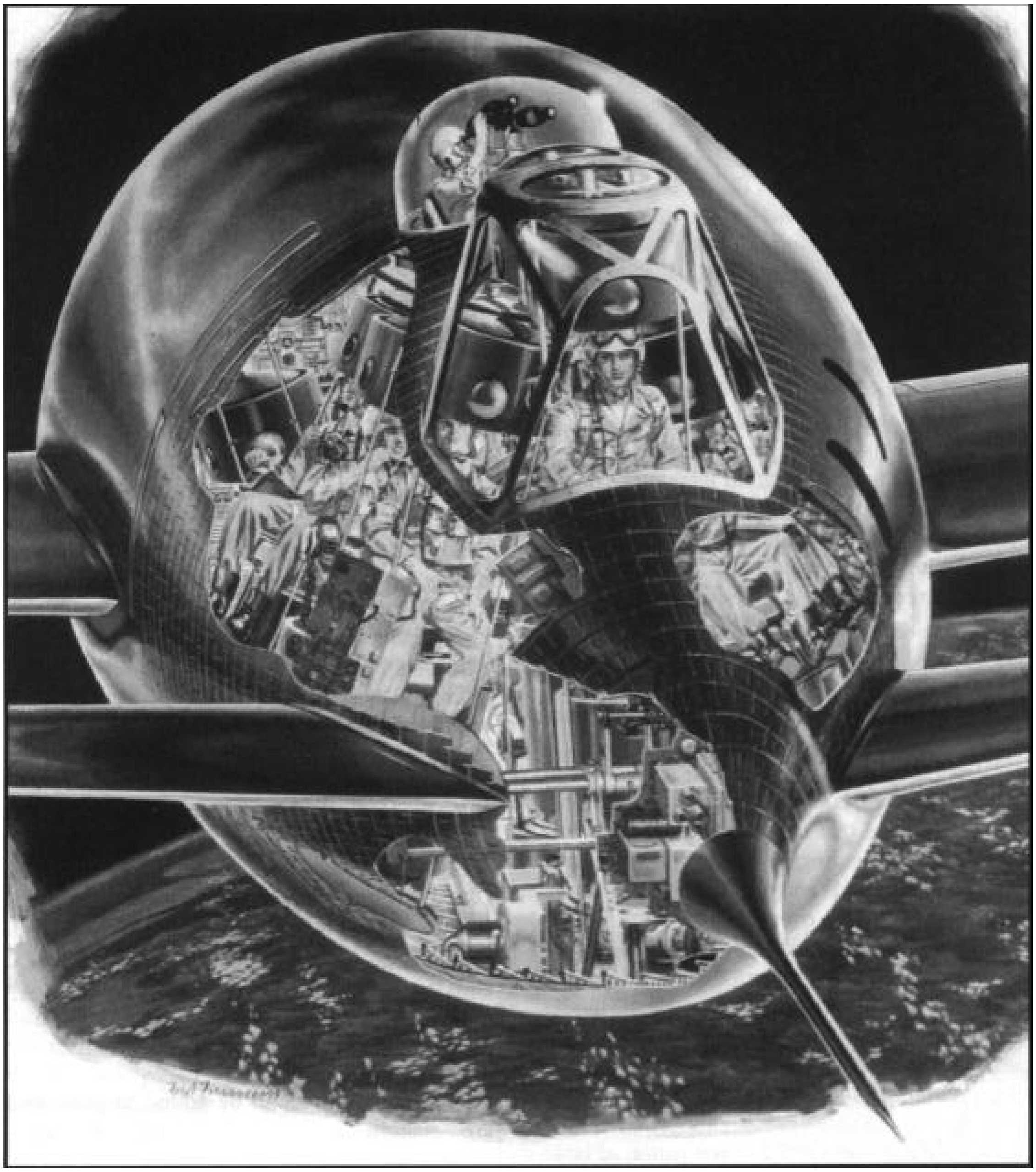
These options can be added to seats and crew stations.

Split Volume

A vehicle design may split the volume of a crew station or passenger seat between two adjacent structures, such as between the body and turret of an armored vehicle or aircraft, or between the superstructure and open mount of a warship. Any person in that position has an equal chance of being hit by rounds that penetrate either portion of the craft, however, and damage from explosive warheads will affect both locations.

Folding Seats

A seat can be designed to be folded up and turned into cargo space. The cargo space produced is half the volume of the seat. The seat costs 5 x normal.



Alien Accommodations and Crew Stations

Statistics for crew stations, passenger seats, and quarters assume the occupant will be a typical human - 1.5 to 2 yards tall, under a yard broad, around 150 pounds, and human-shaped. Seats or quarters designed for another species multiply volume by the average species weight/150, assuming that their density is similar to terrestrial life.

Races with similar but not identical shapes or sizes can use stations, seats, or quarters designed for each other if their sizes are within a factor of 2, although not very comfortably. Assess a -1 (or worse) penalty on skill rolls when using controls designed for a significantly different species.

Similar rules can be used to create crew stations and seats designed to be used by occupants wearing battlesuits (or by robots). Multiply the volume of seats designed to hold suited humans or robots by suit (or robot) volume/4 if the suit is larger than 4 cf.

Alien Battlesuit Systems

Battlesuits (p. VE80) must be tailored for a specific species, and another species cannot use them unless their sizes and shapes are nearly identical. For aliens with different numbers or sizes of limbs than humans, either use a non-formfitting suit, or modify the volume of individ ual locations to suit the alien's shape.

Occupant Access Space

Extra space can be added to vehicles with crew stations, seats, or spaces to allow the occu pants to move around more easily. These are common in commercial passenger vehicles such as buses, railway carriages, and airliners. *Improved access* adds 50% to the volume required and allows occupants to move without displacing anyone else, and/or to recline the seats comfortably. *Superior access* doubles the volume and allows serving carts, wheelchairs, troops with heavy weapons or in battlesuits, or other large objects to move freely.

Galley and Toilet Facilities

Food preparation and waste removal facili ties are included in vessels with quarters. However, craft designed for long trips but which lack proper living accommodations may incorpo rate separate toilet or gallery facilities, e.g., on an airliner, inter-city bus, etc.

Galley (TL 1): A well-equipped kitchen. Adds +1 to Cooking skill at TL5 and below, or +2 to Cooking skill at TL6 and above. Up to three people can work in it comfortably. 3,000 lbs., 400 cf, $1,900, and (at TL6+) 1 kW. For small galley, see p. VE77.

Shower (TL6): A one-person shower. May have hot water on any vessel with a 5-kW or larger power plant. 100 lbs., 50 cf, $50. For 10 lbs., 0.2 cf, and $50, an airlock can have a show er to act as a one-man decontamination unit to clean off NBC contaminants.

Toilet (TL5): A typical vehicular toilet is treated as a seat with double weight and cost. Adding superior access (above) is a good idea. Less-comfortable waste removal systems can be added to a battlesuit system for 5 lbs. and $100.

Power and Fuel

This section provides additional rules and design options for power plants and fuel, expanding on those described in Chapter 8 of GURPS *Vehicles.*

Extra Detail – Fuel Consumption

Some fuel consumption figures in *Vehicles* are understated (see p. VE82), as they are based on normal cruising operation at half or less power. For more realistic fuel requirements, multiply the fuel usage of all jet engines and internal combustion or gas turbine power plants that use coal, wood, jet fuel, gasoline, or diesel fuel by 3

Windmills

Windmills are sometimes mounted on boats, flying islands, or other vehicles to provide extra power. A windmill's basic attribute is the diame ter of its blades, equal to twice the length of a single blade.

To find the cost in dollars, square the diame ter in feet and multiply by 10. Weight is 10 lbs. times the square of diameter in feet at TL5, half that at TL6, 1/4 at TL7, 1/10 at TL8+. Volume is weight divided by 100.

Windmills are normally built in locations with reasonably steady winds; daily average power for a windmill, in kW, can be estimated as the square of the diameter in feet, divided by 1,000. Multiply by 1.5 at TL6, 2 at TL7, or 2.5 at TL8+. For instantaneous power multiply by half the current wind MTF (see *Expanded Wind and Sails Table, p.* 29).

Location: Windmills must be mounted so the blades can freely rotate. This is usually done by mounting them on a mast higher than the blade radius; other mounting methods require GM approval.

Ocean Thermal Energy Conversion

OTEC power plants extract energy from the temperature difference between the warm surface water and the cold deep water of the ocean. They have been proposed as the power source for giant floating aquatic colonies and mining bases.

The basic components are the onboard machinery - pumps, heat exchangers, working fluid, and turbines - and a long (1,000'-2,000') pipe for obtaining cold water. For each kW gen erated, the machinery weighs 200 lbs., occupies 4 cf, and costs $2,000 at TL6. Halve weight at TL7+. The pipe has an area of 1,000 sf times the square root of kW and should be purchased as a vehicle structure; add the surface area to the vehicle's structural area.

Energy Banks – Alternate Power Cells

Power cells are the standard GURPS energy storage device at TL8+. Power cells are capable of storing a great deal of energy and discharging it instantly in order to power lightweight beam weapons, but this exceeds plausible chemical binding energies - realistically, the cells would explode! Here are alternatives for a harder science campaign:

Advanced Batteries (TL8) are a more realistic alternative to power cells. Instead of using the advanced battery entry on p. VE88, assume they are available at the same TLs as power cells, but cost only 30% as much and weigh 10 times as much per kWs. Advanced batteries are described as an alternative in *GURPS Space.*

Power Cartridges (TL8) are chemical-energy pulsed-power generators described in *GURPS Ultra-Tech 2.* They weigh 0.72 times as much as a power cell of the same capacity and cost $100 x weight. They can only be used once, expending all their energy within a single turn. Any unused energy is lost, which usually limits them to weaponry applications or electromagnetic armor (pp. 27-28).

Power Slugs (TL8) were introduced in *GURPS Cyberworld (p.* CW94) as a transitional step to power cells, using the experimental high-temperature superconductors of that setting. They come in various sizes. Power slug energy banks based on the large E slugs are six times the weight and volume of a standard power cell, but only half the cost per pound of weight.

Antimatter Storage

Standard antimatter storage systems are rather heavy, which reduces the utility of antimatter propulsion (p. VE36). Many settings using antimatter assume much more efficient storage. Some possible approaches:

High Capacity AM Storage Bay (TL9): These use alternative antimatter storage technology to the antimatter storage bays on p. VE90. They are more expensive, but substantially lighter and more compact.

Antimatter Storage Fields (TL 11): These exist only if gravitic or deflector field technology is available. They are very light-weight storage units containing slightly pressurized antihydrogen gas.

Annihilation Dampers (TL12): See p. 21, under *Field Generators.*

Antimatter Storage Table

TL	Type	weight	Volume	Cost
9	High Capacity AM Storage Bay	50	0.5	$100,000
10	High Capacity AM Storage Bay	20	0.2	$40,000
11	High Capacity AM Storage Bay	10	0.1	$20,000
12	High Capacity AM Storage Bay	5	0.05	$10.000
13+	High Capacity AM Storage Bay	2.5	0.025	$5,000
11	Antimatter Storage Field	0.05	0.1	$200
12	Antimatter Storage Field	0.025	0.1	$100
13+	Antimatter Storage Field	0.015	0.1	$50

Weight, volume, and cost are per gram of antimatter storage.

Fuel and Fuel Tanks

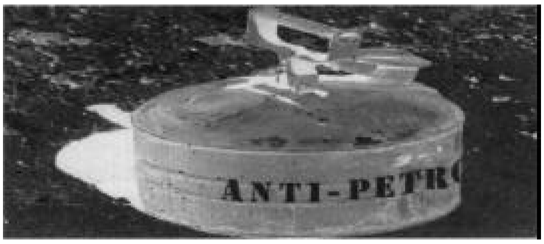
These rules add additional options for fuel storage and describe a new type of reaction

Collapsible Tanks (TL5)

These are made of a light folding material - rubberized canvas at TL5, polymers at higher TLs - and typically erected in a cargo space or open deck. An empty collapsible tank can be folded for storage into a space equal to the empty weight/40 cf. A filled tank will rupture, spilling its contents, if the vehicle makes a maneuver above 1.5 G (30mph/s). Cryogenic fuels can't be stored in such tanks until TL8, and no other weight-reducing options can be combined with the collapsible option. Weight is x 0.1, volume x 1.2 (if filled), cost x 1, and Fire +2.

Solid Fuels – Rock Dust

This is typically powdered asteroid, sifted lunar regolith, or other indigenous material used as reaction mass in a mass driver engine. If intended to be used as a propulsion system, it may be stored in tanks (0.15 cf/gallon) or fuel bunkers. It weighs 180 lbs. per cf and costs $0.1



Extra Detail – Remote Ignition Interruption

This safety system is common on some late TL7+ vehicles that use flammable fuel such as gasoline. If the vehicle suffers a hard shock (typically 20+ points of crushing damage before subtracting DR), a switch automatically cuts off fuel to the engine. It prevents tires resulting from damage to the power plant and disables the engine until reset. This system is available as a free option for any late-TL7+ internal combustion engine.

Extradimensional Components

Perhaps the ultimate in space-saving vehicular superscience is to spread a vehicle's components over more than one dimension.

Extradimensional Interior (TL15)

The vehicle is larger inside than outside! Components placed in the vehicle's own pocket dimension do not contribute to the weight or volume of the vehicle, and usually do not interact with the world outside it.

Extradimensional sensors, weapons, communicators, or drives that require interaction with the outside are rarely usable from within the pocket dimension unless they themselves work across dimensions (GM's option), but extradimensional quarters, cargo holds, or fuel tanks are common applications. The GM may also rule that certain systems, such as teleporters or parachronic conveyers, can operate even if stored extradimensionally. At the GM's discretion, it may be possible to create dimensional "windows" that allow weapons, sensors, and drives to direct their emissions into real space.

Each pocket dimension requires a dimensional interface installed in real space. At TL15, for each cubic foot of pocket dimension, the dimensional interface weighs 0.001 lbs., occupies 0.00001 cf, costs $100, and draws 0.001 kW. If the interface is damaged or powered down, the contents of the pocket dimension are inaccessible. The destruction of the dimensional interface may result in the components (and anyone in them) being totally lost (GM's option). The GM may rule that interfaces for systems that require windows (drives, etc.) are available at TL 16 for 100 times normal weight, volume, cost, and power requirement.

Phase Anchor (TL15)

This is an alternative form of extradimensional storage. A phase anchor stores a component in another dimension, but on command it rotates back into normal space in a specific position relative to the anchor. Components can reappear interlocked with the vehicle as firmly as any other part, or be slightly detached from it as if they were "extradimensional hardpoint loads."

Extradimensional components are ignored when computing performance. As such, heavy armor, heavy weapons, reserve fuel tanks, and auxiliary propulsion systems (for use in different environments) are the most commonly phased systems. Spacecraft may phase the entire payload out of existence to improve acceleration!

A phase anchor weighs 0.1 lbs., occupies 0.02 cf, and costs $10,000 per pound of phased material it can recall. It consumes 20 kWs./lb. on phasing out the object (but none to phase it back

Surface and External Features

These features may be added to the exterior of a vehicle, as per GURPS ***Vehicles*** Chapter 8. They may be added to a vehicle after the total surface area has been determined.

Concealment and Stealth Features

Sculpted or Styling (TLO): The vehicle is shaped to be aesthetically pleasing as well as functional. This includes useless but interesting looking modifications such as spoilers, huge mufflers, or even sculpting it to resemble an animal or other object (dolphin, hot dog, etc.) as much as its shape allows. The GM may rule the design is incompatible with streamlining or stealth features, lowers performance (e.g., -1 SR), or affects reaction rolls.

Stealth, Infrared Cloaking, and Emission Cloaking (TL7-8): Two additional levels of masking are available. "Modest" is a lower level of technology, and can be retrofitted to vehicles (at +20% to cost). It subtracts 0.5 x (TL-4) from detection rolls. "Improved" is a level intermediate between Basic and Radical, and subtracts 1.5 x (TL-4). In both cases, round modifiers down.

Sound Baffling (TL6-7): Four additional levels of Sound Baffling are available. Modest and Improved are as described above. Advanced and Extreme Sound Baffling are levels beyond Radical; and represent the highly sophisticated underwater stealth technology often used by modern nuclear ballistic missile and attack submarines. Advanced Sound Baffling subtracts 3 x (TL-4), and Extreme Sound Baffling subtracts 4 x (TL-4).

Blackout Paint (TL8): A cheap substitute for IR cloaking, blackout paint diffuses IR emissions enough to provide a -2 to rolls for IR detection. It is not cumulative with more sophisticated IR countermeasures.

Distortion Mesh (TL 10): This generates a superscience field that completely blocks radscanners, chemscanners, bioscanners, and multiscanners of equal or lower TL. The mesh itself is detectable, but nothing within it is. Higher TL scanners suffer a -2 penalty to scan.

Hypersink (TL10): This is a superscience form of emission cloaking that allows the vessel to radiate much or all of its thermal and radiation output into another universe; even drive flare (if any) is reduced to a modest glow in the visual spectrum. A hypersink is superscience that may appear at the same TL as a stardrive or hyperdynamic grid, or at a higher TL. It reduces a vehi cle's radiated thermal and radiation signature to that of background radiation: that is, it's effec tively invisible to thermograph, infrared, passive radar, and radscanners as long as it's operating. A hypersink will normally only function in space, with the same limits as a hyperdrive (p. VE39) in regard to atmosphere and/or gravity.

Concealment and Stealth Features

TL	Type	Weight	Cost	Power	Penalty
0	Sculpted or Styling	0.1	$20	0	n/a
7	Modest Stealth or IR Cloaking	0.8	$120	0	-0.5 x (TL-4)
7	Improved Stealth or IR Cloaking	3	$1,200	0	-1.5 x (TL-4)
8	Modest Emission Cloaking	0.8	$120	0	*-0.5 x* (TL-4)
8	Improved Emission Cloaking	3	$1,200	0	*-1.5 x* (TL-4)
6	Modest Sound Baffling	1	$50	0	-0.5 x (TL-4)
7	Improved Sound Baffling	3	$500	0	-1.5 x (TL-4)
7	Advanced Sound Baffling	6	$5,000	0	-3 x (TL-4)
7	Extreme Sound Baffling	8	$10,000	0	-4 x (TL-4)
8	Blackout Paint	0	$0.2	0	-2
10	Distortion Mesh	0.2	$60	neg.	special
10	Hypersink	10	$1,000	1	special
11	Hypersink	5	$1,000	1	special
12	Hypersink	*5*	*$100*	*1*	special

Weight is the weight in pounds per sf of surface area. *Cost* is the price per sf of surface area. *Penalty* is the modifier to detection rolls using the sensor the feature is designed to mask the vehicle from. Except for sculpted, weight and cost are halved one TL after the feature first appears, and halved again two TLs after it first appears.

Cutters, Rollers, and Rams

Hedgerow Cutter (TL6): A light triangular blade that may be attached to a ground vehicle. It is small and low enough that it does not impede firing like other blades. It enables the vehicle to cut a path through brush. A ram from a hedgerow cutter does an extra +1d damage. It weighs 0.5 lbs. *x* body area and costs $2 *x* body area.

Minesweeping Roller or Flail (TL6): A heavy rotating drum or motorized flail with metal chains. It is designed to detonate mines in front of the vehicle.

It can only be used on vehicles with a tracked or wheeled drivetrain, and is usually placed in an open mount (p. VE9) on the vehi cle's front. If the open mount is given limited rotation the entire assembly can be swiveled up and out of the way.

It may not be mounted on a vehicle that already mounts a plow, hedgerow cutter, or bulldozer blade, and the vehicle may not fire front mounted weapons (but may use turret-mounted weapons normally) except when the minesweeper is swiveled up (in which case the situation is reversed). The minesweeper detonates pressure trigger (p. VE117) mines as if the minesweeper weighed 10 times the vehicle's normal loaded weight. Other mines are detonated on a roll of 1-5 on Id. The area affected is (vehicle's Size Modifier) yards in the front arc; uneven ground reduces the effectiveness, as do mines of a higher TL then the sweeper. The minesweeper takes normal damage from exploded mines as if it was one yard away; the front of the vehicle takes normal damage as if it was (vehicle's Size Modifier) yards away. Powerful mines are capable of disabling the sweeper or the vehicle! The chains or roller will also do 3d extra crushing damage in a collision. Maximum speed at which the minesweeper can function at full effectiveness is 10 mph. It weighs 12 lbs. x body area (minimum weight of 1,000 lbs.) and costs $12 x body area (minimum cost $4,000). The minesweeper unit is external to the vehicle but has a volume of weight/20 in the open mount; this is also used to calculate its surface area.

The minesweeper has a base DR 100 at TI-6, DR 150 at TL7, DR 200 at TL8, DR 300 at TL9, and so on. This DR also protects against frontal collisions. Hit points are 2 x area at TL6, 4 x area at TL7, and 6 *x* area at TL8+.

Advanced Ram Plate (TL8): An improved ram backed with advanced shock absorbers. Any collision with the ram plate inflicts an extra +1 per die on the object hit, and -2 per die to the vehicle using the ram plate. Weight is 2 lbs. x body area and cost is $4 x body area. A ram plate must be mounted on a surface with at least DR 40.

Extra Detail – Bubble Generator (TL8)

Supercavitation (see *Supercavitating Hull,* p. 5) may be more easily achieved by injecting quantities of gas along the hull surface to induce flow separation.

Any vessel with a supercavitating hull may have a *bubble generator.* Decide if the generator is self-contained (using an internal supply of hydrogen-oxygen fuel) or water-breathing (transforming water into air bubbles). Then select the generator's bubble factor: this will affect its performance (see p. 30).

A self-contained generator requires that the vessel have a fuel tank; a water-breathing generator normally requires an energy bank.

The generator weighs 1 lb. x bubble factor x cube root of vehicle surface area. It either consumes weight/] 0 gallons of HO fuel every sec ond (if self-contained), or requires 200 x weight kWs power each second (if water-breathing). It costs $50 times weight.

Defensive Surface Features

These are designed to provide protection in addition to a vehicle's armor.

Applique Armor

An external layer of armor may be bolted (or otherwise attached) to a vehicle to provide extra DR. Buy it like an additional layer of armor (it may be a differ ent type) but add 5% to its weight (and thus cost). However, PD is only based on the outer layer.

Calculate two sets of DR and PD - one with and one without the add-on. When the vehicle is complete, calculate two sets of weight and mass figures - one with the added armor weight and one excluding it. Do the same for any performance calculation in which the vehicle's weight or mass is important.

Applique armor may not be added to a vehicle with "good" or better streamlining, or with submarine or supercavitating lines, nor may it be added to the underside of a vehicle with "average" or better hydrody namic lines. A vehicle with stealth loses its benefit unless the applique armor incorporates that level or better of stealth capability.

Applique armor may have an external coat equivalent to modest or basic stealth (weight and cost based on the armor's surface area).

Electromagnetic Armor (TL8)

"EM Armor" is another means of neutralizing shaped-charge warheads - a more advanced (and lighter) alternative to reactive armor. In particular, EM armor may be used to provide protection for armored vehicles against top attack.

It consists of a double layer of thick spaced plates (armor modules) that may either be installed on the outside of a vehicle in a fashion similar to reactive armor or integrated into the vehicle's structure. Integrated into them are high-speed impact sensors, switches, and high-voltage feed lines. It requires an instant-discharge energy bank (not included) such as power cells, power slugs, or capacitors; if superscience power supplies are unavailable, the capacity of the required energy bank will usually be the primary limitation on EM armor.

When a projectile hits the vehicle, sensors detect the impact (generally before it has penetrated more than 3mm) and apply voltage to the plates in the impact area, generating an intense electromagnetic field.

Extra Detail – Reactive Armor Plates (Late TL7)

A powerful-enough shaped-charge warhead can actually penetrate explosive reactive armor (p. VE93). Therefore, instead of the RAP automatically destroying the shaped charge warhead, it provides DR 1,000 against it. This is usu ally enough to defeat small shaped-charge warheads, but high-tech or large warheads may still inflict some damage (unless stopped by other DR). The limitations of RAPS against more advanced HEAT warheads led to the develop ment of newer heavy RAP, described below:

Heavy Reactive Armor Plates (Late TL7): HRAP is an improvement of explosive reactive armor (see *Reactive Armor,* pp. VE92-93) that uses substantially thicker plates. This gives extra protection against kinetic energy-class rounds and is more effective against shaped charges. Unshaped-charge attacks must do 200 hits of damage to count as a "prior hit by a shaped charge" (p. VE93). Against shaped charges (includ ing HEAT and HEDP), it defends as if it had DR 2,000. In addition, detonating HRAP will sheer off the penetrator tips of APS, APDS, APDSDU, APFSDS, and APFSDSDU, effec tively providing DR 700 vs. them. HRAP weighs 90 lbs. and costs $250 per square foot covered. HRAP plates can be repaired at 2% of the original cost per "hit" they have taken.

This creates magnetohydrodynamic instabilities which will disrupt the penetrating jet produced by a shaped-charge warhead, severely degrading or nullifying the warhead's effect. Electromagnetic armor plates also provide a lesser degree of protection against kinetic-energy impacts and plasma or fusion weapon attacks.

To design EM armor, choose its DR bonus, up to half the DR of the vehicle's metal, laminate, and/or composite armor (or the armor on the facing protected, if it varies); the vehicle must have at least DR 16 of metal, laminate, or composite armor. EM armor weighs the same as expensive ablative armor (p. VE22) and costs $100 x weight. The vehicle must have an energy bank; the armor drains 1 kWs *x* DR per hit if triggered. If the energy is not available, the armor does not function.

If an attack penetrates armor (and force screen) DR, electromagnetic armor is triggered. Its DR (abbreviated emDR) protects only against shaped-charge class (p. VE191), kinetic-energy class (p. VE188, including multiple projectiles and explosively-forged penetrators, such as from SICM), and plasma and fusion weapons. Moreover, it *ignores* armor divisors for shaped-charge warheads (and any armor divisors that particular plasma or fusion weapons may have, e.g., the plasmafaust). Attacks which fail to penetrate the normal DR of the armor do not trigger the electromagnetic armor or drain energy.

Example: A light tank has DR 400 metal armor plus emDR 200. It is hit with a missile with a HEAT shaped-charge warhead that does 6d x 9 (10) damage, inflicting 189 points of damage. The vehicle's metal armor DR is divided by 10 due to the shaped-charge armor divisor, so 149 points penetrate. The emDR than triggers: its DR 200 is unaffected by the shaped-charge armor divisor and stops all 149 points, but it drains 200 kWS.

Triggered EM armor can be detected via a MAD as per a railgun discharge *(MAD Modifiers, p.* VE172).

Applique Electromagnetic Armor (TL8): This can be added as an "after-market" add-on, using the rules for applique armor.

Exo-Husk

This is similar to applique armor, but more comprehensive. Treat as applique armor, but add any combination of armor and/or surface features.

An exo-husk is equipped with explosive bolts and is designed to be harmlessly and instantaneously ejected from the vehicle on the press of a button. This is useful for situations where extra acceleration or speed (achieved by reducing vehicle weight) is more important than protection, stealth, or whatever other capabilities are built into the husk.

Buy an exo-husk like a second layer of armor and/or surface features covering the entire vehicle, but add 10% to its final weight and cost.

As with applique armor, calculate two sets of statistics, one including the extra weight of the husk. Normally, the vehicle functions using the "with exo-husk" statistics. However, at the start of any turn, the vehicle operator can jettison the exo-husk. Switch to the "without exo-armor" sets of statistics for PD, DR, and performance. An exo-husk that has been ejected is considered destroyed.

Defensive surface features like stealth that are built into the vehicle rather than the husk do not function until the exo-husk is ejected.

Hyperdynamic Field Grid

What if hyperspace is filled with a medium denser than vacuum? A vessel with a hyperdynamic field grid generates a superscience energy field across its body surface that extends into this hyperspace even as the vessel itself occupies normal space. This generates friction; the result is a spacecraft that can maneuver through space as if it were in an air-filled zero-g environment.

See *Space Performance in a Hyperdynamic Field (pp.* 31-32) for operating parameters. The maximum speed a vessel can achieve without disrupting the grid's energy field will vary, but depends mainly on aerodynamic drag; fast hyperdynamic craft are streamlined! A hyperdynamic grid must surround the entire vessel. It weighs 0.1 lbs., costs $100, and requires 0.1 kW power per sf of vehicle surface area.

Hyperdynamic Field Grids and Superscience Drives: In some universes, a hyperdynamic field grid is a necessary precondition to the operation of reactionless thrusters, conversion thrusters, grav drives (see GURPS *Vehicles* Expansion 2), etc. That is, unless the hyperdynamic grid is installed and operating, they won't work, and when the grid is operating, they can't be used to accelerate past the vehicle's hyperdynamic top speed.

The potency of a hyperdynamic field is governed by the *hyper factor* of hyperspace, which the GM sets. The default is 100 (constant over all TLs), but it may be less or more, up to a maximum of 30,000. The higher the hyper-factor, the greater a vessel's typical performance. It is also possible that various levels of hyperspace exist with variable hyper-factors accessible to higher-TL fields, or that the value may increase with increasing distance from stellar or planetary masses. Hyperspace may even have currents, winds, or calms that locally modify hyper-factor or vessel speed.

Performance and Operations 4

This chapter expands on chapters 10 and 12 of *GURPS Vehicles,* providing additional rules for sailing, submersible, and supercavitating vessels.

Water Performance – Wind and Sails

GURPS Vehicles discusses wind speed and its effects on sailing vessels in two places: under *Sails (p.* VE30), where the wind force according to the Beaufort scale determines the ship's speed, and then again in the sidebar *Sails and Wind* (see p. VE159), which describes the effect of gales and stronger winds.

In fact, the Beaufort scale includes all winds possible on Earth, and is based less on wind speed than the general effect of wind on the sea surface (which is of greater importance to sailors). The scale goes further than the force 7 wind listed on p. VE30, encompassing every thing from complete calm (0 Beaufort) to a violent hurricane (12 Beaufort).

These rules are for use with the expanded sail options (pp. 8-10). They add additional flavor at the cost of extra complexity. The table below summarizes how wind conditions measured on the complete Beaufort scale affect sailing:

Expanded Wind and Sails Table

Scale	*Wind Speed*	*Sea*	*Hazard*	*HRM*	*MTF*	*Sailing*
0: Calm	0-1	calm water	--	0	0	None
1: Light air	2-3	calm water	--	0	1	Slow
2: Light breeze	4-7	calm water	--	0	2	Slow
3: Gentle breeze	8-12	choppy seas	1 day	0	3	Slow
4: Moderate	13-18	choppy seas	4 hrs	0	4	Good
5: Fresh breeze	19-24	choppy seas	2 hrs	-1	5	Fast
6: Strong breeze	25-31	rough seas	1 hr	-I	5	Rough; furl 1/4 sails
7: Near gale	32-38	rough seas	30 min	-1	4	Rough: furl half sails
8: Gale	39-46	rough seas	15 min	-2	3	Very rough: furl 3/4 sails
9: Strong gale	47-54	stormy seas	5 min	-2	0.25	Very rough: furl all sails
10: Storm	55-63	stormy seas	1 min	-3	0	All hands to the pumps!
11: Violent storm	64-73	major storm	1 min	-3	0	Man the lifeboats!
12: Hurricane	74+	major storm	1 min	-4	0	Davy Jones's locker!

Scale: The wind force levels according to the Beaufort scale, with a usual name for each level. *Wind Speed:* Measured in miles per hour.

Sea: The prevailing sea conditions typical at that wind force, which affect Control Rolls according to the sidebar on p. VE152.

Hazard: The time interval at which a Hazard roll must be made as long as the ship is in the area affected by the wind of the listed force. This interval is modified according to the vessel's Size Modifier. A positive modifier shifts the interval upwards one row per +1 (e.g. a ship with Size Modifier +3 in a Gale makes a Hazard roll each 2 hours instead of every 15 minutes), while the penalty shifts it downward. *Exception:* A ship in a Calm area, no matter how small, never makes Hazard rolls due to wind conditions. Treat all Size Modifiers above +6 as +6, and those below -3 as -3.

HRM (Hazard Roll Modifier): This is a modifier to all the Hazard rolls made when the ship is affected by the wind of listed force, in addition to the modifiers from the sea conditions. Do not apply this modifier to ordinary Control Rolls.

MTF (Motive Thrust Factor): Since the only way for a sailing vessel to survive under a strong wind is to furl part or all of her sails, the aquatic motive thrust of her sails is multiplied by this number instead of the wind force. Furling the sails will also prevent the HT loss described in the sidebar on p. VE159.

Sailing: This column gives a short description of what the sailing conditions look like from the perspective of the vessel's crew.

Wind Angle, Movement Rates, and Sailing

Depending on the direction of the wind in relation to the ship's course, its speed may vary significantly. These rules are used with the new MUA statistic (see *Expanded Sails Table, p. 9)*, and apply modifiers to a sailing vessel's speed depending on its angle from the wind. The table below shows the percentage of the top speed at which the ship sails related to the direction of the wind:

Expanded Movement Rates and Sailing Table

Wind Direction	*Angle from Wind*	*Square rig*	*Full rig*	*Fore-and-Aft rig*
On the bow	0°-MUA	(90°-MUA)/5%	-	-
On the bow:	MUA-85°	(90°-MUA)/2%	-	-
Abeam:	86°-105°	50%	80%	90%
On the quarter:	106^0-165^0	100%	100%	100%
Astern:	166°-180°	80%*	80%*	80%*

Exceptions: Simple square rig with single mast: 100%; catamaran or trimaran hull, or any spinnaker rig: 90% (not cumulative).

Submerged Performance – Crush and Test Depth

The *GURPS Vehicles* rules generate crush depths for real-world submarines that err on the side of generosity. For more realistic calcula tions, use these rules. Do not include DR from ablative or non-rigid armor, and take into account the size and shape of the vessel: smaller pressure hulls are inherently stronger than large ones, and spheres are twice as strong as cylinders. The revised crush formula is:

Crush Depth = (DR + 10) x **Frame Modifier** x **Shape Modifier / Size Modifier**

The Size Modifier is taken from the table on p. VE26; modifiers less than +1 are treated as +1 in this calculation. The Shape Modifier is 24 for spherical hulls, 6 for submersible hulls, and 3 for nonsub mersible hulls. (Note: this supersedes the division by 2 mentioned on p. VE133 for nonsubmersible hulls.)

While this system gen- erates absolute maximum crush depth values for sub marines, practical safe limits are more severe. To reflect this, give a submarine a test depth equal to 1/2 of its crush depth. This is the normal maximum oper- ating depth which the submarine will not exceed during routine operations. If it dives deeper, it must make a HT roll on a regular basis, with a +2 bonus to avoid flooding (pp. VE186-187). The roll can be made every hour for routine operations on a well-maintained submarine, or more frequently (e.g., every minute) when a lot of stress is placed on the hull, such as in combat maneuvering, dur ing a depth-charge attack, or if maintenance has been neglected. Every minute of flooding causes damage to the hull equal to 1 d x depth/10 yards. If it then exceeds its crush depth, the sub must roll again to avoid destruction.

Submerged Performance – Supercavitation

A vehicle with a supercavitating hull (p. 5) computes Water and Submerged Performance normally, but has several additional statistics.

Supercavitating Threshold (cThresh): This is the underwater speed the vehicle must reach to supercavitate. Use this formula:

cThresh = square root of [(submerged draft + 11 - B) x **175] mph.**

B is the bubble factor if the vessel is using a bubble generator (p. 27).

Similarly, to find the lowest depth (in yards) at which a vessel can initiate supercavitating speed *(cDepth),* use the formula:

(Underwater top speed squared / 175) -11 + B.

Extra Detail – Explosions and Pressure

When a submarine dives, its hull has to resist water pressure. As concussion damage also takes the form of pressure, these two effects are cumulative, and a submarine under high pressure is more vulnerable to nearby explosions. GMs who wish to represent this may rule that part of the vessel's DR is used to withstand pres sure from depth, and that on:y the remaining DR can be used to stop concussion damage. Check at what fraction of crush depth the sub is operating, and proportionally reduce DR against explosion damage only, remembering that DR is squared against concussion damage. (Thus, a vessel at its test depth uses half its usual DR, squared, against explosions.) This makes a submarine near its crush depth, its hull already groaning, vulnerable to even very small depth charges or torpedoes.

If this gives a result less than submerged draft, or less than zero, the vehicle can't supercavitate: redesign it with less draft or more thrust.

Supercavitating Top Speed (cSpeed): This is the top speed a vehicle can reach while supercavitating. Use this formula:

cSpeed = 6 x **square root of (cThrust/sDrag) mph.**

cThrust includes only the thrust of engines that will function during supercavitation (see *Supercavitating Hull, p. 5),* and sDrag is the vessel's submerged hydrodynamic drag (p. VE132). Round to the nearest 5 mph.

Supercavitating Acceleration (cAccel): Use this formula:

cAccel = thrust/weight x **20 mph/s.**

If result is below 1 mph/s, round to one place; otherwise round to the nearest whole number.

Supercavitating MR (cMR): As per wMR (p. VE132), but shift the column two steps to the *right* and ignore modifiers for flexibody drivetrain.

Supercavitating Deceleration (cDecel): A vessel may decelerate at 4 x cMR mph/s or may use crash deceleration via controlled collapse of the supercavity. In crash deceleration, cDecel in mph/s is equal to (current speed - cThresh) *x* cMR. A control roll for Hazardous Deceleration is required, at -1 per (cMR x 50) mph/s over ordinary cDecel (rather than -1 per 5 mph/s); treat a failure as an ordinary loss of control underwater.

Supercavitating SR (cSR): Use the rules for Aerial Stability Rating (p. VE136), with an extra -1 to SR; note that most supercavitating vessels lack wings. A failed control roll may result in an unplanned deceleration or collision with the bubble wall. If a control roll exceeds SR by 2+, the bubble collapses. The vehicle begins to decelerate at its crash cDecel, and at the beginning of each turn in which speed exceeds uSpeed must make a HT roll as if the vehicle had exceeded its crush depth (p. VE155).

Supercavitating Floor (cFloor): This is the maximum depth, in yards, at which the vehicle can *maintain* supercavitation. The formula is: cFl**oor = (cSpeed squared/175) -11 + B. B is** the bubble generator factor.

This may be greater than cThresh, indicating the vehicle may dive to a greater depth once it has managed to initiate supercavitation. If it is less than cThresh, supercavitation is slowing the vehicle: redesign it without the supercavitating hull. All supercavitating depth and cFloor statistics assume Earth normal conditions. On other worlds, the formula is:

depth (in yards) _

[p x **(speed squared) - 2,000 A] / 175G.**

P is the relative density of the liquid (water = *1), A* is the air pressure (in atmospheres), and G is the surface gravity (in Gs).

Sensors and Supercavitation: The vessel is surrounded by a vapor bubble (except directly forward), which generates a great deal of noise. It cannot use passive sonar, and active sonar is only usable if facing forward. A supercavitating vehicle gains no benefit from sound baffling or other acoustical stealth. Any type of sonar is at +2 to detect the supercavitation bubble. Passive sonar or noise detection gain an additional bonus equivalent to the MAD modifiers to detect fusion rockets (p. VE172), counting any cThrust used as power plants with effective kW = thrust/ 100.

Space Performance in a Hyperdynamic Field

A spacecraft in a hyperdynamic field can maneuver as if it were an aircraft flying in a thin pseudoatmosphere but zero gravity. Thus, it has no stall speed, no acceleration and deceleration due to gravity when climbing or diving, and no altitude losses due to failed control rolls. An active hyperdynamic field changes space performance as follows:

sAccel: Use the normal rules. *sDecel* is the larger of sAccel or 4 mph/s *x* sMR.

sMR: This is equal to sAccel (in G) multiplied by the hyper-factor (see above), unless the vehicle has a lifting body or wings, in which case it is the better of sAccel or a modified aMR.

Compute the lifting body or wing aerial maneuver rating normally. (For even more realism, if hyperspace acts like a real fluid, divide by its apparent density.)

sSR: Calculate it exactly like aSR (see p. VE136). Failed control rolls that give an Energy Loss result instead cause speed loss equal to 2 *x* sDecel. Tailspins still result in spin and wing stress, but no loss of altitude. *Hyperdynamic Top Speed:* Calculate this exactly like aerial top speed (p. VE134), except that thrust is limited to that produced by engines that function in vacuum. Then multiply by the hyper-factor.

If a hyperdynamic field is activated while the spacecraft is traveling faster than its hyperdynamic top speed it decelerates and cannot maneuver until its speed has dropped below hyperdynamic top speed. The GM may decide on the rate of this deceleration: sDecel = sAccel *x* [(current speed/top hyperdynamic speed) squared] or the aerobraking rules (p. VE164) are reasonable; a constant 1 mph/s (or similar value) otherwise.

Gravity Stabilization: At the GM's option, a vehicle in a hyperdynamic field divides felt acceleration (from maneuvers) by its hyper-factor for purposes of determining GLOC (p. VE154) and any structural stress on the vehicle.

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David Pulver's long-awaited supplement for ***GURPS Vehicles*** has dozens of vehicular design options and components – some have appeared in other ***GURPS*** books, and some are brand new! Now you can build:

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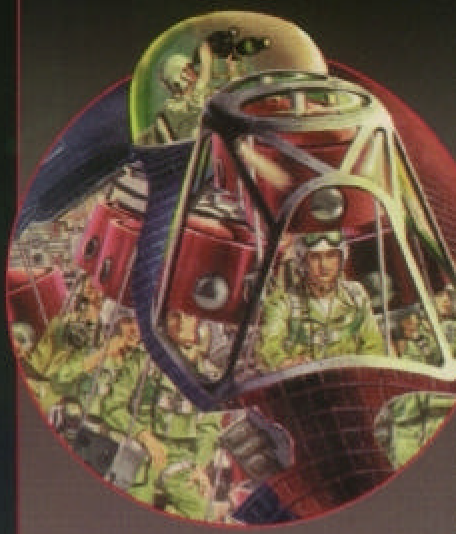

GURPS Basic Set**, Third Edition, Revised* and ***GURPS Vehicles**, Second Edition,* are *required* to use this supplement in a ***GURPS campaign. The ideas in ***GURPS Vehicles Expansion 1*** can be used with *any* roleplaying system.

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