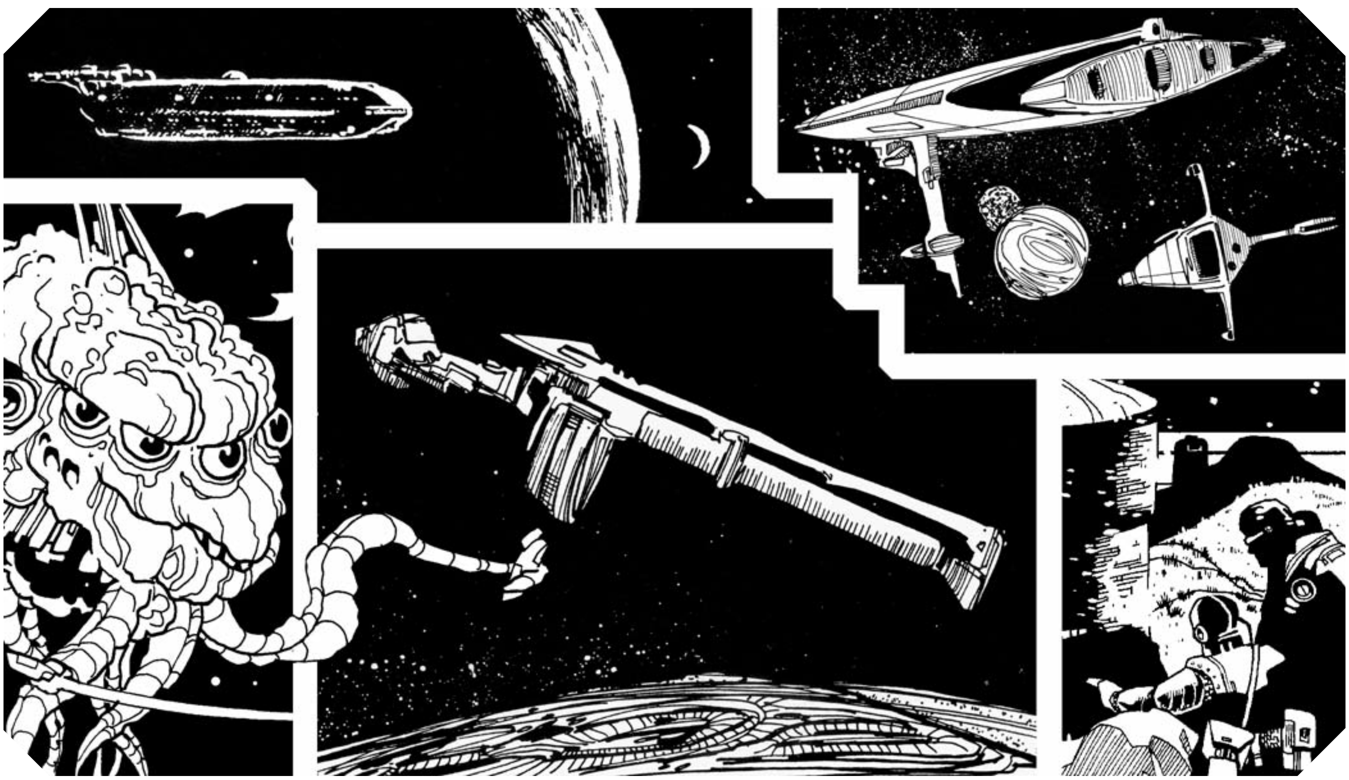
GURPS® Fourth Edition

SPACESHIPS 5

EXPLORATION AND COLONY SPACECRAFT™



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INTRODUCTION

Voyaging across the void, to uncover the mysteries of strange new worlds – this is the great dream and promise of space travel. This book presents a range of unmanned space probes and manned exploration and survey vessels designed to do just that, as well the colony ships that may follow them. In addition, game mechanics for exploration, survey, and contact missions are included, as well as and rules for facing the worst "man against nature" hazards of extended voyages in space, such as cosmic radiation and solar flares.

About the Series

GURPS Spaceships 5: Exploration and Colony Spacecraft is one of several books in the ***GURPS Spaceships*** series. This series supports GURPS Space campaigns by providing ready-to-use spacecraft descriptions and rules for space travel, combat, and operations. GMs will need the core book, ***GURPS Spaceships***, to use this book.

PUBLICATION HISTORY

Some of the survey and contact rules are derived from those found in ***GURPS Traveller: Interstellar Wars*** by Paul Drye, Loren Wiseman, and Jon F. Zeigler.

ABOUT THE AUTHOR

David L. Pulver is a freelance writer and game designer based in Victoria, British Columbia. He is the co-author of the ***GURPS Basic Set Fourth Edition*** and author of ***Transhuman Space, GURPS Spaceships, GURPS Ultra-Tech,*** and numerous other RPGs and supplements.

About *GURPS*

Steve Jackson Games is committed to full support of ***GURPS*** players. Our address is SJ Games, P.O. Box 18957, Austin, TX 78760. Please include a self-addressed, stamped envelope (SASE) any time you write us! We can also be reached by e-mail: **info@sjgames.com**. Resources include:

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Bibliographies. Many of our books have extensive bibliographies, and we're putting them online – with links to let you buy the resources that interest you! Go to each book's web page and look for the "Bibliography" link.

Errata. Everyone makes mistakes, including us – but we do our best to fix our errors. Up-to-date errata pages for all ***GURPS*** releases, including this book, are available on our website – see above.

Rules and statistics in this book are specifically for the ***GURPS Basic Set,*** *Fourth Edition.* Page references that begin with B refer to that book, not this one.

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Extra-special thanks to Kenneth Peters for playtest contributions above and beyond the call of duty.

Chapter One
Spacecraft

Isabelle Schooner gazed out the main terminal window of Earth Station. It was the first time she had really seen the finished starship up close. The ***Infinity*** *was the greatest spacecraft mankind had ever built, larger than the station itself. She was nearly a kilometer long, from her mighty antimatter engines to her forward radiation shield, a monument to a united Earth's determination to reach the stars.*

If only they weren't so very far away . . .

Isabelle's new husband Samuel, the starship's senior engineer, stood beside her. He'd spent the last decade building the great ship, even as she'd been instrumental in fighting the political and economic battles that financed it. They had married yesterday, one of a thousand couples who would crew the vessel. They would board the ship tomorrow. It would be the longest honeymoon in human history.

"There's nothing like her," Samuel said. "She's a beauty, that's for sure."

"That she is, Sam." Isabelle smiled. "Should I be jealous?"

"Can't I love you both?" He chuckled, but then his eyes turned serious. "But we ***must*** *love her, Isabelle, just like we love the Earth." His voice grew wistful. "Our distant descendents may one day walk on another planet. But for us, for our children, for the generations that will follow . . .* ***Infinity*** *will be the only world they'll ever know."*

This chapter presents a wide range of exploration and colonization spacecraft designed using the ***GURPS Spaceships*** rules. However, ***GURPS*** has no default interstellar background setting, and there are thousands of possible combinations of spaceship systems and degrees of superscience. The vessels included draw from three tech paradigms: realistic hard-science designs for TL7 to TL12; ships built with limited superscience propulsion systems, such as a torch drives or stardrives; and pervasive-superscience vessels that make extensive use of reactionless drives and other exotic technologies such as force fields.

These design choices are not the only options. Since the basic system of ***GURPS Spaceships*** is highly modular, it's easy for GMs to swap out components and adjust them to fit their campaign. Feel free to remove or replace any systems , adjusting statistics as described in the ***GURPS Spaceships*** rules.

Probes

Unmanned probes are the first exploration spacecraft launched by a society. Their lack of crew simplifies life support and allows one-way missions, eliminating the need for fuel or power enough to return home. Probes may spend decades or centuries voyaging through space, radioing back their discoveries for as long as they continue to function.

GURPS Spaceships is not intended for building very small vessels, such as many TL7-8 probes, so these designs are large and sophisticated interplanetary and interstellar craft, most controlled by artificial intelligences.

Adventurers don't operate star probes, but efforts to launch them and reaction to news of their startling discoveries could catalyze adventures. Manned exploration or trading vessels may even come upon long-lost probes, now valuable historical artifacts or potential safety hazards. First contact with an alien civilization might be an encounter with one of its robotic space probes.

Icarus-Class Space Probe (TL8)

This is a large, reusable solar-electric powered unmanned spacecraft, designed to operate indefinitely with little or no maintenance. It would be most useful in the inner solar system where solar power is relatively abundant. The probe is 40 feet long with a 30-ton (SM +5) unstreamlined hull. It must be launched from an orbital station or spacecraft. Its small hangar bay deploys surface rovers onto airless moons or asteroids, and launches scientific packages.

Front Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2]	Robot Arm (ST 200).
[3-6]	Hangar Bays (total four tons capacity).
[core]	Control Room (C2 computer, comm/sensor 2, and no control stations).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2]	Science Array (comm/sensor 4).
[3-4]	Solar Panel Arrays (providing one Power Point each).
[5-6]	Fuel Tanks (1.5 tons ionizable reaction mass with 3.6 mps delta-V each).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2-3!]	Ion Drive Engine (0.0005G acceleration each).
[4-6, core]	Fuel Tanks (1.5 tons ionizable reaction mass with 3.6 mps delta-V each).

The probe is unmanned.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL8 (LOW-PERFORMANCE SPACECRAFT)												
8	*Icarus*-class	20	-4/3	12	0.001G/21.6 mps	30	4	+5	0	2	0	$1,227K

Comet-Class Deep Space Probe (TL9)

This is an unmanned probe for fast missions to outer-system planets, the Kuiper Belt, or the Oort cloud. With a delta-V of 192 mps, it goes from Earth orbit to Saturn orbit in under three months. It's built using a 100-foot, 300-ton (SM +7) unstreamlined hull. It uses a fusion pulse drive for propulsion, which provides much higher acceleration than lower-TL ion drives. Even so, it has no ability to land or take off from Earthlike planets and thus needs to be assembled and launched in space. The probe's hangar bays carry its payload and are large enough for a wide variety of scientific instrument packages.

Front Hull	System
[1]	Metallic Laminate Armor (dDR 7).
[2-5]	Hangar Bay (10 tons capacity each).
[6]	Science Array (comm/sensor 7).
[core]	Control Room (C5 computer, comm/sensor 5, and no control stations).

Central Hull	System
[1]	Light Alloy Armor (dDR 5).
[2-6]	Fuel Tank (15 tons nuclear fuel pellets with 24 mps delta-V each).

Rear Hull	System
[1]	Light Alloy Armor (dDR 5).
[2-3]	Advanced Fusion Pulse Drives (0.005G acceleration each).
[4-6]	Fuel Tank (15 tons nuclear fuel pellets with 24 mps delta-V each).
[core]	Engine Room.

The probe is unmanned. It has exposed radiators, and total automation that eliminates the engine room's workspace crew.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL9 (LOW-PERFORMANCE SPACECRAFT)												
9	*Comet*-class	50	-3/5	12	0.01G/192 mps	300	40	+7	0	7/5/5	0	$22.07M

Polaris-Class Multi-Stage Star Probe (TL11)

This is a two-stage slower-than-light star probe. Using a nuclear pulse rocket engine coupled with a magnetic sail, it's capable of reaching 5.9% of light speed to achieve a "flyby" interstellar mission (e.g., Earth to Alpha Centauri) in 75-100 years, dropping off various scientific instruments from within its hangar bays. By allowing extra time for braking via its magnetic sail, it could rendezvous with its target star system and explore it.

Polaris Booster Stage (TL11)

This first stage is little more than a powerful fusion pulse engine and a giant fuel tank built on a 10,000-ton (SM +10) hull 200 feet long. The booster attains an impressive delta-V of 11,200 mps, 6% of the speed of light.

Front Hull	System
[1]	Advanced Metallic Laminate Armor (dDR 30).
[2-3]	Small Upper Stage (*Polaris* star probe).
[4-6]	Fuel Tanks (500 tons of fuel pellets with 700 mps delta-V each).

Central Hull	System
[1-6, core]	Fuel Tanks (500 tons of fuel pellets with 700 mps delta-V each).

Rear Hull	System
[1]	Advanced Fusion Pulse Drive (0.005G acceleration).
[2-6, core]	Fuel Tanks (500 tons of fuel pellets with 700 mps delta-V each).

The booster is unmanned. It has total automation for its fusion pulse drive, exposed radiators, and is controlled from the star-probe state (below).

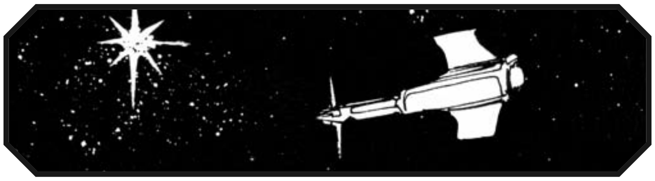
Small Upper Stage

An Upper Stage (***GURPS Spaceships***, p. 26) does not have to take up an entire six systems. A *small upper stage* is an alternative that only occupies two systems in the front hull. The small upper-stage spacecraft is two SMs smaller; for example, an SM +10 spacecraft has an SM +8 spacecraft as its small upper stage. If a hit location roll strikes either of these two systems, roll a hit location and apply damage to the front hull of the upper stage spacecraft instead. Otherwise use the normal rules for upper stages.

Polaris Star Probe (TL11)

The small upper stage of the star probe is an unstreamlined 1,000-ton spacecraft (SM +8) 75 feet in diameter. Its major propulsion system is a second fusion pulse engine that adds 4,410 mps to the first stage for a total delta-V of 15,610 mps (0.084*c*). This is backed up by a magnetic sail for braking against the interstellar medium.

The probe's front hull is heavily armored to protect against collision with dust particles. Larger objects are detected by sensors and destroyed by its fast-firing laser armament. It carries smaller probes and instruments in its hangar bays.



Front Hull	*System*
[1-2]	Advanced Metallic Laminate Armor (total dDR 30).
[3]	Hangar Bay (30 tons capacity).
[4!]	Major Battery (one 30 MJ improved rapid fire ultraviolet laser turret).
[5!]	Magsail (0.001G acceleration for braking/in-system propulsion).
[6]	Science Array (comm/sensor 10).
Central Hull	***System***
[1]	Advanced Metallic Laminate Armor (dDR 15).
[2-6]	Fuel Tanks (50 tons of fuel pellets with 490 mps delta-V each)
[core]	Control Room (C9 computer, comm/sensor 8, and no control stations).
Rear Hull	***System***
[1]	Advanced Metallic Laminate Armor (dDR 15).
[2]	Advanced Fusion Pulse Drive (0.005G acceleration).
[3-6]	Fuel Tanks (50 tons of fuel pellets with 490 mps delta-V each)
[core]	Fusion Reactor (two Power Points).

The probe is unmanned and has exposed radiators.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL11 (LOW-PERFORMANCE SPACECRAFT)												
11	*Polaris* Booster	150	-5/5	12	0.005G/11,200 mps	10,000	0	+10	0	30/0/0	0	$273M
11	*Polaris* Star Probe	70	-4/5	12	0.005G/+4,410 mps	1,000	30	+8	0	30/15/15	0	$68.6M

Exploration Ships

These spacecraft are designed to transport manned expeditions to distant destinations. Exploration ships are built to go farther (or faster) than ordinary commercial or military vessels, go where no one has gone before, and return within a reasonable length of time. They push the limits of what is possible at a given TL, such as chemical-propulsion rockets that go from Earth to Mars at TL8, or fast sublight starships that cross interstellar distances without superscience, traveling light years in decades rather than millennia.

For we are bound where mariner has not yet dared go. And we will risk the ship, ourselves, and all.

– Walt Whitman

Exploration ships feature scientific or multipurpose sensors, onboard lab facilities, and the hangar capacity to carry landing vessels, smaller probes, and planetary vehicles. A major challenge facing their creators is that an exploration ship can't expect to find a friendly spaceport at its destination. Those intended to return home must be self-sufficient, transporting all necessary supplies, spare parts, landing craft, and personnel for the mission. Vessels that use reaction drives have the further complication of carrying enough reaction mass to return home or appropriate refinery equipment to *make* those materials at their destination. If the reaction mass is water, it's easy to get from ice; if it's rocket fuel or hydrogen, it may be possible to process it from indigenous resources using a chemical refinery. Unfortunately, some of the best-performing reaction drives – such as those using antimatter, bomb pulse units, or nuclear pellets – require a major industrial effort to fuel.

Those built using superscience technologies such as reactionless drives or stardrives have fewer limitations. Designs range from small scout ships to giant cruisers for multiyear voyages of discovery. Space-opera exploration starships add powerful weapons and defense systems (such as heavy armor and force fields) to protect themselves from the likely threat of hostile aliens!

Nova-Class Rocket Ship (TL7-8)

Early space-exploration missions are launched by powerful chemical rocket engines. The *Nova*-class is configured to lob a payload from an Earthlike world onto an interplanetary trajectory. Similar in size to the Saturn V that carried the Apollo astronauts to the moon, it consists of two chemical booster stages, the *Nova* I and II (TL7 technology), to which stages may be added depending on the mission. For an interplanetary voyage, the upper stage (*Nova* III) is a *Chariot*-class nuclear booster that *also* carries a payload stage.

Nova I: First Booster Stage (TL7)

This heavy-lift booster uses a 3,000-ton (SM +9) streamlined hull 360 feet high. It adds 3.12 mps of delta-V to help boost the craft into orbit.

Front Hull	System
[1-6]	Upper Stage.
Central Hull	***System***
[1-6, core]	Fuel Tank (150 tons rocket fuel with 0.24 mps delta-V each).
Rear Hull	***System***
[1]	Chemical Rocket Engine (3G acceleration).
[2-6, core]	Fuel Tank (150 tons rocket fuel with 0.24 mps delta-V each).

Nova II: Second Booster Stage (TL7)

The second stage uses a 1,000 ton (SM +8) streamlined hull. It adds a further 3.12 mps of delta-V (total 6.24 mps), allowing the second stage *Nova* to reach low orbit.

Front Hull	System
[1-6]	Upper Stage.
Central Hull	***System***
[1-6, core]	Fuel Tank (50 tons rocket fuel with 0.24 mps delta-V each).
Rear Hull	***System***
[1]	Chemical Rocket Engine (3G acceleration).
[2-6, core]	Fuel Tank (50 tons rocket fuel with 0.24 mps delta-V each).

The spacecraft is controlled from its third or fourth stage.

Nova III: Chariot-Class Nuclear Booster (TL8)

This is the unmanned third stage of a *Nova*-class rocket. It is a 300-ton (SM +7) streamlined hull with a fission rocket propulsion system. It kicks in as the spacecraft is in low orbit, providing 6.24 mps of delta-V, more than enough for entry into an Earth-to-Mars transfer orbit with a substantial reserve.

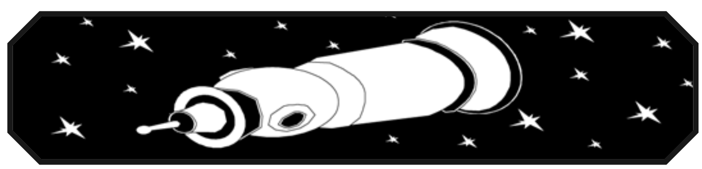
Front Hull	System
[1-6]	Upper Stage (Mars Lander, Phobos, or Deep Space Rocket).
Central Hull	***System***
[1-6, core]	Fuel Tank (15 tons hydrogen with 0.48 mps delta-V each).
Rear Hull	***System***
[1]	Nuclear Thermal Rocket Engine (0.2G acceleration).
[2-6, core]	Fuel Tank (15 tons hydrogen with 0.48 mps delta-V each).

The entire spacecraft is controlled from the upper stage.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL8 (HIGH-PERFORMANCE SPACECRAFT)												
7	*Nova I*	100	-2/4	12	3G/3.12 mps	3,000	0	+9	0	0/0/0	0	$19M
7	*Nova II*	70	-2/4	12	3G/+3.12 mps	1,000	0	+8	0	0/0/0	0	$5.9M
8	*Chariot*-class	50	-3/4	12	0.2G/+6.24 mps	300	0	+7	0	*/0/0	0	$2.8M

* The front dDR depends on the upper stage's front armor.

Phobos-Class Deep-Space Rocket (TL8)



This rocket ship can carry a four-man crew on an interplanetary journey, usually via a transfer orbit (see ***GURPS Spaceships***, p. 38). It is built with a 100-ton (SM +6) unstreamlined hull. In the sample *Mars Mission* (p. 8), this vessel is transported to Mars orbit using a *Chariot*-class booster (see above), then becomes an "Earth Return Vehicle" to achieve Earth orbit. It also aerobrakes and reenters a planetary atmosphere using its disposable soft-landing system.

Front Hull	System
[1]	Soft-Landing System.
[2]	Control Room (C3 computer, comm/sensor 3, and two control stations).
[3-5]	Fuel Tank (five tons rocket fuel with 0.27 mps delta-V each).
[6]	Habitat (five tons cargo).
[core]	Habitat (bunkroom).
Central Hull	***System***
[1-6, core]	Fuel Tanks (five tons rocket fuel with 0.27 mps delta-V each).
Rear Hull	***System***
[1]	Chemical Rocket Engine (3G acceleration).
[2-6]	Fuel Tank (five tons rocket fuel with 0.27 mps delta-V each).

Personnel include two control crew.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL8 (HIGH-PERFORMANCE SPACECRAFT)												
8	*Phobos*-class	30	-1/3	12	3G/4.05 mps	100	5.4	+6	4ASV	0	0	$1.15M

Mars Mission

A manned mission to Mars is often presented as a primary goal of near-future space exploration. Achieving this with TL8 reaction drive propulsion technology is challenging but possible. The most efficient way to do this is via a *transfer orbit* (see ***GURPS Spaceships***, p. 38). A mission requires these minimum delta-Vs:

5.6 mps to lift off into Earth orbit.
3.4 mps for a low-energy transfer orbit (which includes escape velocity) from Earth orbit to Mars orbit. (This takes 131 days.)
0.03 mps (or the use of wings or a soft-landing system) to land on Mars.
2.48 mps to boost from the Martian surface to Mars orbit.

No single spacecraft built at TL7-8 can carry fuel tanks with enough delta-V (almost 12 mps) for a land-and-return mission and still carry a useful payload, so a manned Mars expedition requires more than one multistage spacecraft.

Various proposals exist for manned Mars missions; many were treated in detail in ***GURPS Mars***. They range from multiple launches of chemical rocket ships using "off-the-shelf" technology to sophisticated affairs requiring near-future nuclear thermal or ion drive engines. One popular plan, Mars Direct, involves sending an automated chemical refueling plant first so astronauts can make return rocket fuel using indigenous resources.

The more complex resource-utilization plans are beyond the scope of the simple design system presented in ***GURPS Spaceships***. However, a basic near-future Mars mission using the TL8 spacecraft described in this chapter might involve the following steps:

1. A 3,000-ton *Nova*-class heavy-lift booster (pp. 6-7) is launched from Earth's surface, carrying an unmanned 100-ton *Phobos*-class Deep-Space Rocket (p. 7) to serve as an "Earth Return Vehicle" (ERV). The first two stages are used up lifting the vessel into orbit; the third stage boosts the vehicle into a transfer orbit bound for Mars. A few months later, the third stage and the ERV arrive in Mars orbit.
2. A second *Nova*-class heavy-lift booster is then launched, this time with its fourth stage carrying the two-stage 100-ton *Lowell*-class lander (pp. 13-14) with a four-man crew. It follows the same mission profile and also arrives in Mars orbit.
3. The *Lowell*-class lander descends from orbit to the surface, aerobraking in the Martian atmosphere and putting down with its disposable soft-landing system. Using it as their base camp, the crew spend several months exploring Mars until the next launch window for a transfer orbit back to Earth comes around.
4. The 30-ton upper stage of the *Lowell* (the Ascent Vehicle) blasts off, carrying the astronauts and any return samples into Mars orbit. It docks with the orbiting *Phobos*-class Earth Return Vehicle and the astronauts transfer to it.
5. The Earth Return Vehicle blasts out of Mars orbit and boosts into a transfer orbit toward Earth. Several months later, it arrives in Earth orbit.
6. The Earth Return Vehicle docks with a space station in Earth orbit or, more likely, uses its own soft-landing system to aerobrake and parachute down to Earth's surface.

This procedure ignores a few technical difficulties below the resolution of the system, e.g., the need to use a lower, specific-impulse, storable rocket propellant for the Ascent and Earth Return Vehicles.

Prometheus-Class Nuclear Rocket Ship (TL8)

This nuclear-powered exploration ship is intended for a slow two-way voyage of a few AU in length (e.g., Earth orbit to Mars orbit or to the asteroid belt) while carrying a four-man crew. It is built using a 1,000-ton (SM +8) unstreamlined hull 100 feet long. It's assembled in orbit and so requires the system to have a fairly extensive space infrastructure. On a typical mission, it uses delta-V to maneuver into a transfer orbit and then spends several months cruising. Its hangar carries landing craft for visiting the surface.

Front Hull	*System*
[1]	Light Alloy Armor (dDR 7).
[2]	Control Room (C4 computer, comm/sensor 5, and four control stations).
[3-6]	Hangar Bays (30 tons capacity each).
[core]	Habitat (one bunkroom, two labs, and one-bed sickbay).
Central Hull	***System***
[1-6]	Fuel Tanks (50 tons hydrogen with 0.42 mps delta-V each).
[core]	Engine Room (one workspace).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 7).
[2]	Nuclear Thermal Rocket Engine (0.2G acceleration).
[3-6]	Fuel Tanks (50 tons hydrogen with 0.42 mps delta-V each).

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL8 (HIGH-PERFORMANCE SPACECRAFT)												
8	*Prometheus*-class	70	-3/4	13	0.2G/4.2 mps	1,000	120.4	+8	4ASV	7/0/7	0	$14.7M

Enceladus-Class Exploration Ship (TL9)

Using nuclear pulse propulsion, this cruiser-sized spaceship is capable of transporting a large expedition anywhere in the solar system. Its performance far surpasses chemical or nuclear thermal rockets, but the price paid is the need to manufacture and detonate multiple nuclear bombs for thrust! The heavy armor on the rear section is its hemispherical pusher plate. The exploration ship's sizable hangar bay carries landing craft, robots, or other scientific equipment, and is an additional roll-on/roll-off cargo bay. It can reach an impressive delta-V of 56 miles per second, enough for reasonably fast interplanetary travel with plenty of delta-V remaining for a return. It has an unstreamlined 10,000-ton (SM +10) hull 300 feet long.

Front Hull	*System*
[1]	Steel Armor (dDR 10).
[2]	Science Array (comm/sensor 10).*
[3]	Hangar Bay (300 tons capacity).*
[4]	Habitat (20 cabins, gym, six labs, six-bed sickbay, and 100 tons cargo).*
[5-6]	Fuel Tanks (500 tons bomb pulse units with 5.6 mps delta-V each).
[core]	Control Room (C7 computer, comm/sensor 8, and only six control stations).*
Central Hull	***System***
[1]	Steel Armor (dDR 10).
[2-6, core]	Fuel Tanks (500 tons bomb pulse units with 5.6 mps delta-V each).
Rear Hull	***System***
[1-2]	Metallic Laminate Armor (total dDR 40).
[3]	Steel Armor (dDR 10).
[4-5]	Fuel Tanks (500 tons bomb pulse units with 5.6 mps delta-V each).
[6]	External Pulsed Plasma Drive (2G acceleration).*

* One workspace per system.

The typical complement consists of six control crew, one medic, five technicians, and 12 scientists.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL9 (HIGH-PERFORMANCE SPACECRAFT)												
9	*Enceladus*-class	150	-2/5	13	2G/56 mps	10,000	404	+10	40ASV	10/10/50	0	$293M

Constellation-Class Exploration Starship (TL9^)

Stardrives could conceivably be the fruit of a TL9 technological breakthrough, and this is a first-generation exploration starship equipped with such a stardrive and an early model fusion rocket reaction drive. Its engines use water for reaction mass to make refueling from indigenous sources (comet ice, etc.) simple. It is not designed for planetary landings, but has plenty of hangar-bay space for smaller craft. It is built using a 3,000-ton (SM +9) unstreamlined hull 200 feet long, and has spin gravity.

Front Hull	*System*
[1]	Metallic Laminate Armor (dDR 15).
[2-3]	Hangar Bays (100 tons capacity each).
[4]	Control Room (C6 computer, comm/sensor 7, and six control stations).
[5]	Cargo Hold (150 tons).
[6]	Habitat (eight labs, briefing room, two cages, and five tons cargo).
[core]	Habitat (12 cabins, briefing room, gym, and five-bed sickbay).
Central Hull	***System***
[1]	Metallic Laminate Armor (dDR 15).
[2-4]	Fuel Tanks (150 tons of water with 4 mps delta-V each).
[5]	Science Array (comm/sensor 9).
[6]	Engine Room (two workspaces).
Rear Hull	***System***
[1]	Metallic Laminate Armor (dDR 15).
[2-3]	Fusion Rocket (using water, 0.015G acceleration each).
[4-5]	Fuel Tanks (150 tons of water with 4 mps delta-V each).
[6]	Fission Reactor (one Power Point).
[core!]	Stardrive Engine (FTL-1).

It has spin gravity (0.15G). Personnel include six control crew, one medic, 16 scientists, and two technicians.

In wisdom gathered over time I have found that every experience is a form of exploration.

– Ansel Adams

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL9 (LOW-PERFORMANCE SPACECRAFT)												
9^	*Constellation*-class	100	-3/5	13	0.03G/20 mps	3,000	358.2	+9	32ASV	15	1×	$165.9M

ODYSSEY-CLASS EXPLORATION SHIP (TL9)

Using a 3,000-ton (SM +9) unstreamlined hull 400 feet long, this craft is designed for long-range interplanetary missions. It has a spherical forward section containing the habitat and hangar bay, with the central hull devoted to reaction-mass tanks and sensors, and the rear to its fission gas-core "nuclear light-bulb" engines. Its advanced nuclear rocket engines are simpler than a fusion drive (and much cheaper to fuel), and represent solid, conservative mid-TL9 engineering. A vessel of this class can make direct flights to inner-system planets such as Mercury or Mars, or enter a transfer orbit from Earth to Jupiter. Due to the relatively slow interplanetary speed, the crew may spend much of the journey in hibernation.

Front Hull	*System*
[1]	Metallic Laminate Armor (dDR 15).
[2]	Control Room (C6 computer, comm/sensor 7, and only four control stations).
[3-4]	Hangar Bays (100 tons capacity each).
[5-6]	Fuel Tanks (150 tons hydrogen with 1.12 mps delta-V each).
[core]	Habitat (four bunkrooms, three labs, gym, three-bed sickbay, 16 hibernation chambers, and five tons cargo).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 10).
[2-5]	Fuel Tanks (150 tons hydrogen with 1.12 mps delta-V each).
[6]	Science array (comm/sensor 9).
[core]	Engine Room (two workspaces).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 10).
[2-4]	Fuel Tanks (150 tons hydrogen with 1.12 mps delta-V each).
[5-6]	Nuclear Light Bulb Engines (0.01G acceleration each).

The *Odyssey* has exposed radiators.

The typical complement consists of six control crew, one medic, six scientists, and two technicians.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL9 (LOW-PERFORMANCE SPACECRAFT)												
9	*Odyssey*-class	100	-3/5	13	0.02G/10.08 mps	3,000	208.2	+9	16ASV*	15/10/10	0	$88.5M

* Plus 16 hibernation chambers, although these are intended for the crew.

KILROY-CLASS ARMORED SCOUT SHIP (TL10^)

This is a medium-sized exploration starship designed for operation by a small crew. It's a tough vessel, used to explore dangerous or disputed regions of interstellar space. The *Kilroy* has modest armaments and good scientific sensors, a decent cargo capacity and onboard lab facilities. This scout ship is probably too expensive for most private explorers, but is suitable for a corporate contact-and-trade team or a survey service. It has a streamlined 1,000-ton hull (SM +8) 300 feet long. Designed to make detection difficult, it is used for covert surveys of low-tech worlds. Its wings allow it to glide down into atmosphere without using the fusion drive.

Front Hull	*System*
[1-2]	Metallic Laminate Armor (total dDR 14).
[3]	Tertiary Battery (four fixed mount 20cm missile launchers, 39 tons cargo).
[4]	Habitat (two cabins, two bunkrooms, two-bed sickbay).
[5]	Habitat (two labs and 10 tons cargo).
[6]	Science Array (comm/sensor 9).
[core]	Control Room (C8 computer, comm/sensor 7, and four control stations).
Central Hull	***System***
[1-2]	Metallic Laminate Armor (total dDR 14).
[3-4]	Fuel Tanks (50 tons of hydrogen with 7.5 mps delta-V each).
[5]	Hangar Bay (30 tons capacity).
[6!]	Tertiary Battery (one turret with 10 MJ UV laser, 43.5 tons cargo).
Rear Hull	***System***
[1]	Metallic Laminate Armor (dDR 7).
[2-3]	High-Thrust Fusion Torch Engines (1G acceleration each).
[4]	Engine Room (one workspace).
[5-6!]	Stardrive Engines (FTL-1 each).
[core]	Fusion Reactor (two Power Points, 200 years endurance).

It is winged, with a stealth hull and dynamic chameleon surface.

Personnel include four control crew, one medic, four scientists, one technician, and one turret gunner.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT)												
10^	*Kilroy*-class	70	-1/5	13	2G/15 mps	1,000	123.7	+8	12ASV	14/14/7	2×	$101.5M

Einstein-Class Exploration Ramship (TL11)

This type of sublight starship is also called a ram-augmented interstellar rocket. Built with an unstreamlined 10,000-ton hull (SM +10), it relies on a fusion rocket engine and high-capacity fuel tanks to accelerate to 1,800 mps (1% of light speed). It then uses its ramscoop to gather reaction mass from the tenuous interstellar hydrogen clouds that exist between the stars and accelerates to 50% or more of light speed, protected against dust collisions by its ramscoop and tough hull. Its laser eliminates larger chunks of debris in its way.

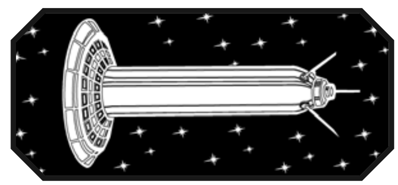
This vessel is intended for multiyear voyages, in ship time . . . thanks to relativistic time-dilation, this might mean centuries or millennia pass in the outside universe while it cruises at high fractions of light speed! Such a craft may even become a time capsule to the future, whose crew are the only ones in the universe who remember their own society – or even their own species.

Front Hull	***System***
[1]	Nanocomposite Armor (dDR 50).
[2!]	Ramscoop*.
[3]	Control Room (C10 computer, comm/sensor 10, and 10 control stations).*
[4]	Hangar Bay (300 tons capacity).*
[5!]	Medium Battery (one fixed mount very rapid fire 100MJ improved UV laser, 300 tons cargo).*
[6]	Science Array (comm/sensor 12).*
[core]	Habitat (20 cabins with total life support, bar, gym, school room, four labs, office, and five-bed sickbay).*

Central Hull	***System***
[1]	Nanocomposite Armor (dDR 50).
[2-6]	Fuel Tanks (500 tons hydrogen with 252 mps delta-V each).

Rear Hull	***System***
[1]	Nanocomposite Armor (dDR 50).
[2]	Fusion Rocket (0.005G acceleration).*
[3-6]	Fuel Tanks (500 tons hydrogen with 252 mps delta-V each).
[core]	Fusion Reactor (two Power Points and 1,500 years endurance).*

* One workspace each.



The spacecraft has exposed radiators. The typical complement consists of 10 control crew, a medic, eight scientists, a teacher, and eight technicians.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL11 (LOW-PERFORMANCE SPACECRAFT)												
11	*Einstein*-class	150	-5/5	13	0.005G/2,268 mps*	10,000	604	+10	40ASV	50	0	$1,532M

* Near-*c* with ramscoop.

Relativistic Travel and Time Dilation

As a spacecraft approaches the speed of light, time seems to run more slowly from the perspective of those aboard it. Time dilation and other relativistic effects are covered in ***GURPS Space*** (see *Relativity Effects,* p. 36). Time dilation can be mostly ignored below 15% of light speed, but increases as the speed of light is approached. For example, at 50% of light speed, ship time is 0.866 of planetary time; at 90% the time rate is 0.436. The formula is:

R = Square root of [1 - (V/*c*)^2]

R is the time rate experienced on board ship (relative to an unaccelerated frame of reference, e.g., a planet), ***V*** is the ship's velocity, and ***c*** is lightspeed (186,282 mps).

Dirac-Class Exploration Cruiser (TL12^)

This fast sublight exploration vessel is built using an unstreamlined 30,000-ton (SM +11) hull 500 feet long. With its antimatter pion drive it accelerates to a maximum of 23% of light speed, using its magnetic sail to decelerate. However, normal cruising speed for a two-way mission is 20,000 mps (10% of light speed) to ensure enough fuel to return home, since it's unlikely it can find antimatter fuel at the destination!

Even a relatively short interstellar voyage can take 30-50 years, so the crewmembers have hibernation chambers to sleep through the trip. Its tough front hull of diamonoid armor is designed to protect against high-velocity dust impacts. The starship has room for a thousand tons of landing craft and expeditionary equipment.

The major obstacle to building a vessel of this sort is manufacturing 6,750 tons of antimatter for the reaction. Scenarios where this is economically feasible involve covering a barren world (e.g., Mercury or the moon) with large numbers of robotic self-replicating solar-powered antimatter factories.

Front Hull	System
[1-2]	Diamondoid Armor (total dDR 200).
[3!]	Magsail (0.001G acceleration).*
[4]	Science Array (comm/sensor 14).*
[5]	Hangar Bay (1,000 tons capacity).*

After the Earth was used up, we found a new solar system, and hundreds of new Earths were terraformed and colonized.

– Shepherd Book, ***Firefly***

Front Hull	System
[6]	Control Room (C11 computer, comm/sensor 12, and only 10 control stations).*
Central Hull	**System**
[1]	Diamondoid Armor (dDR 100).
[2-6]	Fuel Tanks (1,500 tons matter/antimatter with 4,760 mps delta-V each).
[core]	Habitat (50 cabins with total life support, two gyms, 100 hibernation chambers, 20 labs, 10 minifac robofacs, 12-bed sickbay, and 45 tons cargo).*
Rear Hull	**System**
[1]	Diamondoid Armor (dDR 100).
[2]	Antimatter Pion Torch (0.1G acceleration).*
[3-6]	Fuel Tanks (1,500 tons matter/antimatter with 4,760 mps delta-V each).
[core]	Fusion Reactor (two Power Points).*

* Three workspaces per system.

Crew consists of 10 control, 40 scientists, two medics, and 21 technicians.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL12 (HIGH-PERFORMANCE SPACECRAFT)												
12^	*Dirac*-class	200	-3/5	13	0.1G/42,840 mps	30,000	1,065	+11	100ASV*	200/100/100	0	$2.91275B

* Plus 100 hibernation chambers.

Palomar-Class Exploration Cruiser (TL12^)

This extravagantly equipped starship is built for far-ranging exploration and contact missions deep into alien space. Constructed with a 300,000-ton (SM +13) 1,500-foot-long unstreamlined hull, it is heavily armed (for an exploration ship), and is operated by militarized surveys or scout services rather than civilian agencies. Despite the defensive armament, it is designed with an emphasis on crew comfort for multiyear voyages, with spacious cabins and plenty of recreation room. Survey missions are carried out using the sophisticated multipurpose array and extensive lab facilities, supplemented by a full complement of smaller landing craft carried in the hangar bay. Onboard replicator systems permit the crew to survive for decades at a time with little or no access to spare parts, and teleport projectors facilitate covert contact operations.

Front Hull	System
[1]	Exotic Laminate Armor (dDR 300).
[2!]	Medium Battery (three fixed mount 30 GJ disintegrators).
[3]	Control Room (C12 computer, comm/sensor 14, and only 20 control stations).*
[4!]	Medium Battery (two fixed 64cm warp missile launchers, one fixed 30 GJ tractor beam).*
[5]	Open Space (2.5 acre recreational park).*
[6]	Multipurpose Array (comm/sensor 16).*
[core]	Habitat (450 luxury cabins with total life support, 10 briefing rooms, 20 offices, 10 teleport projectors, 10 replicator minifacs, and 750 tons cargo).*
Central Hull	**System**
[1]	Exotic Laminate Armor (dDR 300).
[2!]	Heavy Force Screen (dDR 700, or dDR 1,400 with two Power Points).*
[3]	Cargo Hold (15,000 tons).
[4!!]	Super Stardrive Engine (FTL-2).*
[5-6]	Antimatter Reactors (four Power Points each).*
[core]	Habitat (370 luxury cabins and 20 cells with total life support, five large labs, 10 replicators minifac, 40-bed clinic sickbay, 20 teleport projectors, and 1,550 tons cargo).*
Rear Hull	**System**
[1]	Exotic Laminate Armor (dDR 300).
[2!]	Subwarp Drive (500G acceleration).*
[3]	Hangar Bay (10,000 tons capacity).*
[4!]	Subwarp Drive (500G acceleration).*
[5-6!!]	Super Stardrives Engine (FTL-2 each).*

* 30 workspaces per system.

The starship has artificial gravity and gravitic compensators. Design switches such as FTL/comm sensor array and multiscanner array are common.

Minimum complement consists of 20 control crew, 100 scientists, and 480 technicians.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL12 HIGH-PERFORMANCE SPACECRAFT												
12^	*Palomar*-class	500	0/5	13	1,000G/*c*	300,000	27,472	+13	1,680ASV	300*	6×	$82.785B

* Plus dDR 700 force screen (dDR 1,400 if using two Power Points).

Top air speed is 7,900 mph.

Exploration Landers

Large exploration, colonization, and survey ships may lack the capability to safely perform surface landings and takeoffs. To compensate for these deficiencies, they carry smaller craft optimized to do so, especially from undeveloped planets. Exploration landers may be more robust than ordinary shuttles, and some landing craft have onboard habitats or scientific facilities for use as temporary planetary bases.

> *Curiosity is the essence of human existence and exploration has been part of humankind for a long time.*
>
> *– Gene Cernan*

Artemis-Class Lander (TL8)

This is a landing craft for use on rocky, airless bodies with low gravity, such as the moon or Mercury. Since it can't rely on atmospheric braking, the *Artemis* must use rocket thrust for both landings and takeoff. It is built using a 30-ton (SM +5) unstreamlined hull 45 feet long, and is powered by chemical rocket engines. The habitat and control room are buried in the core to protect against radiation. Its hangar bay can carry instrument packages or a ground or air vehicle.

Front Hull	***System***
[1]	Light Alloy armor (dDR 2).
[2-3]	Hangar Bays (one ton capacity each).
[4-6]	Passenger Seats (two seats each).
[core]	Control Room (C2 computer, comm/sensor 2, and one control station).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2]	Cargo Hold (1.5 tons).
[3-6]	Fuel Tanks (1.5 tons rocket fuel with 0.21 mps delta-V each).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2]	Chemical Rocket Engine (3G acceleration).
[3-6, core]	Fuel Tank (1.5 tons rocket fuel with 0.21 mps delta-V each).

It is operated by a single pilot.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL8 (HIGH-PERFORMANCE SPACECRAFT)												
8	*Artemis*-class	20	-1/3	12	3G/1.89 mps	30	4.2	+5	1+6SV	2	0	$291K

Lowell-Class Planetary Lander (TL8)

This two-stage vessel is designed to land a four-person team and their equipment on worlds that possess a very thin or better atmosphere. It differs from the *Artemis*-class in that it serves as a long-term habitat. This particular design is optimized for a Mars landing (see the *Mars Mission* box, p. 8) – in such a role, it serves as the fourth stage of a *Nova*-class rocket, attached to the Nova III *Chariot*-class nuclear booster's (p. 7) third stage.

Lowell-Class Lander (TL8)

The landing stage uses a 100-ton (SM +6) streamlined hull. It aerobrakes and then employs its soft-landing system.

The upper third of the hull is devoted to an Ascent Vehicle. Key systems include a fabricator that recycles components and provides long-term self-repair capabilities, plenty of cargo space for supplies, two labs, and a hangar for a three-ton rover or other vehicle. The system can then serve as a base for several months of exploration of the surface.

After the mission is complete, the Ascent Vehicle blasts off to rendezvous in orbit with a supporting spacecraft. In the sample Mars mission this is a separately launched *Phobos*-class rocket serving as an Earth Return Vehicle.

Front Hull	***System***
[1-6]	Upper Stage (Ascent Vehicle).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 2).
[2-3]	Habitat (one lab, split between both systems).

Central Hull	System
[4!]	Fabricator ($5K/hour production capacity).
[5]	Soft-Landing System.
[6]	Engine Room (one workspace).
[core]	Habitat (bunkroom).
Rear Hull	**System**
[1]	Light Alloy Armor (dDR 2).
[2-3]	Habitat (one lab, split between both systems).
[4-5]	Cargo Holds (five tons each).
[6]	Hangar Bay (three tons capacity).
[core]	Fission Reactor (one Power Point, 25 years endurance).

Personnel include two scientists, one technician, and one pilot (the last mans the Ascent stage).

Lowell-Class Ascent Vehicle (TL8)

This is the upper stage of the *Lowell*-class Landing Vehicle. Its chemical rocket engines have 3.12 mps of delta-V, enough to lift off from a Mars-like world and rendezvous in low orbit with a mothership or separately launched return spacecraft. It carries five crew and several tons of cargo (samples, provisions, etc.) in its 30-ton (SM +5) streamlined hull.

Front Hull	System
[1]	Light Alloy Armor (dDR 1).
[2]	Control Room (C2 computer, comm/sensor 2, and one control station).
[3-4]	Passenger Seats (two seats each).
[5-6]	Cargo Holds (1.5 tons each).
Central Hull	**System**
[1-6, core]	Fuel Tanks (1.5 tons rocket fuel with 0.24 mps delta-V each).
Rear Hull	**System**
[1]	Chemical Rocket Engine (3G acceleration).
[2-6, core]	Fuel Tanks (1.5 tons rocket fuel with 0.24 mps delta-V each).

It is operated by a single pilot.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL8 (AEROSPACE)												
8	*Lowell* Lander	30	–	14	–	100	13.4	+6	4ASV	0/2/2	0	$8.04M
PILOTING/TL8 (HIGH-PERFORMANCE SPACECRAFT)												
8	*Lowell* Ascent Vehicle	20	-1/3	12	3G/3.12 mps	30	3.5	+5	1+4SV	1/0/0	0	$285K

Helldiver-Class Armored Lander (TL9)

This rugged high-performance spacecraft is designed for orbital and atmospheric operations. It uses a 100-ton (SM +6) streamlined winged hull 120 feet long. It glides down from orbit and uses its fission ram-rockets for atmospheric cruising. It also flies back into orbit, boosting from a planetary surface to rendezvous with a mothership. Thanks to its powerful engines, it operates not only in terrestrial atmospheres but in the upper atmospheres of high-gravity worlds such as gas giants. Its robust construction keeps it safe in such hostile environments, with its habitat and control room buried in the core to protect against radiation.

Front Hull	System
[1]	Advanced Metallic Laminate Armor (dDR 5).
[2]	Hangar Bay (three tons capacity).
[3]	Enhanced Array (comm/sensor 6).
[4-6]	Fuel Tanks (five tons hydrogen and 0.63 mps delta-V each).
[core]	Control Room (C5 computer, comm/sensor 4, and two control stations).
Central Hull	**System**
[1]	Advanced Metallic Laminate Armor (dDR 5).
[2-6]	Fuel Tanks (five tons hydrogen and 0.63 mps delta-V each).
[core]	Passenger Seats (six seats).
Rear Hull	**System**
[1]	Advanced Metallic Laminate Armor (dDR 5).
[2]	Fuel Tank (five tons hydrogen and 0.63 mps delta-V each).
[3-6]	Nuclear Thermal Rocket Engines (ram-rocket, 0.5G acceleration each).

It has emergency ejection and a winged hull. The typical complement consists of a pilot and co-pilot.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL9 (HIGH-PERFORMANCE SPACECRAFT)												
9	*Helldiver*-class	30	0/4	12	2G/5.67 mps	100	3.8	+6	2+6SV	5	0	$12.31M

Top air speed is 3,500 mph. In atmosphere, Hnd/SR is +4/5.

Komarov-Class Winged Lander (TL10)

This is a compact, single-stage-to-orbit vehicle using antimatter rocket engines to achieve high performance. This permits landing and takeoff from high-G worlds. It is designed to glide in for a landing from orbit, but it can operate from a vertical position. The *Komarov* uses a streamlined 30-ton (SM +5) hull 50 feet long.

Front Hull	System
[1]	Advanced Metallic Laminate Armor (dDR 3).
[2-3]	Cargo Holds (1.5 tons each).
[4-6]	Passenger Seats (two seats each).

Front Hull	System
[core]	Control Room (C6 computer, comm/sensor 4, and one control station).
Central Hull	**System**
[1]	Metallic Laminate Armor (dDR 2).
[2-6, core]	Fuel Tanks (1.5 tons antimatter-catalyzed water with 0.72 mps delta-V each).
Rear Hull	**System**
[1]	Metallic Laminate Armor (dDR 2).
[2-3]	Fuel Tanks (1.5 tons antimatter-catalyzed water with 0.72 mps delta-V each).
[4-6]	Antimatter Thermal Rocket Engines (with water, 0.2G acceleration each).

It has a winged hull. It is operated by a single pilot.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT)												
10	*Komarov*-class	20	0/4	13	0.6G/5.76 mps	30	3.7	+5	1+6SV	3/2/2	0	$890K

Top air speed is 3,400 mph. In atmosphere, Hnd/SR is +4/5.

And so man's search for intelligent life on other planets and in other galaxies will continue. For this is the heart and meaning of that great adventure – the exploration of the universe.

– ***Voyage to the Prehistoric Planet***

Grissom-Class Exploration Shuttle (TL11^)

This is a small but tough reactionless drive shuttlecraft, capable of operating in hostile or primitive conditions. Its large central hangar bay is used for vehicles, cargo, or captive specimens, and sophisticated scientific sensors. Its 30-ton (SM +5) streamlined hull is 50 feet long.

Front Hull	System
[1-2]	Nanocomposite Armor (total dDR 10).
[3]	Science Array (comm/sensor 7).
[4-6]	Passenger Seats (two seats each).

Front Hull	System
[core]	Control Room (C7 computer, comm/sensor 5, and one control station).
Central Hull	**System**
[1]	Nanocomposite Armor (dDR 5).
[2-6]	Hangar Bays (one ton capacity each).
Rear Hull	**System**
[1]	Nanocomposite Armor (dDR 5).
[2-4!]	Hot Reactionless Engines (2G acceleration each).
[5-6]	Cargo Holds (1.5 tons each).
[core]	Super Fusion Reactor (de-rated, three Power Points).

Hangar bays 2-6 in the central hull are combined into one large bay. The shuttle is operated by a single pilot.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL11 (HIGH-PERFORMANCE SPACECRAFT)												
11^	*Grissom*-class	20	0/4	12	6G/*c*	30	8.7	+5	1+6SV	10/5/5	0	$2,055K

Top air speed is 6,100 mph.

Science and Survey Vessels

These scientific craft are designed for follow-up expeditions on astronomical, planetary, biological, or sociological surveys. For example, biological survey ships serve as a base for the hunting, capture, or study of alien life forms found during a long-ranged study, and a means of transporting specimens or trophies home.

Orpheus-Class Interplanetary Survey Ship (TL10)

This fusion drive-propelled vessel carries manned scientific expeditions to the outer planets and moons in the solar system, or to the icy bodies of the Kuiper Belt. It has an onboard chemical refinery for processing fuel at the destination. It uses an unstreamlined 3,000-ton hull (SM +9) 200 feet long.

Front Hull	System
[1]	Metallic Laminate Armor (dDR 15).
[2]	Habitat (eight labs, three offices, and robofac minifac).
[3]	Hangar Bay (100 tons capacity).
[4]	Science Array (comm/sensor 10).
[5]	Habitat (five cabins with total life support, two gyms, four-bed automed sickbay, 10 tons cargo).
[6]	Cargo Hold (150 tons).
[core]	Control Room (C8 computer, comm/sensor 8, and six control stations).

Central Hull	System
[1]	Metallic Laminate Armor (dDR 15).
[2-4]	Fuel Tanks (150 tons hydrogen with 36 mps delta-V each).
[5!]	Chemical Refinery (50 tons/hour).
[6]	Engine Room (two workspaces).

Rear Hull	System
[1]	Metallic Laminate Armor (dDR 15).
[2-3]	High-Thrust Fusion Rocket Engines (0.01G acceleration each).
[4-6]	Fuel Tanks (150 tons hydrogen with 36 mps delta-V each).
[core]	Fusion Reactor (de-rated, one Power Point).

It has spin gravity (0.15G). The typical complement consists of six control crew, one medic, and two technicians.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (LOW-PERFORMANCE SPACECRAFT)												
10	*Orpheus*-class	100	-3/5	13	0.02G/216 mps	3,000	261	+9	10ASV	15	0	$146M

Darwin-Class Bio-Survey Starship (TL10^)

This vessel is small enough to be operated by a private company rather than a government. Its streamlined 1,000-ton hull (SM +8) is 150 feet long. It carries laboratories for on-site research, and cages for living samples. The hangar bay holds small craft or ground vehicles, but is also useful for the capture and storage of large creatures – by flooding it, even a whale-sized aquatic creature could be accommodated.

Front Hull	System
[1]	Metallic Laminate Armor (dDR 7).
[2-5]	Hangar Bay (30 tons capacity each).
[6]	Habitat (six cabins).
[core]	Control Room (C8 computer, comm/sensor 7, and four control stations).

Central Hull	System
[1]	Metallic Laminate Armor (dDR 7).
[2-3]	Habitats (six cells each).
[4]	Habitat (two labs and two-bed sickbay).
[5!]	Tertiary Battery (one 10MJ improved laser turret, 43.5 tons cargo).
[6]	Engine room (one workspace).

Rear Hull	System
[1]	Metallic Laminate Armor (dDR 7).
[2]	Fusion Torch Engine (with water, 1.5G acceleration).
[3-4]	Fuel Tanks (five tons water with 5 mps delta-V each).
[5-6!]	Stardrive Engines (FTL-1 each).
[core]	Fusion Reactor (two Power Points).

It has spin gravity (0.1G). Personnel include four control crew, one medic, four scientists, one technician, and one turret gunner.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT)												
10^	*Darwin*-class	70	-1/5	13	1.5G/10 mps	1,000	169.5	+8	60ASV	7	2×	$62.6M

Top air speed is 3,100 mph.

Serengeti-Class Bio-Survey Ship (TL10^)

This small starship descends to a planet and performs a preliminary biological survey. Its streamlined 300-ton (SM +7) hull relies on contragravity supplemented by reactionless drives for quiet landings and takeoffs. The same design is popular as a safari ship for private or commercial hunting parties.

Front Hull	*System*
[1]	Nanocomposite Armor (dDR 10).
[2]	Multipurpose Array (comm/sensor 8).
[3-5]	Habitats (two cabins each).
[6]	Habitat (two-bed sickbay).
[core]	Control Room (C7 computer, comm/sensor 6, and three control stations).
Central Hull	***System***
[1]	Nanocomposite Armor (dDR 10).
[2-4]	Habitats (two cells each).
[5]	Habitat (one lab).
[6!]	Secondary Battery (two turrets with 10 MJ improved lasers, 12 tons cargo).
Rear Hull	***System***
[1]	Nanocomposite Armor (dDR 10).
[2!]	Standard Reactionless Engine (0.5G acceleration).
[3]	Engine Room (one workspace).
[4-5!]	Stardrive Engines (FTL-1 each).
[6!]	Contragravity Lifters.
[core]	Fusion Reactor (two Power Points).

It has artificial gravity and a dynamic chameleon surface. The typical complement consists of three control crew, one medic, two scientists, and one technician. Turrets are controlled from the control stations.

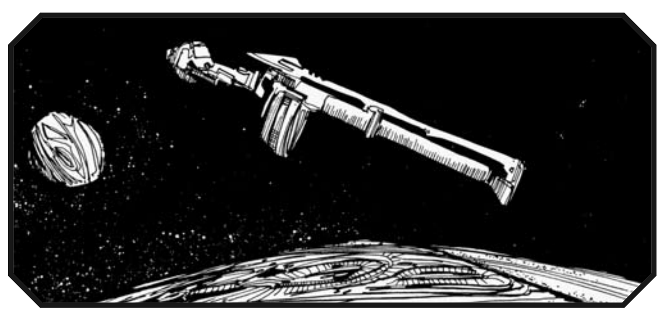
TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT or CONTRAGRAVITY)												
10^	*Serengeti*-class	50	-2/5	13	0.5G/*c*	300	15.6	+7	36ASV	10	2×	$28.2M

Top air speed is 1,800 mph. In atmosphere, Hnd/SR is 0/5.

Columbia-Class Survey Ship (TL11^)

A medium-sized mobile research vessel, the *Columbia* is for both survey and exploration missions. It is built using a 1,000-ton (SM +8) unstreamlined hull. The many laboratories can be configured for one specific type of scientific mission (e.g., biological survey), or it can carry several different labs for a complete planetary study. The living quarters are in the front hull, the laboratories and sensors are in the central hull, and the engineering section and hangars are in the rear hull. The central cages or cells (for specimens) may be replaced by labs or briefing rooms if no biological work is performed.

Front Hull	*System*
[1]	Metallic Laminate Armor (dDR 10).
[2]	Habitat (five cabins and one briefing room).
[3]	Habitat (six cabins).
[4]	Habitat (six-bed sickbay).
[5]	Habitat (four cabins and one gym).
[6]	Habitat (two cabins and four bunkrooms).
[core]	Control Room (C9 computer, comm/sensor 8, and four control stations).
Central Hull	***System***
[1]	Metallic Laminate Armor (dDR 10).
[2]	Science Array (comm/sensor 10).
[3!]	Tertiary Battery (one turret with 10 MJ UV laser, 43.5 tons cargo).
[4-6]	Habitats (three labs each).
[core]	Habitat (four cells, robofac minifac, and briefing room).
Rear Hull	***System***
[1]	Metallic Laminate Armor (dDR 10).
[2]	Hangar Bay (30 tons capacity).
[3]	Engine Room (one workspace).
[4!]	Standard Reactionless Engine (1G acceleration).
[5!]	Stardrive Engine (FTL-1).
[6]	Fusion Reactor (de-rated, one Power Point).



It has artificial gravity (which may be turned off in areas that require zero-G for research).

Personnel include four control crew, one medic, 18 scientists, two technicians, and one turret gunner.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL11 (HIGH-PERFORMANCE SPACECRAFT)												
11^	*Columbia*-class	70	-1/5	13	1G/*c*	1,000	80.1	+8	66ASV	10	1×	$56.6M

Roswell-Class Covert Survey Ship (TL11^)

This is a fast, long-ranged, and stealthy special-operations vessel designed to insert and retrieve first-contact or covert-survey teams on high-tech worlds without being detected by radar or passive sensors. It has an unstreamlined 300-ton (SM +7) hull 60 feet in diameter. Reactionless drives allow silent landing and takeoff. It is armed for self-defense and for protecting landing parties, but normally it relies on its cloaking device to avoid detection and stay out of trouble.

Front Hull	System
[1]	Nanocomposite Armor (dDR 15).
[2]	Multipurpose Array (comm/sensor 9).
[3]	Habitat (two cells).
[4]	Habitat (two-bed automed sickbay).
[5]	Habitat (lab).
[6]	Cargo Hold (15 tons).

Central Hull	System
[1]	Nanocomposite Armor (dDR 15).
[2!]	Cloaking Device.
[3!]	Light Force Screen (dDR 50).
[4!]	Medium Battery (two turrets with 30 MJ improved particle beams, one turret with a 30 MJ tractor beam).
[5-6]	Habitats (two cabins each).
[core]	Control Room (C8 computer, comm/sensor 7, and three control stations).

Rear Hull	System
[1]	Nanocomposite Armor (dDR 15).
[2!]	Super Reactionless Engine (50G acceleration).
[3]	Engine Room (one workspace).
[4-6!]	Stardrive Engines (FTL-1 each).
[core]	Super Fusion Reactor (four Power Points).

It has artificial gravity and gravitic compensators. The typical complement consists of three control crew, two scientists, one technician, and one turret gunner (the other turret is run from the control stations).

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL11 (HIGH-PERFORMANCE SPACECRAFT)												
11^	*Roswell*-class	50	0/5	13	50G/*c*	300	16.6	+7	16ASV	15*	3×	$52M

* Plus dDR 50 force screen.

Top air speed is 1,800 mph.

Star Hunter-Class Covert Survey Ship (TL12^)

Tough skin and a variety of ultra-tech defenses protect this small, stealthy superscience survey vessel. It is optimized for transporting specialists on covert contact missions, but can also venture into almost any situation and have a reasonable chance of coming back with useful information. It uses a streamlined 1,000-ton hull (SM +8) 150 feet long.

Front Hull	System
[1]	Exotic Laminate Armor (dDR 30).
[2!]	Major Battery (fixed mount 300 MJ disintegrator).
[3]	Habitat (three labs).
[4]	Cargo Hold (50 tons).
[5]	Habitat (four teleport projectors, two-bed automed sickbay).
[6!]	Medium Battery (three fixed mounts with 28cm warp missile launchers).
[core]	Control Room (C10 computer, comm/sensor 9, and four control stations).

Central Hull	System
[1]	Exotic Laminate Armor (dDR 30).
[2!]	Heavy Force Screen (dDR 100, or dDR 200 with two Power Points).
[3!]	Stasis Web.
[4!]	Cloaking Device.
[5]	Habitat (three cabins with total life support).
[6]	Science Array (comm/sensor 11).

Rear Hull	System
[1]	Exotic Laminate Armor (dDR 30).
[2-3!]	Super Stardrive Engines (FTL-1, or FTL-2 if given two Power Points, each).
[4-5!]	Super Reactionless Engines (100G acceleration each).
[6]	Engine Room (one workspace).
[core]	Total Conversion Reactor (five Power Points).

It has artificial gravity and gravitic compensators. Personnel include four control crew, six scientists, and one technician.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL12 (HIGH-PERFORMANCE SPACECRAFT)												
12^	*Star Hunter*-class	70	+1/5	13	200G/*c*	1,000	50.6	+8	6ASV	30*	4×	$444.5M

* Plus force screen (dDR 100, or dDR 200 if using two Power Points).

Top air speed is 35,000 mph.

Colony Ships

A colonial voyage is normally preceded with a visit to the system by exploration ships or unmanned probes, although optimistic or desperate colonists rely on long-range astronomical observations, especially in the era of slower-than-light travel.

A viable, self-sustaining colony should have about 10,000 people to have a good chance of social and genetic stability. Colony ships – there may be one or many – also establish temporary outposts (see ***GURPS Space,*** p. 90) that require external support and supply.

A colony can be successful with a smaller population; historical examples of only a few hundred settlers have produced viable outposts such as the Polynesians in New Zealand. Tiny groups (anywhere from a dozen to a hundred people) are at great risk of being wiped out by a disaster, lack of proper skills to handle an emergency, or, over the long term, a lack of genetic diversity that leaves them vulnerable to disease. However, even these may survive if they benefit from external support, ultra-tech such as extensive use of robots or genetic engineering, and/or a regular influx of new immigrants after the original colony is established.

These vessels are designed for the rapid transport of settlers to new or undeveloped worlds. Comfort is rarely a priority (with the exception of generation ship designs). Transports may resemble commercial liners, but they replace luxury cabins and amenities with austere bunkrooms to gain plenty of cargo space. Transport costs are subsidized by whatever nation or organization sets up the colony. Well-funded pioneers may travel in a fleet of ships to provide redundancy in the event of disaster, and to allow various specialized vessels to accompany the colonial carriers: mining craft, cargo ships filled with heavy equipment, science vessels, or military escorts.

Some colony ships are intended for round trips – either their owners intend to use them to plant more than one settlement, or it provides a means of evacuation if something goes wrong. Others are used for one-way voyages, with the empty ship either serving as a space station, or landing and being dismantled to provide the basic high-tech infrastructure (power plants, factories, etc.) for the colonists' first encampment. Generation ships (pp. 21-22) and prison transports (pp. 24-25) are specialized types of colony ship.

They may be privately funded or subsidized by a government (perhaps under a "bureau of colonization" or similar agency). They're also created to carry refugees to escape an interstellar war or other existential disaster.

Mayflower-Class Colonial Transport (TL9)

Using a 3,000-ton unstreamlined hull 400 feet long, this late-TL9 fusion-drive spacecraft is designed to transport a small startup colony across short interplanetary distances – e.g., from Earth orbit to Mars orbit – plus shuttle craft capable of landing. It rotates to provide spin gravity for its occupation. Onboard accommodations are Spartan, but it carries 300 colonists plus the crew.

Front Hull	***System***
[1]	Light Alloy Armor (dDR 10).
[2-5]	Habitat (20 bunkrooms each).
[6]	Habitat (two offices, one lab, one gym, one nursery, one schoolroom, and 10-bed clinic sickbay).
[core]	Control Room (C6 computer, comm/sensor 7, and six control stations).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 10).
[2-3]	Hangar Bays (100 tons capacity each).
[4-5]	Fuel Tanks (150 tons nuclear fuel pellets with 6 mps delta-V each).
[6]	Engine Room (two workspaces).
[core]	Cargo Hold (150 tons).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 10).
[2-5]	Fuel Tank (150 tons nuclear fuel pellets with 6 mps delta-V each).
[6]	Fusion Pulse Drive Engine (0.02G acceleration).

It has exposed radiators and spin gravity (0.15G).

The typical complement consists of six control crew, one medic, and two technicians. Passengers are the scientists, caregivers, and teachers for the labs, nursery, and schoolroom.

TL	***Spacecraft***	***dST/HP***	***Hnd/SR***	***HT***	***Move***	***LWt.***	***Load***	***SM***	***Occ***	***dDR***	***Range***	***Cost***
PILOTING/TL9 (LOW-PERFORMANCE SPACECRAFT)												
9	*Mayflower*-class	100	-3/5	13	0.02G/36 mps	3,000	382	+9	320ASV	10	0	$64.4M

Genesis-Class Colonial Transport (TL10^)

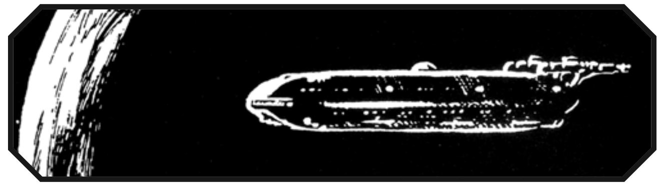
This vessel is a large colonization ship intended to carry 4,000 colonists with their belongings, basic industrial equipment, and livestock across the stars. For its size, it is an efficient design, using a 30,000-ton (SM +11) unstreamlined hull 450 feet long, and propelled by a fusion torch drive and a stardrive. It's not capable of landing on a terrestrial world, but has room for several surface-to-orbit shuttles in its hangar bay if the destination lacks a space station.

These may be subsidized by the government. In addition to carrying settlers, they make capable troop transports. While not designed for landing assault forces under fire, the *Genesis*-class could easily carry a combat brigade and its equipment, replacing its civilian shuttles with military drop ships and fighters.

Front Hull	System
[1]	Steel Armor (dDR 15).
[2-5]	Habitats (200 bunkrooms each).*
[6]	Habitat (50 cabins, 100 bunkrooms, four gyms, four nurseries, four schoolrooms, two briefing rooms, 24-bed clinic sickbay).*
[core]	Control Room (C9 computer, comm/sensor 10, and only 10 control stations).*

Central Hull	System
[1]	Steel Armor (dDR 15).
[2]	Habitat (100 cells and 500 tons cargo).*
[3]	Habitat (200 bunkrooms).*
[4]	Cargo Hold (1,500 tons).
[5-6]	Hangar Bays (1,000 tons capacity each).*

Rear Hull	System
[1]	Steel Armor (dDR 15).
[2]	Fusion Torch Engine (0.5G acceleration).*
[3-4]	Fuel Tanks (1,500 tons hydrogen with 15 mps delta-V each).
[5-6!]	Stardrive Engines (FTL-1 each).*
[core]	Fusion Reactor (two Power Points, 200 years endurance).*



* Three workspaces per system.

It has spin gravity (0.3G). Personnel include 10 control crew and 48 technicians. Caregivers, teachers, etc. are drawn from the passengers.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT)												
10^	*Genesis*-class	200	-2/5	13	0.5G/30 mps	30,000	4,490	+11	4,900ASV	15	2×	$1,816.75M

It's an extraordinary new world, and survival is simply a matter of reaching deep enough to find the extraordinary in ourselves.

– Morgan Martin, ***Earth 2*** *#1.12*

Exodus-Class Colonial Transport (TL11^)

Like many superscience colonial vessels, this is a very large but relatively low-cost spacecraft. It is designed to carry 17,000 people and plenty of supplies across interstellar space directly to the surface of a new planet. It has a 100,000-ton (SM +12) streamlined hull 800 feet long. A single *Exodus* can found a sizable self-sustaining colony in one trip. Most colonists are carried in simple bunkrooms, but it has a few cabins for officials and well-off emigrants. This transport does not have onboard manufacturing capacity – any factories are dismantled and carried as cargo.

Front Hull	System
[1]	Steel Armor (dDR 15).
[2-5]	Habitats (600 bunkrooms each).*
[6]	Habitat (475 cabins, five offices, 10 schoolrooms, 100-bed hospital sickbay).*
[core]	Control Room (C11 computer, comm/sensor 12, and 20 control stations).*

Central Hull	System
[1]	Steel Armor (dDR 15).
[2-4]	Habitat (600 bunkrooms each).*
[5-6]	Cargo Holds (5,000 tons each).

Rear Hull	System
[1]	Steel Armor (dDR 15).
[2]	Hangar Bay (3,000 tons capacity).*
[3-4!]	Standard Reactionless Engines (1G acceleration each).*
[5-6!]	Stardrive Engines (FTL-1 each).*
[core]	Fusion Reactor (two Power Points).*

* 10 workspaces per system.

It has spin gravity (0.5G). The typical complement consists of 20 control crew, 10 medics, and 150 technicians.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL11 (HIGH-PERFORMANCE SPACECRAFT)												
11^	*Exodus*-class	300	-2/5	13	2G/*c*	100,000	14,775	+12	17,750ASV	15	2×	$4,280M

Top air speed is 3,500 mph.

Generation Ships

These "space arks" are colony starships designed for interstellar travel at velocities significantly below light speed. This greatly reduces the drive technology required for the vessel, but means trips to even nearby stars may take anywhere from decades to several millennia! To compensate, the builders plan for the crew to live out their lives, have children, and raise them, all onboard.

Depending on the voyage length, multiple generations may be born, live, and die on the ship before it ever reaches its destination. It can have fewer inhabitants than a colony, since the environment aboard is much more forgiving! It should start with at least 500 to 1,000 occupants (to ensure genetic diversity and a stable community), although voyages with smaller numbers can be attempted at greater risk. Care must be taken to ensure the vessel's systems are self-sustaining (total life support on all habitats) and that there are onboard repair and manufacturing facilities to handle any malfunctions.

Generation ships can be combined with longevity or even immortality technology – in such cases the vessel is designed to support the original crew *and* their descendants, and everyone gets to see the destination. A variant concept is a hybrid sleeper/generation ship in which the crew spend part of their time living and raising families aboard the vessel, but extend their lives through suspended animation.

Science-fiction scenarios involving these ships often feature concepts such as computer-controlled vessels whose succeeding generations forget they are aboard a ship, the development of unique societies aboard such a craft, or conflicts between those who consider the ship their home and those who want to continue the original mission.

Although a popular space-opera trope is a single generation ship, it is much safer to send two or more vessels, especially if inhabitants can transfer between them.

Universe-Class Generation Ship (TL10)

This is an immense antimatter-powered starship built inside a hollowed-out asteroid. It's intended to cruise at 1/500 of light speed, taking two or three thousand years to travel between neighboring star systems. It can perform longer journeys using a "stepping stone" approach: It has sufficient industrial capacity to stop for decades even in an unpromising midpoint solar system, building antimatter production facilities where necessary. Its unstreamlined hull masses 1,000,000 tons (SM +14) and is 1,200 feet long. It contains the equivalent of a small town, capable of supporting 6,000 people in comfort. It rotates for artificial gravity, and its onboard farmland coupled with its life systems provide total life support. Its hangar bays carry a small fleet of supporting craft (including, if necessary, armed vessels for self-defense).

Front Hull	***System***
[1]	Stone Armor (dDR 15).
[2]	Hangar Bay (30,000 tons capacity).*
[3!]	Fabricator ($50M/hour production capacity).*
[4!]	Mining (5,000 tons/hour).*
[5!]	Chemical Refinery (15,000 tons/hour).*
[6]	Science Array (comm/sensor 15).*
[core]	Control Room (C11 computer, comm/sensor 13, and 40 control stations).*
Central Hull	***System***
[1]	Stone Armor (dDR 15).
[2]	Habitat (3,000 luxury cabins).*
[3]	Open Space (five acres of farm).
[4]	Habitat (100 mixed establishments such as gyms, stores, etc., 500 offices, five major labs, 100 school rooms, 100-bed hospital sickbay, and 20,000 tons cargo).*
[5-6]	Fuel Tanks (50,000 tons antimatter-boosted hydrogen with 144 mps delta-V each).
Rear Hull	***System***
[1]	Stone Armor (dDR 15).
[2]	Antimatter Plasma Rocket (0.01G acceleration).*
[3-6]	Fuel Tanks (50,000 tons antimatter-boosted hydrogen with 144 mps delta-V each).
[core]	Fusion Reactor (de-rated to one Power Point).*

* 100 workspaces per system.

It has spin gravity (1G). Personnel include 1,000 administrators, 40 control crew, 10 medics, 1,000 scientists, 100 shopkeepers (business owners, etc.), 100 teachers, and 1,000 technicians.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL10 (LOW-PERFORMANCE SPACECRAFT)												
10	*Universe*-class	700	-5/5	14	0.01G/864 mps	1,000,000	50,600	+14	6,000ASV	15	0	$78.51B

Endeavor-Class Generation Ship (TL11)

This slower-than-light starship is a fast hybrid generation/sleeper ship. Propelled by an advanced fusion pulse drive engine, *Endeavor* travels one parsec every 500 years (including the time to decelerate), and goes from Sol to Alpha Centauri in a "mere" 670 years. Only some of the crew are awake at any one time; the rest are in hibernation, so it carries a village-sized population at any one time. It is built with a 300,000-ton (SM +13) unstreamlined hull 750 feet long.

Front Hull	System
[1]	Metallic Laminate Armor (dDR 70).
[2]	Habitat (1,000 luxury cabins).*
[3]	Habitat (100 stores, 50 offices, three major labs, 10 large labs, 50 classrooms, 50-bed clinic sickbay, 1,200 hibernation chambers, and 2,500 tons cargo).*
[4]	Open Space (2.5 acres of garden).*
[5!]	Fabricator ($15M/hour production capacity).*
[6!]	Mining (1,500 tons/hour).*

From you we will carry the human spirit out into space and we will continue the explorations that you have begin.

– John L. Phillips

Front Hull	System
[core]	Control Room (C11 computer, comm/sensor 13, and 30 control stations).*
Central Hull	**System**
[1]	Steel Armor (dDR 30).
[2]	Science Array (comm/sensor 15).*
[3]	Hangar Bay (10,000 tons capacity).*
[4-6]	Fuel Tanks (15,000 tons nuclear fuel pellets with 420 mps delta-V each).
Rear Hull	**System**
[1]	Steel Armor (dDR 30).
[2]	Advanced Fusion Pulse Drive (0.005G acceleration).*
[3-6]	Fuel Tanks (15,000 tons nuclear fuel pellets with 420 mps delta-V each).
[core]	Fusion Reactor (de-rated, one Power Point).*

* 30 workspaces per system.

It has spin gravity (0.7G). The typical complement consists of 30 control crew, five medics, 100 administrators, 800 scientists, 100 shopkeepers, 50 teachers, and 300 techs.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL11 (LOW-PERFORMANCE SPACECRAFT)												
11	*Endeavor*-class	500	-6/5	14	0.005G/2,940 mps	300,000	12,820	+13	2,000ASV*	70/30/30	0	$26.285B

* Plus 1,200 in suspended animation.

Magellan-Class Worldship (TL11^)

There's no reason a generation ship has to be a slower-than-light design. Even if stardrives are faster than light, transgalactic and intergalactic voyages can still take generations! If the *Magellan*'s hyperdrive travels at a velocity of several parsecs a week without refueling, it would take a century or two to cross the Milky Way galaxy, or to travel between it and a satellite galaxy such as the Large Magellanic Cloud. Nevertheless, this vessel is designed to make the attempt either for exploration and settlement, or to flee a galactic war or other cosmic catastrophe. Built with an SM +15 unstreamlined hull, it masses 3,000,000 tons and is 1,500 feet long.

Front Hull	System
[1]	Light Alloy Armor (dDR 100).
[2]	Habitat (10,000 luxury cabins).*
[3]	Habitat (300 mixed establishments, 1,500 offices, 15 major labs, 300 school rooms, 300-bed hospital sickbay, and 70,000 tons cargo).*
[4]	Open Space (10 acres of farms).*
[5]	Habitat (10,000 luxury cabins).*
[6]	Open Space (10 acres of farms).*
Central Hull	**System**
[1]	Light Alloy Armor (dDR 100).
[2!]	Robofac ($300M/hour production capacity).*
[3!]	Mining (15,000 tons/hour).*
[4]	Hangar Bay (100,000 tons capacity).*
[5]	Science Array (comm/sensor 17).*
[6!]	Light Force Screen (dDR 1,000).*
[core]	Control Room (C12 computer, comm/sensor 15, and only 40 control stations).*
Rear Hull	**System**
[1]	Light Alloy Armor (dDR 100).
[2!]	Hot Reactionless Engine (2G acceleration).*
[3-6!]	Stardrive Engines (FTL-1 each).*
[core]	Super Fusion Reactor (four Power Points).*

* 300 workspaces per system.

Personnel include 40 control crew, 1,500 administrators, 30 medics, 3,000 scientists, and 5,100 technicians.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL11 (HIGH-PERFORMANCE SPACECRAFT)												
11^	*Magellan*-class	1,000	-3/5	14	2G/*c*	3,000,000	174,000	+15	40,000ASV	100*	4×	$634.339B

* Plus dDR 1,000 force screen.

Top air speed is 350 mph.

SEEDSHIPS

Seedships are an unmanned alternative to generation ships (p. 21-22). These craft travel at relatively slow sublight speeds, but their "colonists" exist only in potential, as frozen genetic material. A seedship carries plant seeds and animal, human, or alien zygotes, as well as the necessary artificial womb growth tanks (below) to bring them to term.

After the ship arrives in system, an exploration crew is grown from genetic material, raised and educated by the ship's computer systems and any onboard robots. Indoctrinated with the mission to explore or colonize the system, they build infrastructure and set up conditions to breed further generations naturally or artificially.

Growth Tanks

Growth Tanks (TL9): These artificial wombs can be installed in habitats to grow complex organisms (including humans) from frozen genetic material stored in cargo. 20 growth tanks for human-sized specimens replace a single cabin; raising an organism to the point where it can survive outside the tank requires the normal gestation period (e.g., about nine months for a human baby). Growth takes the normal time. See ***GURPS Bio-Tech*** (p. 20-21) for detailed rules.

Seedships may establish an entire ecosystem on worlds identified by previous probes or telescopic observation as prebiotic, i.e., having the pre-conditions for life where none has actually evolved. They could colonize existing ecosystems, or even totally transform them using terraforming techniques. If an alien seedship appeared in Earth's skies, this could be a particularly terrifying alien invasion: pods dropping from orbit to release potent organisms that infest and alter our own ecosystem. A properly equipped seedship might not require a habitable world (or even a planet) to establish a colony. It could dock with a resource-rich asteroid, for example, and use its onboard factory systems, robots, and newborn colonists to build and populate a large space habitat.

Over time, a series of seedships might spread a species' genetic material through an entire galaxy (or beyond), even with slower-than-light technology.

JOHNNY APPLESEED-CLASS SEEDSHIP (TL11)

This seedship is an unstreamlined 30,000-ton spacecraft (SM +11) 450 feet long. It uses a fusion pulse engine with a cruising speed of about 1% of light speed, and a magnetic sail for braking. It is designed for an unmanned journey to its destination (often taking centuries or even millennia). Upon arrival, onboard robots get to work raising the first generation of a few dozen colonists. The ship's hangar bay carries a range of smaller manned and robotic exploration and mining craft to locate and gather resources for the vessel's nanofactory, which then builds a larger settlement for the next generation.

Front Hull	***System***
[1]	Nanocomposite Armor (dDR 70).
[2]	Advanced Metallic Laminate Armor (dDR 50).
[3]	Habitat (20 bunkrooms with total life support, 1,000 growth tanks, gym, 10 nurseries, nine schoolroom, large lab, 20-bed automed clinic sickbay, and 150 tons cargo).
[4]	Hangar Bay (1,000 tons capacity).
[5!]	Magsail (0.001G acceleration for braking/in-system propulsion).
[6!]	Nanofactory ($30M/hour production capacity).
[core]	Control Room (C10 computer, comm/sensor 11, and no control stations).
Central Hull	***System***
[1]	Advanced Metallic Laminate Armor (dDR 50).
[2-6]	Fuel Tank (1,500 tons fuel pellets with 490 mps delta-V each).
Rear Hull	***System***
[1]	Advanced Metallic Laminate Armor (dDR 50).
[2]	Advanced Fusion Pulse Drive (0.005G acceleration).
[3-6]	Fuel Tank (1,500 tons fuel pellets with 490 mps delta-V each).
[core]	Fusion Reactor (de-rated, one Power Point).

It has exposed radiators and spin gravity (0.3G). It is designed for unmanned operation and has total automation.

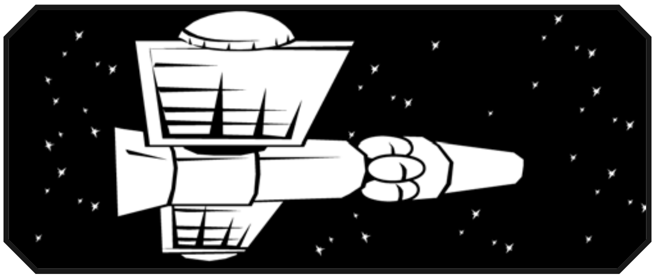
TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL11 (LOW-PERFORMANCE SPACECRAFT)												
11	*Johnny Appleseed*-class	200	-5/5	14	0.005G/4,410 mps	30,000	1,158	+11	80ASV	120/50/50	0	$7,682.25M

So they built this ship in the hopes that their world would be born again far from the reach of their enemies.

– Lotan, ***Stargate SG-1*** *#4.1*

Star Seed-Class Factory Probe (TL11)

This is an advanced solar-sail powered space probe. It is equipped with a nanofactory to reproduce itself at the destination, and growth tanks for growing colonists from embryos. Usually a squadron of several such probes is launched in sequence for redundancy. It is built with a 100 ton (SM +6) unstreamlined hull. It can make interplanetary journeys, diving close to the sun to build up speed or accelerating via a battery of laser cannons to a high fraction of light speed. Its hangar bays carry robots used for exploration and construction.



Front Hull	***System***
[1-3]	Nanocomposite (total dDR 30).
[4-5]	Hangar Bay (three tons capacity each).
[6]	Science Array (comm/sensor 8).
Central Hull	***System***
[1]	Nanocomposite (dDR 10).
[2-6]	Lightsails (0.0001G acceleration each).
[core]	Control Room (C8 computer, comm/sensor 6, and no control systems).
Rear Hull	***System***
[1]	Nanocomposite (dDR 10).
[2]	Solar Panel Array (one Power Point).
[3]	Cargo Hold (five tons capacity).
[4]	Science Array (comm/sensor 8).
[5!]	Mining (0.5 tons/hour).
[6!]	Nanofactory ($100K/hour production capacity).
[core]	Habitat (20 growth tanks).

It is unmanned with no crew requirements.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
PILOTING/TL11 (LIGHTSAIL)												
11	*Star Seed*-class	30	-3/4	13	0.0005G/*c*	100	11	+6	0	30/10/10	0	$30.32M

Prison Transports

Prisons are built in remote settings to make escape or rescue attempts difficult, and there is no more isolated a location than a distant point in space. If interplanetary or star travel is cheap enough to ship convicts to off-world prisons, then specialized ships are built for their safe and secure transport. Their destination might be a secure jail, or it could be a full-fledged penal colony on a harsh frontier world. Penal colonists may be free upon reaching their destination, or be forced into labor camps, indenture, or slavery.

A prison ship may make a direct run between a high-population world and the prison or penal colony. However, if one world doesn't generate enough prisoners, vessels may follow a circuit of several worlds, picking up a few dozen inmates at each stop. They may spend weeks or months aboard before arriving at the destination.

Suspended Animation and Nanostasis

At TL10+ spacecraft with hibernation chambers may use more effective suspended-animation capsules or nanostasis tanks to reduce metabolic activity to zero or near-zero levels, resulting in no aging even on long journeys. No maintenance is needed. See ***GURPS Bio-Tech*** (p. 146-147) for detailed rules.

Prison ships are similar to colonial transports, but with guards and extra security systems aboard and even fewer concessions made to the comfort of their occupants. Some also have light armaments to protect against would-be rescue attempts.

Charon-Class Sleeper Ship (TL10)

This vessel is a low-cost way to ship prisoners to work from orbital stations to asteroid mines. Each transports 72 persons in suspended animation. It is built using a 1,000 ton (SM +8) unstreamlined hull propelled by a mass driver engine (which uses rock for propellant). It is mostly automated but can be manned by a crew. It might also be used as a prisoner transport for permanent transfers.

Front Hull	***System***
[1]	Steel Armor (dDR 5).
[2-4]	Habitat (24 hibernation chambers each).
[5!]	Secondary Battery (one turret with 6cm rapid-fire electromagnetic gun, 45 tons cargo).
[6]	Habitat (cabin, bunkroom, two-bed sickbay, 10 tons cargo).
[core]	Control Room (C8 computer, comm/sensor 7, and four control stations).

Central Hull	System
[1]	Solar Panel Array (one Power Point).
[2-6]	Fuel Tanks (50 tons rock dust with 0.42 mps delta-V each).
[core]	Engine Room (one workspace).
Rear Hull	***System***
[1]	Steel Armor (dDR 5).
[2!]	Mass Driver Engine (0.01G acceleration).
[3-6]	Fuel Tanks (50 tons rock dust with 0.42 mps delta-V each).

It has spin gravity (0.1G). The typical complement consists of four control crew, one medic, one technician, and one turret gunner. An armed escort brings prisoners into the hibernation chambers before takeoff, but since the convicts sleep through the voyage, there's no need to carry a guard force. (Some crew may have security training and small arms, however.)

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (LOW-PERFORMANCE SPACECRAFT)												
10	*Charon*-class	70	-3/5	13	0.01G/3.78 mps	1,000	62.8	+8	6ASV*	5/0/5	0	$18.1M

* Plus 72 in suspended animation.

You're on your way to the penal colony on Cygnus Alpha. Or you will be when the prison ship's refueled. Try to look on the bright side. It must have something. None of the guests have ever left early. In fact, none of them have ever left at all.

– Vila Restal, ***Blake's 7*** *#1.1*

Alcatraz-Class Colonial Transport (TL10^)

The *Alcatraz* transports prisoners, slaves, or involuntary colonists across interstellar distances. Its 3,000 ton (SM +9) unstreamlined hull is propelled by a stardrive and reactionless drive, and carries 180 prisoners in cells.

At a minimum, security precautions include electronics locks, cameras, and barred doors, plus various remote defense systems such as a provision for pumping in anesthetic gas. Some ships are highly automated with extensive computer control and no human contact; others rely on alert guards. One of the nastier ways to quell any attempted riot or prison break is to simply seal off that part of the ship and threaten to adjust the environmental systems. Few prisoners want to risk breathing vacuum.

Front Hull	System
[1-2]	Metallic Laminate Armor (total dDR 30).
[3-6]	Habitats (20 cells each).
[core]	Habitat (two gyms, briefing room, and 15-bed clinic sickbay).
Central Hull	***System***
[1-2]	Metallic Laminate Armor (total dDR 30).
[3]	Habitat (two cabins, office, eight bunkrooms, briefing room, gym, six-bed sickbay).
[4!]	Medium Battery (three 300 MJ improved ultraviolet laser turrets).
[5]	Hangar Bay (100 tons capacity).
[6]	Cargo Hold (150 tons).
[core]	Control Room (C8 computer, comm/sensor 8, and six control stations).
Rear Hull	***System***
[1-2]	Metallic Laminate Armor (total dDR 30).
[3]	Engine Room (two workspaces).
[4!]	Stardrive Engine (FTL-1).
[5!]	Standard Reactionless Engine (0.5G acceleration).
[6]	Fusion Reactor (two Power Points).

It has artificial gravity. Personnel include six control crew, two medics, four scientists, one technician, and three turret gunners. There is one guard per 10 convicts, although that ratio varies depending on the type of prisoners. Some ships rely on robot guards (so they can carry more live prisoners).

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
PILOTING/TL10 (HIGH-PERFORMANCE SPACECRAFT)												
10^	*Alcatraz*-class	100	-2/5	13	0.5G/*c*	3,000	285.6	+9	356ASV	30	×1	$124.3M

Outpost and Research Stations

Outpost stations are established in frontier systems, either in orbit around a colony planet or in deep space next to a jump point or other interstellar travel nexus. They are "jack-of-all-trades" facilities, serving as ports, industrial parks, bases for mining ships, research stations, or symbols of the government or corporation that controls the frontier. Border outposts are points of contact between different governments or even alien races, offering a cosmopolitan atmosphere; they serve as trade and diplomatic centers for multiple cultures or species. In dangerous or disputed territory, these sites are well-armed and may be entirely military in character – or more often, operating under joint military and civilian control.

Van Allen-Class Space Lab (TL9)

This scientific outpost is a medium-sized orbital laboratory complex for scientific research. It is assembled in space from a series of modules that combine to form a 300-ton (SM +7) unstreamlined hull, and it is manned by 6-18 people. The scientists and operations crew occupy the forward cabins while the central-hull bunkroom is a radiation storm shelter and accommodates visiting shuttle crews.

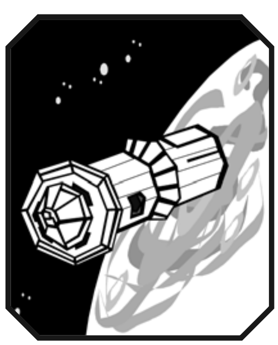
Front Hull	***System***
[1]	Light Alloy Armor (dDR 5).
[2-4]	Habitat (two cabins each).
[5]	Solar Panel Array (with one Power Point).
[6]	Habitat (gym).
[core]	Control Room (C5 computer, comm/sensor 5, and three control stations).
Central Hull	***System***
[1]	Light Alloy Armor (dDR 5).
[2]	Science Array (comm/sensor 7).
[3-5]	Habitats (one lab each).
[6]	Habitat (two-bed sickbay).
[core]	Habitat (bunkroom and five tons cargo).
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 5).
[2-3]	Cargo Holds (15 tons each).
[4!]	Fabricator ($15K/hour production capacity).
[5]	Fuel Tank (15 tons reaction mass, for topping up docked spacecraft).
[6]	Engine Room (one workspace).

Personnel include three control crew, one medic, six scientists, and one technician.

TL	*Spacecraft*	*dST/HP*	*Hnd/SR*	*HT*	*Move*	*LWt.*	*Load*	*SM*	*Occ*	*dDR*	*Range*	*Cost*
9	*Van Allen*-class	50	–	14	–	300	36.6	+7	16ASV	5	0	$26.45M

Margrave-Class Outpost Station (TL10)

This large cylindrical craft is a frontier space port. It spins to produce artificial gravity and has plenty of hangar bay and cargo space capable of docking very large vessels. Built with an SM +15 unstreamlined hull, it masses 3,000,000 tons and is 2,000 feet long. Its tanks can refuel visitors' reaction drives or store water or valuable chemicals. The station is a comfortable place to live with large green areas and spacious accommodation for up to 50,000 people. Its farms provide total life support. The station is equipped with defensive weaponry, and may have a few warships docked in its hangars.



Front Hull	***System***
[1]	Light Alloy Armor (dDR 100).
[2-3]	Habitats (10,000 luxury cabins each).*
[4]	Habitat (100 school rooms, 10,000 offices, 10 major labs, 500-bed hospital sickbay, and 36,500 tons cargo).*
[5]	Open Space (10 acres of farms).*
[6]	Enhanced Array (comm/sensor 16).*
[core]	Control Room (C11 computer, comm/sensor 14, and only 40 control stations).*
Central Hull	***System***
[1]	Light Alloy Armor (dDR 100).
[2]	Habitat (5,000 luxury cabins and 5,000 mixed establishments).*
[3]	Open Space (10 acres of park).*
[4-5]	Hangar Bays (100,000 tons capacity each).*
[6!]	Tertiary Battery (20 turrets with 64 cm missile launchers, 10 turrets with 300 MJ very rapid fire UV lasers).*
[core]	Fusion Reactor (two Power Points).*
Rear Hull	***System***
[1]	Light Alloy Armor (dDR 100).
[2!]	Robofac ($300M/hour production capacity).*
[3]	Hangar Bay (100,000 tons capacity).*
[4]	Fuel Tank (150,000 tons of reaction mass, for refueling other spacecraft).
[5]	Habitat (20,000 cabins).*
[6]	Cargo Hold (150,000 tons).

* 300 workspaces per system.

It has spin gravity (max 1.5G). The typical complement consists of 40 control crew, 50 medics, 2,000 scientists, 30 turret gunners, and 4,500 technicians. Office workers, shopkeepers, etc. are citizens rather than crew.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
10	*Margrave*-class	1,000	–	14	–	3,000,000	495,500	+15	90,000ASV	100	0	$379.739B

Labyrinth-Class Jump Station (TL11^)

This is a huge spherical outpost station, at the center of which is installed a jump gate for receiving spacecraft. It's similar to the TL10 frontier outpost station (see p. 26), but it incorporates many superscience refinements. It's built with an SM +15 unstreamlined hull, it masses 3,000,000 tons and is 2,000 feet long.

Front Hull	System
[1]	Metallic Laminate Armor (DR 150).
[2-4]	Open Space (10 acres of farms each).*
[5]	Habitat (10,000 luxury cabins).*
[6]	Habitat (7,000 cabins, 50 school rooms, 50 nurseries, 10,000 offices, 10 major labs, 200-bed hospital sickbay, and 3,000 tons cargo).*
[core]	Control Room (C12 computer, comm/sensor 15, and only 40 control stations).*

Central Hull	System
[1]	Metallic Laminate Armor (dDR 150).
[2]	Habitat (7,000 luxury cabins and 3,000 mixed establishments).*
[3-5!]	Jump Gates (total 300,000 tons capacity).*
[6!]	Secondary Battery (10 turrets with 10 GJ rapid fire X-ray lasers).*
[core]	Super Fusion Reactor (four Power Points).*

Rear Hull	System
[1]	Metallic Laminate Armor (dDR 150).
[2]	Enhanced Array (comm/sensor 17).*
[3!]	Nanofactory ($3B/hour production capacity).*
[4]	Cargo Hold (150,000 tons).
[5]	Hangar Bay (100,000 tons capacity).*
[6!]	Light Force Screen (dDR 1,000).*

* 300 workspaces per system.

It has artificial gravity. Personnel include 40 control crew, 20 medics, 2,000 scientists, 10 turret gunners, and 4,800 technicians. Office workers, shopkeepers, etc. are citizens rather than crew.

TL	Spacecraft	dST/HP	Hnd/SR	HT	Move	LWt.	Load	SM	Occ	dDR	Range	Cost
11	*Labyrinth*-class	1,000	–	14	0	3,000,000	491,000	+15	48,000ASV	150*	0	$1,249.359B

* Plus dDR 1,000 force screen.

Small Sensor Drones and Probes

Spacecraft may carry scientific packages in hangar bays or launchers. These are equivalent to missiles, but replace the warhead with a sophisticated comm/sensor array.

Sensor Drone: This streamlined missile replaces its warhead with a Science Array whose capabilities are dependent on its caliber. The drone's onboard power supply operates its gear for 15 years, and the comm/sensor array can be controlled remotely. See ***GURPS Spaceships 3: Warships and Space Pirates*** (pp. 35-36) for precise missile performance capabilities. Each drone costs the same as a conventional missile. In combat, it can be *used* as a conventional missile, but it may not be proximity fused; it has a -4 to hit; and it does not receive a (2) armor divisor.

Sensor Probe: This is equivalent to a sensor drone but without propulsive capability. It can be placed in orbit around a world (or other interesting location), or dropped into a planetary atmosphere, descending via parachute. It has one-third the cost and mass of a sensor drone, but cannot be used as a weapon.

Armored Sensor Probe: As above, but capable of surviving in hostile environments such as the atmosphere of a gas giant or on the surface of Venus. It performs like a sensor probe, but with same cost and mass as a sensor drone.

Sensor Probe and Drone Table

Caliber	Array Level	Caliber	Array Level
Up to 20cm	TL-9	48-56cm	TL-6
24-28cm	TL-8	64-80cm	TL-5
32-40cm	TL-7	96cm+	TL-4

Chapter Two
Expeditions and Operations

This chapter explores the motives of exploration and colonization missions – motivations that sometimes overlap with each other. Additionally, it provides game mechanics for specialized tasks performed by survey ships and crews, including remote survey procedures, on-site planetary exploration, and first contact with new species.

Expeditions

Space exploration may be scientific, military, commercial, or private in nature . . . and sometimes all of these at once. For example, a mission to determine the source of a strange signal from a far-off star system could involve the scientific community (who want to solve the mystery and make contact with any aliens), the military (who want to assess and neutralize any alien threats), and large corporations (eager to establish trade relations or gain access to alien technology). This leads to conflicts as each partner pursues its own agenda. The interests and motives behind the mission determine the expedition's character, resources, and goals.

Scientific Expeditions

The desire to make discoveries and prove theories is a powerful motivation for space exploration, especially if there is reason to believe life can be found on other worlds. Remote astronomical observations only reveal the gross physical details of the universe. Studying extraterrestrial planetology, biology, or ecology, and understanding alien societies requires explorers, whether machines or living beings.

A scientific mission may be tightly focused on one goal ("to investigate the red spots moving on the south polar ocean of Crompton IV") or more general ("a five-year mission to explore Frontier Sector"). The expedition can be a relatively low-key affair like many of today's unmanned probes, or a major commitment such as the Apollo moon-landing program. If spaceflight is relatively inexpensive, universities and research institutes may fund interplanetary or interstellar expeditions on their own. Major efforts – like those that require building new designs of spacecraft – require significant government or corporate funding, and thus need to justify their commercial or strategic interests.

Where spaceflight is expensive, scientific missions may be the responsibility of a government space agency. This creates tension between missions intended to serve the government's interests and those that are purely scientific in character.

Strategic and Political Expeditions

Governments sponsor exploration and colonization to gain prestige, subsidize jobs in their aerospace industry, determine the existence of threats such as hostile aliens, or extend their sphere of influence by visiting and claiming new worlds.

Strategic exploration is also driven by a need to map out faster-than-light wormhole or jump points vital to trade and naval operations. If two or more spacefaring powers border the same unexplored area of space, rival armed expeditions may come into conflict as each side races to "plant its flag" on new worlds or star systems, or to establish "facts on the grounds" by creating colonies. These objectives combine with scientific goals, although the science element takes second place to political aims.

This may be handled by a space navy's warships (with some civilian specialists aboard), or by a civilian or paramilitary space agency or survey service operating its own dedicated exploration and research vessels.

Commercial Expeditions

Commercial expeditions are motivated by profit, seeking out resources to exploit or real estate to claim and sell to future colonists. Explorers work directly for interested governments or corporations, or are freelancers hoping to sell what they find. Governments also co-sponsor commercial expeditions to provide assistance to business or because they control the economy.

The missions are only viable if the return justifies the cost. The greatest expense is the spacecraft and fuel to reach the destination. Business-driven expeditions use commercially available equipment to reduce mission costs, though innovative ship designs or components are developed when critical to success (or seen as good investments in themselves).

The viability of commercial exploration also depends on the legal framework in place. Can explorers claim an entire world (including settlement rights and geological and biological resources) for themselves? What are the criteria for a claim: telescopic detection, first robot landing, first people on the ground, or actual homesteading and economic development? Is exploration a lawless free-for-all, or does a central body recognize, distribute, and sell claims, such as a government, a scientific agency, or a religion?

When spaceflight is relatively inexpensive and business interests can claim the worlds they investigate, it leads to a flurry of economic-based exploration. Even when a government claims all new worlds found in their sphere of influence, there's a niche for corporate and independent explorers who receive sizable bounties or royalties (or a monopoly on trading rights) for the planets they explore. They might compete with illegal "pirate" explorers who operate outside the law, keeping their finds secret to allow unregulated exploitation by criminals or ruthless corporations. Depending on the nature of the government, these rogues are portrayed as heroes or villains.

Establishing contact with alien species (or long-lost colonies) is another objective of business interests, and perhaps the ultimate prize of such an expedition. Corporations want to establish monopolistic trade deals and gain privileged access to new technologies. Ruthless explorers have other things in mind, seeking out civilizations or ecologies that can be looted and species to enslave. With the advantage of superior technology, even a small ultra-tech corporation might take complete control of a lower tech-level world!

Commercial missions have goals beyond claiming and exploiting new worlds and civilizations. A media company may commission an exploration as part of a documentary on an exotic astronomical feature, or tourists may pay to go where few have gone before. When alien life is known to exist, someone may want a biological survey expedition. It can take multiple missions over decades or centuries before a complex alien ecosystem is fully understood. Truly foreign plants, animals, and microorganisms are valuable to biotech companies interested in marketing new drugs, foodstuffs, and other products. There may even be a lucrative market for exotic alien pets.

Missionary Expeditions

If extraterrestrial civilizations exist, religions and quasi-religious ideologies may send out missionary expeditions to contact and convert aliens. These may be sponsored by churches or the government, depending on the role of religion in the society.

Adventure Idea: Races and Prizes

Expeditions need not have a practical goal. Private citizens may explore space for the challenge itself, seeking adventure (and fame). However, going where no one has gone before can be an expensive process. Traditionally, competitions and prizes have inspired people or corporations to perform and fund risky ventures. They're offered by private foundations or wealthy individuals with an interest in promoting space exploration or development, or by media corporations seeking exposure. Prizes are often given for "firsts," e.g., "first manned landing on Mars" or "first voyage to another star." The goal may have commercial applications, with achievement fostering the growth of private enterprise in space, and so may also mandate specific tasks (transporting passengers or cargo, establishing a base, or retrieving specific data or samples). If several groups compete, it turns into a de facto race – not just to reach the goal first, but also to get the funding to build or buy the vessel!

Historical examples of aerospace prizes include the $25,000 Orteig Prize for the first flight across the Atlantic Ocean (won by Charles Lindbergh) and the Ansari X-Prize of $10 million for the first non-government organization to launch a reusable manned spacecraft twice in two weeks (won by Tier One's *Spaceship One* suborbital craft in 2004).

It's rare that a large prize covers the entire cost of a project; *Spaceship One* cost $25 million to develop. However, if a big payout or prestigious trophy is offered, it attracts media attention. Local governments, businesses (especially those that manufacture or service spacecraft), and individuals may be interested in sponsoring the team for the publicity and prestige success brings. Sponsorship likely takes the form of a discount on, or donation of, spacecraft components, fuel, or supplies.

Wheeling and dealing for private endorsements is a significant part of the adventure, especially if the crew is attempting to build or custom-refit a spacecraft and needs backers willing to donate each component system. Sponsors demand the workers take time out for speeches and interviews before and after the expedition, ask them to film commercial endorsements, or insist on veto power over crew composition or ship design. Characters can exercise numerous social skills and perhaps become celebrities in their own right even before the vessel is launched.

PCs could call upon their Patron for sponsorship, or they should roleplay finding one through meetings with eccentric and occasionally sinister individuals or organizations, each with its own agenda and preconditions. For example, Jupiter Fuels Inc. might provide the expedition with free nuclear fuel pellets if they paint the spacecraft with the company logos; Lunar City donates half the cost of the fusion drive if they agree to name the ship *Spirit of Luna*; and Lagrange Space Farms offers crew provisions in exchange for video of the crew enjoying their signature L5 Burger. A scientific institute or university might fund a mission if the crew performs a pet experiment at the destination, or brings one of their researchers along.

If it's a race for the prize, a mission may get backing simply by appealing to the competitors of the groups that sponsor their rivals. This is a two-edged sword, however, since a "friendly" event becomes intense when transformed into a contest between opposing billionaires, megacorporations, or governments. The ship crews are now surrogates for existing rivalries! If reputations are on the line, contention could escalate into sabotage before or during the mission.

Colonization Missions

Explorers may seek land to colonize. But why should they want to cross the depths of space instead of making their homeworld's deserts bloom or mining the sea floor? Some possible motivations for extraterrestrial colonization are suggested below.

Freedom

Minority groups whose way of life is threatened by a majority may desire to found a settlement far from their culture's power and influence. The only way to do this on a crowded high-tech planet might be a voyage to another world. The group must be powerful enough to afford the venture, but not so powerful they could just remain behind to change the system. It's a strong motivation, whether to escape persecution or to create a bold new political or social experiment. A majority group may even fund such an effort in order to peacefully exile a troublesome minority.

Running Colonization Campaigns

Most outposts and colonies take years to establish and grow. Their operations have little to do with spacecraft and everything to do with logistical and sociological factors, and the nature and characteristics of the world being colonized. These are beyond the scope of this book: GMs running such games should refer to ***GURPS Space*** (p. 13) for colonial and refugee-based campaigns and ***GURPS Space*** (pp. 90-93) for game mechanics (e.g., necessary population, a planet's carrying capacity, and growth rates).

Population Pressure

A popular justification for colonizing other worlds is to relieve population pressure. In practice, this is difficult. Unless space travel is incredibly fast and cheap, it won't make much difference. However, the socioeconomic stresses brought about by overpopulation (war, famine, overcrowding, reduced resources, lack of jobs, etc.) themselves encourage people to seek a better life, even on another world.

Involuntary Exile

If transport expenses are modest, a government may opt to move criminal or political dissidents to distant colonies, seeing exile as a "humane" alternative to imprisonment, reeducation, or execution (or just a cheaper or more politically expedient alternative, period).

Religious Imperatives

Many religions embrace missionary activities, or encourage followers to procreate. Millions of people have spent lives and treasure on dangerous pilgrimages and multigenerational projects (pyramids, cathedrals, etc.) under the impetus of faith. Future religions may spread these motivations among the cosmos.

Political Rivalry

Opposing superpowers can compete through an aggressive program of space colonization. However, colonies founded for propaganda purposes may face a desperate struggle to survive if the political situation changes due to the collapse or distraction of the founding power bloc.

Incremental Colonization

Sometimes colonization is an accidental side effect of other activities. Off-world outposts may be established for scientific, economic, or military purposes, using temporary personnel. But as they grow and offer more comforts to their inhabitants, it may become easier to extend personnel tours than to rotate them back. Facilities develop to make the outpost self-supporting; people stationed there for long periods have children who see it as their home . . . and eventually, without any prior intent, it grows into a de facto colony.

New Lands, New Resources

If space travel is affordable, colonization may be for the most basic of reasons: to acquire territory to settle and resources to ship home. Another, perhaps more likely, option is the existence of "triangle trade." A colony provides goods to nearby resource-extraction operations – for example, greenhouses and other manufacturing facilities on Mars supply an asteroid-belt mining operation, which then supplies Earth with raw materials, which in turn ships expensive manufactured goods to Mars. Such a program might work if it's cheaper to make certain necessities on Mars for sale in the asteroid belt than it is to lift them off high-gravity Earth.

A Better Life

Historically, wages in new colonies are higher since there's an initial labor shortage. This is especially compelling if there is some way of sending a portion of the earnings "back home" to support one's relatives and/or secure their migration to the new lands.

We have to make people lift their eyes back to the horizon, and see the line of ancestors behind us, saying, "Make my life have meaning." And to our inheritors before us, saying, "Create the world we will live in." I mean, we're not just holding jobs and having dinner. We are in the process of building the future.

– Capt. John Sheridan, ***Babylon 5*** *#2.15*

Industrial Parks

A habitable planet like Earth is a complex ecosystem with a limited "carrying capacity." Even the "empty" deserts and oceans are part of an interconnected biosphere. Changes, additions, and subtractions are unwise. In contrast, lifeless moons, asteroids, and empty space itself may be a great place to build megaprojects and locate dangerous or polluting mines and industry.

To Preserve the Species

Off-world colonies may be established for the same reason people care about secure radioactive waste storage or reversing the greenhouse effect. Conservation movements all involve present sacrifice to benefit future generations. People spend resources on what amounts to a secure off-site backup for the species, so all a civilization's eggs aren't kept in the same planetary basket in the event of unforeseen disaster on a planet-wrecking (or worse) scale. This can justify interplanetary, interstellar, or even extragalactic colonies.

Refugees from Disaster

If an existential disaster *does* occur, there may be time for inhabitants to escape the home planet (or solar system, or galaxy . . .), to avoid destruction or enslavement and seek new homes elsewhere in the cosmos. If there is plenty of warning (and sufficient technology and space industry) it's possible to save everyone who wants to leave. Otherwise, only a fraction of the population may escape, though this could range from a few people to billions. Where time and resources permit, smaller survey expeditions should be sent in advance to find suitable new homes. Otherwise the colony ships carrying the refugees have to do the exploring themselves. They could be in desperate straits, with vessels that are overcrowded, lack fuel and supplies, and hold unskilled passengers who never planned to be colonists. Refugees may also have the psychological scars from whatever disaster drove them into space, especially if only a minority escaped. If they were fleeing war rather than natural disaster, they may have enemies on their tail . . .

Remote Survey Procedures

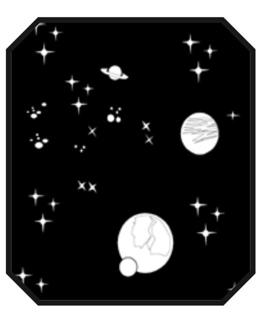
This section describes the tasks an exploration ship crew performs when approaching an unexplored star system. The majority of these procedures are intended for interstellar exploration, but some are applicable to interplanetary missions. They require a vessel's comm/sensor array, and specialists using it must have access to a control station.

Acquisition and analysis of survey data requires a significant investment of time, so procedures use long task (p. B346) rules. The time can be increased or decreased using the *Time Spent* rules; in cinematic games, attempting them almost instantly (at a -10 penalty) is common. The GM may make task rolls for the players to keep them in the dark about whether they are succeeding.

Out-System Survey Tasks

These procedures involve remote evaluation and mapping of the worlds in a target star system. They can be performed over interstellar ranges.

Survey operations begin long before a spacecraft enters the system. A slower-than-light expedition is almost certainly directed toward a target that has already been thoroughly studied. The destination may have been observed for years, even centuries, before any star probes were built. Large telescope arrays perform solar-system detection activities at a range of dozens of parsecs or more at TL8, and hundreds or even thousands at higher TLs. However, such endeavors can take months for each scan, and the galaxy has billions of stars! Also, surveys across thousands of light years are thousands of years out of date unless the sensors operate at faster-than-light speeds. Detected stars or planets are (usually!) still there, but all signs of intelligence such as radio signals are a year old for every light year (3.26 years old per parsec). Civilizations could have risen, fallen, or radically changed by the time their signals arrive. As such, even if long-range survey data is available, it's common for exploration spacecraft to perform their own checks as they approach to gain more recent information that they can trust.



Starships that don't travel through normal space but use jump drives or hyperdrives can appear in a system they haven't studied at all. If so, it's still possible to use any of these out-system procedures from within the star system itself.

System Mapping

This involves studying the space around a star to locate planets and other bodies. Observers find any gas giants, determine the plane of the ecliptic (where most planets orbit), and then hunt for smaller worlds and other masses. (Again, if an expedition is planned to a well-studied but never-visited system, this data may already be available.)

System mapping is a long task using Electronics Operation (Sensor) skill that takes eight hours per attempt. Explorers slowly approaching from many parsecs away can take full advantage of extra time and spend as long as 240 hours per attempt (at +5 to skill).

Modifiers: Add the spacecraft's comm/sensor array level; add a further +3 if it has a science or multipurpose array. No range modifiers apply within 200 AU of the solar system. Otherwise, use the *Size and Speed/Range Table,* but read each yard as "100 AU." A parsec is about 200,000 AU and so is roughly equivalent to a "mile" on the table. Also, apply a modifier based on the approximate size of the largest world in a normal orbit around the star: -12 if it's tiny (like Mercury), -8 if it's small (Mars) or dispersed like an asteroid belt, -6 if standard (Earth), and -4 if large (a few times larger than Earth but smaller than a gas giant). There's no penalty if the largest world is a gas giant. (See ***GURPS Space,*** p. 75, for more detailed definitions of various world sizes.)

Completion of system mapping means all planets within the plane of the ecliptic are located, and the solar system's general outlines are mapped. The existence of asteroid belts (and any Kuiper Belt or Oort cloud) is discovered, as is the presence of larger moons (such as Luna or Titan). However, tracking down the location of every small planetoid or tiny moon and detecting celestial bodies (such as comets and Kuiper-Belt objects) with eccentric orbits may take months or years of additional work. The presence of any stellar-scale megastructures – such as ring worlds and Dyson spheres (***GURPS Space,*** p. 133) – is also known.

System mapping may be a necessary prerequisite for plotting routes to neighboring stars, locating jump points or wormholes, etc.

Still too distant for visual analysis, but the spectrographic analysis looks promising.

– Sandra Benes,
Space: 1999 *#1.24*

Basic Planetary Analysis

Once system mapping is done, an additional study can be made of individual planets. This involves spectroscopic and other data to estimate characteristics such as temperature and atmospheric composition.

Successful study also reveals the presence of seas and oceans (through detection of water vapor) and key biosignatures such as abundant atmospheric oxygen and methane (the likeliest indicator of carbon-based life on the surface). Other clues can come from light reflected from a planet: Photosynthetic life-forms (and some artificial constructs) polarize reflected light in a uniform fashion, giving it a handedness not found in random reflections of sunlight from atmosphere or rocks.

Each planetary analysis is a long task requiring eight man-hours of Astronomy work. Completion provides enough data on the planet's approximate size, mass, temperature, and atmosphere to tentatively assign to it one of the world-type categories listed in ***GURPS Space*** (p. 77), such as Standard (Garden) or Small (Hadean). However, at interstellar ranges a classification is never certain. For example, a recent comet strike could elevate methane or water vapor levels on a world, giving a "false positive" biosignature.

Interstellar Signal Detection

Another task that can be undertaken at interstellar range is seeking out radio or other signals produced by a technological civilization. As a general rule, a people at TL7 or higher produce emissions detectable at this distance, although the GM may decide for whatever reason that a civilization isn't emitting anything. (Maybe they don't have mass media, or communicate with something other than electromagnetic radiation, or live underwater and the signals can't penetrate through to the surface . . .) TL6 civilizations may broadcast signals, but these are too faint to distinguish from noise at interstellar ranges. On the other hand, it's also possible powerful signals might be emitted by exotic alien animals or races (e.g., space-dwelling plasma entities) that naturally use radio for communication.

Signal detection is a long task that requires eight hours per attempt. Roll against Electronics Operation (Sensors) or Electronics Operation (Communications).

Modifiers: Add the comm/sensor array's level. If using a basic, enhanced, or tactical array, apply *Tech-Level Modifiers* (p. B168); these systems are optimized for detecting the signatures common to their own TL, not for outside-the-box solutions. Apply range modifiers from the *Size and Speed/Range Table*, but read "yards" as "parsecs," e.g., no penalty up to two parsecs, -1 at three parsecs, etc. Apply a population modifier. There's no modifier if the world's population is one billion; each order of magnitude increase adds +3; each order of magnitude decrease is -3. Add twice the spaceport class (see ***GURPS Space,*** p. 97, or ***GURPS Spaceships 2: Traders, Liners and Transports,*** p. 24); a system with a busy spaceport has more messages transmitted into deep space. (If the target deliberately beams messages across interstellar distances in the direction of the observers, add +10 or more.)

There is no modifier for TL: Ultra-tech civilizations produce more (and more powerful) emissions, but their signals are more efficient and thus harder to detect.

If the task is successful the observer detects any population that engages in extensive radio and/or radar emissions. This is most TL7+ civilizations with populations over a million in which broadcast radio or TV are in active use. It also includes less-populous groups with extensive industrialization (robot factories, etc.), deliberate space broadcasting (sending messages between off-world ships, satellites, or colonies), or a preference for radio communication. Remember radio or other electromagnetic signals travel at light speed, so observers pick up signals emitted years ago (3.26 years/parsec) rather than what is currently beamed out.

The exact signals detected are the strongest radio or other electromagnetic signals emitted by the star system that would have reached the observer at his current position during the time spent listening. Much of it may be garbled noise, but if there's mass media (or the equivalent), success should glean a number of hours of language samples equal to 10-60% of the time spent listening (see *Linguistic Assessment*, pp. 35-36). Analysis of the content *requires* linguistic assessment.

In-System Survey Tasks

These tasks should be performed after a survey spacecraft arrives in a star system.

Scientific Instrument Survey

Sensor arrays provide a variety of readings such as spectroscopic data, energy emissions, etc. Scientists analyze the data they provide using Chemistry, Geography (Physical), Geology, Physics, and Meteorology skills. Passive sensors are supplemented by active sensors if a ship is within range (see ***GURPS Spaceships,*** p. 45), although vessels forgo active sensors if they are trying to avoid detection.

Each analysis made using a particular skill is a task unto itself taking four hours. Roll vs. the appropriate skill or Electronics Operation (Scientific), whichever is less. For Geology, Geography, and Meteorology, use planet-type specialization (***GURPS Basic Set,*** p. 180).

Analysis can be performed in real time as data comes in, or later. Apply time modifiers based on *both* the duration of the observation and the length of time spent during the analysis. Coming closer to the target as the scan is ongoing changes the range, so modifiers for range are based on the average distance throughout the observation.

Modifiers: Long-Distance Modifiers (p. B241), e.g., -6 at 100 miles, -7 at 300 miles, -8 at 1,000 miles, -9 at 3,000 miles, -10 at 10,000 miles, -11 at 30,000 miles, -12 at 100,000 miles, etc. Add comm/sensor array level; add +4 with a science or multipurpose array. Add +2 if using active sensors, or +4 if this is a superscience multiscanner array.

The information provided by each task depends on the skill:

Chemistry: The atmospheric pressure and composition (***GURPS Space,*** pp. 80-81), with the exception of any organic toxins.

Geography (Physical): The diameter, mass, density, surface gravity, hydrographic coverage, and climate (see ***GURPS Space,*** p. 77). This confirms any earlier discovery of world type. It also provides details of *environment types* (pp. B223-224 and ***GURPS Space,*** p. 142) within the limits of the resolution of any map that was made.

Geology: The levels of tectonic activity and volcanism, and a rough guide to the age of the world. This is a necessary prerequisite for any planetary geological surveys (see below).

Meteorology: The types of weather found on the planet. Success is also a necessary condition for any attempt by a non-native at weather forecasting on the world.

Physics: Details of the planetary magnetic field and radiation belts (if any). At TL9+, study of neutrino and gamma-ray emissions reveals sources of high energy such as power reactors using nuclear fusion (via strong neutrino emissions) or antimatter (via distinctly polarized gamma-rays and large numbers of anti-neutrinos).

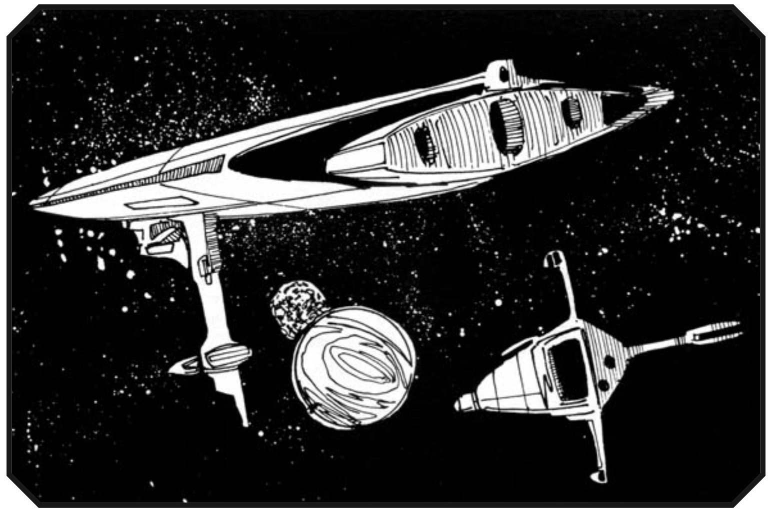
Completion of all these tasks calculates a preliminary *habitability* score (see ***GURPS Space***, p. 88). Any failure means the analysis has not been completed. Further attempts are possible with extra time; a critical failure means incorrect conclusions are drawn.

Direct Planetary Imaging

In addition to the scientific data detailed above, a spacecraft's sensors can provide multispectral images of the planet. Processing and manipulation at a variety of wavelengths and exposure times can improve resolution and create planetary maps.

Rather than rolling to detect any of countless features at different ranges, it's easiest to just determine the smallest object to be resolved at a given range. Find the Range modifier to the world, and take its absolute value (e.g., 66 for a -66 range modifier). Subtract (27 + array level). This is the largest SM feature that shows up in images.

Example: A spaceship with array level 9 is observing planet Rukia at a range of one million miles (a -54 range modifier). Features on Rukia no smaller than 54 - (27 + 9) = SM +18, or 1 mile can be resolved. This reveals the alien cities dotted on the world's surface (and the surprising lack of roads connecting them), but not the flying dragon-like aliens flitting about their towers. It may, however, show the mile-long jet contrails through the atmosphere produced by the planet's extensive aerospace traffic.



As resolution improves, further analysis is possible. The base time required for preliminary analysis is one planetary day (or eight hours, whichever is more); to make a complete, detailed map, ships orbit and map the planet over several days; this provides extra time bonuses. Add +3 if the spacecraft used active sensors (see ***GURPS Spaceships,*** p. 45, for active sensor ranges). Generally, a minimum spatial resolution of SM +5 (15 yards) or smaller is required for useful data.

A successful Cartography skill roll produces an accurate map at the above resolution. Failure means it has enough errors to cause problems for its users (apply a penalty to Navigation rolls equal to margin of failure). Critical failure means the adventure is impacted (e.g., a landing spot noted as flat terrain is actually a treacherous swamp). The GM may wish to roll secretly.

Use Biology skill (with world-type specializations) to make informed speculation on life-forms (such as areas of vegetation) large enough to be visible. It won't reveal anything directly about things too small to spot, but a scientist could draw broad conclusions about the number and type of smaller organisms required to support those larger creatures or areas of vegetation that *are* visible to the sensors.

Use Geography (Political) skill to estimate the existence and extent of any civilization based on visible features. For example, if a civilization has cultivated fields, long straight roads, sprawling cities, etc., these are noticed at a resolution of a couple of miles (SM +18). On the other hand, a small cluster of tents for a group of hunter-gatherers requires a resolution of SM +2. A resolution of SM +5 or less (capable of distinguishing individual buildings, campfires, herds, etc.) allows a roll to identify population and TL to within an order of magnitude (this is the Population Rating, or PR; see ***GURPS Space,*** p. 91).

Planetary Exploration

Every new planet is the product of billions of years of isolated evolution, full of traits unique to itself. Real understanding of any world requires explorers (or their robots) to go down to the surface and get their hands dirty.

Geological Survey

A detailed terrain map from active sensors gives some information about subsurface geological formations and tentative knowledge of the world's geologic activity (see ***GURPS Space***, pp. 119-121), but a complete picture requires on-site inspection. At a minimum, a number of geological surveys equal to the diameter of the planet in thousands of miles at different types of terrain are required.

Each such survey requires 40 man-hours each of Geology and Electronics Operation (Scientific) work and the use of specialized equipment to obtain rock or ice-core samples, seismic readings, and measuring key geologic features. Portable laboratories (see ***GURPS Ultra-Tech***, pp. 66-67) are carried as cargo for this purpose.

Modifiers: -2 if no active sensors were used in mapping; equipment modifiers.

The collected samples are returned to the survey vessel. At the GM's discretion, these may be treated as "on-site" resources for Prospecting; provide evidence of exotic transuranic elements; have fossils or embedded organisms (requiring use of Paleontology skill to analyze them); or possess other properties of interest.

Analysis

A Geology skill task (taking 40 hours of work) provides a preliminary assessment of planetary resources.

Modifiers: Apply modifiers from the spacecraft's geology lab facilities.

This gives a precise estimate of the age of the planet, and identifies any special features about its overall composition. On planets without life-forms, this should be sufficient to determine the Resource Value Modifier (see ***GURPS Space***, p. 87). Determining the exact mineral wealth of the planet (and what constitutes "valuable" varies by TL and setting) and locations for commercial extraction takes months or years of additional work, but the analysis provides enough data within an order of magnitude for decision makers to judge whether to proceed with prospecting and exploitation. Chemistry might be necessary to identify trace elements or the structure of unusual compounds.

Biological Survey

A vessel's integral equipment supports one simultaneous survey per biology or Science! lab aboard. On a garden world with abundant native plant and animal life, it is impossible to do more than the most rudimentary research into the planet's ecology (for that, see below).

During the biological survey, the explorer collects soil, air, and water samples, deploys unattended sensors, recovers seeds and insect equivalents, and traps animal life for later analysis. Small animals can be easily captured for intensive study; large creatures are usually better anaesthetized or killed, then autopsied, to enable gross anatomic studies. Tissue samples, ova, and sperm are collected for gene sequencing and possible creation of research specimens using growth tanks (p. 23).

If available, robots disguised with biomorphic coverings that were grown on-site, or captured animals implanted with neural interfaces, deploy surveillance devices and direct researchers to nests and food sources. Capturing or monitoring animal specimens can play out as a series of mini-adventures so long as the players and GM are comfortable with the details.

A preliminary biological survey requires at least as many study sites as there are distinct environments on the world, although settling for a few representative locations is common. The survey requires at least 60 man-hours of Biology work per environment studied. Specialties may be required (Botany to study plant samples, Zoology for captured animals, Biochemistry or Microbiology for bacteria and soil samples, and so on). On worlds with extensive seas or oceans, GMs may split biological survey work into separate land and ocean surveys, treating each distinctly. Ocean surveys require that the team has equipment for underwater operations, e.g., submarines (manned or robotic), diving gear, etc.

Modifiers: Equipment quality.

Completion of the survey recovers a representative collection of biological organisms and environmental samples (such as soil samples).

Analysis

Analysis is a long task that requires 20 hours of Biology work for *each* survey to catalogue and assay the samples collected. Use the appropriate planet-type specialty (p. B180).

Surveys on Non-Garden Worlds

The survey rules detailed above mostly apply to garden worlds where there is a wide variety of obvious life. On other worlds, it may be uncertain whether life even exists at all! Life-forms may be limited to microorganisms, be found only in a limited number of environments, or simply be too alien for easy identification. If so, the primary goal of a biological survey is to determine whether there is any life. The GM may impose penalties or extend the time required based on how hard the life-forms are to find or analyze. If it is confined to certain environments or regions of the planet, the expedition must search the right spot. For instance, the only life on a world might be located in thermal vents at the bottom of a subsurface ocean beneath 50 miles of ice. A survey performed at the surface would reveal no life; the explorers would only succeed if they breached the ice and sampled the deep ocean environment.

Modifiers: Apply modifiers from the spacecraft's biology lab facilities.

Once analysis is complete, the biological survey yields enough information to get a broad picture of a world's natural history. Major plant and animal orders are understood and the prevalent large species are identified. The researchers discover, at least in outline, the biochemical basis of life on the planet (see ***GURPS Space***, p. 140) and, at late TL9+, have sequenced the genome of several animals and plant species. (At a lower TL, analysis of a genome may take months or years.) Successful study can also answer basic questions for colonists and castaways, such as:

- Is the environment inherently hazardous (will it eat or poison us)?
- Is the environment benign (can we eat them)?
- Is the environment sustainable (do we have to take vitamins, or can we just live off the land)?

Bioengineering skill is invaluable in interpreting the genetic data. If live samples were collected, Animal Handling and Biology (Entomology) may be required to wrangle the critters in the lab.

Ecological Survey

To gain a real understanding of how local ecosystems work, a full ecological survey is necessary. This is a series of long tasks that takes *at least* 3d years to complete. The surveyors must painstakingly identify local species down to the smallest animal and plant forms. Further, the team must observe how they interact over several local years to make sure any seasonal changes are noticed and understood. The survey involves many rolls against various Biology specialties.

Ideally this should be done in advance of any colonization effort, but greed or politics may result in it being delayed until after an outpost or even a full-scale colony is established, sometimes with dangerous or tragic consequences.

First Contact

If explorers have determined intelligent life is present, the question of contact arises. Many starfaring cultures establish contact protocols, sometimes with the force of law behind them. Unofficial expeditions develop their own ad-hoc procedures.

Careful explorers avoid going in to contact a new society "cold"; if possible they secretly observe the natives for weeks, perhaps even months or years, from hiding. Of course, a covert exploration may only be possible if the natives have inferior technology; many space drives have obvious signatures. And sometimes contact is made via radio or other means well before any exploration ship arrives.

In space opera genres, "careful" and "first contact" rarely go together. Boring processes like initial linguistic and sociological assessments are omitted or left for later, or handled by ultra-tech instantaneous translators, and the crew jumps right into either a covert or overt contact situation. (This may explain why there are so many hostile aliens and interstellar wars in such settings!)

Linguistic Assessment

The most important pre-contact task is a study of the major local language. If the native society is at a low level of development (TL0-5), samples of the language must be gathered via direct monitoring of conversations. This means placing audio bugs (or just hiding "open mike" communicators) and/or infiltrating stealthy reconnaissance robots (or microbots) into inhabited areas.

Deploying surveillance systems can be an adventure in itself, with a risk of sudden and inadvertent "overt contact" if the team fails to preserve secrecy. The mission may be trivial if the characters have very advanced technology, such as swarms of tiny microbots or chameleon invisibility suits (see ***GURPS Ultra-Tech***). Alternatively, the activities may require Electronics Operations (Surveillance), Stealth, and Camouflage rolls. Robot spies and hidden bugs are normally almost impossible for a low-tech society to detect. How many hours of useful samples are gathered is up to the GM. Depending on the technology used and the area spied on (assuming they found a settlement to monitor), each bug may get as many as 1d-2 hours of samples (minimum 0) every eight hours of monitoring.

If the natives have electromagnetic communications, remote linguistic assessment should be possible from anywhere in the star system, and perhaps from interstellar distances (see *Interstellar Signal Detection*, p. 32). Where societies use modulated electromagnetic signals, radio and/or television communications can be monitored. Some species may use communications that require special effort to tap into, e.g., an aquatic race using sonar signals, which would require deploying underwater listening devices. The GM has to resolve such exceptions. Sometimes the first challenge is to figure out how a race communicates: Chemical pheromones, telepathy, etc., may impose major challenges!

I've been listening to the distress signal, and I, um, think I made a mistake in the translation.

– D.J., ***Event Horizon***

Radio monitoring can be done from space without risk of detection. Use Electronics Operation (Communications) to tap into local radio nets using the vessel's communication systems; see the rules in ***GURPS Spaceships*** (p. 45) for typical comm ranges. But at high tech levels signals may become difficult to interpret. As analog gives way to digital (normally at late TL7), the eavesdropper must first break the local protocols that encode voice, video, or text data. This is a long task requiring eight hours per attempt and several hours worth of samples.

Use Cryptography skill; apply a -10 penalty; add the Complexity of the spacecraft's computers; and add -2 for every native TL above 8. Ship communicators gather one hour of useful samples for every two hours spent monitoring.

The GM determines how many hours are needed before a working model of the language is derived. If the local language is descended from a known language (as for a lost colony of some kind) then completion of a long task using Linguistics skill, taking eight hours per attempt, may be enough to "break" the new dialect. If the tongue is completely unknown, at least (2d+8) × 10 hours of samples are needed, more if the language has bizarre syntax or is communicated in an unusual manner – which is likely the case if it belongs to a hitherto unknown alien species. In any case, Linguistics rolls are needed to analyze the samples properly and to create a database for the new language, which is a long task taking *at least* 200 hours. At this point, the database is still incomplete and does not permit anyone to learn the language at better than a Broken comprehension level. At TL11+, highly advanced translation programs may allow "real-time" cracking of languages, greatly speeding this process – see ***GURPS Ultra-Tech*** (p. 48).

They Know We're Coming

The orderly step-by-step processes of "linguistic assessment – sociological assessment – covert contact – overt contact" work when an exploration ship is observing a pre-spacefaring culture, or has access to low-signature super-science drives or cloaking device technologies.

However, many realistic space drives such as fusion and antimatter drives are sufficiently "bright" that most populated high-tech worlds can spot the drive flare of a decelerating sublight starship weeks, or even months or years, in advance.

In such circumstances, the decision making in any "first contact" situation is bilateral. Both sides make choices starting with "linguistic assessment" (the locals work to crack whatever messages the starfarers beamed toward them, and vice versa), then proceed straight into an "overt contact" situation.

The natives may have days or even months (depending on the incoming ship's sensor and drive performance) to come up with a response (or several responses, if they lack a single government). They can select ambassadors, prepare (quarantined) quarters for visitors, and, if divided into factions, quarrel or fight over who represents them. If they have the capability, they may choose to meet their visitors in space, for self-defense or to impress them. And if they have anything they feel the urge to hide (war fleets, the presence of dissenting factions or recent conflict, etc.) they may also have time to prepare deceptions!

Sociological Assessment

Once a local language is decoded, explorers may use its concepts and their earlier planetary observations to estimate local cultural, social, and political parameters. Again, this is based on information gathered remotely through covert observation, robotic reconnaissance, and/or radio monitoring. However, even if a language is understood, it takes considerably more work to gain insight into the local culture.

The rules below assume at least 200 hours of language samples have been gathered and are backed up by actual observation of the world. If less is available when the explorers try to make a sociological assessment, apply at a -1 penalty to each skill roll for every 10 full hours of deficit. Extra samples give a +1 bonus for every 100 hours of surplus. Video samples count double if they show natives interacting socially. Rolls are per day of observation for gauging TL or population, or per week of observation for political structure or institutions. These rolls shouldn't be considered a structured set of tasks; rather, they represent a gradual accumulation of insights.

Technology Level: The easiest parameter to assess from a distance is the level of technological development. The overall TL of a society should be obvious by the time the initial language database is complete, without need for skill rolls.

Population: The native population is also fairly easy to estimate by this time. Roll against Geography (Political) to get a better estimate of the world's native population than earlier imagery-based studies (within 25%), and again to estimate the population of any specific area.

Political Structure: A contact team can uncover the world's dominant government types. Intercepted communications give some idea who makes decisions and how political power is implemented. Roll against Sociology to make this determination.

Specific Political Institutions: The *details* of local politics and customs are rarely as obvious as the overall structure. Roll against Anthropology to make a rough remote assessment of local political bodies and laws (including approximate average CR). Unless the world is culturally homogenous, this only gives insight into one or two majority cultures.

Economics: Roll against Economics to assign a Trade Classification (see ***GURPS Spaceship 2: Traders, Liners, and Transports***, p. 36).

Instead of resolving the sociological assessment purely with skill rolls, the GM may play out the process of observation and deduction in greater detail. In this case the GM should provide clues to social parameters by describing the exploration team's observations, perhaps even before the language database is built.

For example, rather than calling for an Anthropology skill roll and telling successful players "this lost Earth colony's dominant society is a highly regimented socialist dictatorship," the GM can describe scenes of cities filled with large, monumental arenas and gray housing blocks; the scarcity of personal vehicles; the long queues outside many buildings; and everyone's drab clothes or uniforms. Of course, some of the explorers' observations can be misleading . . .

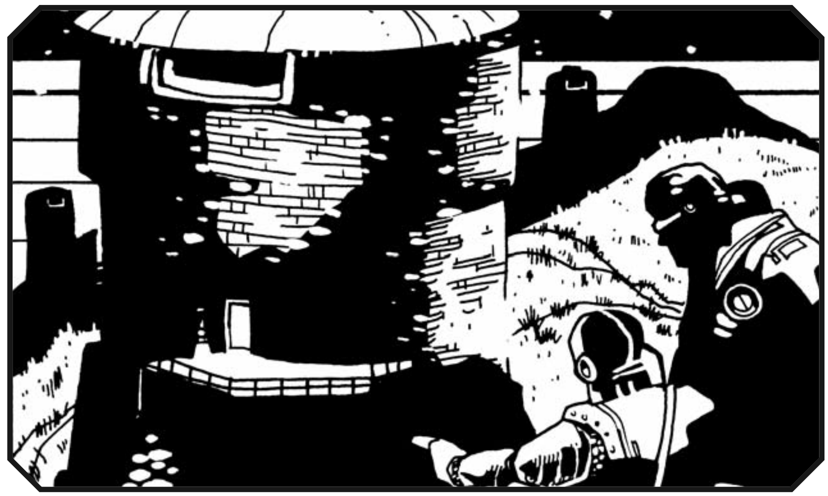
This treatment gives the players more latitude to direct the investigation, perhaps using other skills to ferret out bits of evidence. Once they've drawn and stated their characters' conclusions the GM can make skill rolls, granting bonuses if the players were perceptive or penalties if they were not, and provide PCs with further data based on their success or failure.

If the investigators aren't experts themselves but command a large expedition, the GM may have various NPC scientists present their interpretations, including recommendations on whether it's safe to make further contact. The GM can roll against the advisors' skills, modified by the observations of those NPCs directing them. This gets interesting if the GM decides different experts have their own agendas, interpretations, and requests ("Let's move the ship closer" or "We really have to get bugs into that temple complex"); the survey team has to decide if a culture is ready for contact, or is potentially hostile. It's then up to the PCs in command to decide whose advice to take . . . do they order further covert or remote studies, choose to proceed with overt contact, or even terminate the mission?

hydrogen peroxide, alcohol, etc.). It's difficult to be stealthy if wearing a full-body environment suit, but there may be ultra-tech alternatives like advanced skin-tight suits and transparent masks, sterile robots, and so on. Of course, if a suit or vehicle suffers penetrating damage due to accident or combat, exposure may be unavoidable.

Any covert team planning to remain on a world for long-term observation also needs some way to sustain itself (and power equipment). For example, can they consume food and water, or must they bring in supplies? This may require packing sufficient provisions, vitamin supplements, and power cells for the duration of the mission, and/or insuring proper protection against local microbiological hazards in food and water.

Covert Contact



Once the linguistic and sociological assessments are finished, the leaders of an exploration team may authorize a covert contact mission. This is not intended to open communications, but rather to gather more information without revealing themselves to the natives.

Some first-contact protocols prohibit covert contact, either on ethical grounds ("We have nothing to hide") or because the risk an accidental discovery of the undercover team may lead to an *uncontrolled* "overt contact" situation. Not only might this result in the loss of the team (e.g., they're mistaken for local spies, foreign intruders, monsters, evil spirits, etc.), but it could trigger larger-scale hostilities. In fact, if the native society is of equal or greater TL to the contact team, a covert operation is sufficiently risky that the practical choice is open contact or no contact at all. An exception is covert contact with a far-flung cosmopolitan interstellar society that encompasses numerous alien or bio-engineered races – if so, covert contact is fairly easy, since visitors from distant parts of the polity are common. If you can meet 40 alien races in a spaceport cantina, a 41st race showing up might not make much of an impression!

The whole concept of covert contact implies the capability of explorers to *be* secretive when they move among the natives. If they're different, physically or mentally, covert contact may only be possible with extreme measures. Possibilities include surgery or nanotechnology to physically transform the team into duplicates of the inhabitants; the creation of robotic or biological android bodies that match native physiology; the replacement of locals with such duplicates; the capture of natives and implantation of "puppet" implants to possess native bodies; and the use of psionics to infiltrate the society.

Biohazard and biocompatibility issues must also be considered and dealt with. Based on earlier biological surveys, a cautious team ensures they neither contract diseases from the natives nor spread pathogens among them. Realistically native microbes are unlikely to infect a truly alien species; toxic or allergic reactions from native life-forms are possible, as are attacks by any alien equivalent of mold that considers humans (or their equipment) just another source of edible hydrocarbons. A contact team may trust advanced symbiotic nanomachines or pan-immunity drugs to police their bodies. Even so, the best way to be safe is simply avoid direct contact and clean exposed surfaces with conventional toxic cleansers (iodine,

If, despite these risks, covert contact is attempted, the team must be as familiar as possible with the native language and customs. If they successfully performed the Linguistic and Sociological Assessment steps, they may have enough data to speak a native language at a Broken level, but their understanding of local culture is too incomplete to permit any level of Cultural Familiarity. The team should also make (or steal) clothing and personal equipment designed to fit with local styles. Money is a problem, especially if the local technology produces elaborate currency that is hard to counterfeit without close examination. Instead a team may opt to carry compact valuables such as precious metals or gemstones, or, if their protocols permit, a carefully chosen selection of trade items. Explorers may be able to get away with carrying gear or weapons more advanced than the local TL, but the items should be disguised, implanted, or easily concealed (Holdout skill is useful).

They should arrive in an inhabited area in a frontier or rural region that allows for an unobserved landing. Stealth spacecraft (or drop capsules or teleport projectors) may be used; the expedition might even be equipped with landing craft designed for that purpose. If slipping past local sensor nets, see the *Detection* rules in ***GURPS Spaceships*** (pp. 44-45). Once the team lands, it should make its way into contact with the local population. The team may pretend to be native foreigners visiting from a different region, although this can add its own complications if the inhabitants tend to distrust foreigners! Otherwise the characters may simply avoid attracting attention and set up a secure base in a location that lets them observe the locals and gather samples of artifacts.

Any covert contact mission should be played out as an adventure. Its goal is to gather detailed information about local languages, culture, political structures, society, biology, laws, and customs. Some covert teams have additional agendas, e.g., acquisition of military intelligence to make a threat assessment or to prepare for future conquest, or gathering economic information in advance of opening trade. They may also attempt to obtain samples for local identity documents, currency, personal equipment, clothing, vehicles, animals, and so on to support further operations. They may be assigned to gather recordings of local gatherings, political meetings, stories, or dramatic presentations, as well as collecting scrolls, books, newspapers, downloads from computer networks – anything that improves the expedition's grasp of language and culture. Naturally this means interacting with the local population or resorting to stealth and theft of artifacts (which in some circumstances may be the only practical option!); finding open-minded locals with whom to make overt contact; or even kidnapping "specimens." When the team interacts with residents, GMs should remember to apply all usual penalties to social skills for lack of language or Cultural Familiarity.

Depending on the team's goals it may take one or several missions of varying duration before they decide to conclude the covert stage of a contact operation. In some cases, this phase may proceed for many years, especially if authorities decide overt meetings are dangerous to either party. Successful covert contact missions enable the exploration team to improve their language database (or simply get more practice) so members can buy up to an Accented language comprehension level. Cultural Familiarity may also be purchased.

Contacting new worlds always involves unexpected risks.

– Sub-Commander T'Pol, ***Enterprise*** *#1.24*

Overt Contact

Once covert contact is finished, or if the step was skipped entirely, the exploration team moves to open, overt contact. Some societies have "non-interference" doctrines or laws prohibiting space explorers from legally making open contact with low-technology societies not "ready" for contact, and others are nervous about providing potential rivals with knowledge of their existence.

Overt contact may follow various procedures, but all of these approaches boil down to using Influence skills in the hope of obtaining a favorable reaction; again, be sure to apply modifiers for language comprehension and lack of Cultural Familiarity.

For peaceful contact with TL7+ societies, the simplest form of overt contact is to transmit radio or other communications in the local language(s), with the content of the message based on any study of the local culture and its institutions. Such a message may be open ("This is the Galactic Federation starship *Unity,* transmitting on all frequencies: Greetings, Hives of Xaxnor, we come in peace and seek permission to cross-pollinate with your world-minds").

However, if investigation has determined an open message may destabilize native institutions, the starfarers might instead covertly deliver their message to local authorities or other selected groups, leaving them to decide whether to best break the news of first contact to their people . . . or to keep it secret. The latter amounts to a de facto alliance between the visitors and one or more native factions, often involving the exchange of advanced off-world technology for the right to study and/or exploit the populace or resources and potentially leading to various covert operations.

If the visitors intend a peaceful takeover or assimilation, they might instead dramatically overawe the natives with advanced technology – the "flying saucers on the White House lawn" scenario. There are risks, though: Depending on the society, an entire civilization might overreact, resulting in widespread panic and possible social collapse! Also, since surprised locals may attack, this approach works best if the visitor's vessel is confident in its defenses! With primitive locals, another approach is to pretend to be gods or other supernatural entities, which can be most effective if study allows the newcomers to employ motifs based on local beliefs. Not all contact teams care about local stability or perpetuating existing power structures. If conquest is planned, "overt contact" may be a surprise attack on any space forces, followed (in some cases) by orbital bombardment, troop landings, or both. In such cases, causing a panic is an objective rather than something to be avoided.

Once local authorities or populations have dealt with the initial shock of contact (or have been defeated by an invasion), the overt contact team makes agreements to secure whatever they're after. Some may be open about their goals; others may find it expedient to limit the information presented immediately to the natives, for sociological, security, or economic reasons. For example, high-technology items may be *demonstrated* as a means of proving the team's claims or extraterrestrial origin, but *how* devices work is left to later technology-exchange agreements.

First contact teams may avoid entangling themselves in existing social and political power struggles, at least until they have a good handle on what's going on. But backing one faction or organization (and perhaps even helping it take over the planet) is a useful strategy to secure influence, and may be a necessity if the team is the "front end" of an attempt to colonize, conquer, or assimilate the native society.

Negotiations with newly contacted worlds require a delicate touch. A first contact team may simply secure an agreement for future talks at a governmental level, having no authority to make anything resembling a treaty. In that case, follow-up missions are left to specialized organizations (a diplomatic corps, state department, etc.). Or they may attempt to gain agreements that give access to the local population (enough for in-depth linguistic or sociological surveys), an exchange of ambassadors, a semi-permanent outpost, or permission to settle part of the system.

Chapter Three
Space Hazards

Spacecraft may face danger aplenty before they even make planetfall! This chapter details natural hazards encountered while voyaging through space. These rules are applicable to any spacecraft – not just to colonization or exploration vessels.

Meteoroids and Space Junk

A solar system contains countless *meteoroids*. These are drifting chunks of rocky debris ranging from sand grain to boulder size. Most are fragments formed from billions of years of accidental collisions between larger asteroids. Some faster-moving meteoroids are the residue from comets' tails.

Meteoroids in our solar system travel at 10-12 miles per second (the orbital velocity of the asteroid belt); "meteoroid storms" produced by passing comets reach 40-50 mps. Spacecraft are regularly struck by small meteoroids but the vast majority of these are sand-grain sized, too small to do more than pockmark a vessel's hull. A greater risk is manmade debris. Most space junk, like paint flecks, is too tiny to worry about, but some pieces are large enough to cause damage and all travel at dangerously high orbital velocities. This is 5-6 mps in low Earth orbit, which means a possible closing velocity of 10 mps if the ship orbits in the other direction.

The odds of impacting an object large enough to do catastrophic damage are *very* low in deep space, but are increased in a debris-cluttered planetary orbit (such as modern-day Earth); while traveling the path of a comet; or when moving through the aftermath of a large space battle. Other conditions that put spacecraft in constant danger of hitting asteroids or meteoroids are cinematic; see ***GURPS Spaceships 4: Fighters, Carriers, and Mecha,*** pp. 35-36, for these types of debris fields.

There's no serious risk of collision in interstellar space unless the GM wants one for plot reasons. In interplanetary space, roll every year for a stray meteoroid hit. In debris-cluttered orbits, roll every six months. In hazardous environments, such as orbital space after a battle or in the vicinity of a comet's tail, check at least once, then again each month, and more often if a cascade catastrophe (below) has occurred. Roll 3d; if it's equal or less than the vessel's SM/2 (rounded up) the spacecraft has a close encounter at some point when the crew least expects it.

Time Scale: A meteoroid or debris chunk small enough to escape early notice, but fast enough to cause damage, is detected only at the last moment. Resolve the possible impact using 20-second turns when calculating rate of fire.

Facing: Debris normally impacts the front hull. In complex situations (maneuvering in the wake of a comet, escaping from a debris-choked orbit), roll 1d: 1-3 = front hull, 4-5 = central hull, 6 = rear hull.

Base Relative Velocity: Use 10 mps or the vessel's actual velocity, whichever is greater. Multiply velocity by five in the case of "meteoroid storms" produced by high-velocity comets.

Point Defense: The colliding spacecraft may attempt a Point Defense attack (see ***GURPS Spaceships,*** p. 59). Most debris is SM -10 and any hit destroys it.

Dodging: The spacecraft may attempt to dodge the debris (if eligible to dodge).

Impact: The incoming junk causes 1d damage per 10 mps of velocity.

Cascade Catastrophes

Earth orbit currently contains thousands of fragments of launch vehicles, paint chips, inactive satellites, debris from space weapons tests, and other junk. The same is true of space around other inhabited planets if care was not taken to avoid such problems, or in the aftermath of a major accident or battle. Orbital decay, the sheer vastness of space available even in "crowded" orbits, the tiny size of most debris, and "graveyard orbits" for satellite disposal mitigate any risk this trash poses under normal conditions. However, it is possible a war, terrorist act, or simple accident could result in an ablation cascade event, where space junk crashes into other satellites and space junk, producing a chain of additional collisions and debris and rendering orbital space hazardous to navigation. The aftermath of a catastrophe might require daily or hourly collision checks, and make leaving the atmosphere suicidal for unarmored space vehicles.

Interstellar Impact Hazards

Interstellar space (beyond a solar system's halo of comets) is largely free of meteoroids, but contains stray atoms of hydrogen and helium as well as occasional dust grains. These are very tiny (some 100-200 nanometers across) and thinly spread (maybe 1,000 grains per cubic kilometer). Even so, that's enough to be a hazard to a spacecraft moving at the velocities needed to cross interstellar space in a reasonable timeframe.

Due to the sustained nature of this sort of damage, it's not realistic to roll for hits and damage. Instead, a craft must have enough frontal armor (representing impact shielding) and/or force screen protection to provide necessary continuous protection.

The table shows the ablation effects at various fractions of the speed of light (every 0.1c is 18,628 mps) in terms of lost frontal armor dDR. After frontal armor is utterly ablated, each point instead causes 3d of decade-scale damage to the front hull.

Interstellar dust grains likely contain iron. If a ramscoop-equipped spacecraft moves at velocities high enough for the ramscoop to operate, the GM may rule it ignores these speed limits as the magnetic field deflects the iron. However, a ramscoop-equipped ship won't be able to use the field during the time it is accelerating from lower velocities since doing so would actually brake the spacecraft, so it still needs tough frontal armor to reach these velocities.

Ablation Table

Velocity	Ablation
0.1c	1 per 50 years
0.2c	1 per six years
0.3c	1 per two years
0.4c	1 per eight months (1.5/year)
0.5c	1 per four months (3/year)
0.6c	1 per two months (6/year)
0.7c	1 per month
0.8c	2 per month
0.9c	3 per month

Sir, the possibility of successfully navigating an asteroid field is approximately 3,720 to 1.

– C-3PO, ***Star Wars V: The Empire Strikes Back***

Radiation Hazards

Radiation (see pp. B435-436) is especially deadly in space because ships and stations are beyond the natural shield of a planet's magnetic field and thick atmosphere. Spacecraft electronics (such as computers) are hardened against high levels of radiation. However, the fragile biological occupants are vulnerable to numerous hazards. These include solar flares, cosmic background radiation, and the radiation belts of worlds with magnetic fields.

Cosmic Rays

Galactic cosmic rays are charged particles (atomic nuclei, electrons, positrons, etc.) that originate beyond the solar system, traveling through space at near-light speeds. Their high energy is difficult to shield against; they smash through matter, leaving a train of ionized atoms that kill living cells.

Unshielded individuals may notice these impacts as sporadic bright flashes in their eyes, even in total darkness. Cosmic rays are a hazard anywhere outside a world's magnetic field. They inflict 1 rad per week, and since they are highly penetrating all radiation PF is divided by 100. However, the exposure is halved if the vessel is in the shadow of a planet, moon, or other large body.

The risk of cosmic rays within a solar system is affected by the fluctuation of a star's magnetic field, which provides some shielding within the system. When the sun is especially active (e.g., for a few weeks after a flare – see below) exposure is less (halve the rads/week). At a great distance from the star (75+ AU away from a sun-sized star) and in interstellar space, exposure is greater (double the rads/week).

Solar Flares

Solar flares are storms of high-energy protons emitted by stars. Different stars are more or less energetic; the notes below apply to our sun, a G2 main-sequence star.

Our sun follows a rough 11-year cycle of flare activity, and during peak periods (the solar max) multiple flares may occur within the space of a few weeks. A typical flare lasts several hours. Since its particles travel below light speed, the light of the flare is seen before they hit; this provides about 10 minutes of warning per AU of distance from the active star.

On average, small flares occur 1d times each year and deliver 50-150 rads; midsize flares every 2-5 years delivering 200-1,200 rads; and major ones a few times every decade (at the solar max) delivering 2,000-6,000 rads. These dosage levels apply in space at a distance of 1 AU from the sun; divide by the square of the actual distance. Thus, occupants 0.5 AU from the sun during a small 100-rad flare might take 100/0.25 = 400 rads.

Solar flares are relatively non-penetrating: multiply radiation PF by 20.

Planetary Radiation Belts

Earth (and other worlds with metallic cores, including gas giants like Jupiter) is surrounded by a pair of donut-shaped magnetic fields. Those charged particles produced by the solar wind, and cosmic rays that are not deflected, are stored and trapped there.

Earth's radiation belts are known as the Van Allen belts and are described below.

The highest energies are found in the *inner radiation belt.* It extends 400 to 4,000 miles above the Earth at the equator. However, the belt is actually aligned with the magnetic axis of the Earth, which is tilted away from the axis of Earth's rotation. As a result, while the belt starts 800-900 miles above the surface on one side of Earth, off the coast of Brazil is the "South Atlantic Anomaly" where radiation is especially intense at an altitude of only 150-200 miles. Spacecraft and stations are best positioned in orbits that minimize exposure to the inner radiation belt. Lengthy unprotected exposure can cause radiation sickness and damage electronic systems.

The *outer radiation belt* is more tenuous and found at higher altitudes. It stretches from about 15,000 to 23,000 miles above the equator, although it curves downward toward each pole. Its radiation is primarily lower-energy ions and electrons produced by the solar wind, and so it is less hazardous than the inner belt.

On average, the exposure in the inner radiation belt is about 4 rads/day; the outer belt can be ignored, as even a spaceship's "default" dDR 0 hull is protection enough against it.

Radiation Protection

The risk of radiation exposure is one reason to favor unmanned or robot-crewed vessels for long voyages, but various strategies can mitigate danger to living travelers.

Radiation protection is measured by a Protection Factor (PF). Different radiation hazards are more or less penetrating. Radiation from cosmic rays divides PF by 100, while solar flares and planetary radiation belts multiply the PF by 20: for more details, see *Radiation Protection,* p. B436.

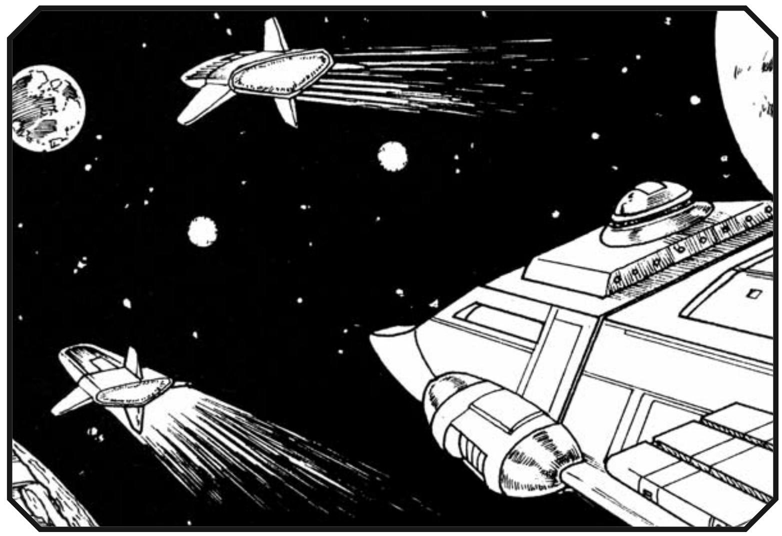
Manned spacecraft are assumed to be configured so the mass of the vessel serves as radiation shielding. That is, living quarters, control rooms, habitats, engine rooms, passenger seating, any system in a [core] location, and similar inhabited systems are all placed so they're surrounded by unoccupied systems, providing natural "mass-shielding."

To determine the PF shielding one of these systems, total the number of non-core systems in that hull section, excluding any Cargo, Habitat, Hangar Bay, or Open Space systems. Cross-index that number with the SM of the spacecraft on the *Radiation Protection Table* (below) to find PF.

Characters may find themselves in non-mass-shielded systems. To calculate radiation PF for occupants of such systems use the same procedure, but only count armor systems.

Any occupants of a core system receive double the effective PF.

Example: An SM +9 starship's central hull has one armor, one habitat, one cargo hold, and three fuel tank systems, plus a control room in its core. There are therefore four non-core systems (the armor and fuel tanks) that count for radiation protection, so the habitat's occupants receive PF 300 and the control room PF 600 (since it's in the core). If an occupant was not in the mass-shielded control room or habitat (e.g., visiting the cargo hold) only the one armor system would count, and so anyone exposed in the cargo hold would get only PF 70.



Mitigating Radiation Effects

Even in a well-shielded ship some radiation gets through, especially cosmic rays (which divide PF by 100), and exposure builds up over time. This is a serious limitation on long manned space missions, but the threat is mitigated at higher TLs.

Anti-radiation drugs provide some protection against exposure, and at TL10+, cell-repair nanotechnology is sufficiently advanced that spacefarers can just take a pill to protect against routine exposure (see p. B436).

Genetic engineering may also create spacefaring parahuman or alien sub-races with advantages such as Radiation Tolerance (p. B79) or Regeneration (Heals Radiation) (p. B80). ***GURPS Bio-Tech*** provides several examples of all three approaches.

Radiation Protection Table

System/SM	*+5*	*+6*	*+7*	*+8*	*+9*	*+10*	*+11*	*+12*	*+13*	*+14*	*+15*
0 systems	7	10	15	25	40	50	75	100	150	200	300
1 system	15	20	30	50	70	100	150	200	300	400	600
2 systems	30	40	60	100	150	200	300	400	600	800	1,200
3 systems	45	60	90	150	200	300	450	600	900	1,200	1,800
4 systems	60	80	120	200	300	400	600	800	1,200	1,600	2,400
5 systems	75	100	150	250	350	500	750	1,000	1,500	2,000	3,000
6 systems	90	120	250	300	450	600	900	1,200	1,800	4,000	3,600

Lost in Space

Vessels traveling through normal space have no problem navigating, but the peculiarities of stardrive technology may result in starships experiencing navigation errors: drive malfunctions that result in a faster-than-light voyage ending up many parsecs from where it's supposed to be. Similar difficulties occur when exploring a new jump point or wormhole. The starship may have the power to get home again . . . but only if the navigator can find out where the ship is in the first place!

The best way for a lost craft to find itself is by using pulsars. These spinning neutron stars emit powerful and directional beams of radio waves that sweep through space with the regularity of an atomic clock. Moreover, each pulsar emits radiation with a unique pulse period and shape. The galaxy's pulsar characteristics and locations are well known, and are the equivalent of lighthouse beacons for lost interstellar travelers. By tracking the exact time of arrival of pulses from a sample of pulsars, a vessel's navigator can determine the position of the starship.

Locating pulsars requires using a spacecraft's comm/sensor array as a radio telescope. Roll against the lower of Astronomy and Navigation skill every eight hours, adding the ship's array level; apply a penalty of -8 if using a basic or tactical array and -4 for a science or multipurpose array. Three successes means the vessel's location is known. Using documented pulsars for interstellar navigation is workable if one is still in the same galaxy or an adjacent satellite galaxy (e.g., one of the Magellanic Clouds).

Space Monsters

Active, aggressive space-traveling vacuum-dwelling creatures capable of threatening a starship are not very plausible, but then again neither is faster-than-light travel . . . and they add interest to a space-opera setting.

The most likely habitat for vacuum-dwellers is a system's Kuiper Belt or Oort cloud (where water – as ice – and complex hydrocarbons are found among comets). Another possible space environment is the (relatively) dense molecular clouds in nebulae, though the being could be a complex magnetic field or energy pattern within a stellar atmosphere. Even more exotic environments are possible: Creatures could be natives of hyperspace.

Space monsters may have a complex reproductive cycle in which some stages live on small bodies, planets, or stars while others migrate through space.

Cryptobiology of Space: Myths and legends of a particular space monster may convince a patron to fund a bio-survey expedition into a distant deep-space location to prove its existence. There may not be a real monster but the expedition itself still faces plenty of other challenges, especially if the creature's rumored haunts are politically sensitive areas (located between warring powers), infested by pirates, etc.

Here Be Dragons: Aggressive space monsters happen to infest a particular region of space – or perhaps live in hyperspace or near wormholes – and don't like spaceships! (Maybe they think they're rival beasts intruding on their territory, or they try to mate with them with catastrophic results.) Such periodic attacks might be a rare menace, or they could be a common "wandering encounter" that justifies arming civilian spaceships.

Moby Dick: Space monsters may produce exotic and valuable substances in their bodies. Maybe they're living superfusion reactors with magnetic monopoles, or they have organs that are the key to faster-than-light travel, or their bodies contain advanced organic superconductors. Hunting them is lucrative, but also potentially dangerous – the creatures themselves are a threat, rival hunters (or game wardens) are present, or other great entities also prey upon them.

Wild Horses: If you capture a space monster, maybe you can tame it and harness it to propel a spacecraft, ride on or in it, or enter symbiosis with it.

The Creature That Ate Space Station Alpha: A space monster (or swarm of monsters) attacks a station or colony! The colonists have inadvertently upset the monster – perhaps they mined an asteroid or comet that was really one of its eggs or nests, or a megaproject (building a Dyson sphere) encroached on its territory. Maybe they just had the bad luck to settle a system in the path of a million-year migration cycle for a swarm of battleship-sized fusion-powered space locusts! Solving the problem involves a combination of exobiology (to find out more about the aliens' strengths and weaknesses) and space warfare (to stop them).

If space monsters don't exist naturally, it may be possible to build them. ***GURPS Bio-Tech*** (p. 98) contains character creation guidelines and examples of living bio-spaceships. These rules can be easily adapted to create natural space monsters.

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. . . journey to all the undiscovered countries, boldly going where no man . . . where no one . . . has gone before.

– Captain James Kirk, ***Star Trek VI: The Undiscovered Country***