

OBJECTS IN THE GAME

This section provides in-depth descriptions and rules for each of the possible objects in the game – rockets, facilities, colonies, and any add-ons and modifiers which may be available for them. This is much more detail than is provided on the tech library pages; if the point-form notes on a complex item don't make sense, refer to this section for their full text.

Some objects can be purchased with a *rating*. This rating describes certain specifics of the design. For example, since "one Generator" implies a given amount of power, a set of solar panels with this spec made for Photon Flux +1 (aka the orbit of Venus) is much lighter than one made for Flux -2 (out in the asteroid belt). A given Photovoltaic Generator is therefore specified with a rating equal to the Flux it was designed for. Researching an item once gets you access to all its possible ratings.

If the stats on an item are flagged with an asterisk, see the full text for details.

ROCKETS

Chemical Rocket - ISP 0.5, Thrust 8

Macro 0.5, Nano 0, Research 0

The energy in chemicals is easy to extract, and easy to make powerful... but it takes a lot of chemicals to extract, what is, on this scale, not all that much actual energy. Not recommended for trips longer than to Luna (and even then, really expensive for large payloads), but invaluable as a lander for the last stage of a trip.

Solar Thermal Rocket – ISP 1, Thrust 1*

Macro 0, Nano 1, Research 2

A huge balloon, half silver and half transparent, concentrates the sun's rays on a reaction vessel. It adds the Photon Flux value of the zone it is in directly to its Thrust. If crossing Flux boundaries, the thrust may be different at each end - use whichever end gives the smaller thrust, to calculate the rocket's thrust for that leg. May not be stacked to increase its thrust. A solar therm with only zero-mass items in its payload counts as mass 0.25 for working out fuel costs.

Fission Reactor/Rocket - ISP 2, Thrust 7

Macro 2, Nano 1, Research 1; Cooling 8, Radiation Shielding; can satisfy (Generator)

A nuclear reactor works as a generator because it produces heat; the same heat can be used for propulsion. In game terms, the stats are equivalent whether it's configured as a generator or a rocket. You can even convert one into the other; this is instantaneous on the scale of the game. When used as a rocket, it is often Open Cycle Cooled (see Modifiers section) down to ISP 1 because of its high heat. When used as a generator this is not an option, so it may be a high-mass solution in many applications.

Arcjet Electric Rocket – ISP 2, Thrust 2

Macro 1, Nano 1, Research 1; Generator requirement

The simplest kind of electric rocket. An excellent starter engine if you have beamed power available (because of the receiver's low mass), but often trumped by more exciting designs by mid-game.

Mass Driver – ISP 3, Thrust 3

Macro 5, Nano 1, Research 4; Cooling 8, Generator

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OBJECTS IN THE GAME - ROCKETS

A linear accelerator (it could be a coil gun, rail gun, or one of a few other configurations) makes a highly versatile drive. Its characteristics as a rocket aren't the best, but its nature allows it to use anything – spare parts, expended consumables, garbage, rocks – as reaction mass (see the Gather site action). If set up attached to a facility, it can be used to fire off shipping packets; see the Extraction Mine facility for more details on shipping. And, to top it all off, it's a weapon system in its own right. Just in case. Note – ISP 3 rounds to ISP 2 if halved (such as by Open Cycle cooling).

Metastable Hydrogen Rocket – ISP 4, Thrust 5

Macro 2, Nano 7, Research 10; Disaster Target

The theoretical limits of chemical energy storage are much higher than we manage with our conventional chemical propulsion. This is one proposed alternative which takes chemical fuels to a new level. Its characteristics as a rocket compare favorably to other alternatives – especially with the lack of requirements. Unfortunately, it's highly unstable. There are disasters in the deck which specifically target this type of drive, and it has the Disaster Target keyword which can itself be a problem.

Laser Thermal Rocket – ISP 4, Thrust 5*

Macro 1, Nano 4, Research 7; Beamed Power, Cooling 2

By leaving the power source far away, this "teakettle" rocket manages to pack a solid ISP into a lightweight package. Lasers focused on the reaction chamber of this rocket and concentrated by a laser mirror bring the propellant to plasma-high heat. Unfortunately, this means that you'll never be able to go more than three orbitals away from a laser source (Earth, a Powersat, or a Microwave Relay in stationary orbit). The key advantage of a laser thermal rocket is that you can increase the thrust by adding more beamed power channels... every doubling of the number of channels provided adds +1 to the rocket's base thrust (thus with two channels its base thrust is six, with four the thrust is seven, and so forth). Note that this means there's never any point in doubling the rocket itself, since that would double the energy requirements too, but cost more.

Orion Pulse Rocket – ISP 4, Thrust 9

Macro 10, Nano 0, Research 3

A big steel plate, some massive coil springs, and a 1kT nuke every few seconds out the back. What could possibly go wrong? This is, actually, a remarkably effective design, it's just quite massive. Players with Earth Boost or offworld Macro resources might want to look into this one as their first rocket. The design means that it has very high heat, but it cannot be cooled using anything other than Open Cycle cooling – so those modifiers are already included in the base stats. As a bonus, the drive itself is not only a weapon, it also provides protection from many weapons in case of piracy. It also counts as radiation shielding for any crew present, thanks to the massive shock plate.

JxB Accelerator Rocket – ISP 8, Thrust 1

Macro 2, Nano 3, Research 8; Generator, Cooling 4

Magnetically accelerating the output of an electric rocket gives a boost to the reaction mass exit velocity, increasing the ISP. JxB (pronounced "Jay cross bee") is the basic equation governing this behaviour. A good step up from the ArcJet Electric, but lower thrust.

D-T Fusion Reactor/Rocket – ISP 8, Thrust 5

Macro 1, Nano 8, Research 24; Cooling 8, Radiation Shielding

Inertial or magnetic confinement of deuterium-tritium fusion yields a high-energy source suitable for use as an exceptional drive. A high research cost provides an initial obstacle, but after that you'll

seldom be sorry – this drive puts out both good efficiency and high thrust in a compact package. Like the Fission Rocket, any Fusion rocket can be converted to a generator.

Ion Drive Rocket – ISP 16, Thrust 1

Macro 4, Nano 1, Research 2; Generator, Cooling 4

Accelerating ions to very high velocities yields a very high specific impulse, with very low thrust. Well suited to moving unmanned cargoes a long way at high efficiency and low speed. Used today on a number of missions, the minimal research cost is actually just the time it takes to design one *this big...* hundred-kilo versions with micronewton thrusts are common today.

Magnetoplasma (or MPD) Rocket – ISP 32, Thrust 3

Macro 5, Nano 6, Research 19; 2x Generator, Cooling 10

The heavy lifter of the electric rocket world, MPD rockets such as the VASIMR project have a higher thrust-to-weight ratio than other electric drives, and exceptional efficiency... but also a high power usage, heat output, and complexity.

H-B Fusion Rocket – ISP 128, Thrust 6

Macro 3, Nano 16, Research 29; Cooling 10, Radiation Shielding

An even higher-energy fusion reaction than deuterium-tritium, the H-B fusion rocket requires exotic and unproven theoretical steps (like magnetic monopoles) to get working... but if you do, it will make for a truly exceptional drive.

³He-D Fusion Rocket – ISP 256, Thrust 7

Macro 6, Nano 20, Research 36; Cooling 24, Radiation Shielding

The highest-energy fusion drive in High Trader. If you've got one of these, you'll be flitting about at brachistochrone rates anywhere you want to go.

Annihilation Drive – ISP 512, Thrust 9

Macro 16, Nano 27, Research 54; Cooling 16, Radiation Shielding, Disaster Target

Matter-antimatter reactions are awesome stuff. Building them into a drive is dangerous, tricky work... but the resulting rocket is literally the best one you can get in the game. Players have spent their entire games working toward one... and not been sorry. Like the Mass Driver, the Annihilation Drive can quite simply use anything it wants for reaction mass (see the Gather site action), although in this case it does suffer a penalty of half its ISP when using dirt and rocks, rather than conventional hydrogen propellant. It's also a very effective weapon. Just don't screw up; if it goes, it goes big.

Photon Sail – ISP infinite, Thrust -1*

Macro 1, Nano 5, Research 10

Some designs of solar sail are built to use the solar wind (helium nuclei), others focus on using pure light pressure. Both alternatives are equivalent in game terms. When using a sail, you simply ignore propellant costs. Dots on the trip count as additional orbitals of distance instead. Your major limitation is the minimum acceleration of the transfer orbit you wish to use, but this limit is a big one. The base thrust of -1 (minus one) is added to the Photon Flux value of the zone it's in to yield the actual base thrust (don't forget that your fully-loaded mass will also enter into the thrust calculation). This will confine most sail operations to staying as close to the sun as Earth, or at most perhaps out to Mars orbit; past this, and the thrust-mass ratio will make it simply impossible. If crossing Flux boundaries, use the poorest Flux to calculate the rocket's thrust for that leg.

Laser Sail – ISP infinite, Thrust -2*

Macro 1, Nano 7, Research 15; Beamed Power (one or more channels)

Another sail approach is to build one engineered to fly using the light pressure of a focused laser beam. This gets around the limitations of worrying about where you are compared to the sun, but leaves you dependent on your launching lasers instead. The base thrust of -2 is achieved when the sail is driven by a single channel of beamed power (the usual range of three orbitals applies). You can increase this thrust by increasing the number of channels: two channels increases the laser sail's thrust by one (to -1), four channels increases it again (to 0), and another +1 Thrust per doubling of the number of channels. As with photon sails, you pay no fuel, but count dots as added orbitals instead.

COOLING SYSTEMS

Standard Radiator (for Cooling X)

Macro X, Nano 0, Research 0

BeO dust systems enable reradiation of heat into the depths of space at a reasonable efficiency. The rating, X, is based on how much cooling the object needs – the object's requirement is listed as Cooling X. Basic radiators of various ratings may add their ratings together to cool an object.

Advanced Radiator (for Cooling X)

Macro X/2 (round down), Nano X/2 (round up), Research 15

Liquid metal droplet radiators and other more sophisticated systems enable a better mass-to-dissipation ratio, at the cost of added complexity. A must if trying to get the best possible ISPs from many rockets. Advanced radiators cannot be added together with each other (it screws up the rounding), although they may be combined with basic radiators if desired.

Open Cycle Cooling

Macro 0, Nano 0, Research 0; ISP x1/2, Thrust +1, rockets only

A common, and very effective, solution to heat on a working rocket is to design it to dump the heat out the back with the rocket's exhaust. For many systems, like fission rockets, this would in fact be the default. This costs nothing, apart from designing for it, and satisfies the full Cooling requirement of the rocket, and even increases the effective thrust... but it does reduce the rocket's efficiency considerably. (Round fractional ISPs up, in the one case where this is relevant.)

Note that this can't be used to dump the heat of anything but the rocket it's built into... onboard systems like weapons or life support have to find their own cooling, as do stationary facilities. Rockets with no Cooling requirement cannot be fitted with Open Cycle Cooling in an effort to improve their Thrust; it has to have at least Cooling 1 to qualify. Also note that unlike all other add-ons, Open Cycle is intrinsic to the rocket's design, and thus cannot be retrofitted either out or in.

Dirtside Cooling

Macro 0, Nano 0, Research 0; grounded facilities only

Compared to dumping heat in the vacuum of space, sitting on any body – no matter how small the asteroid – makes it a piece of cake to dump heat. Cooling requirements are automatically satisfied for any grounded operation. Note, though, that this doesn't cover operations in transit – and colonies usually put out significant heat even enroute, for things like, oh, not freezing to death, and breathing, and stuff like that. Dirtside Cooling also counts as Radiation Shielding, for free.

GENERATORS

Photovoltaic Generator (up to Flux X)

Macro (by chart), Nano 1, Research 0

Simple photoelectricity is effective and simple, but can get pretty heavy. The mass of a generator using photovoltaics is based on the lowest Photon Flux zone it can operate in. Even one Flux Zone outside of its rated area, and it's only half a Generator... much less useful. Because of overvoltage protections, it does *not* become a "double Generator" in higher-Flux zones than its rating, but it doesn't lose output, either. Probably not cost-effective outside of roughly Martian orbit.

Flux Rating	+2	+1	0	-1	-2	-3	-4	-5
PV mass	0.5	1	2	4	8	16	32	64

Advanced Photovoltaic Generator (up to Flux X)

Macro (by chart), Nano 3, Research 15

Biomaterials, advanced nanostructures, and other novel approaches all offer the promise of lower mass photoelectricity. Advanced Photovoltaics follow all of the same rules as Basic Photovoltaics, except for the different cost characteristics.

Flux Rating	+2	+1	0	-1	-2	-3	-4	-5
AdvPV mass	0	0.5	1	2	4	8	16	32

Microwave Receiver

Macro 0.5, Nano 1, Research 1; Beamed Power requirement

Often the lightest generator is the one where you don't carry the generator with you – you just send the power via zero-mass photons! Also known as Myrabo power after one of its strongest proponents, Anton Myrabo. Needs one channel of beamed power, and satisfies one Generator requirement.

Palmer Aerosol Lens

Macro 0, Nano 1, Research 12; Beamed Power requirement

If even the mass of a Microwave Receiver is affecting your payloads, one solution is an advanced design which uses an aerosolized liquid lens design, making it so lightweight that in game terms it weighs nothing at all. Still turns one channel of beamed power into one Generator of onboard power, but obviously you can pack as many of them as you can afford to build.

Fission or Fusion Reactor

Any fission or fusion rocket can be converted to a nuclear power generator. Designing them with that capability is free on gamescale. The most common is obviously the Fission Reactor, but there are situations where the D-T Fusion Reactor may be worth its price.

Magnetohydrodynamic Generator

Macro 0, Nano 2, Research 5; onboard rockets with Thrust 4+ only

This is the science of extracting usable energy from the exhaust of a rocket. In game terms, an MHD Generator allows any qualifying rocket – it must have Thrust 4 or higher before adjusting for mass – to also function as one Generator for some onboard system while in flight. It can't supply it to the rocket itself – you can't get power from nowhere! But it could be a weapon, or a colony, or whatever else may need power. You can mount more than one per rocket, but the minimum Thrust increases by one per extra MHD.

TOYS, TOOLS, AND THREATS

Robotic Guidance

(not an item, has no cost)

This "item" is included here for completeness. It's not actually an object as far as the game is concerned. It's a default. If you do not have a Hab, Colony, Cyborg Guidance, or AI Guidance object present at this location (whether it started that way or not), then anything that happens here occurs under Robotic Guidance instead. You may not play defensive cards on behalf of something which is under only robotic guidance. Bot teams (see below) perform less efficiently under robotic guidance. And you risk being slowed down even further by the Software Glitch disaster card. But... on the plus side, it's free, doesn't eat or breathe, and never asks for a pay raise.

Bot Team

Macro 0.5, Nano 1, Research 2 (or 0, see below)

When pursuing a program of unmanned spaceflight, you still occasionally need hands and eyes on location. Or grippers and CCDs, as the case may be, not to mention spectrophotometers, leak detectors, and laser drills. In order to do a surface exploration, or turn a facility from an inert payload into a functioning structure, you need either crew or a Bot Team. Unless you've put a Bot Team under the control of Cyborg Guidance or A.I. Guidance, it suffers from the usual disadvantages of robotic guidance, plus a less efficient performance of the job... the Bot Team uses the full object mass or full surface gee to calculate onsite times, not half the mass/gee (the value used by crew). However, since it's not sucking up consumables the whole time, many mission planners feel it's well worth the wait. You can omit researching the tech if all you want is a *Limited* Bot Team, able to perform only a single crew action specified upon construction – "Explore Lunar North Pole" or "Assemble Extraction Mine on Khufu". After two points of research you can instead build regular Bot Teams, able to perform any crew action you desire.

Microwave Relay

Macro 0.5, Nano 1, Research 2

A microwave relay is made up of an antenna which receives beamed power, and a laser array which sends it out again refocused. If it is supplied with beamed power, up to two channels per Relay, then it can send those channels anywhere within the usual three spaces of itself. In this way you can build up a network of beamed power which has more reach than just the range of the original satellite. Typically dropped off by itself without even a rocket attached, to orbit the sun and do its job. Remember that it will need to be deposited in a stable orbit (facing a corner), you can't just drop it off while flying by.

Radiation Shielding

Macro 0.5/1/2/4, Nano 0, Research 0

A massive "Storm Shelter" protects crew from harmful radiation from various sources, including drives and generators which produce harmful radiation, Van Allen belts and other radiation zones in space (see the Route Plan section), and the Solar Flare disaster card. The mass of the shielding is 0.5 for a hab, 1 for a small colony, 2 for a medium colony, and 4 for a large one. This reduces your chance of getting hit by a Solar Flare disaster or Solar Storm event, and is required if your drive emits dangerous radiation and you want to put people onboard.

Extended Life Support

Macro 0.5/1/2/4, Nano 0, Research 0

A consumables package for use by habs and colonies, this allows them to last beyond the six months which is standard with those items (see Manned Exploration). For a hab this masses 0.5 and adds three months to the life support clock; for colonies it adds one month, and masses 1 for a small colony, 2 for a medium colony, and 4 for a large one. Not replenishable (unlike the six-month base).

Cryogenic Hibernation

Macro 0, Nano 10, Research 15

Modifies any Hab or Colony. Target's Macro cost is reduced by 25% and its Cooling requirement by 50%, it does not consume life support, does not provide guidance, and gains the Disaster Target trait. There are disaster cards which affect only frozen colonies. Defrosting the crew takes three months, during which time it *does* consume life support. Does not collect Achievements until fully defrosted.

Closed Cycle Infrastructure

Macro 1, Nano 4, Research 7; Cooling 2, Generator

Genetically engineered vegetation and nanofiltration systems extend life support on a Hab module (not a Colony!) to indefinite; you can stop counting months. Be careful – disasters can still put you back on the clock.

Cyborg Guidance

Macro 0.5, Nano 1, Research 13

If robot guidance is leaving you too exposed, but the mass and time limits of manned spaceflight are still prohibitive, one solution is the good old Brain In A Jar method. Whether it's a neuron net grown in-situ, or an actual once-human "volunteer", is up to you. Plentiful sensors, radiation shielding, robot waldos and Facebook page included. Ships with cyborg guidance no longer suffer the defects of robotic guidance... mostly. If they attempt to play a defensive card, roll a die; on 3-6 it works, but on 1-2 set the card aside and either try a different one or take the hit. Return the card to the owner's hand.

A.I. Guidance

Macro 0, Nano 1, Research 32; special build cost: Research 1

Another solution to dealing with the limitations of so-called "expert systems" and robotics is to invent Artificial Intelligence. It's a big project, but the payoff is fully functional guidance without any of the limitations of robots, mess and variability of cyborgs, or biological needs of people. Note that the build cost of one A.I. Guidance system are unusual – one Nano and one Research, separate from the initial Research cost to develop the technology. Copying A.I. over and over is cheap; making it *just* individual enough not to go insane takes a little effort. Note that this requires custom hardware, different than for simple robotic guidance, and thus must still be physically shipped.

Long-Range Crawler

Macro 0.5, Nano 0, Research 3

Maybe you want the ability to pick and choose your sites before settling down on a large body, maybe you want to stage a raid cross-country... if you need to move mass overland, this is the tool you use to do it. The long-range crawler consumes effectively no fuel, and takes as long as an exploration (half the surface gravity in months, the full grav if robotically guided), to move itself plus up to two mass from one site to another on a single body. If this sounds long, imagine trying to get from Rio de Janeiro to Vancouver, without roads or a reliable map, carrying fifty tons. Multiple crawlers may be aggregated to transport larger items.

Weapons System

Macro 0.5, Nano 1, Research 5

These costs are the generic costs of various possible ways to hurt each other in the depths of space. Each time you research this, you gain one of the following subtypes; further types cost another 2 research each. See page 51 for piracy and combat; this will go into the further details of the (fairly minor) differences between the types of weapon.

- ❖ *Nuclear Warhead* – No further requirements. Destroys own ship.
- ❖ *Weapons Laser* – Requires Cooling 1.
- ❖ *Laser Mirror* – Requires Beamed Power. Otherwise same effects as a weapons laser.
- ❖ *Particle Beam* – Requires Generator.
- ❖ *EM Cannon* (railgun, coilgun, etc) – Requires (and expends) 0.5 macro of ammunition per combat. Regolith will suffice; see Mass Driver rocket and piracy section.
- ❖ *Boarding Gear* (armored spacesuits, personal weapons, drones, etc) – No further requirements.

FACILITIES

Solar Power Satellite (Flux X)

Macro (by chart), Nano 2, Research 4; Cooling (by chart)

A solar powersat provides beamed power channels. It can also be used to represent a ground-based solar array, but the output is halved (round down) for being subject to night/day cycles, and halved again if the body has an atmosphere. On the plus side, it can use Dirtside Cooling if grounded, which may yield a net win. Normally

these are placed in the player's choice of stationary orbits. They have a transmit range of three orbitals. Do not require assembly

Flux Rating	+2	+1	0	-1	-2	-3	-4	-5
Solarsat Mass	5	5	4	3	2	1.5	1	1
Channels	8	4	2	1	½	¼	1/8	1/16
Cooling Req.	12	6	3	2	1	0	0	0

time, but all solarsats belonging to one player at one site are considered only a single facility for scoring. A solarsat built for one flux may be used at a different flux; the channels and cooling requirements are based on whichever is worse, the flux it's in or the one the sat was built for.

Science Station (Cool Factor X)

Macro 6, Nano 10, Research 6; Generator required

By setting up a permanent facility to study the characteristics of an interesting site, all kinds of research from pure physics to practical engineering is possible. A science station's effectiveness scales with the unusual qualities of a site in the same way that human interest does (Cool Factor). A science station's resource equation at Cool Factor 0 is **[money: 1][time: 2] > [research: 1]**; for every Cool Factor point above this, either the money cost is halved, or the time cost is halved, player's choice when designing the station. Changing the equation (so as to move it somewhere else or change your time/money priorities) can be done but requires a two-nano package of supplies. This equation assumes human, cyborg, or A.I. guidance; robotic guidance doubles the time cost.

Extraction Mine

Macro 6, Nano 1, Research 3; Generator and shipping arrangements required

An extraction mine is very simple – an operation to dig the most valuable items out of the ground and refine them as much as is feasible before shipping them home. This works for metal finds (Macro), carbon finds (Nano), water finds (Propellant), and rare isotope finds (sold to Earth for money); the procedure is the same in each case. This facility gives you the goods onsite, in large enough quantities and cheaply enough that the rate limit is usually based on your shipping capabilities.

Propellant is often useful just left onsite, needing no further processing for use. A Propellant find with an Extraction Mine is a propellant resource with equation **[as chit] > [propellant: 1]**, where the costs

are given by the mine's exploration chit. Everything else will need to be shipped to Earth or to a facility which can use a resource equation directly (a Factory/Nanofab).

Shipping the Output of a Mine

Shipping by rocket is very complicated to do accurately, but for our purposes we use an abstraction. In brief, you "remove" a rocket from play, work out the money and time costs of the route based on the rocket's characteristics over the trip taken, and use those costs as a resource equation at the other end. The detailed procedure:

- ❖ Pick a rocket (or a set of rockets, or crawlers, or stationary mass drivers flinging cargo) to dedicate to the route. They must be *able* to reach the destination with the propellant onboard (or be sitting at a propellant supply), that's all we ask. The trip itself is behind the abstraction wall and does **not** consume propellant outside of the abstraction. The rockets thus dedicated are locked into the route as of the moment your mission tells them to "Begin Shipping" as a site action. They are not still available for anything else; they have become part of the resource equation. A cargo packet fired out of a land-based mass driver is treated exactly like a "rocket" with ISP 3, Thrust 6, and dry mass one.
- ❖ Plot a sample trip from the mine to the destination using this ship, empty. (Ignore the trip back to the mine again, for this.) A Hohmann transfer is always your best choice for the purposes of this abstraction, unless your thrust dictates a Spiral transfer; if a Spiral is used, double the time cost you calculate later. Don't forget takeoffs and landings (including a lander is okay).
- ❖ To get the money cost of the route, work out the **mass ratio for the trip**. The mass ratio is that blue line on the nomogram, remember. If a takeoff or landing is involved, use the worst mass ratio – the landing, the takeoff, or the trip in between. For crawlers, sails, or ISPs off the top of the chart, use zero. If what you're shipping is nano or rare isotopes, subtract [money: 0.5]. If you have an offworld propellant resource at either end, halve the result. The money cost of the shipping route's equation is the result, or the site's money cost, whichever is higher.
- ❖ To get the time cost, count the **distance** of the trip. Also find the *hauling thrust* – that's the **net thrust of your rocket**, again assuming it's empty of cargo, minus the **required thrust for your trip**. If takeoffs or landings are needed, use the worst hauling thrust of any leg. Overland distance equals the surface gee, and crawlers have a hauling thrust of 0.5 each. Sails' added dots-as-orbitals do count toward the distance here. Divide the distance by the hauling thrust. Divide by the number of identical ships (or mass drivers or crawlers) you assign to the route. The time cost is the result, or the site's time cost, whichever is higher.
- ❖ Round money and time costs under 1 to the nearest 0.25, under 3 to the nearest 0.5, otherwise to the nearest integer. Write down the resulting resource equation on your faction sheet and on this mission. You can access the equation at either end of the shipping route. If the shipping "chokes" the money or time costs of the site, you may even be able to use the equation with different efficiencies at either end; it still maintains one common queue of jobs to be done.

Von Neumann Colony

Macro 0.5, Nano 6, Research 25; Generator and shipping required

Self-replicating micro- or nano-bots are programmed to spread through the mineral deposits of a site, store the most valuable parts, use the rest to build new copies of themselves, and return to base once full. The Macro cost is mostly the base station; the actual Von Neumanns are miniscule by game standards. Performs all the functions of an Extraction Mine, this just has better stats.

Offworld Factory

Macro 12, Nano 1, Research 5; Cooling 8 and Generator required

Mineral resources are richer in some places than others, but macroconstruction is possible anywhere. An offworld factory includes a mine, refinery, and automated shop floor, for construction of various structures. On a high-quality metal find will this be really valuable – it counts as a Macro resource with **[as chit] > [macro: 1]**. Even at a site with no Macro discovery, the factory can still build at **[money: 1.5][time: 2.5] > [macro: 1]** at most sites (which could have drawn macro if you'd been lucky), or **[money: 2][time: 3] > [macro: 1]** at an icy site (where there was no chance). If it is at the end of a Macro shipping route it can use the route's equation if you prefer. Objects built are at this location, not in LEO, and may need to be brought back to LEO or to have their Nano components brought to them. If you have a functioning Extraction Mine (or shipping route) feeding Macro to the Factory, you can save 4 macro from the Factory's cost.

Factory add-on: Nanostructure Tanks (Nano X)

Macro X, Nano X, Research 10

For those who want to put all their construction in one place, the Nanostructure Tanks offer a way to include some Nano in their Macro assembly capabilities. This does not require a Carbon find; the rating includes a stock of irreplaceable parts, and the rest uses materials available onsite and byproducts of the Factory's operations. The Nanostructure Tanks give an Offworld Factory the additional equation **[money: 2][time: 2] > [nano: 1]**, with the primary advantage over defaults being that it is built onsite. However, it can only be used for objects whose individual Nano cost is no higher than the rating of the tanks.

Offworld Nanofab

Macro 8, Nano 8, Research 7; Cooling 7 and Generator required

Carbon is a highly versatile material, and a prized find. Microgravity and vacuum are very useful for many of its uses, like crystallization, carbon nanotube growth, and nanoassembly. The equation on a Nano discovery is **[as chit] > [nano: 1]**. At most sites (where you could have drawn nano if you were lucky), you can still build at **[money: 1][time: 3] > [nano: 1]**, and even on a metallic or stony site (where you had no chance) at **[money: 1.5][time: 4] > [nano: 1]**. Or, if it is at the end of a Nano shipping route, you can use the route's equation. As with the Factory, objects built are located onsite and may need transport. If you have a functioning Extraction Mine (or shipping route) feeding Nano to the Nanofab, you can save 3 macro from the Nanofab's cost.

Nanofab add-on: Carbon Fiber Macrofab (Macro X)

Macro 2X, Nano 4, Research 8

Carbon isn't the ideal structural material for everything... but sometimes it's awfully close. Make use of your Nano find for big things too, by including a Carbon Fiber Macrofab with your Nanofab. Grants the Nanofab the additional equation **[money: 2][time: 1.5] > [macro: 1]**. Can only build objects whose Macro is no higher than the rating of the Macrofab.

Outpost Infrastructure

Macro 6, Nano 5, Research 6; requires Offworld Factory (or Macrofab)

A collection of blueprints, facilities, supplies, and tools sufficient to provide life support to a Small Colony indefinitely. An Offworld Factory or Macrofab must be present and operational before the Outpost assembly can begin; the required facility's equation isn't reduced and is still usable as normal.

Settlement Infrastructure

Macro 7, Nano 5, Research 7; requires Outpost Infrastructure and a Propellant (water!) income

The equipment necessary to expand the colony, dig in away from solar radiation, troubleshoot larger problems both technical and social. Extends a Medium Colony's life support to indefinite. You need a functional Outpost Infrastructure facility (though it can be empty), and you need a propellant resource available with a time cost of less than **[time: 4]** per point; this doesn't actually consume the output of these requirements, they just have to be present. A propellant find onsite plus an Extraction Mine will do it, or you may need to set up shipping from a propellant Extraction Mine somewhere else.

Dome City Infrastructure

Macro 6, Nano 7, Research 12; requires Settlement Infrastructure and an Offworld Nanofab (or Nanostructure Tanks)

Though it's called a Dome City, there are many other strategies – tenting a crater, hollowing out an asteroid, living in caves on Ganymede, or stranger plans. This object represents the mass and costs to expand the settlement to an actual (if small) city, regardless of how you decide to do it. As ever, this does not actually consume the output of the required facility.

MANNED SPACEFLIGHT

Note – these objects include both the actual structure and the crew onboard. In most cases the two are synonymous. Occasionally, however, events may reduce the size of the crew units inside – from medium to small, from small to hab, or from hab to all dead. This does not affect the mass of the item.

The basic life support allowance of a Hab or any Colony is six months. See the Extended Life Support item or Cryogenics (both in the Toys and Tools section) if this is insufficient for your needs, and/or look into the appropriate Infrastructure in the facilities section.

Damaged crew units or used up life-support months can be fully replenished (back to full size or six months) on any stop in LEO or at any colony larger than itself which has full Infrastructure. If the colony is built outside LEO, the crew units start out depleted to zero and must be replenished somewhere – you can't just build the *people* in your macrofab.

Hab Module

Macro 1, Nano 0, Research 0

A small crew of three or four people locked in a tin can for months on end. Sounds like fun! The hab is the smallest unit of crew. It's not a "colony" and can't fulfill colony missions, but it can do guidance, exploration, troubleshooting (defensive cards), onsite assembly, and a host of other useful functions.

Small Colony

Macro 8, Nano 3, Research 5; Cooling 8, Generator

A small community of about fifteen to twenty people is the smallest useful community for long-term homesteading on another world. Only elites will make the cut. Some disasters refer to a colony's "size" – a Small Colony is size one. Almost always supported by an Outpost Infrastructure facility.

Medium Colony

Macro 12, Nano 3, Research 6; Cooling 12, Generator

A larger community of up to fifty people makes a colony capable of more than simple subsistence. Art and culture distinct from the home planet can develop. Still limited to the best and brightest applicants available. You can also create a Medium Colony by merging two functional Small Colonies. This is considered size two. Supported by the Settlement Infrastructure facility.

Large Colony

Macro 16, Nano 4, Research 7; Cooling 18, Generator x2

With over a hundred people, a Large Colony has a legal structure and a governing philosophy, unique art and a cultural identity, and complex group dynamics. Humanity is finally beginning to learn what it is really like to live, as social animals, off the world of our birth. Size is three. You can also create a Large Colony by merging two Medium Colonies. Supported by Dome City Infrastructure.

Colonial Metropolis (size Y)

Build requirements: special

A Colonial Metropolis is the term for multiple Large Colonies merged together to get an even larger colony. Each one is built separately, and supplied separately with Infrastructure, but together they constitute a Metropolis of size Y. The smallest possible Metropolis, made of two Large Colonies, counts as size four; three counts as size five, and so forth. If you use Dome Cities to support a Metropolis, one Nanofab/Tanks suffices for all of their requirements – you don't need one for each.