Mechanics 101

Foreward

Legal information: This fan-based companion to the Serenity Role Playing Game is non-profit, and is designed to supplement the said game by including expansive information. Serenity, Firefly, and so on are registered trademarks that are switching company hands rather rapidly. This information is based on the Firefly series.

On with the show: Well, if you're reading this, then you are a great deal like me and quite unsatisfied with “technobabble” that the Serenity RPG suggests that players use to determine the effects of a ship. This was originally designed for just myself, then myself and my GM, but I've decided to write it like this just in case it is publicized on some forum. You have my permission (if you need it) to distribute this online or whatever. Have fun, good rolls to you.

At any rate, this document (written January 14, 2006) details the core mechanics of a boat in the 'Verse, and explains the general underlying theory behind that, as well as some issues with the boats that might not occur at first glance. This is not official. It merely offers an alternative method to “technobabble” of looking at the ship mechanics. Most of the scientific principles here are correct (the outstanding exception is the Gravity Drive). But it's as close as I can get.

-Joshua Pawlicki
Ship Mechanic of the Swan

Reference Tables

Mach # = (speed of object/speed of sound) = 761 mph (1225 km/h) (at sea level, standard pressure)
At higher altitudes, there being less air, sound travels slower, so Mach # increases as speed stays constant.
Mach <1 is subsonic, .8-1.2 is transonic, 1-5 is supersonic, Mach >=5 is hypersonic (at which point the air around the ship gets compressed enough to really start screwing with you).
Speed of Sound = Mach 1 = 1225 km/h = 761 mph.

Assumptions:
Gravity Drives can control gravitational fields through electromagnetism:
1. **Screening -** Reduces gravitational attraction between two objects.
2. **Artificial Gravity -** Creates a point that has the gravitational attraction of a planet, but only within a screening field, or on a planet-wide basis (terraforming)
3. **Inertial Control -** Setting screening and artificial gravity against each other can reduce the inertia of an object (only in one direction). Also known as Inertia Reduction. Check out the source book for more information on this.

FUNCTION	*DEVICE*	*FUEL/INPUT*	*EXHAUST*	*BRIEF DESCRIPTION*
Gravity	Gravity Drive	Electricity	Electromagnetic Radiation	See *Assumptions.*
Power	Fusion Reactor	H_2O Packs	He_2, O_2, Heat, Electricity	A hydrogen fusion power generator.
Heat	Heat Sinks	Heat	None	Heat storage.
Propulsion	Thrusters (Pods):	(See Below)	(See Below)	A reconfigurable multi-mode jet engine.
	Turbine	Electricity, H_2	Heat, Fumes	Spins a turbine to intake air, then ramjets it.
	Ramjet	H_2	Heat	Compresses air and heats it, expanding it.
	Scramjet	H_2	Heat	A supersonic version of the ramjet.
	Rocket	He_2 / H_2*	Heat, Fumes	Output of superheated gases provides thrust.
	Pulse Engine	Heat, Electricity, Gas*	Superheated radioactive gas	A really big rocket with gravitational aid.
Hull	Hull	None	None	Vacuum and radiation shielding.
Atmosphere	Algae Tanks	CO_2, Heat, Light	O_2	Photosynthetic creation of oxygen.
Water	Tanked Water	None	None	Basically you just bring it along.
Food	Stored Food	None	None	Basically you just bring it along.
Waste	W. M. S.	Waste, Electricity	Dehydrated waste, H_2O	Centrifuged, purified, then compacted.
Navigation	Computers	Electricity	None	Pre-placed beacons assist your computer.
Sensors	Sensors	Electricity	None	RADAR-like, but not just radio waves.
	Scanners	Electricity	None	More advanced and specific than sensors.
Communications	Com. Transmission	Electricity	None	As scanners do, it sends out a EM signal.

(A slash indicates "or", a comma indicates "and".)
(* - In theory the pulse engine and rocket mode of the pods can use just about anything gaseous that'll expand when heated. It is most efficient to use the superheated helium exhaust from the fusion reactor, however, since this serves no other purpose on the boat.)

REQUIRED SUPPLIES
Refueling Needed:
- H_2O Packs — Bought at resupply depots. Dideuterium Oxide (^2H_2O) and Ditritium Oxide (^3H_2O) for the fusion reactor. See *How it Works: Fusion Reactor*.
- H_2O Tanks — Standard cheaper water containing various isotopes of hydrogen for drinking and washing.

Self-Produced:
- Carbon Dioxide (CO2) — Produced by human breath.
- Electricity — Produced by the Fusion Drive. All you could want.
- Heat — By-product of the Fusion Drive. See *Exhausts: Heat*, also.
- Light — Commonly produced by electricity.

EXHAUSTS
- Human Waste — Poop and the like.
- Contaminated Water — From laundry, showering, washing dishes, etc.
- Superheated H2 Gas — From the Thrusters and/or Pulse Drive.
- Heat — It's hard to dump heat into space. There's no molecules to heat up. Heat is thus stored in heat sinks. Most ship designs allow you to use that heat to superheat water and eject it into space as an emergency overheating backup, thus ridding yourself of heat.

Introduction

Hey, so let's face it. Technobabble is for fools with no scientific interests and no desire to expand their understanding of what's really going on. This is a semi-scientific document detailing a basic layman's understanding of the processes going on in the ship.
This document was designed for the ship engineer and the GM so that they can know what the heck is going on, and hopefully wow their non-physicist friends into oblivion. Pilots should also read the *How It Works: Atmospheric Flight* and *How it Works: Space Flight* sections.
I have no extreme education in the field of physics. So some of this could be a little wrong. Please correct it if you can. But this is what I've gained from hobbyisting it. If something in here confuses you, check out the topic at www.wikipedia.org. Happy flying.

How It Works

When thinking about flight, there are two major modes to consider: in atmosphere and out of it. Flying in atmosphere gives you friction, which produces heat, which can pretty much burn you up if you go to fast and aren't aerodynamic enough. The upshot, however, is that you can lose heat to your surroundings (well, that's usually an upshot anyways), and that you can use the air itself for propulsion.

Atmospheric Flight

The problem with fast in-atmosphere (atmo) flight is overcoming the resistance of the air against your hull. Anybody can fly a boat slow. Anyone can drive a car slow. But you never see anyone doing that. There are several solutions to generating efficient propulsion in atmo and beating the resistance of the air. Aerodynamicy will reduce the resistance of the air because you can channel it well so that it's bouncing off you less. The trick with the flight is staying up there. Modern aircraft use airfoils on the wing to keep them up (which, in small detail, uses air flowing over the wing to push up on the underside of the wing while also creating a lack of air that pulls up on the top of it). You may choose to include these in your boat or not. The further you get from the fuselage (the main body part of an airplane), typically the less distorted air you get, and the more stability. Thus, typically, a larger wingspan means more force directed properly on the airfoil, and better lift. Properly designed airfoils have minimal drag, slowing you down less than poorly designed airfoils. This is, however, limited by materials. The force exerted on the tips of the wings of a too-far-reaching boat will literally rip the wings right off, and then you're in trouble. Of course, the "screening" ability of the gravity drive makes this totally unnecessary.

So right now you're probably thinking that you didn't want to talk about a plane, instead a spaceship. Airfoils are a neat thing for a mechanic to know, but your boat probably has big huge engines, not wings. In the Firefly/Serenity universe, most boats have large engines that swivel and provide lift to gain effects similar to a VTOL. Well, the design of these engines is (with modern materials) rather difficult to make reliably, although given perfect strength materials it could be done easily. The primary engine, known as a thruster or a pod, is a four-part engine. The basic principle relies on bringing in air, compressing it, superheating it, then letting it out the back of the engine. Since hot materials expand, it leaves at a speed considerably greater than the speed at which it entered, producing a force which then, by Newton's Third Law of Motion, pushes the engine forwards. This concept is called a ramjet engine. Given an constant source and concentration of fuel, a ramjet engine will accelerate until the forces of the air rip it into shreds. The trick is to thus limit the fuel that heats the air. Ramjet engines are extremely efficient, but will only work if you're already traveling at a certain speed roughly equal to half the speed of sound (around 620 km/h or 380 miles per hour), and are inefficient unless going even faster.

The question, then, is how to get up to that speed, which is where the turbine comes in. In the engines of the 'Verse, a turbine exists in each engine, powered electrically from the electricity generated by the fusion reactor (we'll get to that later). Anyways, once you have this turbine (basically a big fan) rotating, you can "suck" in air at sufficient pressure to run a ramjet-like process on it and do the same thing. The problem is that you can only go so fast before the force of the air pushing on the turbine rips it apart. Also, this requires a lot more fuel and electricity, and thereby should be used as little as possible. Once you get up to a sufficient speed, the turbine blades fold back or retract depending on the design and cease to turn. In theory you could reverse engineer a turbine to rotate at high speeds as an electrical generator (I.E. a windmill/wind power), but they're not designed to do so, and fusion power systems really negate the need. Either way, this is when the engine becomes a ramjet engine. The speed varies depending on the design and power of the turbine, but is usually around 600 miles per hour or 1000 kilometers per hour.

Once you pass Mach 1 or so (depending on design), forces of compressed air start bouncing around inside the ramjet engine due to the compression (it compresses the air to subsonic speeds). This can generate unwanted stress just about everywhere and eventually lead to all kinds of bad. The engines reconfigure somewhere within the transonic range to become scramjet engines (the method of how they reconfigure themselves depends on design, although the end products are similar if not the same). Scramjet engines are merely ramjet engines with a slightly different shape so as to allow supersonic air to pass through efficiently. They can usually get you up to Mach 28 or so (modern scramjets are capable of Mach 20-24, and it can be assumed that those in the 'Verse are constructed with better materials), which is more than enough to break the gravitational pull of the planet (you can orbit a planet from a low space orbit at Mach 22 safely, although of course scramjets don't work in space).

The final configuration of the engines of Serenity/Firefly ships is a more optional use, at least in atmosphere. When in the rocket mode, the front of the engine closes, and superheated gases (likely helium exhaust from the fusion generator, although some designs use a fission reaction on the hydrogen fuel) are shot out the back. The upside of this is that it'll work in unusual conditions, such as a vacuum. The downside is of course that it burns tons and tons of fuel very quickly and, when compared to the ramjet-family, is extremely inefficient. But it is useful to know.

Space Flight

Ah, finally, the most inexplicable topic of them all. The big problem with space travel is not losing energy to friction. It is quite simply the dog-gone massive distances involved. For short range travel in space (between moons, orbit, etc), one would use the reaction

drives to save on energy (that will be expanded on in the next section). Reaction drives are simply your atmo thrusters in rocket mode. The problem is the amount of gas you're dumping into space while doing it.

The key thing about space flight in the 'Verse is that it is unneccessary to go faster than the speed of light: star systems are very close to each other. However, you still need to go pretty darn fast, and there's one way to due that: The pulse engine. Due to the gravity drives (in a process later explained as inertia reduction, see *Gravity Drive*), one can effectively create a localized field in which the speed of objects can be accelerated greatly. Detecting someone who is moving in another inertial reduction field is tricky, but can be done pretty well by computers, although it's not a perfect science. The key to it lies in tracking the fore and aft parts of electromagnetic radiation exiting the inertial field of the other ship. The pulse engine is basically a really big rocket that provides a huge burst of acceleration within this field. It is more efficient than the pod rockets because some of the excess heat is converted into energy to power the localized gravity drive fields (see *Gravity Drive*).

Gravity Drive

The gravity drive is the principle thing that makes the ship run. In addition to simulating the artificial gravity on the ship, it creates the pressure necessary to create the fusion reaction (see *Fusion Reactor*). This also sucks a huge amount of power, understandably. The gravity drive can be used to create the three assumptions (see *Reference Tables*), and is the key part of the ship. Without it, the fusion reactor will shut off, and that results in losing all power, air ventilation, and further systems. It is extremely difficult to repair, and almost impossible to cold start without a jump from another ship (most ships carry extra power cells that they can use to power it just in case: invest in these). The device works off the basic concept that quantum gravitation (gravity between atoms) is based on magnetic polarities. The hull of the ship is lined with electromagnets that, given sufficient power, can create an artificial gravitational field within and on the surface of the hull of the ship. The "gravity drive" in the sense that most people think of it is only a single major component of the entire drive (which is spread throughout the ship). This part is known as the gravity drive hub, and is typically seated nearby the fusion generator. It's primary purpose is to complete the complex mathematical calculations required to determine the pulses of energy that should be sent to each of the electromagnets throughout the ship. In theory, it can be engineered and modified to allow complete manual control of the gravitational fields in the ship, but most devices do not support this feature by default (for obvious security reasons). The largest electromagnet in the entire ship is attached to the pulse drive for the purposes of very fast travel, which uses inertia reduction to increase the local of objects. Look up Superstring Theory and Quantum Gravity for more.

To reduce the need for power and required size of the fusion reactor, the fusion reactor's electromagnet is the only one that is constantly on. The rest of the electromagnets (those set in the hull that make you walk, not float, for example) are only on about $1/4^{th}$ of the time (depending, as always, on design). The magnets turn on for a duration of 250 microseconds, then off for a duration of 750 microseconds. The pulse effect is similar enough to real gravity to fool any living being into thinking that it is constant, while only using $1/4^{th}$ of the required power. Newtech systems have managed to get this into even smaller ratios, and average about $1/8^{th}$ to $1/12^{th}$ on time. The current record of minimal power consumption in the 'Verse while maintaining 1G is $1/45^{th}$ in controlled lab conditions. In atmospheric flight, the ratio usually normalizes more, going to ½ the time or $2/3^{rds}$ on time to allow upside down flight and so forth when another gravitational factor is an issue.

As the gravity drive relies on electromagnetic waves, EM radiation becomes a huge issue. Most hulls have radiation shielding plated within them. Those that don't are short-range only and rarely have a pulse engine. Most of the radiation is in the exhausts of a ship, and enough of it is at a high enough frequency to completely strip an atom of electrons instantaneous. While flying in another ship's exhaust is a good way to remain hidden from heat sensing, it will slowly decay your hull, and eventually reduce your boat to a cloud of subatomic particles. How long a hull can hold out against this radiation depends on how much rad-shielding it has and design. A normal radiation suit or vac suit will not hold out long against this level of concentrated radiation, and shuttles, having much weaker hulls than boats, can't sit in there for long either. On the other hand, the radiation is a very good way to destroy the exhaust of a ship and not leave helium gas everywhere where you've been (which would be pretty easy to track with a decent computer).

Fusion Reactor

The fusion reactor is the power source for the ship. By using a compressed artificial gravity field, it creates the pressure of a star and fires superheated hydrogen isotopes (specifically deuterium and tritium), which combine to form a helium atom and a free neutron that contains enormous energy (more than enough energy required to combine two more atoms). Ultimately, it's a self contained power generation system that requires hydrogen fuel and exhausts helium. This energy is used to superheat a plasmatic substance that is used as a medium (or a vector fluid) to heat up water in another chamber. The water evaporates, and the steam pressure turns a turbine that generates electricity. Look up Nuclear Fusion for more. There are two ways to fuel this: H_2O packs, small backpack-sized tanks of specialized water, or the longer-term fuel cell (described in the book), which is basically a bunch of regulated H_2O packs. You have to switch it less often and it's slightly safer, so most mechanics prefer the fuel cell over the individual packs.

Shipboard Recycling Systems

One of the major problems with modern spacecraft is limited oxygen. Firefly/Serenity solves this problem by constructing a miniature ecosystem on board the ship by utilizing tanks of algae. The algae recycles the carbon that humans release by respiration, producing breathable oxygen as a result (look up Photosynthesis for more). The carbon, however, is not taken from the algae, which maintains an equilibrium due to crowded conditions and starvation. The air is pumped by fans through the algae tanks, dissolved into the water, and then extracted by filtered evaporation. The upshot is that this can also keep the hydration levels of the atmosphere on board acceptable. The downside is that if your Gravity Drive breaks, your fusion reactor shuts off, the power shuts off, you lose ventilation, and the air goes bad. Human Waste is heated to evaporate as much water as economically possible, then compacted into cute little cubes using artificial gravity. You can filter contaminated water to some degree by evaporation, of course, if you have the spare heat (which most ships do), but few ships include designs for this, as water is a common resource and easily purchased anyways.

When Things Go Wrong

So what happens if something gets shot? Shaken up? Shuts down? The core systems named in this documentation all have really nasty effects if they shut off, and possibly worse ones if they are running damaged.

Thrusters

There's a really huge problem with running thrusters damaged. Yeah, you can manage to reconfigure a rocket to swivel in another direction to offset some damage on the side, but if you lose something while in ramjet mode, or worse, scramjet, pressure will start to shoot out of the rupture and severely alter your flight path. Worse, if the pod is not attached well enough (highly likely), it may detach from the boat and go on its own merry way for a bit. Why this is a bad thing is only too obvious. Turbines, if active when damaged, tend to fly apart because of the fast-rotating pieces of sharp metal and send shrapnel everywhere. Generally taking a hit to the thrusters is only something that can be done without severe effects in space, although that makes repair trickier. Alternatively, if a thruster merely shuts down (stops pumping fuel or stops turning in turbine mode) it can be difficult to fly with, but not nearly as dangerous as a ruptured pod.

Hull

Simply put, a puncture in the hull of a ship in space will destroy it. The hull is designed to withstand internal pressure, and the lack of external pressure may cause it to implode on some designs. Some ships have failsafe systems that separate sections and rooms of the ships into miniature airlocks so that it is possible to, say, seal off the bridge when it's smashed and maintain atmospheric integrity and pressurization in the other chambers. Keep in mind that holes can be made from the inside, too. Some sections of hull can be safely punctured, however. Those that contain only wiring and materials that could normally survive in the vacuum of space will be fine.

A boat can usually take some punctures while in atmosphere, assuming the pressures are somewhat constant. Thus, people and cargo may be sucked out through the hole, but the hull will not implode.

Gravity Drive

The gravity drive is symbiotic with the fusion reactor. If one shuts down, so will the other. A problem with the gravity drive is arguably more dangerous, though, as repair without specific replacement parts is difficult to do. Shutting down the gravity drive results in several effects, including the loss of pulse drive, localized inertia field, power, artificial gravity, resistance to the gravitational pull of planets, and sends you drifting. Running the gravity drive when it is damaged is dangerous- random gravitational fields capable of crushing waste into superdense cubes and simulating the pressure in a star could easily cause the destruction of the boat and it's crew.

Fusion Generator

You've heard countless times that fusion reactors don't explode. This is true. Mostly. In theory, one could make a hydrogen bomb out of a reactor and then yes, it would proceed to explode. A fusion reaction, if upset, will typically unbalance itself, and use up its fuel too fast. This will likely evaporate the remaining fuel (safely kept in H_2O), and cease the reaction. The result is a blast of radioactive energy but not much else. The radiation is nothing to laugh at, though. The long and short of it is that a fusion reaction destabilizes itself and burns out, unlike a fission reaction, which pretty much will continue to react with everything it finds nearby. However, a fusion generator leak is quite possible and exceedingly dangerous. The fuel input can be increased to compensate for the lost radiation and energy, although it won't be exact and won't fix the problem. Typically the only thing that can go wrong with the generator is a lack of fuel (in which case it safely shuts down), lack of plasmatic vector fluid (in which case, it will starve as soon as the fuel shuts off and just heats up constantly (dangerous, but not like a nuclear fission meltdown), breach of the containment (radiation bath, anyone?), or a breakdown of a turbine or something (in which case the device must be shut down and the part repaired or replaced). The problem with the fusion generator is that it's hard to repair, and shutting it off shuts off your only way to get it back on (unless you brought some of those electro-chemical backups to power the gravity drive long enough to restart the fusion reactor).

Shipboard Recycling Systems

Life Support systems are, unhappily, those that go wrong the most. What happens if a ventilation fan breaks down and no one notices? By the time you realize, it may be too late. It's wise to keep tabs on those things that make a boat habitable. The effects are pretty obvious, so I'll only mention the slightly unpredictable.

A long-dead ship that has lost human habitation will run out of CO_2. This will starve the algae that convert CO_2 to O_2. Without their intake of food, they will perish, and the ship will likely need a transplant to get running again.

The rupture of a tank of algae that spills onto the deck of the ship will, ironically, still work just fine. It'll just be a pain to walk around in, and the algae growth might get out of hand, so a crew usually will clean it up right quick.

The destruction of the waste management system is not going to be pleasant. That's a pretty clear one.

Keep in mind that these are just general core systems on a ship: not every system is this critical. If you would like some less critical effects, I encourage you to be creative. Get ideas from various things, including the effects column of the Technobabble chart. They should be easy to explain away. Good luck, mechanics and GMs!

Complete Parts List

Device

Part - Part Description

Subpart - Part Description

Note that not all of these parts are mandatory on a ship (for example, the cargo bay doors). However, most designs include the majority of them, and the more options one has, the more dangerous situations one can wiggle out of.

Gravity Drive (Remember that the gravity drive is actually spread out around the ship in electromagnetic form. This is the hub.)

- Central Processing Unit - The CPU of the gravity drive performs the calculations of when and how to pulse the electromagnets.
  - RS SDRAM - Radiation-shielded random-access memory. Approximately 1 kilobyte. Stores time/date information.
- Pulse Iterator - The Pulse Iterator constantly shuts the hull electromagnets on and off to save energy.
  - Pulse Capacitor - The Pulse Capacitor charges during the off periods to provide enough power for the on periods.
- Fiber Optic Cables - Fiber Optics, faster than the conventional copper wire, are required to run calculations this fast.
- Power Input Cables - The electricity travels to the grav drive from the fusion reactor through this highly-protected wiring.
- Output Cables - The electricity is pumped through the capacitor from the reactor to the hull electromagnets with these.

Fusion Reactor (The fusion reactor is actually a pretty simple system, and usually has a backup computer control on the bridge.)

- Reaction Chamber - A torus shaped chamber containing the fusion reaction.
  - Plasma Exit - Superheated helium is exhausted through this controlled escape mechanism.
  - EM Layer - Coating the torus is an enormous electromagnetic coil that is used to provide the gravity.
    - Wires - Wires run from the EM layer to the main gravity drive to communicate the amount of energy needed.
- Fuel Injection Manifold - A device that controls the injection of hydrogen into the system.
- Convection Chamber - The chamber mounted externally that contains water, is heated by the plasma.
  - Turbine - The turbine which the convection of the water turns. Is connected to the generator.
  - Generator - The generator which produces the electrical current from the rotational kinetic energy of the turbine.
- Fuel Tank - Tritium and deuterium is stored here bound to oxygen as water.
  - Interface - You place an H_2O pack or major fuel cell here to empty it into the fuel tank.
- Electrolysis Chamber - This chamber, between the injection and the fuel tank, separates the hydrogen isotopes from the oxygen.
  - Immediate Store - This stores hydrogen isotopes that have been separated before their injection into the reaction chamber.
  - Oxygen Exit - Oxygen is exhausted through this pipe.
- Computer Control - The computer that calculates the power of the electromagnets and amount of fuel to inject.
- Emergency Interface - A hard-to-get-to computer interface that can regulate the processes of the reactor.
- Emergency Kill Switch - A hard-to-get-to manual valve that stops hydrogen injection into the reaction.

Thrusters (per Pod) (The pods are relatively simple by nature and use little of the electromagnetic energy that the rest of the boat uses.

- Injection Manifold - Where the hydrogen is injected into the engine to heat the air moving through it, or burn in rocket mode.
- Chassis - The external aerodynamic shape of the engine, in which everything is contained.
- Swivelplate and Bearing - The device by which the engine can rotate radially. Some designs prefer a ball-in-socket approach.
- Intake - The device that at which air flows in by. Closes off in rocket mode.
- compressor - The central device that forces the air into smaller volume. Cone-shaped. The turbine deploys from this.
- Turbine - Collapsible blades which spin rapidly, forcing air into the pod. Fold up at Mach .5.
- Combuster - This is the spark system used to cause the hydrogen reaction within the point of compression.
- Nozzle - This is the exit point of the engine, and ejects severely pressurized air and rocket fuel.

Hull (The hull is made of superstrength alloys and superdense plastics, typically, and can withstand most radiation.)

- Heat Sinks - These are efficiently designed storage places for heat.
  - Heat Pumping - These pipes can contain unused superheated helium, which then transfers heat into the heat sink.
  - Coolant Pumping - Coolant (liquid or gas) can be pumped through the heat sinks, vaporized, and then used for propulsion.
- EM Radiation Shields - Lead and other radioactivity-blocking materials make up several layers of hull.
- Airlocks - Everyone needs a way in and out.
- Cargo Ramp Door - Some designs come with a ramp that extends or lowers so that cargo can be easily moved into the boat.
- Cargo Elevator - As an alternative to the ramp door, a platform can be lowered on wires or pneumatic pumps.
- Shuttle Launch Bay - Just another door alternative to get a shuttle out of the boat.
- Bomb Bay Doors - Popular with dropping cargo or craft without landing.
- Windows - Specially finished polarized plastics that allow light to pass through but not other EM radiation.
  - Tints - Another window outside the normal window. Light-blocking gas can be injected into the space between.

Atmospheric (The atmosphere is recycled by algae used to produce oxygen. However, this has several mechanical parts as well.)

- Algae Tanks - Containment tanks for the algae and the water through which the oxygen is filtered.
- Input Ventilation Shaft - Introduces the contaminated air into the tank and mixes it into the water.
- Ventilation Network - Runs throughout the ship. Powered by gravitational bellows.
- Filtration Network - A series of filters drains water from the top of the tank without taking in algae.
- Evaporation Shaft - The water is then heated and evaporated into gases again.
- Output Ventilation Shaft - The water vapor and oxygen is pumped back out into the ship.

Waste Management (The compaction of waste is one of the simplest systems on the ship.)

- Centrifuge - The waste is centrifuged here. Water is pushed through a semi-permeable wall to the evaporator shell.
  - Evaporator Shell - The outer wall is heated by the superheated helium from the fusion reactor, causing evaporation.
  - Exhaust Shaft - The water is they recycled through this shaft and added back into stores.
  - Transfer Shaft - This drops the somewhat dehydrated waste into the compacting chamber.
- Compactor - This chamber subjects the waste to extreme heat, fusing it in compacted form.
  - EM Shell - The electromagnet surrounding the compactor that causes the gravitational compression of waste.
- Storage Cell - The compacted waste is then stored here, dropped from the Compactor in.

Communications (Used for sensors and navigation as well.)

- Main Computer - Located on the bridge, does all navigation calculations.
- Pilot's Controls - Interface that the pilot uses to electronically control the ship.
- Receiving Devices - The entire ship is as described in the book, a huge antenna used to find and intercept EM signals.
- External Sensors - On larger ships that are harder to design as an antenna, external interceptors of EM signals are used.
- Scanners - Scanners must be externally mounted so that the hull's EM shielding doesn't block the signal.