NaGa DeMon 2012

Starships, Solar Systems, and Space Trade – Oh my.

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Introduction

Hi there.

This document contains the results of my participation in NaGa DeMon 2012 – the National Game Design Month. I decided that I really need starship and solarsystem creation rules for my SF setting... and NaGa DeMon is a good excuse to set these up.

My goal is to create systems that allow consistency; I'll try for as much plausbility as I can but this will not be an engineering or astrophysics textbook.

These documents will contain various "Designer's Notes" sections, in which I explain and discuss the decisions behind the systems; obviously, this file is not intended as a finished "product".

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Ship Design

Concept

Before you start designing your space ship, you should pause and give some thought to what it is you are designing. Is it a planetary defense craft? An interceptor? A battleship? A tramp freighter? What is the length of a mission it will embark on, and what tech level will it be constructed at?

These simple decisions will help you decide what components to pick, later.

There are three key measurements you will track over the course of your ship design: Volume, Mass, and Price.

- Volume is measured in cubic meters.
- Mass is measured in metric tons
- Price is measured in Imperial Credits.

It makes sense to set yourself a volume and price budget, but unless you have a specific design need, you usually do not worry about mass during construction. Mass determines ship performance, however, so if you have specific performance parameters in mind you will probably also make informed choices about the mass of components you pick for your ship.

Tech Level

> *Designer's Note:*
>
> So the first “sub-system” to design is our tech level chart. I have been working on that on and off for a while; it's a lot of research. Tech Levels are a staple, and I guess every designer has their own philosophy on how to set the levels. I am assuming that 0=no technology or stone age technology and major breakthroughs that revolutionize the world come every 2-3 tech levels. That way, we can have an “early” and a “mature” level of technology for each.

TL	Description	Examples of Technologies
0	None/Early Stone Age	Cudgel, club, handaxe, spear, harpoon Needle Hunting and gathering Huts, caves – mobile lifestyle Clothing made from furs and leathers
1	Late Stone Age	Bow and arrows, baskets, boats, plough, yoke, chisel, hoe, loom, earthware Domestication of plants and animals – agriculture Organized warfare, permanent settlements
2	Bronze Age	Potter's wheel, metal working: copper and bronze tools and weapons Craft, trade, City-state and empire Fortifications, carts, chariots
3	Iron Age	Iron tools and weapons, national economy cities connected by roads, countries and empires, hill forts matches, paper, bridges and suspension bridge water mill, gear, screw Lighthouse, catapult, concrete, aqueduct, irrigation, drainage
4	Medieval	Mechanical clock, spectacles, windmill Horseshoe, trebuchet, modern sailing ship, plate armor crossbow, pointed arch, gunpowder and cannons castles, sawmills, crop rotation, paper, printing press
5	Renaissance	Blast furnace, arequebus, musket parachute, astrolabe, drydock and floating dock newspaper, paddle-wheel boat
6	Industrial Revolution (until circa 1900)	Cotton spinning, steam power, railroads, steam ship machine tools, gas lighting, sheet glass, canals, factories light bulb, hot air balloon, photography
7	WW1 (ca 1900-1930)	Petroleum refining, hydroelectric power, automobile Electrification, telegraph, telephone, tabulating machine

TL	Description	Examples of Technologies
		Germ theory, tanks, airplane, dirigible, radio Sound recording, chemical weapon, motion picture
8	WW2 (ca 1930-1960)	Radar, jet engine, rocket Nuclear power, nuclear weapons, primitive satellite Analog computers
9	Information Age (ca 1960-2000)	Digital computer, large passenger jets, mass tourism Satellites, spaceships capable of moon landing, industrial robots
10	Interplanetary Age (ca 2000-2050)	Manned spaceships capable of landing on other planets Primitive terraforming
11	Fusion Age (ca 2050-2150)	Fusion power Terraforming
12	Early Interstellar (ca 2150+)	Hyperdrive, AI
13	Interstellar	
14	Early Gravitic	
15	Gravitic Age	
16	Antimatter	Cheap anti-matter generation; antimatter weapons; antimatter power
17	Planetary Engineering	Complete re-engineering of planets Total elimination of aging
18		Megastructure construction: Banks Orbitals Body rejuvenation
19		Jumpgates, force-fields Moving worlds
20		Matter conversion, matter transportation Full-sized ringworlds Personal force-fields
21		Dyson swarms
22		Vacuum energy Dyson spheres
23		Galactic engineering
24		
25		Artificial big bang
26		Custom universes

Ships will almost always be built at a specific tech level. You can reasonably deviate by one TL in either direction; if the ship-building society already has access to the higher tech level these could represent “cutting edge” or experimental systems and should at least cost multiple times list price. A ship that has many or only lower tech level components could be an outdated model.

> <u>*Designer's Note:*</u>
>
> Okay, the chart has a lot of gaps in it; but I think it's one I can use as a basis. TL8 is the age of simple ballistic and orbital flights; TL9 is where true spaceflight begins The science fiction universe uses TL12 for all early interstellar colonization. The FN was TL13-15. The Terran Federation and Empire are TL14-15.

Design Process

After you have decided on a concept and set a budget (if any) and tech level, it's time to start picking systems for your spaceship. There is no mandatory order – I recommend beginning with the primary system that is required for your ship's mission: A passenger liner will need staterooms, a freighter will need cargo space, and so on. Not every ship will need all systems, of course – for example a civilian ship could well be unarmed.

Weapons Systems

Fire Control

Combat between space ships involves high velocities and long distances. Human gunners can't “eyeball” targets, unless they are very close and very slow-for example if one ship attempts to board another. For all other situations, gunners need the assistance of special sensors and computers.

A fire control station can control any number of weapons, but can only engage one target at the same time.

Fire Control Station: TL9; 5t; 5m³. Requires 1 workstation.

Larger ships with multiple FC stations – and especially military vessels – will have additional workstations on the bridge for weapons officers who assign targets and weapons to fire control stations.

Control Systems

Bridge

Flight deck, cockpit, command-and-control bridges on capital ships

Contains a number of workstations.

Captain: If a dedicated commanding officer is on board, he will have his own workstation from which to command the ship. On smaller ships, the commanding officer doubles as some other function and will use that workstation instead.

Fire Control: Weapons officers assign targets and weapons to fire control stations.

Signals & Detection

Engineering / Damage Control

Ship's Computer

Every spaceship – except very primitive capsules – needs a computer of some sort.

The predecessors of computers are invented at TL6 and become slightly more general-purpose at TL7 – at this point they are still largely mechanical and use punch cards to operate. At TL8, computers become usable on spaceships. First in the form of custom-built special-purpose ballistic computers, later, as computers became more commonplace and more powerful, in the form of computers built from off-the-shelf parts.

Designer's Note:

NASA started using on-board computers with Gemini. The space shuttle went through several generations of its on-board computers, which gives us a nice comparison on improvements in the technology.

Note that as I write this, the specs for computer of TL 10+ are completely bogus...

TL8 Space Capsule Ballistic Computer: 0.1m^3; 30kg; 95W.

TL9 Space Shuttle General Purpose Computer Mk 1: 0.3m^3; 300kg; 650W.

TL9 Space Shuttle General Purpose Computer Mk 2: 0.2m^3; 150kg; 550W.

Name	**TL**	**CPU**	**Memory**	**Volume**	**Mass**	**Price**
Ballistic Computer	8	1	1	0.1		
GPC Mk 1	9	5	10	0.1		
GPC Mk 2	9	5	10	0.1		
Mainframe	9	10	15			
	10	10	20			
	11	15	30			
	12	20	40			
	13	25	50			
	14	30	60			
	15	35	70			

Software:

Flight Control: Software that controls the thrusters of a spaceship, turning the pilot's commands into signals for the engines and at the same time ensuring that small mistakes and inaccuracies are compensated for.

Astrogation: Calculates course for a space-ship.

Astrogation (Hyperspace): Calculates courses through hyperspace.

Hyperdrive Control: Takes courses calculated by the Astrogation (Hyperspace) program and control the hyperdrive for the duration of the trip.

Encyclopedia: Primitive data storage software containing facts and figures about any topic imaginable.

Galactopedia: Vastly advanced, more detailed version of Encyclopedia.

Autopilot: Primitive expert system/autonomous system that enables a spaceship to conduct maneuvers entirely by itself – for example delicate docking maneuvers.

Drone AI: This software enables a spacecraft to operate completely autonomously.

Sensors

Communications

Other Systems

Living Space

> *Designer's Note:*
>
> It seems that $28m^3$ per person is considered the minimum for long-duration spaceflights.
>
> This is a volume 2m high, 2m wide and 7m long. Sounds spacious until you take into consideration that this encompasses one persons share of ALL the living space in the ship.

28m^3 – minimum (military vessels, early exploration ships, etc)

Cabin sizes of cruise ships[1] – picked a large Disney ship at random ("Disney Fantasy").

Type	sq. ft.	Persons	Int/ext	Balcony?
A: "Interior"	169	4	Int	0
B: "Deluxe Interior"	204	4	Int	0
C: "Deluxe Oceanview"	204	4	Ext	0
D: "Family Oceanview"	241	5	Ext	0
E: "Deluxe Verandah"	203	4	Ext	38
F: "Family Verandah"	256	5	Ext	38
G: "Concierge Family Verandah"	263	5	Ext	38
H: "Concierge Bedroom Suite"	536	5	Ext	76
I: "Concierge Royal Suite"	887	5	Ext	100

Same data for Royal Caribbean "Allure of the Seas"

Type	sq. ft.	Persons	Int/ext	Balcony?
A: "Stateroom Interior"	172	4	Int	0

1 Data from: http://www.cruisedeckplans.com/

Type	sq. ft.	Persons	Int/ext	Balcony?
B: “Atrium Promenade View”	194	5	Int	0
C: “Family Interior”	260	6	Int	0
D: “Oceanview”	179	5	Ext	0
E: “Boardwalk and Central Park View”	191	3	Int	0
F: “Family Oceanview”	271	6	Ext	0
G: “Superior Balcony”	182	5	Ext	50
H: “Boardwalk and Central Park Balcony”	182	4	Ext	52
I: “Family Balcony”	271	6	Ext	82
J: “Junior Suite”	287	4	Ext	80
K: “Grand Suite”	371	3	Ext	105
L: “Royal Family Suite”	580	8	Ext	238
M: “Owners Suite”	556	3	Ext	213
N: “Crown Loft Suite”	545	4	Ext	114
O: “Aqua Theater Suite”	823	8	Ext	772
P: “Sky Loft Suite”	722	4	Ext	410
Q: “Presidential Suite”	1142	14	Ext	476
R: “Royal Suite”	1274	4	Ext	334
S: “Royal Loft Suite”	1524	6	Ext	843

Designer's Note:

100 sq ft = 9.2903 sq meters. Let's round it down and call it 9sq meters – or in other words, 3x3 meters.

These cabin sizes are designed to house people for a few weeks maximum. Also, these listings ONLY include the cabin itself – passengers have lots of additional space to use all over the ship.

Cold Sleep Capsules – both for passengers and for emergencies

> *Designer's Note:*
>
> Coffins seem to displace about 1m^3[2]. Add machinery, monitoring equipment, storage for fluids, emergency batteries and so on, and 2-10m^3 seem reasonable.

Consumables

> *Designer's Note:*
>
> Models for actual missions to Mars seem to assume just under 5kg/day/person for consumables. We can assume that this includes recycling as much as possible, but no hydroponics or anything like that.

Hydroponics

Life Support Systems

Facilities

Lab Space

Mess hall

Entertainment facility

Brig

Cargo Hold

Air Locks / Docking Rings

Passenger airlock

Cargo airlock / Cargo bay doors

Vehicle Bays

Ground vehicles

Fighters and shuttles – Hangar or mounted on hull; BSG-style launch tubes

Drones

2 A 68m^3 container can fit 64 coffins: http://www.directfuneralproducts.com/FAQ.html

Engineering

Tanks/Fuel

Capacitors

http://en.wikipedia.org/wiki/Capacitor

http://en.wikipedia.org/wiki/Capacitor#Pulsed_power_and_weapons

http://en.wikipedia.org/wiki/Types_of_capacitor

Power Plant

Fission

Fusion

> *Designer's Note:*
>
> A fusion reactor needs trivial amounts of fuel – a 1500 MW D-T fusion reactor would consume about 1kg of fuel per day (600g tritium and 400g deuterium)[3].
>
> It should be noted that a 1500 MW reactor is a sizable power generator comparable to an average nuclear power station and would provide energy to about 0.7-1.5 million households. For comparison, the one generator still running at Three Mile Islands has a capacity of 802 MW; the Three Gorges Dam has a maximum capacity of 22.5 GW. The closest match in the US is the Surry Nuclear Power Plant in Virginia, with a capacity of 1600 MW.
>
> Obtaining fuel is not a major hurdle either. Deuterium is abundant in natural water; it accounts for approximately 0.0156 percent of all the naturally occurring hydrogen in the oceans[4].

3 Source: http://www.ccfe.ac.uk/FAQ.aspx#Day
4 Source: http://en.wikipedia.org/wiki/Deuterium

Tritium, on the other hand, is very rare, and needs to be produced. It is produced at a slow rate in heavy water used in nuclear reactors (percentages are probably too small for large-scale applications). The preferred method seems to be neutron activation of Lithium-6 which can be done as a byproduct of the fusion reaction itself (which produces neutrons).

Lithium-6 makes up 7.5% of natural Lithium, the rest being Lithium-7. Lithium is an abundant material, but needs to be mined and/or refined from rock of which it makes up 20-70ppm. It does occur at up to 0.25 ppm in seawater (up to 7ppm near oceanic vents)[5]. If my understanding is correct, 3 Lithium-6 atoms + 1 neutron will yield 4 Helium-2 atoms and 1 Tritium atom. Note that this does produce energy (about 25% of the amount of D-T fusion).

In 1998, a pound of Lithium cost US$43.33[6].

It is possible to build fusion power plants that use a D-D fuel cycle, but according to wikipedia:

> "The disadvantage of D-D compared to D-T is that the energy confinement time (at a given pressure) must be 30 times longer and the power produced (at a given pressure and volume) would be 68 times less."

D-D fusion does produce Tritium and Helium-3.

D-He3 is another possible fuel cycle, requiring larger power plants which produce only marginally more power (5%)[7].

Finally, p-Boron11 fusion has energy densities that are far lower than that of D-T; de facto 700-2100. However, since a p-B fusion reactor is aneutronic, i.e. produces very few neutrons during its operation, it would require less shielding, less maintenance and could be safer[8]. The inefficiencies involved probably mean that it is not desirable for a spacecraft, but colonies – especially decentralized settlements – could perhaps use p-B reactors.

Solar Panels

Designer's Note:

Earliest solar cells had 4.5-6% conversion to electricity.

Current (2012) standard is about 12-18% and maximum is just under 20%.

Prototypes have been built that can achieve up to 40% efficiency[9].

Note that starlight follows inverse square law.

Chemical fuel

Chemical battery

STL Drives

Reaction drives

Gravitic drives – mass rated!

5 Source: http://en.wikipedia.org/wiki/Lithium#Terrestrial
6 Source: http://minerals.usgs.gov/minerals/pubs/commodity/lithium/450798.pdf
7 Source: http://en.wikipedia.org/wiki/Helium-3#Power_generation
8 Source: http://en.wikipedia.org/wiki/Aneutronic_fusion#Power_density
9 Photovoltacis efficiency: http://en.wikipedia.org/wiki/Photovoltaics#Current_developments

Hyperdrive

The Hyperdrive shifts the starship into an alternate dimension called "Hyperspace", then propels the ship towards its direction at a speed that exceeds that of light in our own universe. Upon arrival, it shifts the ship back into our dimension.

The shifting of the starship requires vast amounts of energy for a small fraction of a second. Ships carry vast banks of capacitors to meet that energy demand.

Hyperdrives become more efficient as technology improves.

TL	**12**	**13**	**14**	**15**	**16**	**17**
LY/Day	0.03 – 1	4	8	16	24	48

Microjumps!

> *<u>Designer's Note:</u>*
>
> At TL 14-15 (TF and Imperial level) a ship can expect to cross all of human space in 4-6 months. Values will be adjusted accordingly – as my map is shrinking with v2, I will need to revisit Hyperdrive speeds. The values in the table, above, were chosen merely to show what sort of progression I am looking at.

The Hull

Hull, Structure, Armor, …

Hull shape: open, standard, streamlined

Wings/airfoils

Vtol thrusters

Finalizing Your Design

Sample Ships

Need to create sample ships:

- Several drones
- Small tramp freighter
- Maybe a military patrol vessel
- Small ships and fighter craft

Star Systems

This is a place-holder :-)

Trade

Freight, Passengers, Speculative Trade.

Need to make sure economy work out!

Space freight will use a system similar to air freight.

http://www.hoodlogistics.com.au/airfreight-containers.php

List of Trade Goods

Bulk Goods vs individual items.