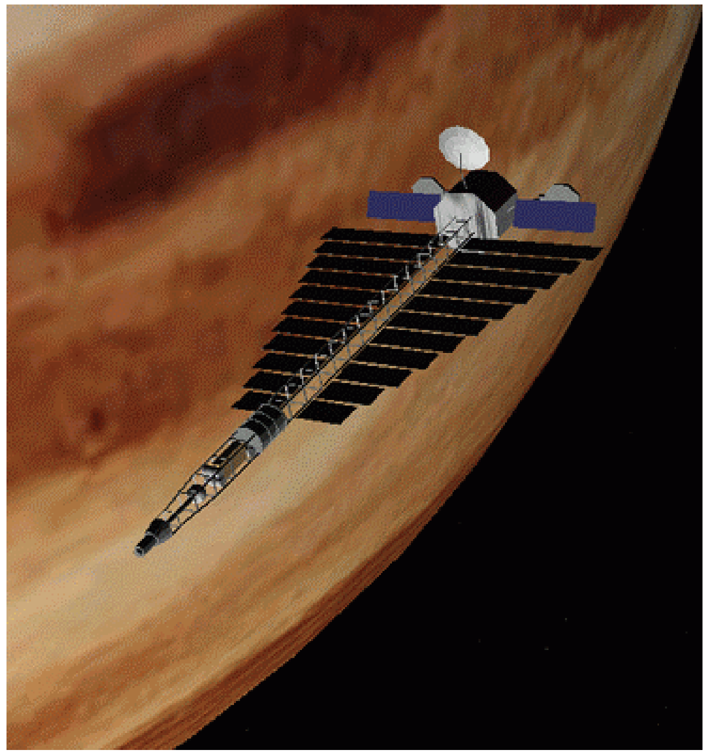
ORBITER Space Flight Simulator
Jupiter Icy Moons Orbiter

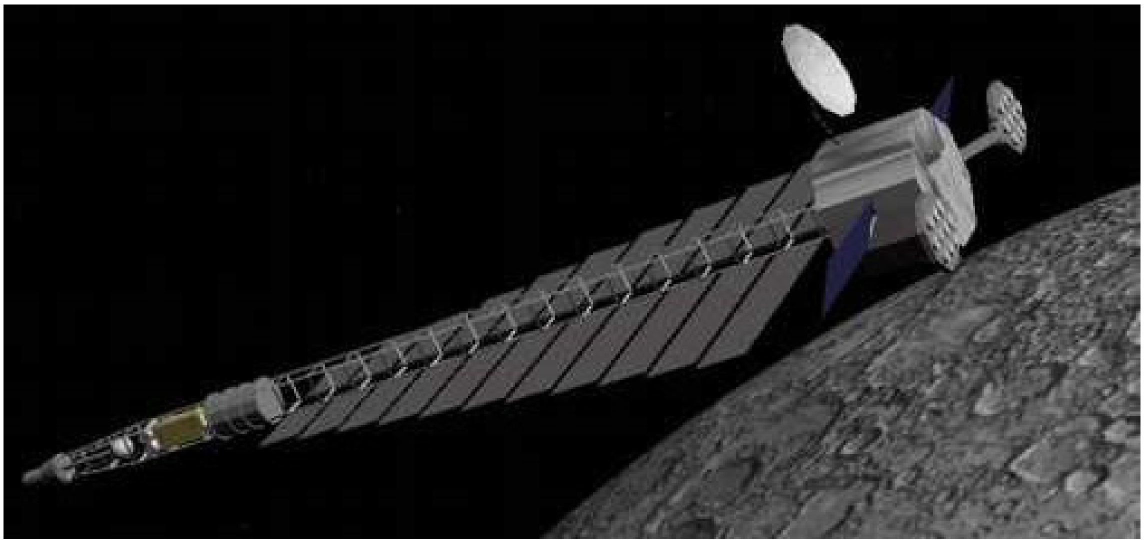
Vers. 0.1, July 2003 by Francisdrake, for *Orbiter* release 030303



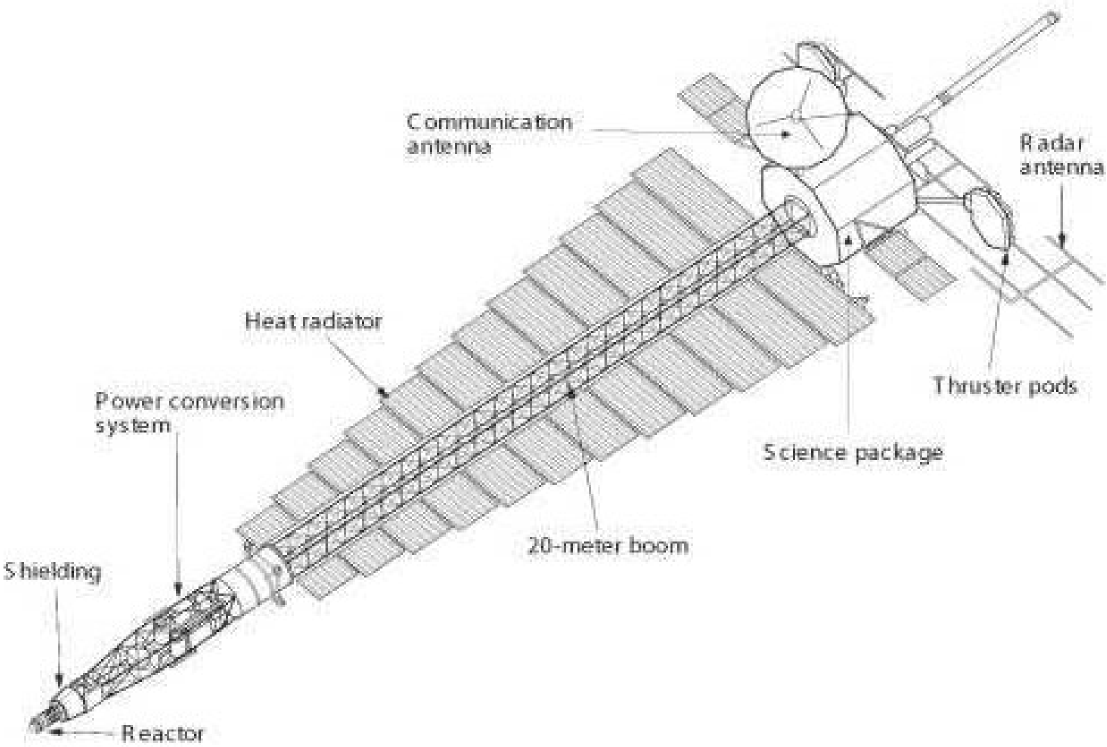
1. What is the Jupiter Icy Moons Orbiter?

The text below is from NASA's fact sheet. It can be downloaded as a pdf-file from (1).

NASA is developing plans for an ambitious mission to orbit three planet-sized moons of Jupiter – Callisto, Ganymede and Europa – which may harbour vast oceans beneath their icy surfaces. The mission, called Jupiter Icy Moons Orbiter, would orbit each of these moons for extensive investigations of their makeup, their history and their potential for sustaining life. (...)



The JIMO misssion will also raise NASA's capability for space exploration to a revolutionary new level by pioneering the use of electric propulsion powered by a nuclear fission reactor. This technology not only makes it possible to consider a realistic mission for orbiting three of the moons of Jupiter, one after the other, it will also open the rest of the outer Solar System to detailed exploration in later missions.



2. Mission Description

Launch

The included scenario uses the Delta 4 Heavy launcher. This is a separate add-on, made by Observer. It can be downloaded at Avsim (2).

The payload weight of 23 ton is very close to the performance limit of the Delta 4 Heavy.

Currently the scenario file contains a cheat, stating a lower paylod mass. The scenario may cause problems (boosters may not start as expected, reaching LEO is difficult, crash to desktop may occur). This shall be improved in future versions.

<u>Proposed ascend profile:</u>
(Note: This is temporary only and will be subject to revision)

- Pre-set instruments: Surface HUD, Surface MFD, Orbit MFD.
- Launch: Press Numpad '+' to enable the automatic launch sequence control to fire the boosters
- Start tipping over towards 90°.
- MaxQ: Throttle back the core stage to 50% and leave it there.
- Boostered ascend: Gaining speed is more important than altitude (ascend at 200-500 m/s)
- After booster separation: gain speed.
- When MECO comes closer point upwards and go for upward velocity > 1200 m/s.
- Stage 2 separates and starts automatically
- Burn prograde or slightly upward to get the periapsis out of the dense atmosphere
- Cut the engine when an intermediate orbit is reached
- At apoapsis restart the engine and circulize the orbit.
- Cut the engine and separate the payload using the 'J' key.

When the payload is separated it automatically deploys from the stowed to the flight configuration. Currently this happens suddenly, interfering with the second stage nearby. This shall be corrected in future versions.

Spiraling up

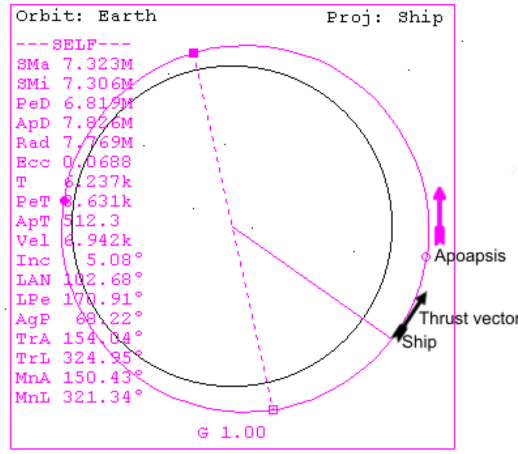
One major difference between chemical rockets and and ion drives is the thrust level. Ion drives have a very low thrust level. Orbit changes require a long term „spiraling up", compared to the „kick" of a chemical rocket. JIMO is equipped with 2 engine pods, carrying 10 engines each, one engine providing 0.1 N thrust.
This adds up to 2 N thrust, which can roughly be compared to the weight of a Big Mac ϑ.
As you will see, pushing a 23 ton space truck with a Big Mac to Jupiter takes its time ...

!	To improve playability in *Orbiter*, the thrust is exaggerated by a factor of 200, giving a thrust of 4000 N. This was done as *Orbiter* does not support prograde orientation at high time acceleration levels. Without this, long term, low level thrust can not be handled properly. For those with a lot of patience: You can set „MaxMainThrust = 2" in the cfg-file to experience the real thrust.

Note: The higher thrust level does not increase the available delta-V.
The total available delta-V is about 30 km/s. Nearly two thirds of it will be spent to escape Earth and inject into a Hohmann transfer orbit to Jupiter.

Even with the increased thrust level it takes several orbits to spiral out of Earths gravity field. Sprialing up can be performed in 2 ways:

a) **Chasing the apoapsis**
The engine burns continously. Try to keep the apoapsis ahead of your ship. Switch to 10x time acceleration every now and then and hit the Prograde-key to keep your ship oriented prograde within ± 10°.



This works quite well for lower obits. Unfortunately for higher orbits this tends to result in a rather eliptical orbit, something that should be avoided when spiraling up.

b) Burn at apoapsis only
The engine is shut down. It is turned on about 30° before the ship reaches apoapsis. After some time the former apoapsis will become the new periapsis. The burn continues until approximately 30° after the new periapsis, then the engine is shut down. This is repeated as necessary.

Escaping from Earth
Above the height of the geostationary orbit (~R 42000 km) the (thrust increased) ion drive is capable to escape Earth with one long thrust. Thrusting starts approximatley when being opposite to the desired escape point. Thrusting continues until the orbit changes over to a hyperbolic shape, the flight vector pointing into the desired direction.

Setting up the transfer to Jupiter
In the scenario a cruise phase of 2 months is foreseen between leaving earth orbit and injecting into the Jupiter transfer orbit. This is to establish an undisturbed solar orbit and to adjust the Transfer MFD for the burn. The orbit is planned on the Transfer MFD. When reaching the start line the engine is activated and burns until the desired tranfers velocity is reached.
Remaining fuel after the transfer burn is about 38%.

Cruise

Depending on the speed of your computer it takes about 5-7 hours to reach Jupiter in 10000 time acceleration. A midway course correction shall be performed to adjust the trajectory and align orbit inclinations.

Jupiter Capture
About 1 AU (150 Mil km) away from Jupiter switch one MFD to orbit (Ref: Jupiter) and burn to align the orbit inclination to around ± 1°. This is because all the moons of Jupiter orbit more or less within the ecliptic plane. Adjusting the orbit inclination out here costs less fuel than later in the orbit.

The aimpoint for the periapsis depends on what mission you have in mind. Generally it is more fuel conserving to start with the outer moons. The aimpoint shall be somewhat above the desired periapsis, as slowing down has to start early and this will lower the periapsis, too.

The capture burn starts about 90° before reaching periapsis.

Navigating the Moons
Navigating in Jupiters gravitational field is treacherous. Its strong gravity dominates by far the small moons. To get into a stable orbit the vessel has to come quite close to a moon, but try to avoid a hard hit on the target ϑ.
Another danger are unwanted swing-bys around others than the targeted moon, which can ruin a perfectly sychronized orbital rendevous. You might want to save often.

3. Design Data Sheet

Design Data Sheet for Jupiter Icy Moons Orbiter

Feature		JIMO	Reference	Comments
Engine			NSTAR Engine	as for Deep Space 1
Quantity	-	20	1	
Size (dia.)	m	0,3	0,3	
Weight	kg		8	
ISP	m/s	30400	30400	
Thrust (single engine)	N	0,1	0,092	
Total thrust	N	2		
Engine power (single)	kW	2,5		
Total engine power	kW	50		
Efficiency	-	0,8		
Electric power	kW	62,5		
Reactor				
Type	-		SNAP 8	
Electric power:	kW	65	60	
Thermal power:	kW	325	300	
Efficiency	-	0,2	0,2	
Reactor mass	kg	195	180	
Plant mass	kg	737	680	
Shield mass	kg	200	200	
Primary cooling	-	Li	Li	
Second. cooling	-	K	K	
Core temp.	°C	787	787	
Radiator temp.	°C	367	367	
Radiator area	m²	110	45	given size
Vessel				
Structure	kg	5000		
RCS fuel	kg	800		Hydrazin
Instruments	kg	2000		
Lander	kg	0		
Propulsion				
Dry mass	kg	8932		incl. RCS fuel
Fuel mass	kg	15000		Xenon
dV req	km/s	30,0		
dV calculated	km/s	30,0		
Total launch mass	kg	23932		
mass ratio (dry/ total mass)	-	0,37		

4. Future Outlook

This was the first step to implement the Jupiter Icy Moons Orbiter. It was about figuring out masses, ratios, power and speed requirements, building a mesh and implementing the vessel using a cfg-file.

But developement shall not stop here. Things to develop are:

- Tidy up the model, add a few textures and some more details.
- Write a DLL to perform basic functions, including custom exhausts of ion-thruster and RCS.
- Improve the launching scenario.
- Make the DLL to switch between payload and deployed configuration (not animated yet).
- Improve the DLL to support continous thrusting at low power by adding the capability to keep pro- and retrograde orientation even during high time acceleration.
- Add some kind of energy and heat management to the DLL.
- Animate the changeover from payload to deployed configuration.

- Build a Europa-lander, to be attached to JIMO and being released in the moons orbit.
- Make a package with some landing sites and scenery on Jupiters moon.
- Try to enable aerocapture by adding a heat shield to the bottom of the orbiter.
  (This could enable Jupiter return missions. Requires to modify the Jupiter.cfg file to add an atmosphere.)

- Build a Mars Sample Return lander and ascent stage, carried by JIMO.
- Try to catch a comet. (Somebody's got to make one first ϑ)
- Reach out for other planets, that is Saturn, Uranus, Neptun.

5. Personal Comments

I came across the „Jupiter Icy Moons Orbiter“ project occasionally when looking for future space propulsion systems. The possibilities and simplicity of the concept fascinated me. The drive is a combination of proven systems:

- A Xenon ion drive engine, which first flew on the famous „Deep Space 1“ probe in the late 1990s.
- A nuclear fission reactor. The first one to fly in space was SNAP 10A (electrical power 668 W) on top of an Atlas Agena in 1965!

Since then nuclear reactors have been used on some military reconnaisance satellites, but no detailed information has been released to the public.
(Note: Reactors are not to be confused with thermo-electric isotope-batteries as used on Pioneer, Voyager, etc.). The batteries provide only low power (below 1 kW), while reactors can provide up to 100 kW and more.

If the fission reactor & ion drive concept proves succesful, it will provide a versatile type of craft, putting the outer Solar System in reach of closer examination.

6. Sources

(1) Jupiter Icy Moon Orbiter.pdf: http://spacescience.nasa.gov/missions/JIMO.pdf
(2) Avsim, the download portal: http://www.avsim.com
(3) Jupiter Icy Moons Orbiter Home: http://www.jpl.nasa.gov/jimo
(4) Deep Space 1: http://nmp.jpl.nasa.gov/ds1/