General spacecraft conceptual designs

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Introduction

In this paper we will be discussing basic design concepts for a manned mission to the Jovian moon Europa, I will explore the possibilities for a one way and 2 way mission.

The challenges of reaching Europa are large but not beyond modern technology, the two basic parts that will be needed are a spacecraft to take the crew to Europa, and a spacecraft that can deliver the crew to the surface. Seeing that the crew is not going to just take pictures and leave they will also need an array of equipment and possibly surface vehicles to aid in their exploration, logistically this poses a challenge, sending everything in one go is not very feasible for the time being unless you really want a very large and complex exploration craft. In reality the best bet seems to be multiple craft, one craft for the crew, and one for the surface equipment.

1. Basic concepts

First off we can look at the crew transfer vehicle or "CTV", the CTV is the craft that will transport the crew from Earth to Europa, in its most basic form it should consist of 4 main parts, an engine section, fuel section, habitat section and a shield in the direction of flight. One challenge a mission to Europa will face that no other manned mission has is crossing the Asteroid belt between Mars and Jupiter, although the chances of impacting a large body are still relatively small because the asteroids are fairly spread out, the amount of smaller debris ranging from dust to small rocks is higher in this area then in the inner or outer solar system. As a result to help protect crew and main systems a shield facing the direction of travel would be useful to prevent micrometeoroid strikes on the main habitat and other systems.

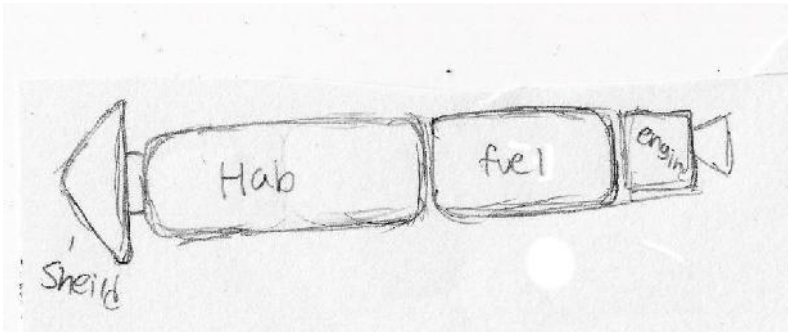

Image 1: basic outer solar system vehicle construction

2. Keeping the crew safe and healthy

Humans are not made for space flight, more precisely we need gravity, in a weightless environment we start to slowly deteriorate bone and muscle mass degenerate, fluid balances are thrown off, behavior changes ECT. Another problem with prolonged weightlessness is gravity acclimation, when astronauts return from the space station no matter how much they exercise to slow their degeneration, they always suffer from gravity acclimation, it takes them days sometimes months to get used to the gravity of Earth again, on a mission to another body be it Mars or Europa this could cause problems.

Upon landing the crew will want to get to work, but adjusting back to a gravity field will slow the work and cause discomfort to the crew, this could impact over all mission success and efficiency. There are 2 ways to counter this.

2.1 Hibernation

One option is a more experimental one, Mammalian hibernation, the concept is still in the research phase but it could in the future be a viable technology for long duration spaceflight, the concept originally got its start in the 50s – 60s during the pioneering of heart surgery. Doctors discovered you could increase the time you had to work on the heart without cause brain damage by cooling the patient into a hypothermic state before operating, it would slow functions and energy usage, fast forward to today researchers have started working on ways to induce hibernation in humans by cooling the brainstem with a tube inserted into the nose. Once in hibernation electrodes would be used to stimulate muscle groups to prevent atrophy and nutrition would be given via IV and feeding tube.

Human trials are in the beginning stages and it's not known if it would even be viable for spaceflight, NASA has vested interest in the concept because it would allow for a much smaller and lighter spacecraft seeing the crew would not need much space as they won't be moving around.

It's an interesting idea but again very new and experimental.

2.2 Artificial Gravity

The second concept which is a little more viable and less questionable is the use of artificial gravity, a centrifuge that rotates a habitat module around the center of the craft to generate centrifugal force giving the same effects of gravity for the crew. In the centrifuge that could be adjusted to produce 0.5 g or 1.0 g (depending on size and materials) the crew would be able to sleep normally, work at a desk normally, and exercise normally, in this way the crew has no need to acclimate to gravity when they arrive because they have been experiencing gravity for a large portion of their flight.

Different approaches are available for this, a 2 – 4 module pendulum idea where you have separate modules opposite of one another rotating around the main body of the spacecraft, another option would be a single module torus system, where you have a large ring that rotates around the center of the ship providing gravity on the inside edge of the ring, such a concept is not new, Werner von Braun was a big advocate for ring stations and spacecraft so that astronauts need not suffer weightlessness as they explore the solar system. NASA and other space corporations like Biglow Aerospace have worked on the idea of inflatable station modules, an inflatable centrifuge module to test an artificial gravity centrifuge has been proposed to test the concept on the ISS and for other future spacecraft.

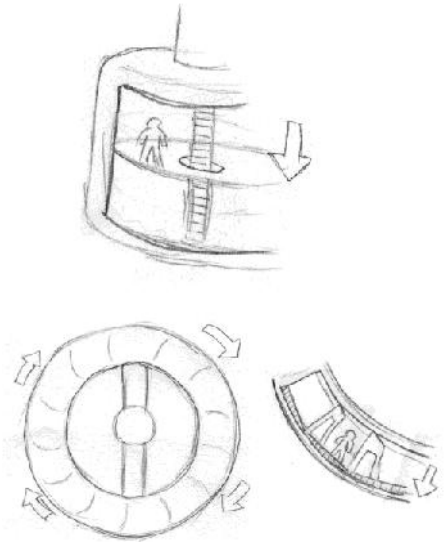

Image 2: concepts for torus and pendulum centrifuge operation

Another positive for having a centrifuge module is it would offer directional stability for the craft as it was in operation. The torus would offer more room but the pendulum would be easier to construct and could be constructed out of rigid material easier than a torus, which is important because the centrifuge would not be protected by the debris shield and would need additional protection to prevent damage from micro meteoroid impacts. However the Torus could be lighter and could be covered in rigid plating after being inflated in Earth Orbit so is still a valid idea.

3. One way or two way?

Logistically and ethically is a one way mission preferable? Possibly, people would volunteer for such a mission knowing they won't come back, but ethics aside what are the technical problems? For one it's fuel mass. To reach a target you need to use a fair amount of fuel to just get there, then more to get back, this usually means you need to carry all the fuel with you which results in a heavy spacecraft, of course that's with conventional chemical engines. A chemical rocket is not practical for a manned mission to other planets, let's face it, for such a mission you need an efficient low cost high speed rocket, the two factors being Delta V and specific impulse. Delta V is the change in velocity required to achieve maneuvers and burns, such as the potential amount of velocity change an engine can provide. Specific impulse is the impulse delivered per unit of fuel, the higher the specific impulse the less fuel you need.

One option is a VASIMR engine or Variable Specific Impulse Magnetoplasma Rocket, it uses a gas like Xenon as a fuel and ionizes it to project it out as thrust, a VASIMR or other Ion thrusters have low thrust but high ISP and high Delta V meaning you don't need much fuel and can gain high speeds cutting travel time. With such an engine you could carry enough fuel for a 2 way mission or enough to get to Europa and have enough to get back sent to Europa before the manned craft on a Europa utility lander sent ahead of the crew so the craft can refuel for the return trip, or just arrive and stay.

Another option is less efficient but has advantages of its own, a thermal nuclear propulsion system uses Liquid hydrogen fuel and a reactor core to heat the hydrogen for thrust, such an engine like the US NERVA engine could be a viable engine for a manned mission to any destination in the outer solar system, for one thing it's fuel is hydrogen, hydrogen is very common in the universe and is very common in the outer solar system, this can be a bonus in outer solar system exploration because once arriving at Europa the lander or utility lander could be used to mine ice which can be processed into hydrogen for the return trip. Nuclear engines have been tested on the ground but the programs where canceled in the 60s so the technology is tried and tested, but never in space which is a bit of a problem seeing that it needs to be used in space.

The ability for a 2 way mission is practical with modern technology, the main problem I've seen is if you want to send crews under the ice, drilling a submarine into the ice is comparatively easy compared to climbing back up kilometers to reach the surface again, this could be solved by only using robotic probes for the deep ocean exploration and keeping the crew on the surface or a few dozen meters under the ice for radiation protection, or use a tether system so the sub surface ice exploration craft could be pulled back up to the surface, or have the craft climb out with a corkscrew system or impellers. Whichever option is used subsurface ice dwelling will be an important part of the mission, after landing radiation in the Jovian system will cause problems, so setting up a base camp under the ice would almost be a necessity to reduce radiation exposure.

3.1 short stay

A concept we can call "short stay" would give the crew a modest stay on Europa, a longer return trip to address problems such as possible cross contamination, and more research in the interplanetary space between Earth and Jupiter. With a short stay mission the crew lands on Europa and only stays on the surface for a few weeks or a couple months, then they return to the orbiting drive section and depart on a longer trip back to Earth then the departure trip, this could also give the crew a Mars flyby if the correct window was chosen.

3.2 long stay

Long stay is a concept where the crew will spend a little over a year on the surface of Europa before returning, in this approach the return time can be much shorted then long stay and more efficient because the crew can stay on the surface until Earth arrives back at an ideal position for a quick transfer from the Jovian system to Earth, a Mars flyby is less likely in this situation but not impossible. The frame work would be the crew arriving and landing on Europa, there they stay for a little over one Earth year letting Earth do one revolution around the sun and then move into a position to account for Jupiter's orbit, once the launch window is approaching the crew would return to Europa orbit and dock with the command module, during the return the centrifuge will gradually increase in speed, first simulating Europa gravy at the start and slowly moving up to Earth gravity to better acclimate the astronauts for when they return.

3.3 One way

A one way mission provides a cheaper and generally easier mission at the cost of the crew never returning, in this mission the crew would only need fuel to get to Europa, once there they could dismantle the transfer vehicle and use it's modules to construct a subsurface base under Europa's ice and would eliminate the need for the crew to return to Europa's surface, letting them explore the ocean and study the moons interior for as long as they want. One problem that would need to be addressed is what happens after the crew expires? If you leave human remains under the ice there is a large chance of biologically contaminating the Europan Ocean and possibly destroying the native ecosphere, a way to completely sterilize the hab and equipment after the mission would be required to ensure long term protection of the possible Europan ecology, a 2 way mission would not have to worry about this because the crew and crew vehicles would return to the surface and not risk contamination.

4. Full concepts

As we have covered in other sections we have the option of a direct mission where we take everything in one go, and a semi-direct mission where we use two (or more) launches to achieve the mission objectives. A semi-direct method using two craft would be the most cost effective in terms of transport to Europa. The first launch window would see the launch of the Europa utility lander with the subsurface exploration craft and supplies, shortly after the crew would depart in the crew transfer vehicle and arrive a little later then the utility lander.

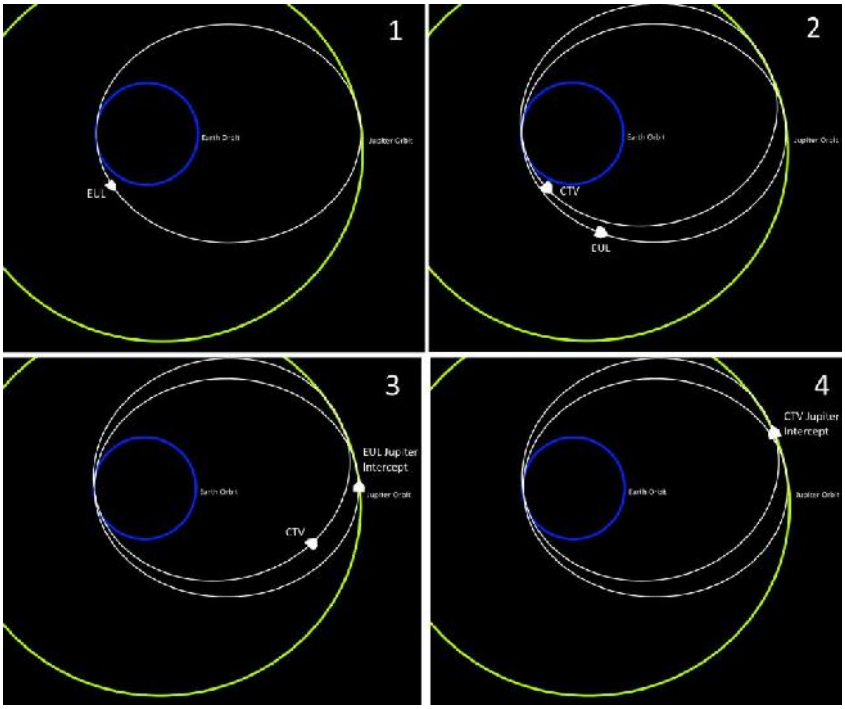

Image 3: Europa transit for semi-direct concept

With such a mission the crew would arrive at Europa in a crew transport vehicle (with or without an attached lander) and would rendezvous with the utility lander either in Europa orbit or on the surface depending on the mission design.

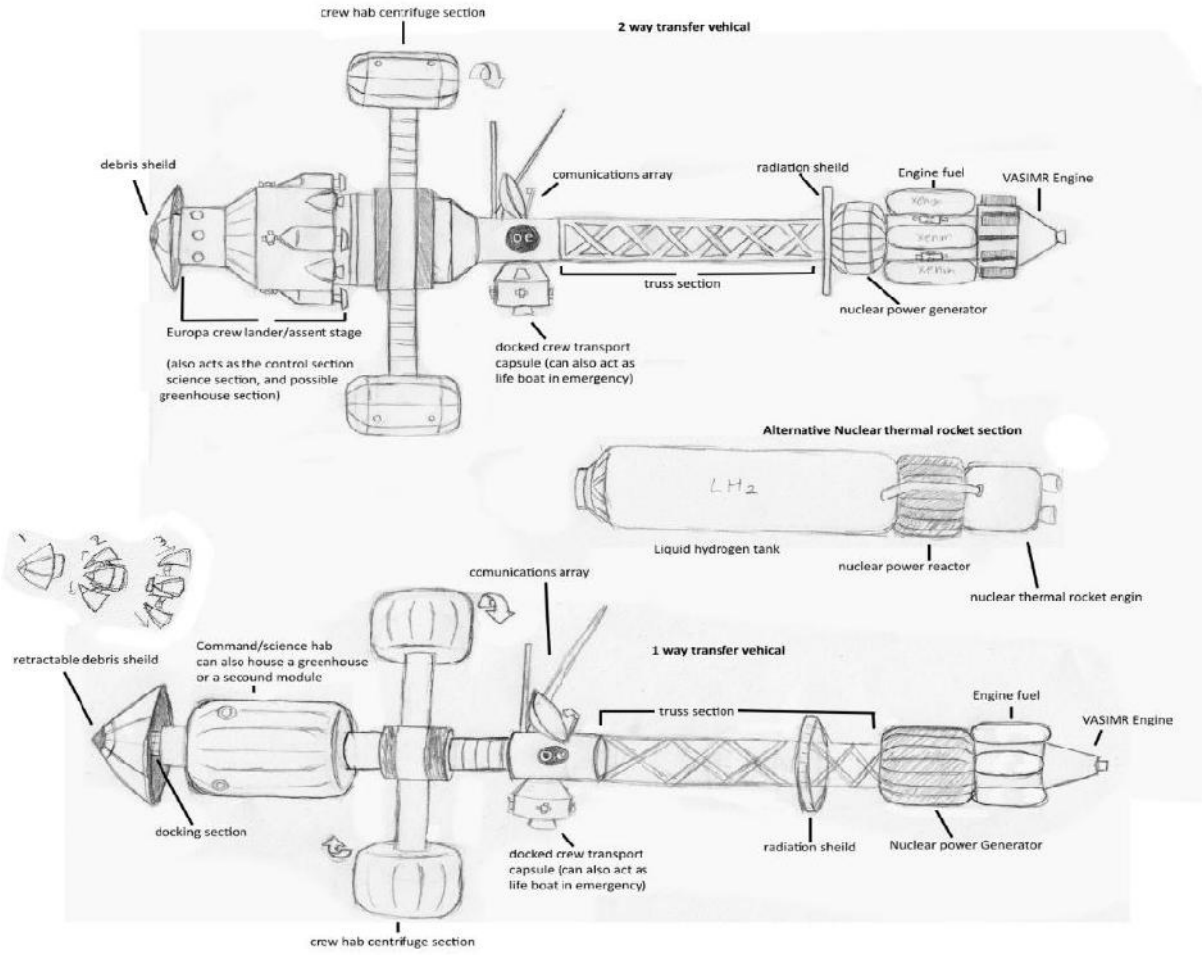

Image 4: Crew transport vehicle concepts

In both a one way and two way mission the CTV can have an attached lander, but in a one way concept the CTV could simply dock with the utility lander in Orbit, and the crew could land on Europa using it without the need to bring a second lander. A one way CTV could have a retractable shield that protects the docking ring and crew hab during transit and is then opened to allow for inline docking with the EUL. Alternatively for a 2 way the CTV could forgo the need for multiple inflatable hab modules and have an attached lander accent craft which would serve as the command deck, science deck, and possible greenhouse deck, so the crew can take everything down without having to leave vital components in orbit with the drive section. The lander would have a debris shield on the front/top to protect it and the craft during transit, and would have retractable landing gear for landing.

When it comes to engines the utility lander can use a basic hypergolic engine like used during the Apollo era, a simple concept where the fuel will ignite upon contact with on another cutting out the need to ignite the propellant with an energy source. Hypergolic propellants tend to be very corrosive and after the engine has been used it's done, it can't be used again, for the Utility lander this is not a problem seeing that it won't be going anywhere after landing.

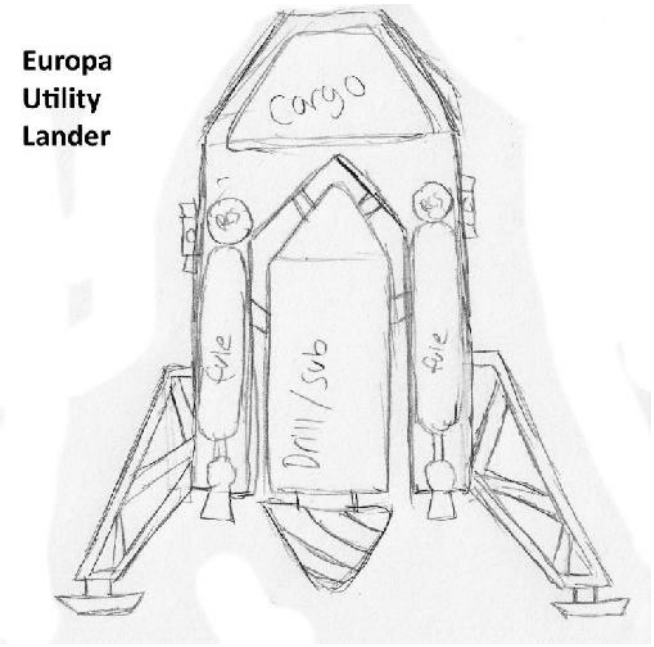

Image 5: concept for EUL including cargo and subsurface vehicle components

For the crewed lander if a one way trip is the mission then the same engine can be used, however if a two way mission is in the cards a different engine would have to be used, one that can be re-ignited and used for accent as well as decent (unless the lander is a two stage system with a separate landing engine and separate accent engine). The engine would be located radially around the base of the lander so the bottom of the lander can be used as the docking ring and airlock for egress on to Europa's surface cutting the need for a very long latter.

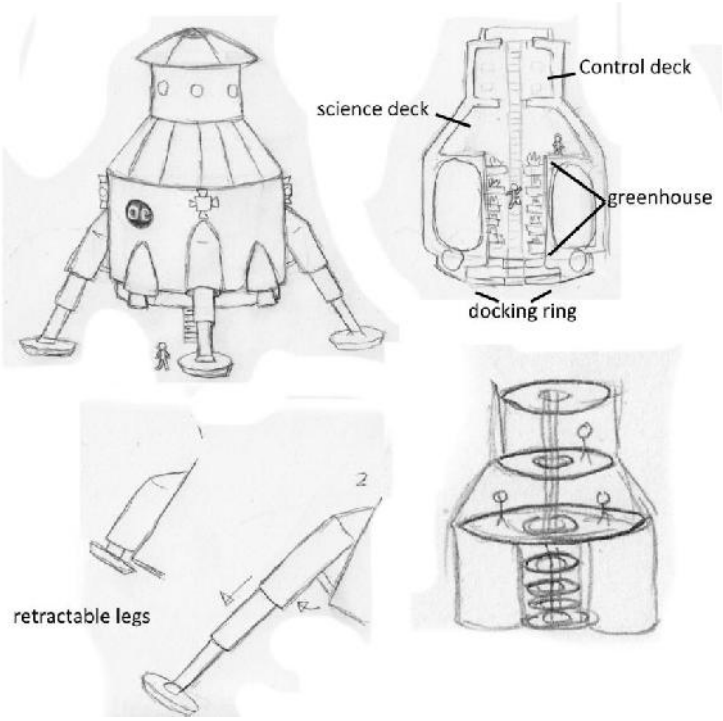

Image 6: Crew lander concept

The lander would be a self-sustaining Spacecraft in its own right used as a base for surface operation after landing, it would need more shielding to provide protection from radiation as it's going to be there for a long time, the crew could drill into the ice and set up a base of operations a few dozen meters below the ice, or a system could be put into place where after landing ice could be drilled up and packed around the lander in inflatable bags to provide extra shielding, the bags of ice would be dropped before launch.

Another idea would to just do the full thing in one flight, have an extra-large lander that can accommodate the subsurface vehicles and all the supplies needed, as well as an accent stage for the crew to return if they are too.

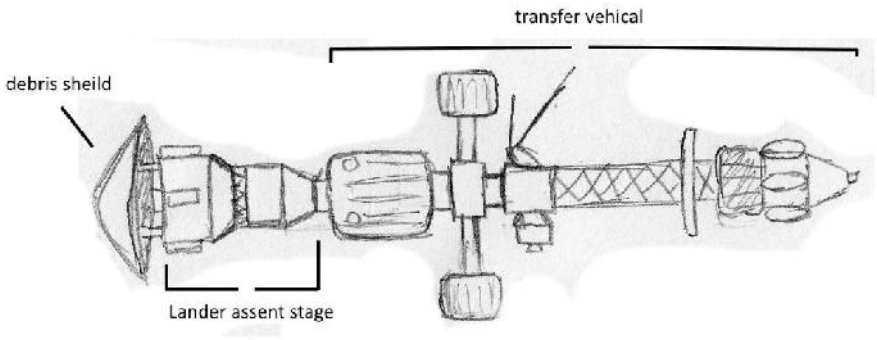

Image 7: alternative Europa direct configuration with utility and manned lander in one

4.1 power

For any mission beyond Mars power is a bit of a problem, most inner solar system missions use solar cells because the sun is very abundant in and around Mercury to Mars, however Jupiter is a long way out and solar cell efficiency drops out significantly, most missions to places around Jupiter and beyond have used RTG generators, aside for a few exceptions such as the Juno spacecraft which is on its way to Jupiter and is powered by high efficiency solar cells, and the ESA Rosetta mission which has used solar cells out as far as the orbit of Jupiter, but these are small probes made to draw very little power, a manned vehicle requires a lot more power to maintain a crew for a long time.

The world is currently facing a global Plutonium shortage because the only reason it was mass produced was for nuclear weapons (something that no one has mad in any large quantity since the cold war) so RTGs are becoming harder and harder to produce, also an RTG powerful enough to power a manned craft of this kind would need to be impractically massive. Inspiration to solve this problem has come once again from Dr. Wernher von Braun, in is concept for most manned missions he used a small nuclear reactor, it's very prevalent in his plan for a Mars mission, basically it would be a nuclear mass (could be Uranium, thorium, or another easily produced nuclear fuel) that would heat a silicon oil that would expand and be used to turn a turbine that would power a generator for the ship. The concept is a bit inefficient by modern standards but the basic concept can be modernized for Spacecraft use, a miniaturized nuclear reactor power generator could be placed on the back of the ship in the engine section to generate power for the entire ship, it can be placed on a very long truss section to keep radiation from effecting the crew or a shorted truss section with a shield disc between the reactor and crew sections. If a nuclear engine is used the hydrogen fuel tanks would act as shielding as is.

If solar cells where used they would need to be very large to provide power and this adds extra mass and more surface area for impacts by debris, for the time being it's not a very practical option unless they get a massive boost in operational efficiency.

5. Conclusion

The trip to Europa will not be an easy one, many concepts have been put forth and many more will continue to be produced, I hope I adequately showed some framework for a viable Spacecraft and system. The technology exists for both a one way and two way mission, more technology will need to be developed to further the success and reach for the mission but as it stands we have a fair bit of technology and experience in space to work from to achieve this goal, Europa is just the first step, the solar system is full of ice moons and large asteroids that may have or have been confirmed to have liquid water oceans under there surface.

Moons like Enceladus, Titan, Calisto, Ganymede, Triton, and others are waiting for their secrets to be unwrapped, to see if life exists in more than one place in the solar system, a trip to Europa would open the door for further exploration of the Ice moons. We have the technology to accomplish this goal, we have the ability to construct spacecraft and systems to do such missions, and it's only a matter of taking the first step.

6. Acknowledgements

I would like to thank Robert Zubrin and David Baker who came up with the concepts of Mars Direct and Mars semi-direct which where an inspiration to some of my concepts, I would also like to thank all the engineers and scientists around the world who work on concepts for human space flight and provide information online for free and in print to fire the imaginations of readers and others around the world including myself.

7. References

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