Exploration vs Settlement in Space

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INTRODUCTION

This essay arises out of a discussion about the differences between Exploration Missions and Settlement Missions and the activities associated with each. It is apparent that we are now on the cusp of being able to have a large number of people in space and ultimately on either the Moon or Mars or both as well as living and remaining in space.

These populations will not remain static but will grow and shrink as commerce and industrial activities develop. Equally, these populations are going to need to be supported from Earth until they become self-sufficient.

Self-sufficiency implies that they can produce enough power and food for their comfort and commercial needs. Implicit in this statement is the fact that all biological functions will have to be catered for. This will inevitably involve the recycling of water and gases and the production of solid waste that can be further recycled. Structures will need to be built and maintained. All these structures will be built for specific needs and will have different requirements from the basic habitation systems. All structures must be shipped in from somewhere else, initially from Earth and probably in kit form.

The other aspect of settlement that promises to have a far greater effect on the way in which settlements work and evolve is going to be communications. Routine communications involving the transfer of supplies, information and products will be necessary as will the more personal communications of individuals.

All these needs must be catered for.

COMPARISON OF EXPLORATION MISSIONS WITH SETTLEMENT MISSIONS

There are significant differences between Exploration and Settlement missions. Typically, an exploration Mission starts from a single point and takes with it everything that they consider necessary to accomplish the mission. As things stand right now all exploration missions start from the surface of the Earth. This is not really a viable way to pursue expanded Solar System exploration, particularly if missions are manned.

It is not lost on the author that most exploration architectures make the same assumption about starting from the surface of the Earth and continuing to require support from the Earth before returning to the Earth.

So, what would space exploration and settlement look like if we could partially or completely decouple the major elements of exploration and settlement from direct support from the Earth?

There is usually no provision for re-supply of an Exploration Mission although supplies may be pre-positioned along the route for the early part of the mission. Equally, there is generally a

relatively high risk associated with such missions and such missions will have to have a large degree of self-reliance.

The initial activities of settlement generally take enough for survival until re-supply ships arrive with more goods, consumables and construction materials. The personnel on the first settlement ship will be the party that establishes what amounts to a “Base Camp”. The re-supply missions will be scheduled to arrive just after the original landing and may carry both settlement personnel, equipment and supplies. There may also be specific materials related to accommodation, healthcare, scientific research and commerce. Heavy equipment to move materials around will also be needed. Operations and Maintenance will be an important part of any Base development as will the reconstruction and testing of equipment shipped as kits for assembly on site.

RATIONALE FOR DEVELOPING A SPACE INFRASTRUCTURE

The rationale for developing a space-based infrastructure is based on the following thoughts:

- That the large ships of space that will be involved in inter-planetary journeys should be built in space and should not land on planetary surfaces. This way they can be constructed for the singular task of transferring cargo and/or personnel around the Solar System and not be limited in size by planetary launch and landing constraints.

- Smaller spacecraft will be required for transferring cargo and personnel from low orbit to the surface.

- Payloads and consumable items can be freely transferred around the Solar System between Outposts in orbit around the target bodies such as the Moon and Mars. It is more economical to ship materials around in space rather than continuously launch materials from planetary surfaces. This allows the material to be lifted once and stored on orbit for future use without inhibiting the development of a space-based manufacturing economy.

- Once material has been launched into space it represents a considerable investment of effort, time and money. So, in order that some economy of scale can be found each payload should be the maximum for that launch vehicle.

- Logistics is going to be of vital importance to the overall development and health of the system throughout its life.

- Once material has been landed on other bodies it should not generally return to space.

- For a complex system of this nature to function a sophisticated Communication and Navigation system will be required.

DEFINITION OF A SPACE INFRASTRUCTURE TO SUPPORT SETTLEMENT ACTIVITY

The development of a space infrastructure will be an evolving task that will eventually reduce reliance on support from Earth and may also function as an adjunct to the activities on the planet. The following characteristics are noted below:

- The key Outpost will be in Low Earth Orbit (LEO), receiving materials from Earth on a constant basis and filling orders from other Outposts and Bases. The Outpost will also transfer high value items back to Earth.

- It makes sense for this Outpost around Earth to be the first Outpost established in this plan.

- It is also sensible for the Outpost around the Moon to be the second Outpost established. This will validate the processes by which Outposts and Bases are built, allowing the Martian system to happen quite rapidly even though at a much greater distance.

- Outposts of this nature will also allow for the evacuation of Bases if an accident or serious issue occurs that threatens the survival of the Base.

- It also makes sense to construct Basic Outposts around target bodies prior to establishing a settlement. Such Basic Outposts will be able to support exploration missions to determine the optimum areas where Bases may be built and the Outposts themselves will be built out as Base construction occurs, and personnel move to the new Base.

- Outposts will be capable of servicing the planetary Base and other missions of exploration. As such, they will have to store large volumes of fluids and all sorts of stores and equipment. Of necessity, they will be large structures capable of housing permanent and itinerant personnel.

- As production from Lunar and Martian Bases comes on-line the support required from earth will drop. This should be true for fresh foods and gases and propellants and perhaps construction materials as well as other high value items.

- It is anticipated that ship construction will occur in LEO and later around the Moon and Mars using locally produced materials. Initially all materials will have to be shipped from Earth but with space assembly techniques that have yet to be developed the cost of launching suitably packaged components will be much lower than trying to ship completed spacecraft and structures.

- Each Outpost will require specialized spacecraft to transfer personnel and cargo to and from space to the respective planetary surfaces. It will be necessary to

develop a propulsive vertical landing technique for use on Earth, the Moon and Mars.

There are several issues requiring solution that go along with the simple establishment of Outposts and Bases. Chief among these are the requirements to:

- Keep some sort of standard time. The Deep Space Atomic Clock represents real progress in that area and every Ship, Outpost and Base will need to have at least one and possibly more to ensure that they are all coordinated. There needs to be a “Solar System Time” that all message and file traffic can use. This is how digital communications must work as messages etc may be broken into components for transmission and will have to be re-assembled at the destination.

- Communications and the channels for communication are going to be vitally important for the development of the overall system. The overall communication system must be designed to provide the maximum possible bandwidth and data rates when planets and the Bases they house are on opposite sides of the Sun. This is going to be solved initially for the Base on Mars and is going to increase in complexity as we move into the Asteroid Belt. It is proposed that a series of relay satellites be placed in heliocentric orbits normal to the Plane of the Ecliptic and far enough from the Sun to provide continuous coverage without the Sun increasing the receiver noise level. Such satellites would also have store and forward capability in the event that transmission failures occur.

- Such communication channels must be completely transparent to the traffic passing through them. Such a policy places the burden of complying with message structure on the generating system and the subsequent re-assembly and decoding of message traffic. For this reason, all traffic will have to be time-tagged and have unique origin and destination identifiers applied. We do all this on the Earth today with computer and assorted digital communication systems. The same can be done in space with Ships, Outposts and Bases having one or more points of access to the data communication system. Acting upon the reasonable assumption that each Ship, Outpost and Base will have its own Internet of Things, (IoT) we will have begun to generate a Solar System network of IoT systems.

- There is a need to provide computer a storage “Cloud” in space. It is probable that computer clouds will exist in some form an all Ships, Outposts and Bases communicating through the aforementioned communication channels. it is possible that all the communication relay stations could have Cloud Computing capability.

- Navigation around the Solar System is going to require both precise timing and some very good star maps. A system akin to a “super” GPS will be required and Outposts will have to have beacons similar in nature to those currently found at Airports but operating in three dimensions.

- The generation of power is going to be a problem because current thinking says that photo-voltaic generation is preferred but there is no way that solar power can provide enough power to support the power intensive requirements of Ships, Outposts and Bases. The only logical process for producing the power levels necessary is to use some form of nuclear generation. Initially this will be using Fission Reactors but hopefully Fusion Reactors will be the preferred solution. Small modular reactors are probably going to be the optimum solution in the near term.

- Associated with the power problem is the task of thermal control and the use or disposal of waste heat. Some waste heat can be diverted to secondary power generation and storage, chemical processing and growing food. However, there is as yet no good thermal model for any of these processes.

- Production of foods will be necessary in large quantities. Bases will probably be in a position to produce excess food for sale further on in the system. It is also likely that Ships and Outposts will have food production capabilities suited to the size of their permanent and itinerant crews and travellers.

- Recycling and processing of air and water for re-use in food production and the generation of potable air and water will be necessary. Recycling of all forms of solid and liquid waste will be necessary. This will include all dry solid waste including all packaging and paper materials as well as obsolete equipment and all biological waste materials.

- All Ships, Outposts and Bases will have to have some form of medical capability. Outposts should be able to use Base facilities for anything more complex than first aid, and triage. Ships will require more comprehensive facilities as they will be facing relatively long distances and times between Bases and Outposts.

CONCLUSIONS

Several conclusions are immediately evident, and the primary conclusion is that there is a vast amount of R&D that needs to be done with respect to the engineering of Ships, Outposts and Bases. The issues involve structural engineering as well as the ability to manufacture and manipulate large structures and components in a micro-gravity environment. Base structures and components on planetary bodies will be manipulated in a similar way to those on Earth.

Provision of the complex communications system will have to occur in tandem with the development of the Martian Outpost and Base.

We must have a reliable way of providing large quantities of power that does not rely on photo-voltaic systems. The only viable alternative is nuclear power generation. Work continues to try and scope the needs of ships, Bases and Outposts for general power requirements and also for electrically powered propulsion and radiation protection systems.

Thermal control problems: use and disposal of heat must be addressed. In Outposts, and on Ships, thermal management may present a problem. This is also true of planetary bodies that have thin or non-existent atmospheres.

Many of the concerns noted above are inter-linked and will need careful consideration.

Further work is already underway within SFO to further define and characterize each of the areas of concern and any other issues that are found as a result of this work. As information is developed by SFO it will be published.

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