Green Fields, Black Sky:

Logistics Considerations for a Large, New Space Program

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Introduction

The title of this paper may seem a little odd but when one talks of a "green fields" venture one is usually considering a brand new facility in virgin territory. This is exactly what SFO is proposing, both on the surface and in space.

The process of space exploration today has been likened to crossing the Pacific Ocean in a rowboat; it's possible, but is it really the right way to go about exploring? The answer is no. The right way is to take a larger vessel and equip it appropriately for the task in hand. If you cannot rely on the availability of local water etc., you have to take them with you. Now the challenge of space exploration begins to look like climbing Mount Everest.

The solution to the problem of climbing Mt. Everest is to start with a Base Camp and continually build new camps at successively higher altitudes until you can attempt the summit. Conquering space will need a similar approach.

The other aspect of space exploration that is not considered is the sheer volume of material that has to be shipped into space in order to allow even a moderate sized base to exist. It is this set of tasks that includes construction both on the surface and in space, the development of two independent but inter-related launch systems and associated equipment that is going to present a very real challenge to the logistics community. In fact, the idea of "logistics" as a discipline may have to be radically altered since in this case the entirety of logistics is subsumed by a number of systems engineering functions. In order to support that of logistics that is considered the normal purview of the subject we will have to have Logisticians thinking much more like systems engineers and have them involved early in the programs to be part of the system partitioning arguments and the subsequent reliability, maintainability and configuration analysis and control.

SFO Program

SFO has been investigating the problems associated with the large-scale exploration of space for about four years now. Our approach is predicated on the thought that space exploration is a human endeavour for which technology is merely an enabling agent.

Consequently any system solution proposed by SFO is going to be "human sized". That is to say, that we are going to build systems that human beings can live in and with and that can be serviced by people trained to service such systems. This "human sized" base will be established in space and initially serviced from the surface of the Earth. SFO is firmly convinced that the only way to effectively explore the space environment is to get enough material into space to allow for a great

deal of autonomy and ultimately to allow a self-sufficient colony to be established. Only then will we have an exploration capability equivalent to Earthly colonists of earlier years.
As with any base the majority of the people involved in the expedition will only go as far as the base, with each new camp beyond the base staffed with smaller and smaller numbers of people. In fact, the majority of folk will not go much beyond the base. These people will staff the base and enable further outward journeys to be undertaken. We postulate a crew size of around 150 to support the anticipated size of the science and engineering tasks to be performed at the Base. Crew size is expected to grow as the structure matures. This is not the final size of the Base personnel capability, we have to be able to accommodate itinerant personnel from all sorts of projects that will require space to live and work. We are making an initial guess at this being an additional 150 people.

Therefore, now we have a big, bold idea and we can service it from the surface. How do we achieve this goal? We cannot rely on the Space Shuttle – or any other developed launch vehicle; they are just not big enough to support this task.

The realization that a new launch vehicle with greater capability is required came with the realization that we were also being freed from low Earth orbits. Shuttle can get to about 350 km or so, but with little duration at that altitude.

Consequently, SFO developed a Design Point Mission that included the following components:

1. The base as already described.

2. A Heavy Lift Vehicle, (HLV) capable of raising 250 Tonnes to an 850 km circular orbit. This is undoubtedly a large vehicle but it is within our capability to construct such a large rocket. Further investigation has led to an optimum payload size between 150 and 175 Tonnes.

3. A Manned Vehicle, (MV) capable of transporting between 15 and 20 people to the base. This reusable vehicle will only carry people, baggage and any small, high value or urgently required items. Such a vehicle may be launched atop an Ariane V derivative vehicle. Several vehicles will be required to allow continuous operation if required.

4. In addition, we have to consider the requirements of the Surface Support Infra-structure. We expect to have co-located manufacturing and launch, horizontal integration will be the norm and a Logistics activity to support the base will exist from a very early stage in the program.

It is expected that as the project matures the management of the base will transfer to the space segment. This will extend to all exploration effort as well as spacecraft engineering and “for profit” activities with other corporations using the system as customers. Table 1, Primary Components of SFO Design Point Mission, provides a brief overview of the primary characteristics of each component.

Preliminary requirements have been developed for all these systems and work is progressing to refine the mission and vehicle requirements.

ITEM	HLV	MLV	BASE	GROUND
Payload to orbit	150 – 175 Tonnes	5 - 8 Tonnes	N/A	N/A
Personnel Passengers Flight Crew	 None None	 20 2	 Up to 150 Approx. 150	TBD
Power	Batteries, may be recoverable and re-usable.	Batteries/Fuel Cells	Nuclear Solar Dynamic Fuel Cells Solar PV Batteries	N/A
Stages	3	3	N/A	N/A
Special requirements	Capability to orbit 2nd. and 3rd. stages Control Electronics will be housed in the Payload Bay beneath the payload support structures and recovered from orbit for re-use.	Potential study to attach Jet Engine(s) to the MV for expanding the atmospheric flight capability On orbit loiter capability of 3 – 4 days for servicing missions.	"End over end" rotation to simulate gravity. Storage for bulk: LOX/LH2 Liquid Air Gases Hypergols Water	5 new HLV Launch Pads. Specialized infra-structure. LOX/LH2 Liquid Air production. Gases Hypergols Water
Interfaces	HLV Data to GND HLV Data to P/L HLV Data to Base 1st. and 2nd. Stages to have common engines.	MV to/from GND Comm. MV to/from GND Data M/V to/from Base; Comm. and data	Mechanical Electrical Power Data Fluids Communications	Air Sea Land Space
Launch Frequency	Every 7 to 10 Days	As required 36 Hour notice	N/A	N/A
Launch Site Equatorial Orbits Polar Orbits	 Kourou Alcantara? TBD	 Kourou Alcantara? TBD	N/A	N/A
Orbit Equatorial Polar	 Under Consideration Under Consideration	 Under Consideration Under Consideration	 Under Consideration Under Consideration	 N/A N/A
Altitude	N/A	N/A	1) 850 km min. 2) Between 1000 and 2000km Max.	N/A

Table – 1, Primary Components of SFO Design Point Mission.

Launch Frequency

For any exploration concept to work it has to be accomplished in a reasonable amount of time. This project will have a long lead-time of 8 to 10 years. At the end of that time, we will have in position all the systems we need to start the exploration proper. Initial Operational Capability, (IOC) will be achieved with 21 launches of the HLV. This will be a period between 21 and 30 weeks. Sometime about four weeks later, the base will be declared "operational" and should be capable of generating revenue. Construction will continue until a permanent, self-sustaining system has been created.

Launch Site Location

Given the size of the HLV, it is virtually certain that no US launch site could handle this vehicle. There is no longer any possibility of having Heavy Lift Pads built north of Complex 39 at KSC. There is also no possibility of obtaining manned and unmanned launches in the quantity needed to support this venture.

We are left, therefore, with Kourou in French Guiana and Alcantara in Brazil as potential sites with the Australian Cape York site as a possible contender. These sites are generally for equatorial launches. We have to consider the possibility of Polar launches but there is no candidate site identified. Operationally, polar orbits have some environmental advantages over equatorial orbits. Trade studies are in progress to see if it is worth attempting a polar placement.

Space Operation

Initial placement of segments will occur with two launches of essentially inert segments. Rendezvous and Docking of these two segments will be automated. Following docking an activation crew will arrive within twenty-four hours and dock with one segment. A period of seven to ten days is available to activate and configure the Base. The next HLV launch should lift to orbit a structural node with six docking adapter rings and hatches. This node will eventually form the center of the Base and become the center of rotation. The fourth and fifth launches will connect to the outboard docking adapter of the structural node.

The Role of Logistics

Contemplation of a program of this size leads to the realization that vast quantities of material are going to be needed at the launch site not just to support the launch activity but also to support the construction of facilities to enable the launches.

In practice, four separate programs have to come to completion at roughly the same time. Contrary to what might be expected the Manned Vehicle has to be ready first. This is because it has to be an operational system prior to the first launch of the HLV.

In looking at what logistics is, I fell back on a definition used by Blanchard and Fabrycky in their work, "Systems Engineering and Analysis". They consider System Support to be the composite of all considerations necessary to assure the effective and economic support of a system throughout its programmed life cycle. The net effect of this should be to ensure that the logistics concepts are included in the early systems work. This is not normally the case in most programs, even those that espouse concurrent engineering. However, for this project to work there are many interlocking components that have to come together at the right time. Concurrent Engineering has to be the name of the game.

The impact of logistics in the early phase of a program should really start at the level of the initial system design and partitioning. Figure 1; early Systems Work shows just how early this involvement is.

The logistician is going to be particularly interested in the following areas:

1. Reliability Partitioning.
2. Maintainability.
3. Acquisition Logistics for all items.
4. Spares Policy.
5. Transportation, both on the surface, to orbit and on-orbit.
6. Transportation planning on the surface, cargo manifest to orbit and on-orbit support.
7. Provisioning of “lifed” or perishable items
8. Acquisition and disposal of Radioactive materials
9. Technology insertion for system upgrades.
10. Bulk storage of Propellants, Water, Gases and Cryogenic fluids
11. Surface construction planning.
12. System level test and commissioning.
13. Software availability, testing and deployment, both commercial and “in house”.
14. Configuration monitoring and management support.
15. Surface warehousing, computer controls, database and software.
16. Transitioning the entire logistics management effort to the space segment.

Not all these tasks will happen at once but it may be seen that the logistics effort has to start early if it is to be effective.

Logistics activities are going to be found in almost every phase of activity, to the extent that they may not be called out as a separate discipline. The quality of people performing the functions has to be very high because it is intended that we use a very highly automated tracking system from freezing the design to the ultimate delivery to orbit.

The four separate projects overlap and interlock considerably both in timing and in equipment. There is also the resource allocation problem that has not been addressed but which will doubtless exist! Avionics and communications are a case in point. We intend to use common avionics fits for the HLV, the MV and the Base. We also intend to recover avionics equipment from the HLV’s and re-use them in either the Base or MV’s.

Once the Base is in existence the problem changes from one of initial activity to one of re-supply. The nature of the cargoes will also change to include much more in the way of foodstuffs and perishable items, but also bulk items such as propellants, gases etc. Late access to the HLV for stowage may present some interesting challenges to the logistics folk.

On top of all this will be the logistics associated with the paying customers. Payloads, payload components and personnel will all have unique, mission specific requirements that will have to be met. These requirements will probably be generated at relatively short notice and will need considerable flexibility on the part of the surface logistics people to fill.

Conclusions

One thought that has come out of the studies performed to date is that it is as necessary to design for logistics as it is for any other requirement or design driver.

Throughout our studies, we have looked for analogues in the space and other industries. The only one we have found is in the Oil Industry in the North Sea. Oil rigs have to be capable of being self-sufficient for several weeks at a time during the winter months. The Oil Rigs are a good analogy to establishing a Base Camp on a mountain because that is exactly what they are. They explore from the rigs – which offer all the necessary accommodations and comforts for the inhabitants.

So, there are analogues and experience that can be tapped for this project. SFO is currently refining all the system requirements and in the next year will a set of system requirement s for design to proceed. We are beginning to engage the services of Architects, both regular and Naval to make the final designs as livable as possible given the constraints on size. We are also about to start talking to the financial community with a view to raising the capital necessary to complete the program. We are not looking for government participation; this is a commercial project.