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Paper Session I-A - Generation of a Launch Infrastructure that Supports the Commercial Use of the Space Environment

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In this paper the author investigates the requirements that apply to a launch site that is purely commercial in nature. This launch site is optimized for high volume, high rate commercial space operations including co-located vehicle manufacturing; launch operations of both manned and unmanned vehicles and personnel support on orbit.

A conceptual design for such a base and its associated Range and facilities are presented. This design is contrasted with the facilities that are currently available to support space launch operations.

Lastly, several geographical locations are investigated in which it would be possible to build a range of this nature.

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Acronyms and Abbreviations

FAA	Federal Aviation Administration
GPS	Global Positioning System
HLV	Heavy Lift Vehicle
IVHM	Integrated Vehicle Health Monitoring
Kg	Kilogram
LEO	Low Earth Orbit
LH2	Liquid Hydrogen
LOX	Liquid Oxygen
LB	Launch Base
M&C	Maintenance and Construction
MV	Manned Vehicle
RP-1	Rocket Propellant-1 (Kerosene)
SB	Space Base
SEP	Space Exploration Plan
SFO	Space Frontier Operations, Inc.
TC	Transport Cradle

Introduction

Commercial operations in space are going to require a much greater commitment of time, energy and resources in the environment than anything hitherto attempted. People are going to have to be able to operate effectively in space in order to accomplish large-scale tasks such as those contemplated by various interested organizations. However, it is not going to be possible to continue with the exploration and exploitation of the space environment without a large foothold in space. This project is just the first part of gaining that foothold. Indeed, the U.S. Department of Commerce (Ref. 1)

recognizes that the single most important technical need for accelerating the growth of space commerce is effective, cheap, reliable and large-scale access. Large-scale access implies that there is something at the other end of the path into space that is capable of receiving and processing both the material and personnel necessary to support the commercial activity.

Several years ago, Space Frontier Operations, Inc. (SFO) proposed a large and comprehensive plan known as; "The Space Exploration Plan" (SEP) (Ref. 2). Subsequent to the publication of that plan at the 37th Space Congress considerable work has been done to both elaborate on and refine many of the technical and operational aspects of the various components.

The primary components of the SEP are:

1. A Space Base with a completed mass of around 32000 Tonnes in a circular orbit at an altitude of 1700 Km.

2. A Heavy Lift Vehicle capable of lifting 170 Tonne Payloads to the Space Base.

3. A Manned Vehicle with a crew of 2 and a passenger capability of 20 that can reach the Space Base.

4. A Launch Base capable of supporting the first three items listed above.

This paper addresses the Launch Base. Like the three other components it is designed to support the commercial operations made possible by the existence of the Space Base, the Heavy Lift Vehicle and the Manned Vehicle. As such it has to support not only the manufacture and launch of the vehicles and components of the Space Base but also the logistics requirements for both the Space Base and its commercial customers. The Space Base is designed to have a life of at least 100 years. The Launch Base will need to be able to service the Space Base and customers for at least that period of time.

Why a New Launch Site?

There are several distinct concerns that have to be addressed when considering a new launch site. These may be summarized as follows:

1. A site that is capable of servicing the proposed mission.

2. Social issues connected with establishing and operating such a site.

3. National political issues associated with establishing a launch range.

In order to investigate these in a little more detail we have a list of requirements that can be construed as necessary for commercial usage of any range:

1. A launch site that is dedicated to supporting a singular set of commercial flight operations.

2. A site that can support the flight rate required of a commercial entity.

3. A site with co-located manufacturing and launch operations in order to reduce transportation costs.

4. A facility where payloads and vehicles can be assembled rapidly, thereby reducing the payload dwell time at the launch site.

5. Safety and security aimed at protecting and supporting the commercial plant and mission and not necessarily supporting third party government needs.

6. A launch site that is not owned or operated by, or on behalf of, a government or government agency.

7. Operation of the Launch Base and associated Range will be purely civilian.

8. Meeting the flight rate will require significantly enhanced logistics functions.

As is usually the case, it is easiest to consider the technical issues first and progress to the social issues as the scale and implications of the technical solution becomes obvious. The requirements basically devolve into two categories; Operational Parameters and Launch Base Design Parameters. These will now be considered.

Operational Parameters

Before any work was started a few ground rules were laid for the operation of the Launch Base. Ground Rules of this nature have a profound effect on the way in which vehicles and payloads are processed and on the design of facilities for production. As a direct result of these considerations we have established the following ground rules:

1. Horizontal Integration and Transportation of the Heavy Launch Vehicle to the Launch Pad for erection, propellant loading and launch.

2. Heavy Lift Vehicle will spend no longer then 5 days on the Pad.

3. Manufacturing and Launch Facilities should be co-located.

4. Manned Vehicle to be processed separately and in parallel with the Heavy Lift Vehicle.

5. Payloads to be manifested and packed in shipping containers for flight at the Launch Base, either as complete payloads or as components.

6. Heavy Lift Vehicle will ship all types of payloads from bulk cryogenic liquids to bulk solids, powders and components of all types. Some containers will be available for food transportation.

7. Manned Vehicle has the capability to trade seats for small volume, high value cargo items and will provide the Late Access & Early Entry capability.

8. Capable of supporting near simultaneous launch operations from two separate pads.

The items noted above can be said to embrace the philosophy of the task but what determines the scale of the task is the flight rate and the rate at which it is necessary to construct the Space Base and then service it.

In order to support the requirement for a new and larger Launch Base we took a look at the current capability of the worldwide launch market to orbit the quantities of material needed by the Space Base. Table 1, "Approximate Worldwide Launch Tonnage per Year vs. SEP Requirement", shows the recent history of annual orbited mass achievement and compares that capability with our requirement.

Parameter	1999	2000	2001	2002	2003	Annual SEP Requirement
Approximate Tonnage Capability to LEO	657	831	627	679	520	**11050**
No. Of Launch Vehicle Types	26	25	22	25	27	**1**
No. of Launches	77	85	59	65	63	**65**
Average Tonnage/Launch	8.5	9.8	10.6	10.4	8.25	**170**

Data Source: FAA ; Year in Review Documents for 1999, 2000, 2001, 2002 & 2003 respectively.

Table 1, Approximate Worldwide Launch Tonnage per Year vs. SEP Requirement.

The SEP mass requirements are two orders of magnitude greater than anything that is currently available from all of the worlds launch sites. This comparison of current tonnage capability versus required tonnage capability effectively closes the case in favour of a completely new launch site dedicated to processing the mass requirements for the SEP.

To a limited extent, Table 1 addresses McClesky's, (Ref 3) comment: "For instance, tracking the amount of cargo mass loaded and unloaded from worldwide launch sites per annum, has not been uncovered". The numbers developed in Table 1 have been derived from data in published FAA documents. (Ref 4). These numbers are approximate and used only to illustrate the disparity between current capability and SEP requirements.

What Table 1 illustrates is that worldwide there are many launches on many different vehicles from several launch sites. Not only is the tonnage to orbit completely inadequate but the logistics of using all these vehicles and sites would be a nightmare! It would be impossible to tailor the commercial lift requirement to so many different vehicles and hope to attain any sort of efficiency of operations. The requirement for a new launch vehicle and launch site is thus further validated.

Launch Base Design Parameters

Having decided that we need a new Launch Base and having the luxury of a "Green Field Site" we have to decide what it is going to look like. Starting at the business end we need to determine the number of new Heavy Lift Pads that will be necessary to support this program.

Launch Pads

Traffic models used during the construction and subsequent "use phases" indicate that the flight rate for the Heavy Lift Vehicle can exceed 65 flights per year and in fact this is the design point for the launch systems. The Manned Vehicles will fly less frequently, but will still fly about 15 times a year. Both of these figures are in excess of anything so far attempted

The first thing to look at is the projected flight rate of the Heavy Lift Vehicle. At sixty-five flights a year we are going to need several Launch Pads. Sixty-five launches a year is one launch every five and a half days. Clearly we need more than one pad to support this flight rate. If pad dwell time for a vehicle is no more than five days and refurbishing time can be kept down to about ten days than we can use the pad every fifteen days or about twenty-four times a year. At that rate we need at least three new pads. In practice this is considered to be extremely optimistic because pad refurbishment will likely take around twenty days. This puts launches on twenty-five day centers and the rate per pad drops to about fourteen launches a year. This number yields a requirement for a minimum of five pads with some reserve capacity. We are choosing to build six pads and thus some spare capability in the event that any one pad suffers severe damage in a launch failure.

Pads will essentially be "clean" in that structures appearing above ground will be minimized. The Heavy Lift Vehicle will be transported on the Transport Cradle (TC) to the launch pad in the horizontal position and erected at the pad. The Transport Cradle will become the launch tower after erection, being withdrawn just prior to flight. All vehicle umbilical connections will be through the aft end of the HLV. The Launch Table will be established at the pad over the entrance to a flame trench.

Fibre optic and copper data paths will be available to all pads at the pad surface. Power systems will also be available. Provision will be made to isolate the power to an uninterruptible system for launch operations. Depending on the final location of the base it may be necessary to provide lightning and/or thermal protection for the vehicles while on the pad.

Pads will be equipped with LOX and LH2 Dewars and Kerosene, (RP-1) tanks and delivery systems as well as a Water Deluge System for sound suppression. Usage requirements for LOX, LH2 and other cryogenic gases used on the surface and on orbit may dictate that we manufacture cryogens on-site.

It is anticipated that the Manned Vehicle will be flown from the runways associated with the Launch Base and recovered on the same runways. Cryogens and various propellants will need to be available at the Manned Vehicle facility.

Final Assembly Area

The final assembly area will allow the assembly and test of a Heavy Lift Vehicle in about eight days. This will include final checkout and test prior to moving the stack to the pad. Faults will be repaired by replacement at this point. We intend to make use of as much automated checkout and Integrated Vehicle Health Monitoring (IVHM) technology as we can. Two vehicles will be in Final Assembly and Test simultaneously.

Stages are delivered to Final Assembly with all engines and controls fitted and tested. We expect the Surface Support Equipment (SSE) that the stages are assembled on will become the Transport Cradle and part of the launch support structure for transportation and erection.

The final piece of hardware integration will be the payload, assembled elsewhere in the facility and brought to the launch vehicle for integration. We expect there will be no active interfaces extending from the launch vehicle into the payload. In fact, we expect all but refrigerated payloads to be completely passive.

Transport from the Final Assembly Area to the Launch Pads will be by rail.

Payload Assembly

There are two basic types of payload that will be shipped to the Space Base via the heavy Lift Vehicle. They are:

1. Space Base Maintenance and Construction (M&C) payloads

2. Customer and Operations payloads

We anticipate that maintenance and construction payloads will taper off as the Space Base is completed. New construction will represent new investment either by the owners of the Space Base or customers requiring the construction of their own facilities. M & C payloads will also be the bulk shipping method for many items. Specific cargo carriers will be available for all forms of cargo.

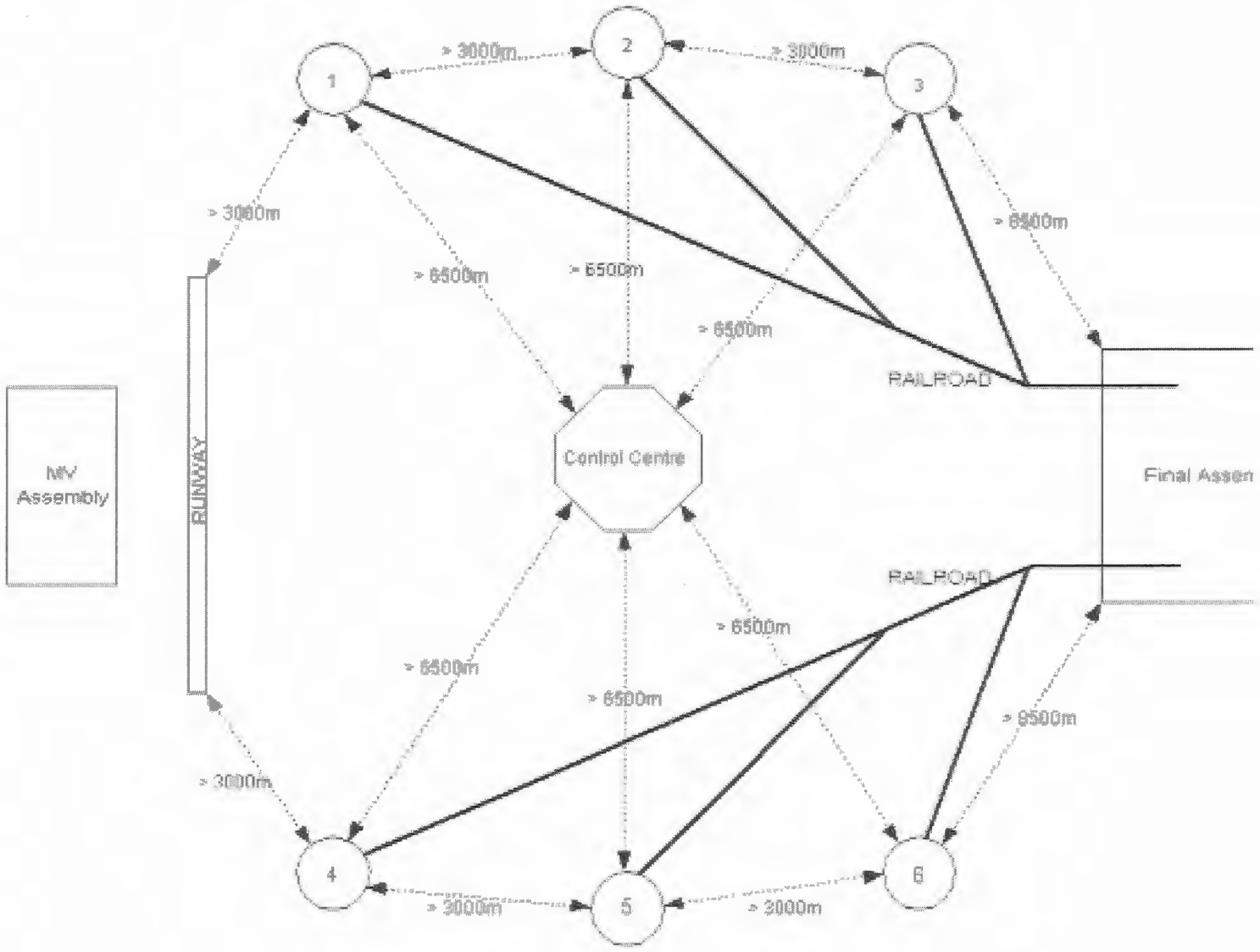

Fig. 1 Proposed Range Head and Launch Pad Layout

Customer payloads are just that – anything the customer needs to place in space. There is one important caveat that must be stated and that is that the Heavy Lift Vehicle will not deliver completed spacecraft payloads to operational orbits. Customer spacecraft will be shipped either complete or in component form to the Space Base for Assembly, Integration, Test and launch.

Stage Assembly Areas

Each HLV stage will be assembled and tested using IVHM and other automated systems prior to delivery to the Final Assembly Area. At this point we are not sure how much of the non-structural manufacturing will be done on site because the components are becoming quite small and are easily shipped.

Control Centre

This building will be centrally located with respect to the pads and to the runway so that all traffic control functions can be exercised from a single location. All flight control functions for launch and injection and Manned Vehicle launch and recovery will be located here. Real time data from launch operations will be fed into the centre from remote down-range locations for processing and storage. Manufacturing locations that will be monitoring tests will also feed data to the Control Centre. Data will be fed automatically from the Control Centre to the Space Base. The Control Centre will be capable of fully supporting two simultaneous HLV Launches and one MV operation.

Manned Vehicle Facility

This facility will be located close to the runway(s) in the manner of a standard airport with Hangars and Taxiways. To all intents and purposes the Manned Vehicle Facility will be a commercial airport with capabilities for accepting Category 3 traffic. The purpose of this facility will be construction, surface operation and servicing of the Manned Vehicles as well as the surface storage base for the vehicles between flights. Real time data from MV operations will be fed into the Control Centre from remote down-range locations for processing and storage. Manned Vehicles are expected to operate from the runway and to return to it at the end of flight. Some Manned vehicles will be based permanently at the Space Base.

Miscellaneous Facilities

Behind the primary facilities are a host of smaller workshops, warehouses and offices dedicated to specific tasks concerning the engineering, production and maintenance of all the vehicles and facilities on the Launch Base. It is unnecessary to go into detail here except to recognize that these functions are required.

Range Operations

Range operations will be important to the ultimate success of any given launch. At the moment we envisage having telemetry receiving stations located downrange to recover and forward by Internet the data from Heavy Lift Vehicles and Manned Vehicles in flight. These stations may be resident in foreign countries and will require some international coordination using the good offices of the host nation.

The use of radar in the context of tracking targets in flight is not considered necessary for nominal flight characteristics because we will be using GPS data to generate the necessary track data. However, if we experience a failure in flight that leads to the deliberate or accidental destruction of the launch vehicle the necessity to track components to impact has to be addressed. In such a scenario it is unlikely that GPS

data will be available and we will have to rely either on propagated GPS data or skin track radar data to constrain the uncertainty ellipse of the impact footprint.

Radar located on the Launch Base is probably a requirement for the successful operation of the Manned Vehicle. Such radar systems can be used for both Beacon and Skin tracking of the Heavy Lift Vehicles in the early stages of flight and perhaps as far as first stage separation.

In addition to the technical aspects of Range Operations there will also be the administrative aspects such as controlling airspace during launch operations. It may also be necessary to control ground incursions during launch operations as well.

Logistics Operations

In the context of the Launch Base, logistics has to encompass everything that enters and most of what leaves the Launch Base by whatever means. The logistics requirement falls neatly into two areas;

1. Flight related items

2. Surface related items

Flight related items are basically anything that will fly, either as a payload component or as a launch vehicle component.

Surface related items are the products and materials used to support both the Launch Base and the flight vehicle production equipment. Surface related items may have flight interfaces and therefore should be treated as flight items.

With the flight rates noted earlier the logistics function is going to require considerable automation. Flight manifests are going to be developed in the logistics world so that preparation and packaging of the individual payload components can proceed with little or no impact to the preparation of flight vehicles. There will inevitably be some interchangeability of payload components based on the way in which material comes together from individual customers.

The logistics functions developed on the surface will be duplicated on the Space Base. There will be a requirement to establish what amount to "Bonded Warehouses" in both locations in order to track and control the equipment that is shipped and to ensure that it reaches its appropriate destination.

Safety Operations

Safety in the context of launch operations is a mixture of tools and processes involving everything from the relatively mundane occupational and manufacturing process safety issues to major safety issues involving large quantities of extremely hazardous materials and explosive ordnance. All these risks have to be quantified and controlled in such a way as to protect personnel and aid the progress of the overall task.

Flight, Range and Ordnance safety are directly applicable to the operation of both the Heavy Lift and the Manned Vehicles. Occupational and Process safety are applicable to the operations and manufacturing processes used in production of the vehicles and the Space Base. These processes will migrate to the flight environment as the Space Base becomes operational.

Ordnance safety is essentially a set of procedural disciplines aimed at safely using and storing explosive ordnance and accounting for the use and disposition of ordnance components.

Flight and Range safety is self-explanatory in that vehicles are monitored in the early phases of flight and may be subject to deliberate termination of flight in the event of anomalous performance but it also includes analysis of the risks associated with any particular launch. Range safety also includes the concurrence of the host nation in the launch effort and the associated underwriting of the launch risk in terms of international law.

Social Implications of Establishing a Large Launch Base

Social implications in this context are the impact of a project of this size on the indigenous economy and people. It is quite probable that this project will be located in a relatively unpopulated area of the world. Under such circumstances we have to approach the building of a base of this nature with sensitivity and circumspection, endeavouring to do as little damage as possible to the local and down-range environments and economies. In fact, it is highly probable that we will be importing people into the area to work in the facilities we construct. Demands that are placed on the local economy for housing, recreation, training, hospitals and transportation etc. will probably have to be met from resources belonging initially to the corporation with local people taking these over as the area matures. It is not possible to avoid placing additional loads on the local infrastructure for power, transportation, schools and policing etc but the cost of these should be met from the considerable increase in the local tax base. Given the length of time this project is designed to operate over, the economic impact to the launch area will be considerable.

National Issues

In addition to the local and state/provincial issues that affect the immediate environment of the Launch Base we have to consider the impact of Range Operations on neighbouring countries. In the first years we are probably going to be dropping spent first stages in the oceans. It is imperative that we operate in a manner that is conducive to securing the cooperation of the national host country. Although there will not be government ownership of the facilities and vehicles there will still be a national interest in both the safety and success of the system. The potential economic benefits to the host nation are significant and of long duration. Those benefits will need to be protected, preserved and enhanced.

Potential Launch Sites Identified

During our search of the world for potential launch sites we identified several areas that could be possible launch sites. However, one of the prerequisites for being used as such is that the country has a history of political stability. There are some countries like the USA, most of Europe and some places in Asia where it is no longer possible to build a site of this size privately simply because all the commercially available land has been used for other purposes. This and other geopolitical issues rule out a lot of countries at the moment and we were left with the initial list of countries and sites shown below:

1. Canada; Fort Churchill, MB
2. Australia; WRE Woomera, SA
3. Brazil; Alcantara
4. United Kingdom; Northern Scotland

It is possible to construct the necessary facilities in any of these countries. At the time of writing we are about to commence initial discussions with all of these countries. It is by no means certain that we will be successful in anything other than a marginally populated area.

Conclusions and Future Work

The sheer size of the SEP launch requirements mandate a new launch facility; there are no sites capable of supporting this launch rate or mass requirement to orbit in the world today. Indeed, most of the current ranges are not optimized for one vehicle; they have to support several R & D systems. The demonstrated need is for a dedicated launch site with considerable industrial capability.

We are actively pursuing discussion with the governments noted in the list of potential launch sites.

With respect to the Launch Base, work is continuing to refine the industrial and operational components of the launch area. This work is proceeding in parallel with work to further refine the designs of both the Heavy Lift and Manned Vehicles.

One of the major areas in which work is proceeding rapidly is with the development of an Internet Capable Telemetry Receiving System housed in a small trailer.

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