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The Astral Highway: A National Space Infrastructure+

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Abstract

This paper discusses the need for a national space transportation and in-space logistical support infrastructure. It proposes that this space infrastructure be built through a partnership of the Government and private industry. A scenario and schedule for developing this infrastructure and suggested technical approaches for building its primary elements are described.

Introduction

The United States has the technological capability and clear need to begin to build a robust space transportation, habitation, and in-space logistical support infrastructure in the first decade of the new century. This national space infrastructure will revolutionize all three sectors of the U.S. space program—commercial, civil, and national defense. While it will improve the safety, reliability, and affordability of the current space operations, more importantly it will enable and stimulate the creation of new human and robotic space operations. In creating a robust space infrastructure, the United States will further enhance its world leadership position, stimulate continued economic growth, and position itself as the first true spacefaring nation.

The opportunity at hand

Critical decisions are now being made that will determine the course of U.S. space activities for the next quarter of a century. NASA will lead with a decision on how to proceed with the Reusable Launch Vehicle (RLV) program now underway with the Lockheed Martin X-33. The Air Force will decide how it will transition from an air force to the aerospace force envisioned in *Global Engagement: a Vision of the 21st Century Air Force* (Ref.1). The U.S. commercial space sector will decide what to undertake next once the expansion of satellite-based communication systems, such as Teledesic, are completed.

While the leaders of these space sectors might pursue making these decisions in isolation, the true opportunity for creating a spacefaring nation—the vision that has fueled the U.S. space program for 30 years—lies in how their needs and plans can be integrated. Fortunately, the United States now has the technological ability to affordably make this

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vision real; but only if the three currently segregated space sectors are joined together to build a national space infrastructure—an astral highway.

Why a national space infrastructure should be built now

The simple reason for starting to build a national space infrastructure at this time is that, drawing upon our history with such ventures (i.e. satellite communications, Global Positioning System, Internet, etc.), we are better off being first in undertaking new ventures with significant economic and national security benefits.

Being first in building new infrastructure enables early U.S. industry leadership in the creation of the enterprises and the formation of the standards and protocols that exploit the new capability. This, in turn, enhances the U.S. industry's technology leadership that is a foundation of our national defense strategy. Being first has led to much of the United States' prosperity and national security since World War II. Given the growing importance of space to our nation, there is no apparent reason to believe that similar benefits would not be achieved from being first in building a national space infrastructure.

What is needed

The proposed national space infrastructure is to be developed and deployed in two phases (Ref. 2):

Phase 1 (2001-2020) activities would design, develop, build, deploy, and operate a space infrastructure extending from the Earth's surface to the surface of the Moon and Mars. This infrastructure would fulfill the common needs of commercial and governmental human and robotic activities in circumterrestrial space, in circumlunar space, and on the lunar surface. It would support the initial human exploration of Mars and the near-Earth asteroids and comets.

During Phase 2 (2020-2040), the space infrastructure would be extended to support extensive human settlement and industry in circumterrestrial space, in circumlunar space, and on the lunar surface. Further, it would support the initial human settlement of Mars, the exploitation of near-Earth asteroids and comets, and the beginning of the direct human exploration of the rest of the solar system.

How this infrastructure would be built

Phase 1 of the proposed space infrastructure has six primary elements—transportation, habitation, in-space logistical support, communications, energy production and distribution, and administration. The first three are discussed in detail to demonstrate that the technological capability to proceed now exists.

Of the latter three, the communications needs are expected to be satisfied with evolutionary improvements to the satellite-based communication systems now being built. Energy production and distribution systems will initially be incorporated directly into the large habitats described below. However, as future in-space energy demands grow, an in-space energy production and distribution system will be needed. An administration element—the United States Space Infrastructure Authority (USSIA)—would be needed to oversee the planning, building, and operation of the infrastructure. This administrative element, similar in purpose to the Tennessee Valley Authority, is discussed below.

RLV Transportation

The first of three transportation systems incorporated into the initial space infrastructure would be RLVs. They would provide scheduled "airline-like" transportation of people and materiel to and from low Earth orbit (LEO). These RLVs would carry roughly 11,400 kg

(25,000 lb) payloads to spaceports in LEO. They could also be used to directly deploy satellites.

The critical technologies for RLVs have been under development for over 25 years. By the completion of the X-33 program in 2000, approximately $4 billion will have been spent on RLV technology and concept development in the last fifteen years.

RLVs will be designed for safety, operability, payload carriage compatibility, and overall affordability. Possible RLV configurations include: single-stage-to-orbit (SSTO) systems such as the Lockheed Martin VentureStar; augmented SSTO systems which use some means of launch assistance, such as the Boeing Reusable Aerospace Vehicle; ground-launched two-stage-to-orbit (TSTO) systems; or, air-launched TSTO systems where the carrier aircraft is the first stage.

Just as with commercial aircraft, the selection of the specific RLV configurations would be the prerogative of the developers based upon their technological expertise and chosen means to best satisfy their customers' needs. Undertaking a specific technical approach, such as airbreathing propulsion or SSTO, is not required to implement a safe and affordable first-generation RLV capability.

The proposed space infrastructure should have a minimum of three distinctly different RLV designs to provide assured access to space for critical government spacelift missions such as launching national security payloads and supporting expanded civil and military capabilities in space. At least three designs are also necessary to create and sustain competition in the privately-owned spaceline operations that will provide spacelift services supporting the space infrastructure. This competition, a vital element of successful shared infrastructure, will stimulate improvements and reduce costs in much the same manner subsonic commercial aviation has experienced during the last 50 years.[1]

Heavy Spacelift

Building infrastructure inherently requires transporting large and heavy components of permanent facilities to a construction site. On the Earth, special flatbed trucks, railroad cars, helicopters, and cargo aircraft are used for this purpose.

For similar reasons, building a space infrastructure requires a heavy spacelift capability to LEO. Rather than imposing this requirement on the RLVs, it can be best met with an expendable Shuttle Derived Vehicle or SDV (Figure 1). RLVs can then be sized, in terms of payload capacity, to affordably meet routine spacelift needs while the SDV heavy spacelift system is used to launch the large payloads necessary to build the orbiting elements of the infrastructure.[2] This approach also provides an affordable means of launching large commercial, civil, and national security payloads that would otherwise not be feasible to consider.

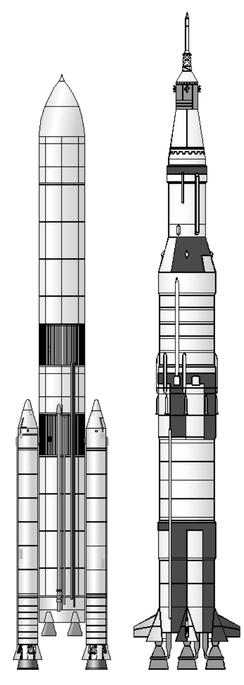

Figure 1
SDV (left) &
Saturn V (right)

Intentionally, the SDV concept reuses many Space Shuttle technologies, as well as fabrication, vehicle assembly, and

[1] Compare the advancements in subsonic commercial aviation, where competition exists, with the lack of advancement in supersonic commercial aviation where there has been no competition.

[2] Magnum, a Shuttle-derived system, is under internal study by NASA Marshall Space Flight Center.

launch facilities. This preserves facilities and expertise that would otherwise be abandoned as RLVs are brought into service and extends the benefits derived from the substantial investments already made in these resources. This approach avoids much of the development and facility costs inherent in developing an entirely new system, enabling the crucial heavy-lift launch capability to be affordably re-established. It also provides a sound economic basis for updating selected portions of this infrastructure, such as replacing the solid rocket boosters with fully reusable liquid fly-back boosters, to improve both the affordability and reliability of the SDV.

The SDV's heavy spacelift capacity enables large modules, weighing upwards of 90,000 kg (200,000 lb), to be built and fully tested on the ground and launched into orbit ready for immediate use or integration into orbiting facilities.[3] This provides an affordable means to build large spaceports—another element of the space infrastructure—needed to house the people who would operate and use the space infrastructure. Commercial, civil, and national defense sectors can also use the SDV to build space facilities larger in size and of greater complexity than would otherwise be achievable or affordable.

Spaceplanes

Orbit-based spaceplanes would extend the RLV "airline-like" transportation network into circumterrestrial space to connect spaceports with co-orbiting space facilities and clusters of similar facilities in different low Earth orbits.[4] Spaceplanes, as this new capability matures, would be used to transport people and materiel to higher earth orbits for satellite maintenance, repair, and recovery. Eventually, they could also ferry exploration crews back to the Moon and support the exploration of near-Earth asteroids and comets to search for needed natural resources, primarily water for propellants and life support.

In the early 1990s, the Department of Defense undertook a research program with McDonnell Douglas to build an experimental 20,500 kg (45,000 lb) Delta Clipper-Experimental (DC-X). Renamed the "Clipper Graham," this fully-reusable rocket successfully demonstrated the critical technologies and integration of these technologies into a flying testbed that is representative of a first-generation spaceplane in terms of weight, propellant types, and performance (Figure 2). A spaceplane derived from this DC-X-demonstrated technology base, augmented with technologies being developed by NASA for the X-38 Crew Return Vehicle, would meet the initial in-space transportation needs of the space infrastructure (Figure 3).

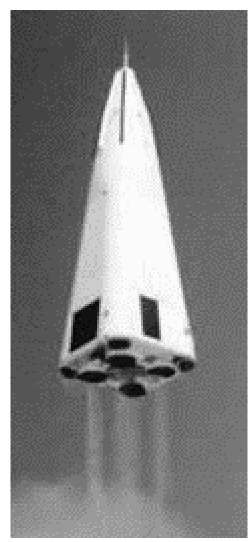

Figure 2
DC-X

Carried into orbit in the payload bay of an RLV, these DC-X size transports would be based, maintained, and serviced at the orbiting spaceports. Specialized modules attached externally would be used for moving people and materiel to co-orbiting space facilities, deploying and recovering satellites out through geosynchronous orbit, and conducting emergency space search and rescue.

[3] It is far less expensive, even for aerospace systems, to build the systems on the ground and launch them fully or substantially assembled into orbit.

[4] The nomenclature "spaceplane" is used to draw upon the essential characteristics of safety, reliability, and operability inherent in modern aircraft. That the spaceplane may not have wings is no more significant than the fact that a modern ship does not have sails as they had for millennia.

Toward the end of Phase 1, larger versions of these spaceplanes, the first interplanetary spacecruisers, could be carried into orbit on the SDV. Commercialized versions operated as spaceliners would be used for space tourism cruises around the Moon. Government-operated versions would be used to establish and support permanent bases on the Moon and to explore and exploit near-Earth asteroid and comet resources. They may also be used by a "Space Guard" for space search and rescue. Equipped with spaceplanes modified for surface landing, as demonstrated in the DC-X program, these spacecruisers would transport exploration and operating crews to and from the Moon and could support a manned Mars exploration program.

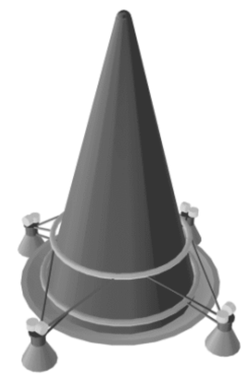

Figure 3
Notional small spaceplane

Orbiting Spaceports

Large LEO spaceports would provide the primary in-space facilities for the proposed space infrastructure during Phase 1 (Ref. 3). These spaceports would be the primary destination for ground-based RLVs, the operating base for spaceplanes and interplanetary spacecruisers, the initial orbital habitats, the primary shared infrastructure logistics operations base, and the anchor for a growing cluster of co-orbiting space facilities.

Suitable large spaceports can be constructed from modules launched into orbit using the SDV. For example, the spaceport configuration shown in Figure 4 is comprised of four spokes attached to a central hub. It is 270 m (890 ft) in length along the hub and 190 m (620 ft) in width across the spokes. The internal volume is approximately 20,000 cubic meters. This spaceport configuration is designed to rotate about the hub at approximately two revolutions per minute to produce sub-Earth gravity in the spokes.

Eight SDVs are used to launch the modules for assembling this spaceport: one SDV launch for each spoke, one launch for each of the airlocks located at the ends of the hub, and one launch for the central hub module to which the spokes are attached. The remaining SDV launch is used for oversize components such as the solar arrays and waste heat radiators.

This spaceport configuration, like the SDV, adapts the existing Space Shuttle technol-

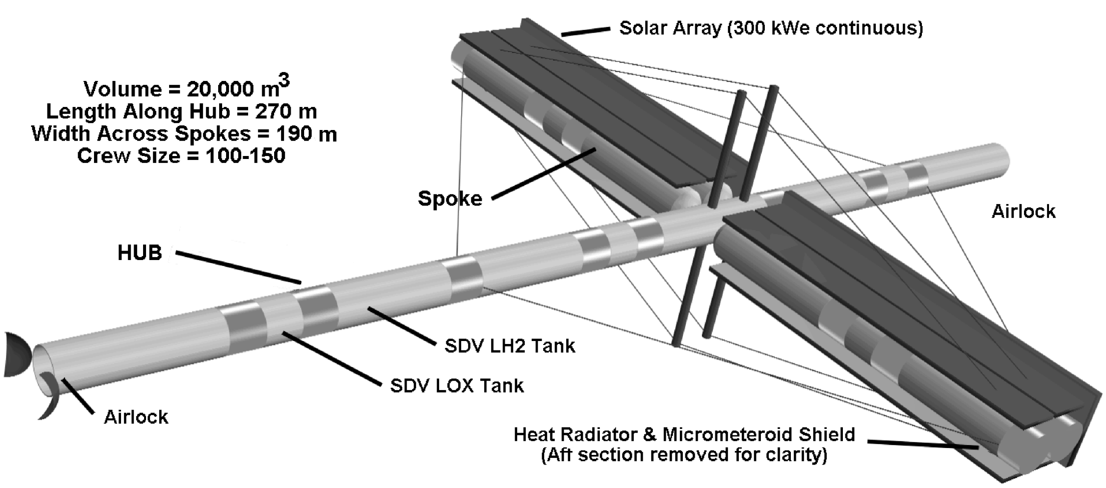

Figure 4
Notional LEO spaceport - basic configuration with four spokes

ogy and support infrastructure to minimize development and production costs. The primary spaceport modules would be fabricated using the same manufacturing facilities currently used to build the liquid hydrogen (LH2) and liquid oxygen (LOX) propellant tanks for the Space Shuttle and would also be used to build the SDV propellant tanks. This enables large modules—8.4 m in diameter and 30 m in length (27.5 ft diameter by 100 ft in length)—to be economically fabricated without requiring the development of a costly new production facility and processes.

These primary spaceport modules would be fabricated in three configurations. The airlock module is capable of holding the 4.3 m (14 ft) diameter by 9 m (30 ft) long payload modules transported to orbit in the RLVs. This enables loading and unloading passengers and materiel within the pressurized airlock without the need for extra-vehicular activity (EVA). It also provides the ability to maintain and repair satellites and service spaceplanes within a pressurized environment.

The hub's spoke attachment module is designed to accommodate 12 spokes arranged in four rows (Figure 5). This enables the basic spaceport configuration of four spokes to be tripled in size to 12 spokes and provides a simple method to add capability to meet the specialized needs of space infrastructure users.

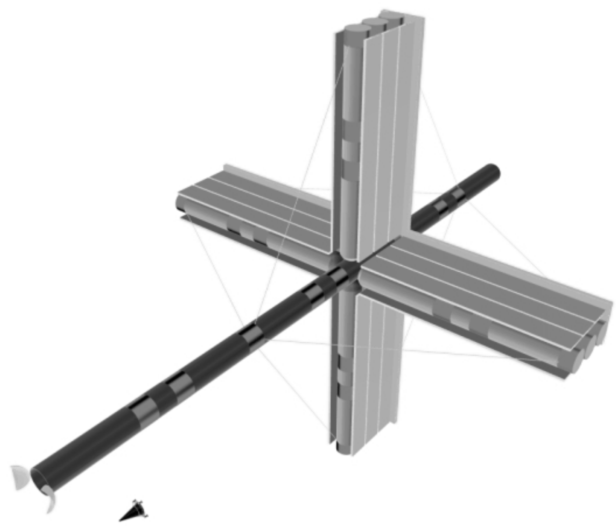

Figure 5
Notional spaceport with 12 spokes
(Spaceplane shown adjacent to airlock)

The spaceport's design has been developed to incorporate the SDV's LH2 and LOX tanks directly into its configuration. An examination of a spoke will show that it is comprised of a spoke payload module on the inside where it attaches to the hub, followed by the LOX tank and then the LH2 tank. Essentially, each spoke is comprised of the core of the SDV launch vehicle—the payload module, the LOX tank, and the LH2 tank (See Figure 1). The SDV propellant tanks integrated into the spaceport in this manner would be designed for on-orbit retrofit and would include provisions to add orbital debris and radiation shielding.

Artificial gravity, created by rotating the spaceport, enables each spoke to be divided into 17 floors. In the basic configuration of four spokes, this totals 68 floors with a usable floor area of 3,300 m^2 (35,000 ft^2). In the expanded configuration with 12 spokes, there are 204 floors with a usable floor area of 9,900 m^2 (105,000 ft^2). This would provide about 33 m^2 (360 ft^2) per person for a crew of 100 with the basic configuration and a crew of 300 with the fully expanded configuration.

After the completion of the initial spaceports, modified modules can be used to build special purpose co-orbiting facilities. Examples are space manufacturing facilities, space hotels, research and development facilities, and construction facilities for building solar power satellites and assembling manned planetary exploration vehicles.

<u>In-Space Logistical Support</u>

The proposed space infrastructure will provide its own in-space logistical support. This will include: fueling transports, performing preventative maintenance and upgrades, undertaking repairs, maintaining stocks of replacement parts and expendables, providing repair and maintenance facilities, maintaining life support systems, disposing of waste products, and providing trained support personnel. It will also provide for the living, health care, recreation, education, and safety needs of the permanently-stationed and transient spaceport personnel.

As this logistical support capability is an integral part of the national space infrastructure, it would be available for use by the commercial, civil, and national defense sectors to reduce the cost of developing and operating their specialized operations. Developers can relax standards for quality and redundancy to levels comparable with terrestrial aeronautical systems. Scheduled maintenance can be used to reduce the risk of unplanned system outages, just as is commonly done on terrestrial systems. Provisions for replenishment and upgrades can be provided to prolong the useful life and allow technology advancements to be periodically incorporated. Just as with terrestrial activities, the ready availability of logistical support permits the specialized space operators to focus on effectively executing their specialized operations while the space infrastructure handles the logistics support.

The availability of in-space logistical support should enhance public and private investor confidence in the success of new space ventures. Political support, reflecting growing public confidence and the more affordable costs of such programs, should also increase for Government-led projects such as manned space exploration programs and building space settlements.

The roles of the Government and private industry

The federal Government has two key roles in creating the national space infrastructure. The first is that of anchor customer for space infrastructure transportation and logistical support services. This is essential for creating the market demand crucial to generating the private investment required to establish new commercial space services.[5]

The second federal Government role is the formation of a new organization to oversee building and operating the space infrastructure. Modeled after the Tennessee Valley Authority, the United States Space Infrastructure Authority (USSIA) would be a federally chartered, not-for-profit corporation. Its responsibilities would include:

- Oversee the creation of the commercial space services that would provide the backbone capabilities for the national space infrastructure.
- Act as the Government's agent in contracting for services such as spacelift and spaceport operations.
- In the name of the Government, own critical elements of the infrastructure, such as the LEO spaceports, necessary to protect the public's interest and ensure fair access by Government and commercial users.
- Maintain control over the type and location of facilities co-orbiting with the spaceports to protect public safety and ensure unobstructed passage to the spaceports.
- Regulate access to space facilities, e.g., spaceports, as necessary to protect safety and ensure the efficient operation of these facilities.
- Collect revenues from commercial and Government users to provide for its operating needs and finance future infrastructure expansion.

[5] The federal Government would also provide technical and administrative assistance to the USSIA and the commercial service providers.

- Ensure the faithful execution of the principles, practices, and standards necessary to make all infrastructure elements safe and interoperable.

The third element is the companies that will, through competitive selection, provide the backbone commercial services. Examples include: spaceline companies to own and operate the RLVs; a launch service company to build and launch the SDVs; orbiting facility managers to build and operate the LEO spaceports and related orbital facilities; and, spaceplane operators to build and operate the orbit-based spaceplanes.

Executing Phase 1

Just as with large-scale terrestrial projects, building the national space infrastructure would be undertaken through a series of projects to yield an integrated capability. Figure 6 provides a top-level view of the proposed Phase 1 development and deployment schedule.

Planning and Systems Architecture Definition

Building the Astral Highway would begin with a planning phase. This will include:

- Establishing the overall infrastructure architecture;
- Defining key interfaces;
- Selecting the guiding engineering principles, practices, and standards;
- Defining basic performance requirements for the major elements such as the RLVs;
- Establishing the roles of the Government, USSIA, and the commercial suppliers in building the infrastructure; and,

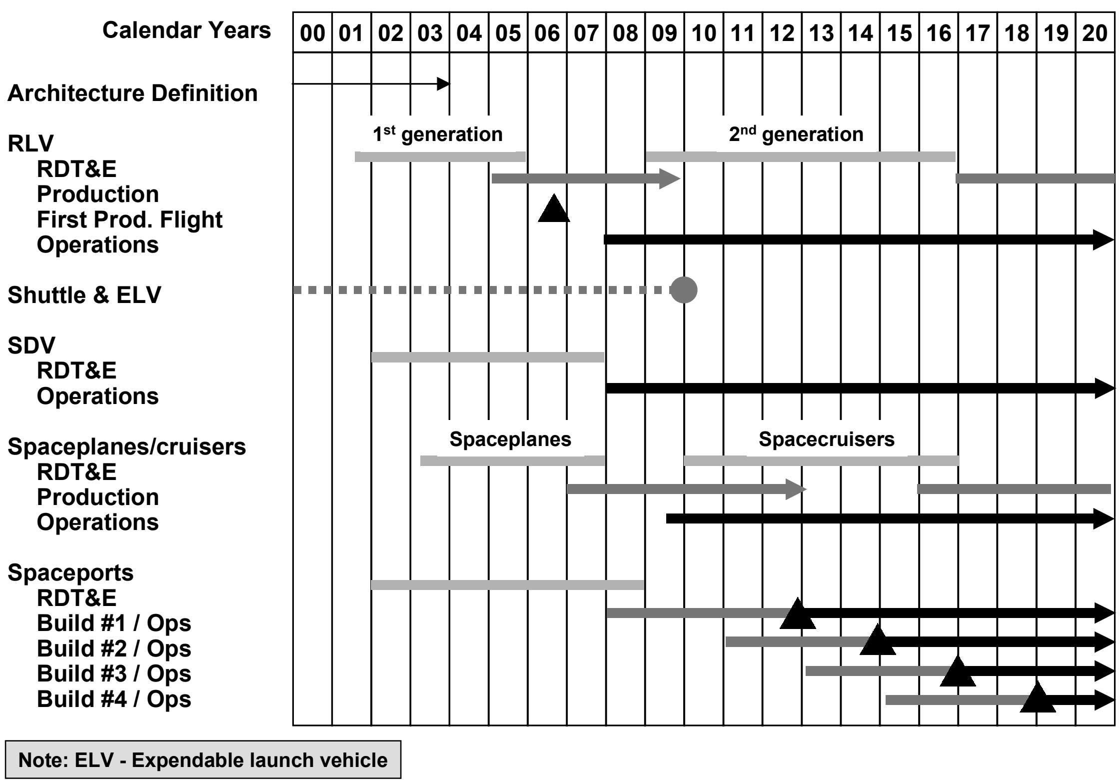

Figure 6
Notional Astral Highway Phase 1 Schedule

- Establishing the baseline schedule.

The initial cost, schedule, and risk measurement metrics used to monitor progress throughout the research, development, test, and evaluation (RDT&E) phase would also be established during this planning phase.

RLVs

With the assistance of the Government agencies it will represent, the USSIA would establish RLV performance, interface, safety, and operability requirements, projected minimum flight rates, and an initial desired availability date. A Request for Proposal (RFP) would be released to U.S. industry to contract for spacelift services using flight systems responsive to these requirements. Three commercial spacelift service providers would be selected based upon proposals responsive to the RFP. Selection considerations would include:

- Proposed initial availability date;
- Projected initial and final flight rates;
- Non-recurring and recurring flight costs;
- Required Government progress payments during the RDT&E phase;
- Key cost, schedule, and performance metrics;
- RDT&E progress payment and exit criteria;
- Critical technology availability;
- Relevant technical and management expertise;
- Amount, type, source, and limitations of private financing;
- Proposed approach to meet Government and USSIA safety, operability, payload interface, and assured access requirements;
- Partnership arrangements with the prime aerospace contractor(s) that will develop and build the RLVs; and,
- Marketing plans to attract commercial users of these RLV spacelift services.

Following source selection, each of the three selected contractors would receive a multi-year spacelift service contract from the USSIA. This contract would provide for the purchase of approximately 15 RLV flights per year per provider—for a total of 45 flights—for a period of up to seven years at a negotiated cost per flight.[6] It is projected that the per flight cost would be in the range of $50M to $100M, depending upon the total amount of any progress payments made during RDT&E.[7]

Additional Government and USSIA RLV flights during the period of this contract would be competitively purchased at market prices. This is expected to be in the range of $5 to $10M per flight.[8] To stimulate commercial demand for spacelift services, commercial RLV customers would also purchase RLV flights at market rates directly from the spacelift companies.

The USSIA baseline spacelift service contracts would be negotiated to ensure the use of at least three different RLVs designs to meet Government assured access needs. With a

[6] This is an average rate over the life of the contract. The early flight rate would be lower and the flight rate at the end of the contract higher.

[7] As the anchor customer, the initial spacelift service contract is expected to cover a substantial percentage of the RDT&E costs of the RLVs. However, the extent of the Government's payments of these costs would be negotiated in the selection of the spacelift service providers.

[8] Commercial expendable launch vehicles currently cost $40M to $80M per flight. The cost of a Space Shuttle launch is approximately $300M per flight.

required fleet size of at least four flight systems of each type, this provides a minimum of twelve RLV flight systems. At a flight rate of once per month per flight system, this provides an initial capacity of 108 flights per year based upon a 75 percent availability rate. The Government and USSIA would use 45 flights per year for replacing the Space Shuttle and expendable launch vehicle (ELV) launches and for testing and building the orbiting elements of the space infrastructure. The remaining 63 flights per year would be available for commercial purchase.

As the flight rate builds to one flight per week per flight system by 2015, the total annual capacity would grow to 468 flights per year. At this time, the Government and USSIA are expected to require 150 to 200 flights for space infrastructure support and to meet civil and national defense needs. These would be purchased using competitive bids after the initial spacelift contracts have expired.[9]

The RLVs are expected to enter service in 2008, following approximately 18 months of operational test and evaluation of the initial production vehicles. Initially, they would be used to launch Government satellites and support the RDT&E of space infrastructure elements, such as spaceplanes. As these vehicles achieve specified reliability milestones, they would replace the Space Shuttle for crew rotation launches for the International Space Station. Flight operations of the Space Shuttle and ELVs should be completed by the end of 2009.

Spaceports and SDV

Similar to the process used for RLVs, the USSIA would establish performance, safety, interface, and operability requirements for the LEO spaceports and the SDVs. An RFP incorporating these requirements would be released to U.S. industry following the selection of the RLV contractors.

Unlike the RLVs where multiple service providers and RLV designs would be used to mitigate risk and stimulate competition, this approach does not appear to be appropriate for the spaceports and SDV. This is because of the major facilities required to support SDV fabrication and launch, the limited number of launches per year, and the close linkage between the design of the SDV and the spaceport. It is expected that a single contractor or consortium of contractors would be selected to develop, build, and launch the SDVs and develop and build the spaceports.

Initial preliminary design contracts would be issued to at least two contractor teams responding to the RFP. Following a one-year competitive preliminary design phase, a down-select to a single contractor would be made for the first spaceport and the SDVs required to launch the spaceport's modules. Options for three additional spaceports would be included in the contract, as would options for additional SDV flights to meet Government and USSIA heavy spacelift needs.

The schedule of the spaceport and SDV development programs would be paced by the RLV programs. As seen in Figure 6, the SDV is targeted for operational availability in 2008, the same time as the targeted operational availability date of the RLVs. This timing has been selected to provide a clean transition from manned Space Shuttle to unmanned SDV launches during the 2008-2009 time period. The objective is to maintain a constant launch rate of five to eight launches per year at the Kennedy Space Center in order to minimize transition disruptions as Space Shuttle operations are phased out.

[9] At $10M per flight, 200 Government and USSIA flights per year would cost less that the current annual cost of eight Space Shuttle flights.

The early SDV flights would be used to launch prototype spaceport modules and infrastructure elements into LEO for test and evaluation. SDVs would also be available to launch large Government payloads such as a prototype space-based laser for missile defense and a Hubble II space observatory. Commercial users of the SDVs, perhaps for launching large geostationary communication satellites, would purchase SDV launches directly from the SDV contractor.

Assembly of the first spaceport would start in 2009 using modules launched via the SDV and supported with assembly crews transported to LEO in the RLVs. Assembly would be completed in 2012, followed by one year of facility testing and crew training. Eight SDV launches and 25-30 RLV flights would be used to undertake the spaceport assembly, testing, and crew training.[10]

To maintain cost-efficient spaceport module production and corresponding SDV flight rates, three additional spaceports would be built starting in 2011 and completed in 2018. This will require four SDV flights per year. With a projected capacity of 12 flights per year, this provides eight additional SDV flights each year to launch large Government and commercial payloads as well as expansion spokes for the spaceports. Following completion of the fourth spaceport in 2018, it is expected that commercial and non-U.S. demand for spaceports and co-orbiting facilities will maintain a steady production rate of spaceport modules and SDV launches.

Spaceplanes

The development of the orbit-based spaceplanes would begin in 2003, timed to follow the completion of the critical design reviews for the RLVs. This timing will permit the spaceplane to share technologies with the RLVs, draw upon technical expertise being developed in the RLV program, and ensure that the payload interface between the RLV and the spaceplane is well defined.

Two independent spaceplane designs would be developed and produced to address the technical uncertainties of these first generation systems. Prototype spaceplanes would be first flown in LEO in 2006. They would be launched into space using the Space Shuttle or a medium-lift ELV. Flight testing of the production spaceplanes would begin in 2009. They would be transported into orbit and recovered from orbit in the payload bay of the first operational RLVs.

The first operational spaceplanes would be deployed to the first spaceport's construction site in 2010. They would be used primarily for crew training and space search and rescue support for the construction crews. Derivatives of these spaceplanes configured as spacetugs would also be developed and deployed to the construction site during this time period.

Larger, interplanetary versions of these spaceplanes—the first spacecruisers—would complete RDT&E in 2015 and enter service in 2018. They would be built on the Earth and transported into orbit by SDVs. They, along with modified versions of the original spaceplanes equipped for surface landing, would be used to extend the integrated space transportation system to the Moon and beyond.

2020 Capabilities

At the end of Phase 1, four spaceports, expanded with additional spokes and housing 300 people each, would orbit the Earth at inclinations of 15 deg, 30 deg, 45 deg, and 75

[10] RLV flights purchased by the USSIA as part of the initial spacelift services contract would be used to support spaceport assembly and initial crew training and rotations.

deg. Serving as nodes in the integrated space transportation system, they would provide access to all LEO and medium Earth orbits (MEO) from equatorial to polar orbit. The 15 deg orbital inclination spaceport would also provide access to geostationary orbit.

The initial fleet of commercial RLVs would fly approximately 450 flights to and from LEO each year carrying over 6,000 tons of payload. About 125 of these flights would support the basic spaceport operations. The remaining flights would support infrastructure customers. The initial RLVs would be nearing the end of their design life of 1,000 flights. Second-generation RLVs, perhaps incorporating advanced airbreathing propulsion systems, would be nearing introduction into service.

Space-based logistical support for space-deployed platforms would be commonplace. This would be undertaken by capturing smaller satellites and returning them to one of the spaceports for repair or transporting a repair team to the larger platforms. Long-range spaceplanes would provide this transportation function. These spaceplanes would also be used to capture obsolete and non-functional platforms to meet space environmental control requirements.

Interplanetary spacecruisers would transport lunar exploration crews to and from the Moon. They may also take tourists on seven-day cruises around the Moon and support large space construction projects, such as solar power satellites. As experience and confidence with using these spacecruisers for deep space missions grows, they would be used to explore near-Earth comets and asteroids and to support a manned Mars exploration program.

Conclusion

Once the technological barrier to developing a new frontier falls, the expansion of human civilization into that frontier is rapid. The Ohio frontier, which in the late 1700s was the “west” in “go west, young man,” became fully settled and integrated into the United States in a brief 35 years. Much of this speed was due to the rapid development of road, canal, and river transportation networks within the Ohio frontier. A similar rapid pace of expansion and settlement occurred with the western states in the mid-to-late 1800s, spurred by the building of the transcontinental railroads in the 1860s-1880s.

As the 21st century dawns, the United States finds itself in the fortunate position of having the technological capability to become the first true spacefaring nation and lead the march of civilization into space. History has shown that there are clear political, economic, and national security benefits to being first.

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