Achieving Mastery of Space Operations by Transforming Space Logistics

By James Michael Snead, P.E.

The American Institute of Aeronautics and Astronautics' (AIAA) Space Logistics Technical Committee (SLTC) focuses on innovative, near-term space logistics to establish safe and affordable human and robotics spacefaring operations throughout the Earth-Moon system and beyond. To help accomplish this vision, the SLTC and the Space Logistics Division of the International Society of Logistics (SOLE) are taking steps to reestablish a previously successful partnership between SOLE and the AIAA that as waned in recent years, perhaps reflecting the recent woes of the American space program.

Space still has the allure of the mysterious that provokes a return to the imagination of our youth. Yet, while still a new and exciting frontier today, its future for human civilization revolves around the creation of new space logistics capabilities that will make human space operations safe and routine. The focus of this article in on describing how near-term space logistics capabilities can be achieved and, equally important, why building these new capabilities is important.

Defining Space Logistics

The SLTC has adopted the following broad definition of space logistics, based on the generally accepted definition of military logistics. Space logistics is the science of planning and carrying out the movement of humans and materiel to, from, and within space combined with the ability to maintain human and robotics operations within space. In its most comprehensive sense, space logistics addresses the aspects of space operations both on the Earth and in space that deal with: (1) Design, development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of space materiel; (2) Movement, evacuation, and hospitalization of people in space; (3) Acquisition or construction, maintenance, operation, and disposition of facilities on the Earth and in space to support human and robotics space operations; and (4) Acquisition or furnishing of services to support human and robotics space operations.

Achieving Mastery of Space Operations

The context for understanding the renewed importance of space logistics was established in early 2001 by the Commission to Assess United States National Security Space Management and Organization (generally referred to as Space Commission).

The first era of the space age was one of experimentation and discovery. Telstar, Mercury and Apollo, Voyager and Hubble, and the Space Shuttle taught Americans how to journey into space and allowed them to take the first tentative steps toward operating in space while enlarging their knowledge of the universe. <u>We are now on the threshold of a new era of the space age, devoted to mastering operations in space.</u> (Emphasis added)

Mastering near-earth space operation is still in its early stages. As mastery over operating in space is achieved, the value of activity in space will grow. Commercial space activity will become increasingly important to the global economy. Civil activity will involve more nations, international consortia, and non-state actors. U.S. defense and intelligence activities in space will become increasingly important to the pursuit of U.S. national security interests.[1]

What the Space Commission focused on with these findings was the fact that opening new frontiers involves a key transformation in operational capabilities. The initial era of exploration and scientific study does not generally emphasize the establishment of routine, affordable logistics operations to, from, and within the new frontier. However, with time, as economic and other advantages of the new frontier become apparent, government and private enterprise begin to make logistics infrastructure investments to reap these rewards. This is an important turning point because the act of planning and building the initial logistics infrastructure necessarily creates the knowledge, experience, and industrial base—how I define mastery of operations—necessary to establish economically useful, acceptably safe, and acceptably affordable logistics capabilities within the new frontier. Once these are established, this new mastery becomes the important foundation for creating and supporting new government and private operations in the new frontier.

Von Braun's Original Spacefaring Vision

As the recent investigations into the technical and economic challenges necessary to overcome to repair the Hubble Space Telescope highlight, we have not yet achieved an initial mastery of space operations. This is a consequence of decisions made over the course of nearly five decades that emphasized immediate operational goals without making necessary investments in space logistics.

In the early 1950s Dr. Wernher Von Braun, at the time probably the most widely recognized “rocket scientist,” introduced his ideas on how to become a spacefaring civilization. This was a period of significant public interest in aerospace technology with the breaking of the “sound barrier” in 1947, the first western flights of rockets into space, the emergence of peaceful uses of nuclear energy, rapid progress in aircraft design, the initial growth of TV, and the initial period of sightings of UFOs and related sci-fi movies. Starting with an initial technical conference in Texas, moving on to a series of well-illustrated articles in the leading popular magazine of the day, Collier’s, and culminating in two specials on the Walt Disney TV show, Dr. Von Braun explained to a captivated public how to become spacefaring.

By the end of the 1950s, the essence of Von Braun’s spacefaring vision was captured in the American space program. Recently, Dr. Roger Launius, previously the chief historian of NASA (1990-2002) and currently the Chair of the Division of Space History of the Smithsonian Institute’s National Air and Space Museum), looked back at these early years. It was viewed as an *“integrated space exploration scenario centered on human movement beyond this planet and involving these basic ingredients accomplished in essentially this order:*

1) *Earth orbital satellites to learn about the requirements for space technology that must operate in a hostile environment.*
2) *Earth orbital flights by humans to determine whether or not it was really possible for humanity to explore and settle other places.*
3) *Develop a reusable spacecraft for travel to and from Earth orbit, thereby extending the principles of atmospheric flight into space and making routine space operations.*
4) *Build a permanently inhabited space station as a place both to observe the Earth and from which to launch future expeditions to the Moon and planets.*
5) *Undertake human exploration of the Moon with the intention of creating Moon bases and eventually permanent colonies.*
6) *Undertake human expeditions to Mars and eventually colonize the planet.”*[2]

Acting to fulfill this vision, the United States undertook a wide variety of technology development programs. In addition to the well known X-15, lesser known programs included the X-20 DynaSoar partially reusable Earth-to-orbit spaceplane, the first “aerospaceplane” program, several nuclear thermal rockets for to- and in-space propulsion, and Project Orion, an interesting concept for nuclear-powered interplanetary space propulsion. And all of this within a dozen years of breaking the believed to be impenetrable sound barrier!

Being unfamiliar with this initial phase of the American space program, many today believe that the human space program started with President Kennedy’s famous 1961 address to Congress establishing the goal of landing humans on the Moon by the end of the decade. What actually happened, as Dr. Launius’ article indicates, is that President Kennedy eliminated steps 3 and 4 of the integrated space exploration scenario to accelerate step 5. This change effectively eliminated building a useful and sustainable space logistics infrastructure. Referring to comments Dr. Hans Mark, director of the NASA Ames Research Center during the 1960s, made in 1987, Dr. Launius noted, *“Mark suggested that the result of Apollo was essentially a technological dead end for the space program. It did not, in his view, foster an orderly development of spaceflight capabilities beyond the lunar missions.”*[3]

These remarks are not meant to disparage the remarkable

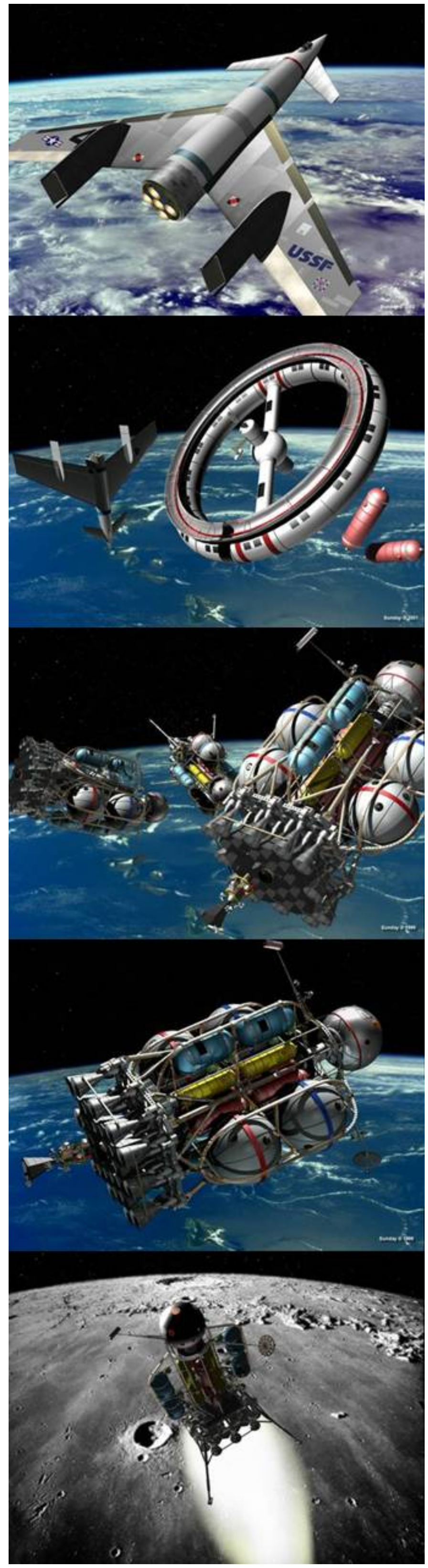

Figure 1
Von Braun’s concepts used in Collier’s Magazine (copyright©Terry Sunday, used with permission).

accomplishments of the lunar landing program. The American space program has always, and still is, part of broader landscape of national and international political activities. What this brief recap of the early years of the American space program is meant to highlight is the fact that the SLTC's vision is essentially a return to the original American vision of human spacefaring operations of the 1950s—a vision that emphasizes building permanent to-space and in-space logistics capabilities.

Near-Term Space Logistics Opportunities

The previously cited comments by the Space Commission anticipated that an opportunity for transforming space logistics would happen as the Space Shuttle ended its operational period. With the release of the updated U.S. Space Transportation Policy, the current time frame for ending Shuttle operations is 2010, or so, coincident with the completion of assembly of the International Space Station. From a planning perspective this provides a target for assessing options for implementing improvements in space logistics capabilities. One focus area of the SLTC is to "provide example innovative logistical architectures and related system concepts to support future mission planning and improved public understanding." We have undertaken this by developing examples, much as Dr. Von Braun did in the 1950s, of what may be achieved.

Logistics Functions Needed

The goal for transforming space logistics is to establish within space a logistics support environment that enables human and robotics space operations to be undertaken with "aircraft-like" safety, effectiveness, and operability. The initial functional capabilities to achieve this were evident in Dr. Von Braun's conceptualizations in the 1950s.

1) Reusable Earth-to-orbit-and-return space transportation for passengers and cargo.
2) Spacelift for oversize and heavy cargo, space platforms, and components of space facilities and large spacecraft.
3) Space logistics facilities in low Earth orbit (LEO).
4) Reusable transportation within space for passengers and cargo.
5) Mobile logistics support capabilities throughout the Earth-Moon system.
6) Space habitats (e.g., hotels) in LEO to support human operations.

Defining "Near-Term"

In developing new operational capabilities there is always a "tug of war" between the systems engineers and the technologists. To provide value, technologists need opportunities to bring new technologies into operation. As a result, they argue, often passionately, for system solutions incorporating new technologies. Systems engineers, on the other hand, wish to be able to meet the customer's needs for capability with acceptable cost, risk, and schedule.

Some programs are designed to provide technologists with the maximum opportunity to insert new technologies. The X-30 National Aerospace Plane and the X-33 Venture Star programs of the 1980s and 1990s were two examples. Both were aimed at achieving reusable, single-stage spacelift; a goal requiring significant advancements in flight vehicle technologies.

Other programs are intended to provide a new operational capability quickly. A classic example is the British challenge, in the late 1930s just prior to the outbreak of hostilities, to build a coastal early warning radar capability. Sir Robert Watson Watt led this effort and, as a result, coined his "Law of the Third Best" to address such situations. Watson Watt argued that when responding to critical near-term needs that cannot be satisfied through available systems, the *best* solution never comes and the *second best* solution takes too much time. Instead, he argued, identify the *third best* solution—*"the one that can be validated and deployed without unacceptable cost or delay."*[4]

Sir Watson Watt was not arguing that near-term imperatives prevented the use of technologies that had not yet been operationally deployed. Rather, he argued that a measure of the maturity of the technology at the time the system development is begun needs to be considered. Today, this is accomplished through the use of Technology Readiness Levels (TRL) where the current maturity is assessed on a scale of 1-9 with "9" being a technology or subsystem currently in successful operation. Within the aerospace industry, it is generally accepted that when the enabling technologies reach a TRL of 6—system/subsystem model or prototype demonstration in a relevant environment (ground or space)—the technologies are sufficiently mature to support a decision to initiate a formal development program. Hence, near-term system solutions are those employing TRL 6-9 critical technologies whose development can be initiated without unacceptable cost or delay.

Transforming Space Access

There is no avoiding the fact that to transform space logistics and achieve an initial mastery of space operations, space access must first be transformed. This is an area that has been the subject of considerable debate, but without clear resolution. The primary issue is a broad public perception of what may be called a "space access barrier." Reinforced by the loss of two Space Shuttles and the failure of the X-30 and X-33 programs to realize their single-stage goals, the popular perception is that substantial further technology advancement is required to achieve "aircraft-like" routine and safe space access. However, popular perceptions are not always on target. Looked at from the context of what practical near-term options are available today, two sets of solutions become evident.

First would be the development of fully-reusable, vertically-launched, rocket-powered two-stage-to-orbit space transportation systems. These would replace the Space Shuttle and Expendable Launch Vehicles for transporting passengers and most medium-class payloads to LEO. Recall that the original Space Shuttle design proposals from the late 1960s were fully reusable, rocket-powered, two-stage systems—only later changed to the current partially-expendable system design to meet development funding constraints. With nearly 35 years of further technology advancement, there is no reason today to believe that industry could not now successfully develop such systems. Recent government and industry conceptual design studies support this contention. These studies indicate that these unmanned reusable systems would transport 25,000-35,000 lbs to LEO, when launched east from Kennedy Space Center (KSC). With the carriage of a small winged spaceplane in place of an external cargo module, the system could also transport about 10 passengers to LEO. (See Figure 2.)

Consistent with the current TRL 6-9 technologies used in these systems, they would be suitable for what is referred to as "routine" spacelift. Each of these flight systems would be capable of being turned around for re-launch about every four weeks at the initial operational capability (IOC) and perhaps as frequently as every week when full operational capability (FOC) is achieved. Such systems are thus distinguished from a "responsive" spacelift capability, discussed in the updated U.S. Space Transportation Policy, that aims for turning a system around in only one day or less. Recent studies indicate that responsive spacelift systems, as well as system designs employing advanced airbreathing propulsion, require further technology investment prior to the start of development and, hence, are not considered to be near-term options.

To meet the U.S. Space Transportation Policy's requirement for assured space access, at least two types of near-term systems would be deployed. With three operational systems of each type, six operational systems would be brought into service. Assuming that one system of each type in is depot for maintenance, the four systems in flight status would have a mission _capacity_ of about 50 missions per year at IOC and perhaps as many as 200 missions per year at FOC. With an average delivered cargo of 12 tons and 80 percent of the missions used to transport cargo, this modest fleet could transport about 1,900 tons and 400 passengers to orbit each year once FOC is achieved.

It is expected that these projections of mission capabilities will be greeted with some measure of skepticism; in part because similar claims were made during the early years of the Space Shuttle program. However, noting that by the time these new reusable spacelift systems could be initially flying around 2012 and reach FOC in about 2017, their design will have benefited from over 40 years of technology and system design advancements since the start of the Space Shuttle program in 1972. It is time to update expectations of what is possible to achieve. After all, this is nearly twice the length of time as took place between the breaking of the sound barrier in 1947 and the first lunar landing in 1969.

The other near-term option is to augment the near-term reusable spacelift capability with an unmanned super heavy spacelift capability. This would be a Saturn V-class system capable of placing approximately 160,000-180,000 lb into an east orbit from KSC. For perspective, this is the equivalent to the weight of about three empty Shuttle external tanks.

Why the need for such a super heavy spacelifter? Because this provides the capability to launch large and heavy components of space systems into orbit for later assembly in LEO, as described in more detail below. The need to be able to transport oversize components during the construction of terrestrial logistics infrastructure is quite common. The additional transportation cost is offset by the assembly and operational advantages achieved.

Figure 2
Generic TSTO reusable space access system with externally-carried cargo module and passenger spaceplane.

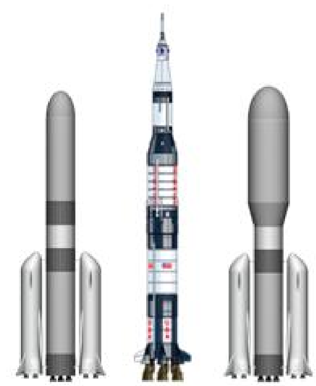

Figure 3
Generic super heavy spacelifters with reusable fly-back boosters, shown with the Saturn V. The reusable boosters would be similar to the first stage of the reusable space access system shown above.

The third best solution for meeting this super heavy spacelift need has been under study for almost 30 years. It is a Shuttle-derived system as shown in Figure 3. Because this super heavy spacelifter would be developed concurrently with the reusable space access systems, this solution would provide acceptable performance and flight rates—perhaps 3-5 flights per year—while minimizing program development cost and risk compared with a "clean-sheet" approach. This solution also provides for generating continued value from and providing for a measured upgrading of an important element of the existing space industrial base. It neatly transforms the existing manned Shuttle system into a critical element of an emerging integrated space logistics infrastructure.

These two near-term solutions, which through the emphasis on the use of TRL 6+ technologies could be available near the time Space Shuttle operations are ended, provide a significant improvement in space access for passengers and cargo. Not only will this change substantially decrease current space access costs, it will also provide additional capacity to exploit the lower costs, as typically happens as new logistics infrastructure is brought into operation. More importantly, these changes provide the transportation improvements needed to take the next steps in transforming in-space mobility and logistics support.

Initial LEO Facilities

As with all new frontiers, the space frontier needs facilities to receive and house arriving passengers and cargo, service the transportation and other space systems, and support general assembly and construction. This will enable scheduled transportation and other logistics support services to be established that, in turn, enable new private and government space operations to be undertaken with improved confidence. To accomplish this, two types of initial orbiting facilities would be built. One will be a general-purpose logistics base and the other will be a combination space hotel and space office park.

The design of all logistics facilities inherently incorporates capacity constraints. For highways, it's the number of lanes. For airports, it's the length and load bearing capacity of the runway and ramps. For seaports, it's the channel and dockside depth and ship maneuvering area. For orbiting space facilities, it's the size of the pressurized space hangars and other pressurized compartments.

When environmental conditions for conducting logistics servicing operations are important, hangars provide a controlled environment where cargo and vehicles can be received or

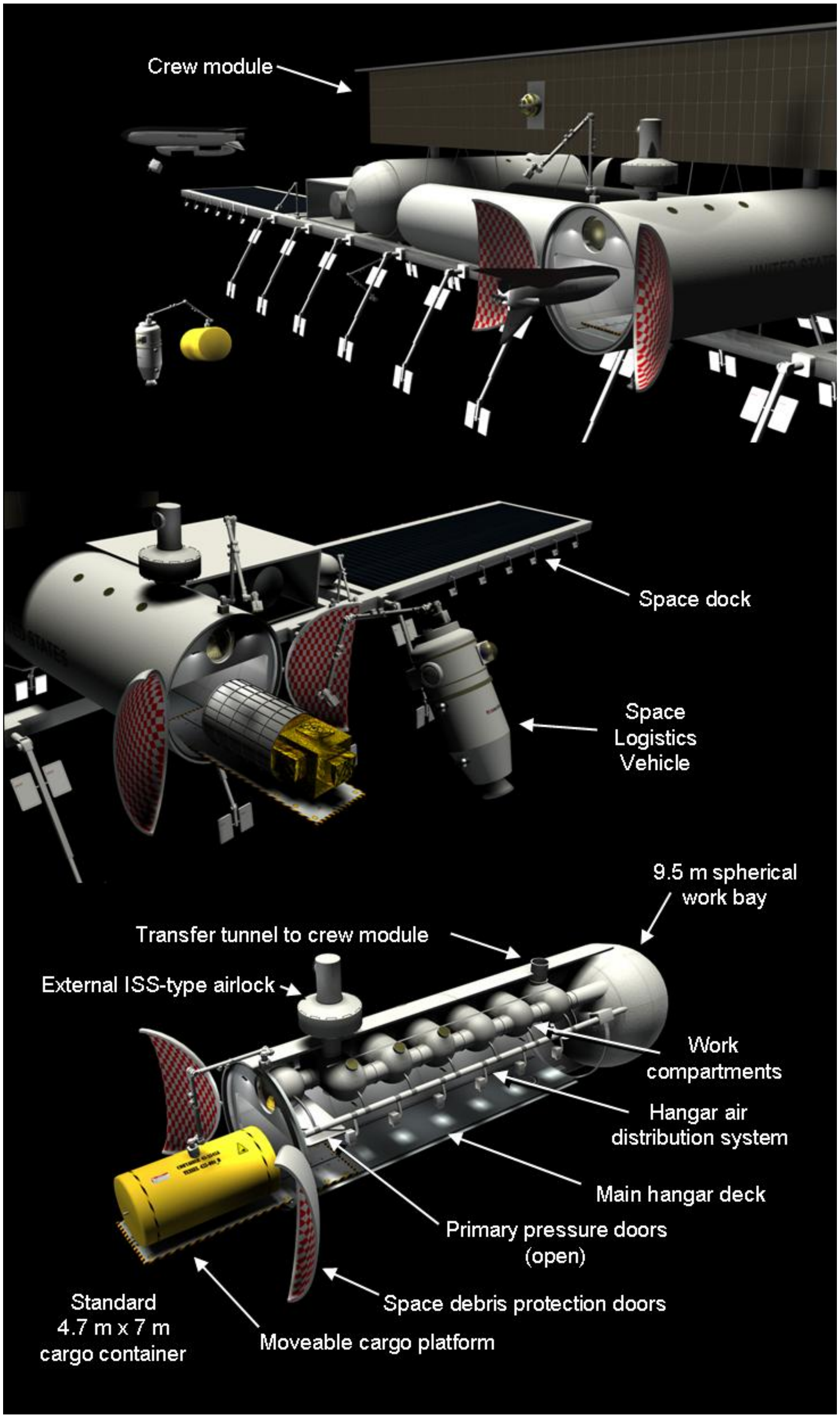

Figure 4
LEO Space Logistics Base showing a cut-away view of one of the base's two space hangars for conducting on-orbit servicing and support.

discharged in the “natural” environment and but they can also be enclosed within an artificial environment designed to facilitate good human functioning—pressure, temperature, humidity, lighting, maneuverability, etc.

An important attribute of orbiting space logistics facilities will be their ability to conduct effective logistics support. As repair operations on the Hubble Space Telescope and external repair operations on the International Space Station have shown, conducting such logistics servicing operations while wearing a space suit is difficult. While design and technology advancements in space suit designs will help, the near-term solution to expanding in-space logistics supportability is to provide space hangars of sufficient size that the satellites, spacecraft, and other components requiring servicing can fit within the orbiting logistics facility’s pressurized space hangar.

The near-term TSTO reusable space access systems discussed earlier can transport cargo and passengers to orbit. The cargo container dimensions will be in the range of 4.7 m in diameter by 9 m in length; about one half of the Shuttle Orbiter’s payload bay. For passenger transport, small spaceplanes with a wingspan—perhaps after folding the wing tips—of about 7 m would be used. Space hangars must have a pressurized envelope and primary pressure doors of sufficient size to receive items of this size.

One configuration for such a space hangar is shown in Figure 4. Approximately 10 m in diameter and 35 m in length, the hangar’s primary pressure boundary structure, including the forward flat pressure bulkhead, primary pressure doors, and aft spherical work bay, would be launched into orbit as a single payload of a super heavy spacelifter. Internal hangar components, such as the internal work compartments, would be carried into orbit as cargo on the reusable space access system and then taken into the space hangar for installation when pressurized.

This hangar configuration provides three separately pressurizable sections—the main hangar deck, the spherical work bay, and the upper internal work compartments. Vehicle and satellite servicing, cargo unloading, and passenger transfer would take place in the main hangar deck. Large component servicing and zero-g training would be performed in the spherical work bay. Bench-level component servicing would be undertaken in the work compartments.

While this space hangar is quite large when compared with the ISS modules, it is only about 20 percent larger in diameter and about the same length as the Shuttle’s External Tank. Hence, it would be built using the same manufacturing methods used today to build the External Tank or improved methods such as spin forming. Either way it would be probably be built on the same manufacturing line that would build the center core propellant tanks for the super heavy spacelifter.

The Space Logistics Base, shown in Figure 4, uses two hangars. These are mounted on “top” of a long structural truss that serves as a “space dock” for assembling and supporting large space platforms and spacecraft. The hangars face in opposite directions to de-conflict the movement of cargo and vehicles into the hangars. In between the two hangars are “recycled” center core propellant tanks from the super heavy spacelifters used to launch the hangars. These are used to store the air when the hangars are evacuated. On top of the hangars, within the rectangular array of solar arrays and waste heat radiators, is the crew module. It includes the command and control facility, crew support, and crew rest quarters for a crew size of about twenty. This base design would require 5 super heavy spacelifter flights to launch the base’s larger components such as the twin hangars. On the order of 40 reusable space access flights per year, over a period of about two years, would be required to transport the smaller components and the construction personnel and their equipment and supplies to orbit. Building this base would make first use of the Super Heavy Spacelifter and would use much of the extra capacity of the reusable space access systems during their first years of operation.

Once operational, the Space Logistics Base would provide a base of operations for supporting on-orbit assembly and servicing of satellites, supporting in-space business operations, and assembling other space facilities, large space platforms and spacecraft. It would also provide a base of operations for reusable in-space mobility systems that would deploy and recover satellites. The initial Space Logistics Base would probably be assembled in a 28 deg inclination orbit, which equates to a due East launch from Kennedy Space Center. This maximizes the launch performance of the new space access systems and provides a base suitable for supporting logistics operations to geostationary orbit and to lunar orbit. Future bases may be positioned at higher or lower orbital inclinations, depending on mission needs. It is also be possible that smaller versions of this base may be assembled in lunar orbit or geostationary orbit to further expand in-space logistics support capabilities.

One early use of the space dock would be to assembly a space hotel. While the Space Logistics Base would have some capacity for housing transient personnel, it would not be suitable for housing business travelers, researchers, and tourists. A separate facility, co-orbiting with the Space Logistics Base, would be needed.

One concept for building a space hotel would be a design using the space hangar and crew module elements of the Space Logistics Base (See Figure 5). This design is characterized as a hub and spoke design with the hangars being incorporated into the hub and the crew module serving as the spokes.

This configuration has two advantages. First, the hotel can rotate about the long axis of the hub to produce modest levels of artificial gravity in the spokes. This enables the spokes to be divided into floors with different floors being used for housing, support facilities (e.g., mess halls and medical facilities) and leased work areas for business use and research and development. The baseline 4-spoke configuration shown in Figure 5 has about 2,300 m^2 of useful floor area in addition to considerable volume in the hub. This would provide sufficient area for approximately 100 people. A 12-spoke configuration would have about 7,000 m^2 of floor area and could accommodate about 300 people.

The second advantage of this configuration is that it can be deployed with a reasonable number of Super Heavy Spacelift missions. The 4-spoke, 100 person, configuration requires 3 Super Heavy Spacelift missions for the hub, one for each spoke, and one for carrying oversize components such as the solar arrays—a total of 8 missions. The 12-spoke configuration would require about 10 additional missions.

As mentioned previously, the core propellant tanks of the Super Heavy Spacelifter would be "recycled" to provide additional pressurized volume. This is used with both the Space Logistics Base's crew module and the hotel's hub and spokes. This feature, which would be incorporated into the design of the Super Heavy Spacelifter, both reduces the number of required launches and simplifies the on-orbit assembly by minimizing the number of components requiring handling. These recycled tanks would be used for "low tech" applications such as sleeping quarters, storage, etc. They would be internally reconfigured in orbit, while pressurized, as part of the assembly of the base and hotel. This approach should substantially reduce the time and cost of building these large facilities.

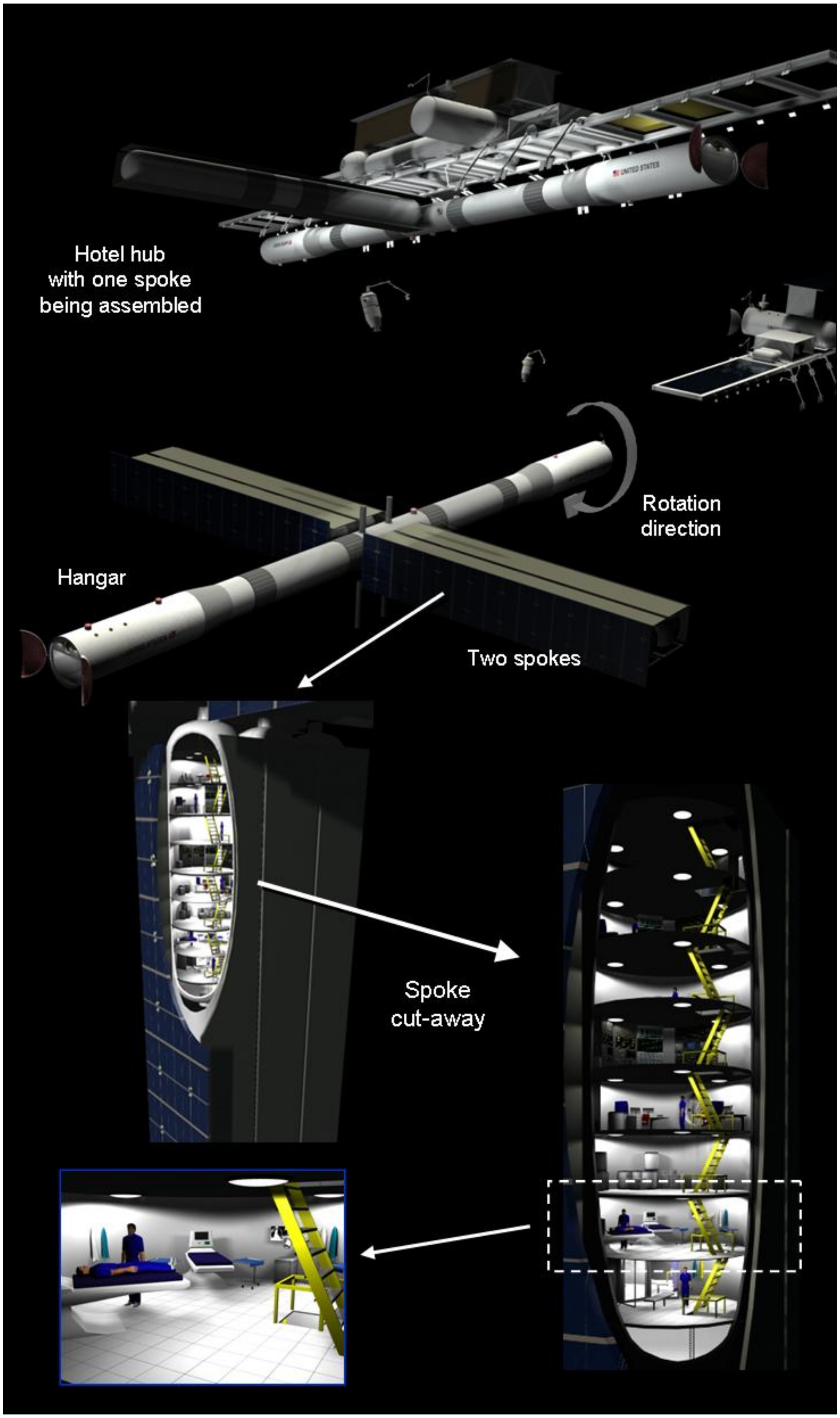

Figure 5

LEO Space Hotel/Office Park shown being assembled at the LEO Space Logistics Base's space dock. Cut-away views of the hotel's spokes show the internal arrangement of the floors in each spoke.

In-space Mobility

The Space Logistics Base would serve as the operating base for two reusable spacecraft. The Space Logistics Vehicle (SLV) comes in several configurations. The "tug" version, shown in Figure 4, is used for local cargo handling, passenger transport, and supporting space dock assembly operations. Modular in design, the SLV can be crewed or operated remotely. Its components are sized to fit both within the reusable space access system's cargo module as well as within the base's space hangar for servicing and support.

Larger versions of the SLV would provide increased mobility within Earth-GEO-Moon space. Single, extended-performance versions could depart the LEO base, travel to geostationary orbit, conduct a servicing mission on a satellite, and then return to the base. Two of these SLVs, operating as a staged vehicle, could deploy large satellites into geostationary orbit or delivery a standard cargo container to lunar orbit. On completing the delivery, the SLVs return to the LEO base for servicing in preparation for the next mission.

After completing assembly of the space hotel, the space dock would be used to assembly the Space Logistics Transport (SLT). The SLT would have two functional capabilities; transporting cargo and passengers, and providing "on-site" logistics support.

The SLT is primarily a modified space hangar with an added propulsion module. The modified hangar would be launched to the space dock using the Super Heavy Spacelifter. The smaller components, such as the propellant tanks, flight deck, and rocket engines, would be transported using the reusable space access systems. With this approach, all of the components, except for the SLT's hangar, can be checked out and configured for installation within the base's pressurized hangars.

Incorporating a hangar into the SLT's design enables the logistics support architecture—parts, tools, equipment, technicians, training, etc.—developed initially for LEO logistics operations to be extended throughout Earth-GEO-Moon space. This is a key step in extending mastery of space

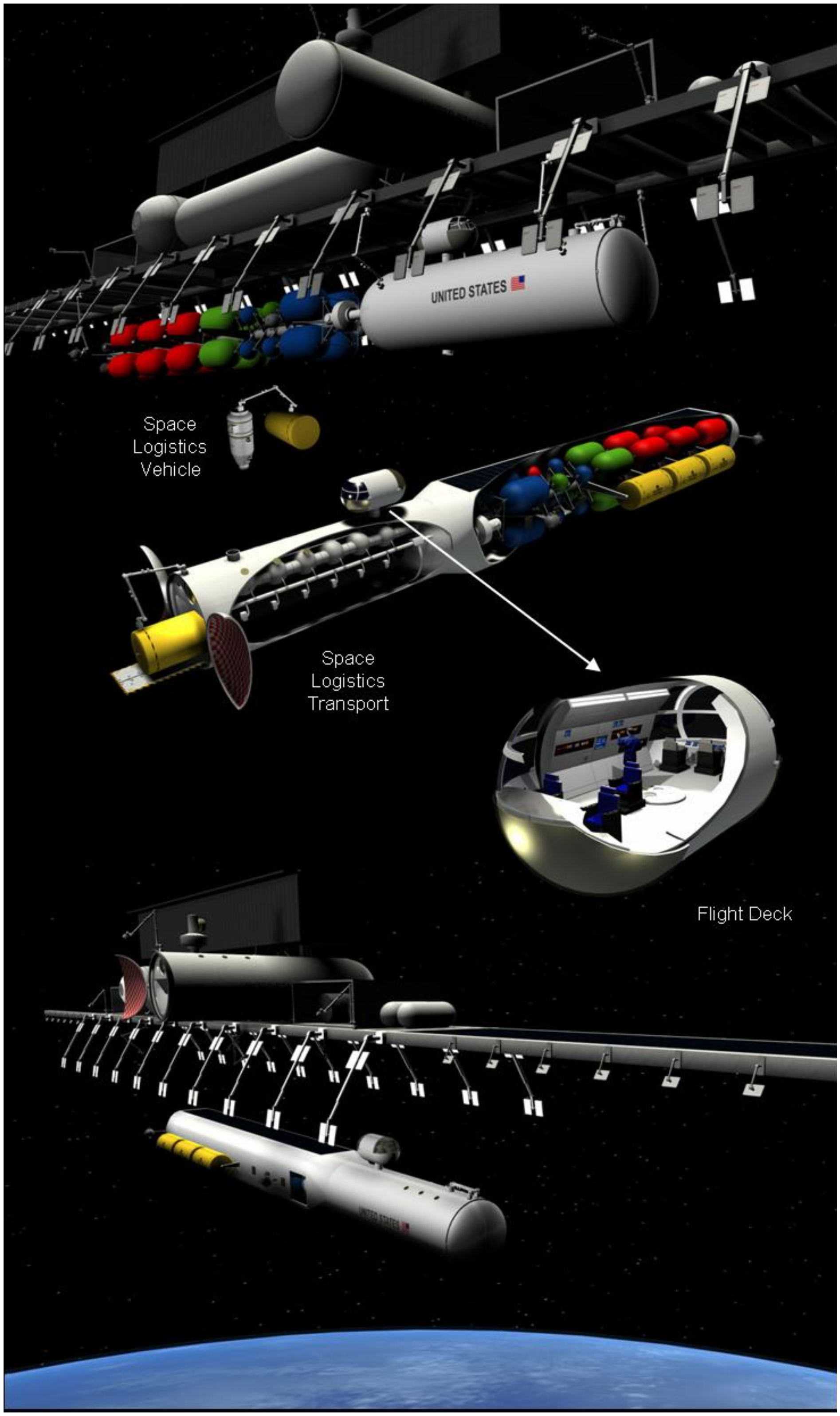

Figure 6

Space Logistics Transport shown being assembled at the LEO Space Logistics Base's space dock and departing the base for a cargo delivery mission. The cut-away views show the forward space hangar, the aft propellant module, and the flight deck.

operations. If affords future space mission planners, developers, and operators a defined set of available logistics services that can be included in their operational model. And, as a direct consequence, this also provides a set of critical subsystems, e.g. propulsion and power, and an associated supplier base that can be tapped to design these new missions at a lower cost and with increased confidence.

With the use of nuclear thermal propulsion, the SLT would be capable of conducting missions to geostationary orbit, lunar orbit, and the Earth-Moon libration points. The SLT would be able to transport astronauts and cargo for the renewed lunar exploration program to lunar orbit or delivery new space telescopes to the libration points. It could also be used to support the deployment of large satellites, such as ultra-high power communication satellites built in the Space Logistics Base's space dock, in geostationary orbit.

The SLT can also carry and refuel smaller spacecraft such as the SLV. Configured for surface landing, modified SLVs could be used to ferry passengers and cargo to and from the lunar surface. Thus, the combination of near-term reusable space access systems, LEO bases, SLT, and SLV would provide an integrated space transportation network capable of transporting passengers and cargo almost anywhere within the Earth-Moon system, with the next step, of course, being on to Mars.

Conclusion

In the late 1960s, Dr. Von Braun spoke at an early meeting of SOLE in Huntsville, Alabama:

We have a logistics problem coming up in space, however, that will challenge the thinking of the most visionary logistics engineer. As you know we are currently investigating three regions of space; that near-Earth, the lunar region, and the planets. … While it is safe to say that all of us have undoubtedly been aware of many or most of the logistics requirements and problems under discussion, at least in a general way, I think it is also safe to state that many of us have not realized the enormous scope of the tasks performed in the logistics area. I hope the discussions bring about a better understanding of the fact that logistics support is a major portion of most large development projects. Logistics support, in fact, is a major cause of the success or failure of many undertakings.

Opening the space frontier requires mastery of operations in space. This mastery can be achieved by establishing an integrated space logistics infrastructure in low Earth orbit, extending this first throughout the Earth-Moon system and, then, on to Mars. The importance of creating these new logistics capabilities is apparent today, just as it was in the 1950s and 1960s. A growing partnership between SOLE and the AIAA can help to provide an improved public understanding of how these needs can be met with safe, operationally effective, and affordable near term solutions.

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[1] Final Report of the Commission to Assess United States National Security Space Management and Organization, pp.21.

[2] Roger D. Launius, "Kennedy's Space Policy Reconsidered: A Post-Cold War Perspective," Air Power History, Winter 2003, p. 22.

[3] Roger D. Launius, "Kennedy's Space Policy Reconsidered: A Post-Cold War Perspective," Air Power History, Winter 2003, p. 26.

[4] Arthur M. Squires, "The Tender Ship: Governmental Management of Technological Change," Birkhäuser, 1986, pp. 122.