AIAA Space Logistics Technical Committee Position Paper
(http://www.aiaa.org/tc/sl)

Recommended Government Actions to Address Critical U.S. Space Logistics Needs

Introduction

The purpose of this position paper is to highlight the importance of assessing the nation's space logistics needs and to propose specific Government actions to undertake this assessment. The three recommended actions are:

1. Establish a space logistics task force to assess the capabilities of the industrial base and the value of establishing the basic elements of an integrated space logistics infrastructure including: assured, routine space access for passengers and cargo; in-space mobility within the central solar system for passengers and cargo; and, in-space logistics support for civil, commercial, national security, and space exploration missions.

2. The space logistics task force, perhaps through appropriate supporting Government organizations, should contract with industry to conduct the conceptual design studies of near-term, reusable space access systems, e.g., two-stage RLVs, suitable for providing first-generation passenger and cargo transport to and from earth orbit.

3. In parallel with the operation of the space logistics task force and the conduct of the reusable space access conceptual design trade studies, establish a space logistics commission to identify and recommend the preferred strategy for organizing and funding Government and industry efforts to effectively and affordably undertake the development, production, and operation of an integrated space logistics infrastructure.

Background

Space Logistics Definition

The definition of space logistics, derived from the commonly-accepted definition of military logistics, is:

> 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: (a) design and development, acquisition, storage, movement, distribution, maintenance, evacuation, and disposition of space materiel; (b) movement, evacuation, and hospitalization of people in space; (c) acquisition or construction, maintenance, operation, and disposition of

> facilities on the earth and in space to support human and robotics space operations; and (d) acquisition or furnishing of services to support human and robotics space operations.

Future Space Logistics Needs

In 2001, the Commission to Assess United States National Security Space Management and Organization noted the need to advance our nation's capabilities in space through mastery of operations in space:

> 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. *We are now on the threshold of a new era of the space age, devoted to mastering operations in space.* (Emphasis added)

The commission went on to address the expected value to the nation of achieving mastery of operations in space:

> 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. (Emphasis added)

In 2002, the Commission on the Future of the United States Aerospace Industry, chartered to "study the issues associated with the future of the U.S. aerospace industry in the global economy, and the industry's future importance to the economic and national security of the United States," stated the importance of being a spacefaring nation:

> The Commission concludes that the *nation will have to be a spacefaring nation in order to be the global leader in the 21st century*—our freedom, mobility, and quality of life will depend on it. America must exploit and explore space to assure national and planetary security, economic benefit, and scientific discovery. (Emphasis added)

Today, a spacefaring nation is defined, according to American Heritage Dictionary, as one that is capable of "launching vehicles into space." This is a capability the United States has had since the 1960s. Yet, the future of this nation in space requires mastery of operations in space and this mastery is critical for global leadership, not only for scientific discovery, but for the equally important areas of security and commerce. The findings of these two national space commissions establish the clear understanding that a continuation of 20th century spacefaring capabilities will not be sufficient in the 21st century and, hence, a different strategy needs to be identified and followed.

The Importance of Logistics Infrastructure

In 1985, President Reagan issued a proclamation addressing America's transportation systems. It began, "Our Nation's history can be traced through the development and growth of transportation in America. Our country has grown as transportation has given us access to new geographic, economic, and technical frontiers."

Since 1806, with the legislation enacting the nation's first public works program—the National Road from Cumberland Maryland to the Mississippi River—building public infrastructure has been a constant and central strategy for opening new frontiers to settlement. These public and private works have created the economic infrastructure of transportation, communications, food, energy, and materiel supplies essential for fostering economic growth and increasing the standard of living. Building infrastructure creates wealth, enhances national defense, and provides the opportunity for new private and government enterprises. The National Road and the Erie Canal, that followed shortly thereafter, were just the start of what is today an extensive network of federal, state, local, and private infrastructure capabilities that are, in large measure, the means by which the United States economically and socially prospers today.

These two centuries of successful experience have shown that building new infrastructure is an important means of creating the expertise, experience, and industrial capabilities that constitute mastery of operations in a new frontier; whether this is the opening of new lands, such as with the Transcontinental Railroad, or the opening of new virtual frontiers, as with the Internet. The clear need to develop mastery of operations in space can best be addressed by building the first generation of true space logistics capabilities enabling routine human and robotic operations throughout, first, the Earth-Moon system, and then the central solar system.

History's View of Space Logistics Capabilities

The idea of a space logistics infrastructure originated 75 years ago with a young Viennese engineer named Eugene Sänger as part of his proposed doctoral thesis while at the *Technische Hochschule* in Vienna in 1929. Sänger, as described by Dr. Richard Hallion, the Air Force chief historian, "proposed examining the possibility of developing a winged spacecraft that would boost into earth orbit and rendezvous with a space station, followed by reentry and a glider-like descent to landing." These basic concepts on reusable space access and on-orbit logistical facilities were incorporated into the structure of the American space program as it was developing in the late 1950s. Writing in a recent article in Air Power History, Dr. Roger Launius,* stated that the American space program involved 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."

This scenario was not pursued when President Kennedy decided in 1961, shortly after the first American suborbital flight, to set the ambitious goal of landing a man on the moon by the end of the decade. Space planners realized that there would not be sufficient time to first develop the reusable spacecraft and permanently inhabited space station. Dr. Launius addressed the impact of this decision:

> Dr. Hans Mark, director of NASA's Ames Research Center during the 1960s, recently voiced a less positive result for Apollo. "President Kennedy's objective was duly accomplished, but we paid a price," he wrote in 1987, "the Apollo program has no

*Former NASA Chief Historian and currently chair of the Division of Space History at the Smithsonian Institute's National Air and Space Museum.

> logical legacy." 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.

The impact of President Kennedy's decision is also reflected in the recent remarks of the Air Force Scientific Advisory Board. In a 2000 report addressing the Air Force's interests in hypersonics, which includes space access, the Board noted:

> The Air Force published *Vision 2020: Global Vigilance, Reach and Power* stating a desire for "controlling and exploiting the full aerospace continuum." If that vision implies frequent, routine, on-demand operations into and within space, the enabler for this vision is an affordable, responsive, reliable, robust space launch capability. Getting to orbit requires Mach 25 flight—and all speeds between 0 and Mach 25. This interpretation of the vision cannot be fulfilled within the likely Air Force investment program using expendable launch vehicles (ELVs); *reusable launch vehicles (RLVs) will be necessary to make routine space operations affordable. Airbreathing hypersonic systems are one of the two concepts that show promise of allowing the realization of these capabilities—the other being rocket systems. On the other hand, if the vision simply implies doing more of the same things done today, the Air Force can probably live with ELVs indefinitely*. (Emphasis added)

Elsewhere in this report, the Air Force Scientific Advisory Board drew the following conclusions while discussing potential military utility:

> We envision that a TSTO launch system [discussing an airbreathing first stage and rocket-powered second stage] would lift substantial payload weight to LEO at a cost per pound of an order of magnitude or more lower than current or next-generation ELVs ($800 to $100 per pound depending on design and launch frequency). Such a system would be designed to be launched, recovered, and prepped for the next mission using procedures as much like current aircraft operations as possible, thereby providing affordable, reliable, responsive space launch to enable on-demand military space operations. *Such a system would not only provide for affordable, reliable military space launch, but would also enable many more space and near-space missions (military, civil, and commercial) that today are made unaffordable by the high cost of access to space. Probably no other single technology offers such great promise of enabling the future of military space operations and civil space activities*. (Emphasis added)

Today's Perceptions of Space Logistics Impossibilities

In 1935 a misunderstanding of early wind tunnel testing of transonic flows over airfoils and the inadequate representation of test data taken as sonic velocity was approached led to newspaper reports of the existence of a "sound barrier" to manned aircraft attempting. As NASA's aeronautics history notes, knowledgeable aerodynamicists soon came to understand that wind tunnel design and instrumentation capabilities, at that early stage of transonic experimentation, were the root of the reported results. However, the public's perception of a sound barrier to manned flight persisted until it was dramatically "broken" in 1947 (and announced in 1949) with the XS-1.

Space logistics and, in particular, routine space access appears to suffer today from a similar public perception of a space access barrier. As previously noted, planners in the late 1950s anticipated the development of reusable spaceplanes for space access and permanently inhabited space stations for logistics support. This was the path the United States was on until redirected in 1961. The Space Shuttle and International Space Station attempted to put us back on track, but political and funding issues led to a less than desired outcome. This outcome, coupled with the subsequent failed single-stage RLV attempts, has created the impression of a technological barrier to routine space access and routine space logistics operations. As a result, space logistics has fallen off the table for serious discussion during future space program planning. Left unaddressed, this perception will most likely result in choosing a path for space program investment that will fail to achieve the mastery of space operations needed to advance America's civil, commercial, and national security space operations in the 21st century.

What Might a Future Space Logistics Infrastructure Look Like

The reorganization of the SLTC was undertaken to provide a conduit for the exploration and communication of innovative space logistics architectures and systems that will support a broad expansion of human and robotic space operations throughout the central solar system. An **example** space logistics infrastructure is described in the following written description and illustrations:

1. Near-term, two-stage RLVs for routine, airline-like transport of passengers and materiel to and from low Earth orbit. (Fig. 1)

Discussion: Such near-term RLV systems, developed and brought into operation by approximately 2012, would emphasize the use of existing state-of-the-art technologies and subsystems. These systems would be capable of flying about once per month per system to start and increasing to once per week per system as maturity and confidence improves. *At least two types of RLVs would be deployed to provide assured space access*. These systems, operating from terrestrial spaceports, would provide scheduled launch services for both the Government and commercial users.

2. Shuttle-derived heavy spacelifter for launching heavy and oversize unmanned payloads. (Fig. 1)

Discussion: Within terrestrial transportation systems the ability to transport heavy and oversize payloads is a critical capability, often resulting in the development of specific systems for this purpose such as the C-5 Galaxy aircraft. The expansion of human spacefaring activities, including human space exploration and space science programs, will require the ability to build new and substantially larger facilities and systems in space. Previous Government and contractor studies have identified several design approaches for transforming the current Space Shuttle into a Saturn-V class, unmanned space launch system. Such a Shuttle-derived heavy spacelifter, brought into operation in 2012, would complement the two-stage RLVs and provide an integrated space transportation capability for launching payloads of virtually any desired size into Earth orbit.

3. LEO space logistics bases and hotels (Figures 1 and 2)

Discussion: Until a breakthrough in propulsion technology for space access is achieved, LEO will remain a nexus of human operations in space. Building space logistics facilities in LEO provides both a transfer station for passengers and cargo and a location from which in-space logistics support services can be undertaken. The technical capability to build these orbiting facilities would come from the use of the Shuttle-derived heavy spacelifter to launch, as was done with Skylab, large pre-fabricated modules. This enables facilities with large pressurized compartments—needed to house and support travelers and to conduct satellite and space system servicing inside pressurized space hangars—to be economically assembled in orbit.

4. Spacecraft for in-space mobility of passengers and cargo. (Fig. 1)

Discussion: An integrated space logistics infrastructure will extend the safe and routine transportation of passengers and cargo throughout the central solar system. As with terrestrial transportation systems a number of different reusable spacecraft will be deployed to provide these capabilities. The initial spacecraft will move cargo and passengers in LEO and support in-space logistics support for satellites. Large spacecraft, configured for longer duration missions, will provide routine mobility, first, within the Earth-Moon system and, then, throughout the central solar system. These larger spacecraft, just as with aircraft, will be configured and specialized for various missions including space tourism, cargo delivery, and on-site logistics support.

This example space logistics architecture provides for the progressive expansion of spacefaring capabilities. The initial RLV operations would take the place of the EELVs for launching unmanned payloads and, then, the Space Shuttle for transporting passengers to the International Space Station. As the Space Shuttle human transport mission ended, the heavy spacelift mission would begin with the deployment of the modules for the first LEO logistics space base. The initial launch rate of the heavy spacelifter would be about three times per year to build the first two space bases and then the first hotel. The RLVs would be flying about a dozen times per year for launching government satellites, about a dozen flights per year for International Space Station crew rotation and logistics support, and about 25 missions per year for completing the assembly and supporting the operations of each space base. After the first space base is completed, in addition to providing the initial ability to provide in-space logistics support, the base would be used to assemble the first space hotel (see Fig. 2). These operations would effectively make use of the growing space logistics capabilities until the first space bases and space hotel are in operation. At this point, the infrastructure is ready to support the expansion of human and robotic space operations including the renewed human space exploration missions to the Moon and Mars.

Conclusions

For over 75 years the basic needs of an effective space logistics infrastructure—reusable space access and in-space logistics support—have been understood. This was the initial path of the United States space program in the late 1950s. It is the path that needs to be reestablished to enable the United States to practically and affordably become a true spacefaring nation undertaking a broad range of expanded and, perhaps, revolutionary civil, commercial, and national and planetary security operations in space. Examination of existing industrial capabilities provides important insight that the current technological capabilities appear adequate for initiating this new era of the space age through the rapid development and deployment of integrated space logistics capabilities.

Recommendations

Recommendation 1: That the United States Government establish a space logistics task force to assess the technological feasibility and the value of establishing the basic elements of an integrated space logistics infrastructure including: assured, routine space access for passengers and cargo; in-space mobility within the central solar system for passengers and cargo; and, in-space logistics support for civil, commercial, national security, and space exploration missions.

Rationale: The widely held perception of the impossibility of effectively and affordably deploying an integrated space logistics infrastructure may be having an undue influence on forthcoming national space policy decisions. Given the significant national investment to be made to realize the President's new Vision for Space Exploration, a full assessment of the ability of industry to develop and deploy basic space logistics capabilities without unacceptable costs or delay should be thoroughly and rapidly investigated.

Recommendation 2: That the space logistics task force, perhaps through appropriate supporting Government organizations, contract with industry to conduct the conceptual design studies of near-term, reusable space access systems, e.g., two-stage RLVs, suitable for providing first-generation passenger and cargo transport to and from earth orbit.

Rationale: Assured space access with reusable systems has been recognized for many years to be the key to opening the space frontier to rapid growth. Achieving this capability is akin to the commercialization of jet-powered aircraft and their revolutionary impact on commercial aviation and the global transformation of travel and commerce. While many studies of RLVs, for example, have been conducted in recent years, full participation by industry in developing preferred configurations that can, in their view, successfully achieve routine space access needs to be accomplished. As with commercial aviation, it is important that prospective reusable space access system developers' be given adequate time and resources to identify what capabilities they believe can be developed and deployed without unacceptable cost or risk. Compared with the potential for national and economic benefit to be realized with successfully building and operating practical reusable space access systems, the modest cost of conducting these conceptual design studies is well worth the investment and will provide important information for the space logistics task force and space logistics commission.

Recommendation 3: In parallel with the operation of the space logistics task force and the conduct of the reusable space access conceptual design trade studies, establish a space logistics commission to identify and recommend the preferred strategy for organizing and funding Government and industry efforts to effectively and affordably undertake the development, production, and operation of an integrated space logistics infrastructure.

Rationale: Building new infrastructure has generally been successfully undertaken through the creation of a new entity, e.g., a port authority, specifically organized to focus exclusively on the successful accomplishment of building and operating new infrastructure. Hence, an independent commission, functioning in parallel with the space logistics task force and the reusable space access conceptual design studies, is needed to address the issues of organization, operation, and funding of an integrated space logistics infrastructure. The independence of this commission is especially important to ensure that the findings of the space logistics task force and the conceptual design studies are thoroughly and impartially evaluated and incorporated into the final commission's findings and recommendations.

Concurrence

This position paper reflects the consensus view of the SLTC members.

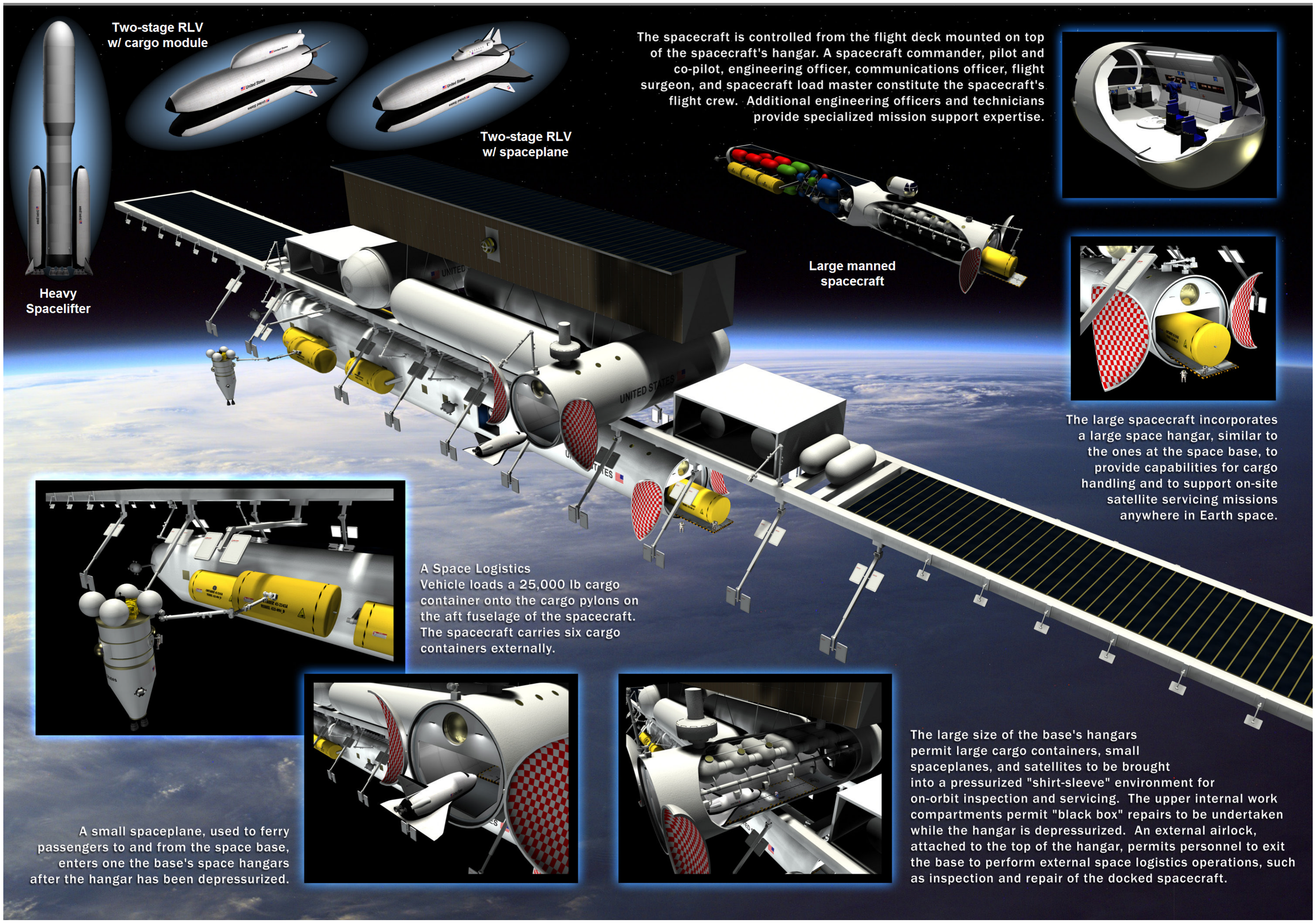

Figure 1: Depicts several elements of the example space logistics infrastructure, including: Shuttle-derived heavy spacelifter; two RLVs for carrying cargo and passengers; LEO space logistics base with space dock; large manned spacecraft being serviced in the dock; a space logistics vehicle loading cargo onto the spacecraft.

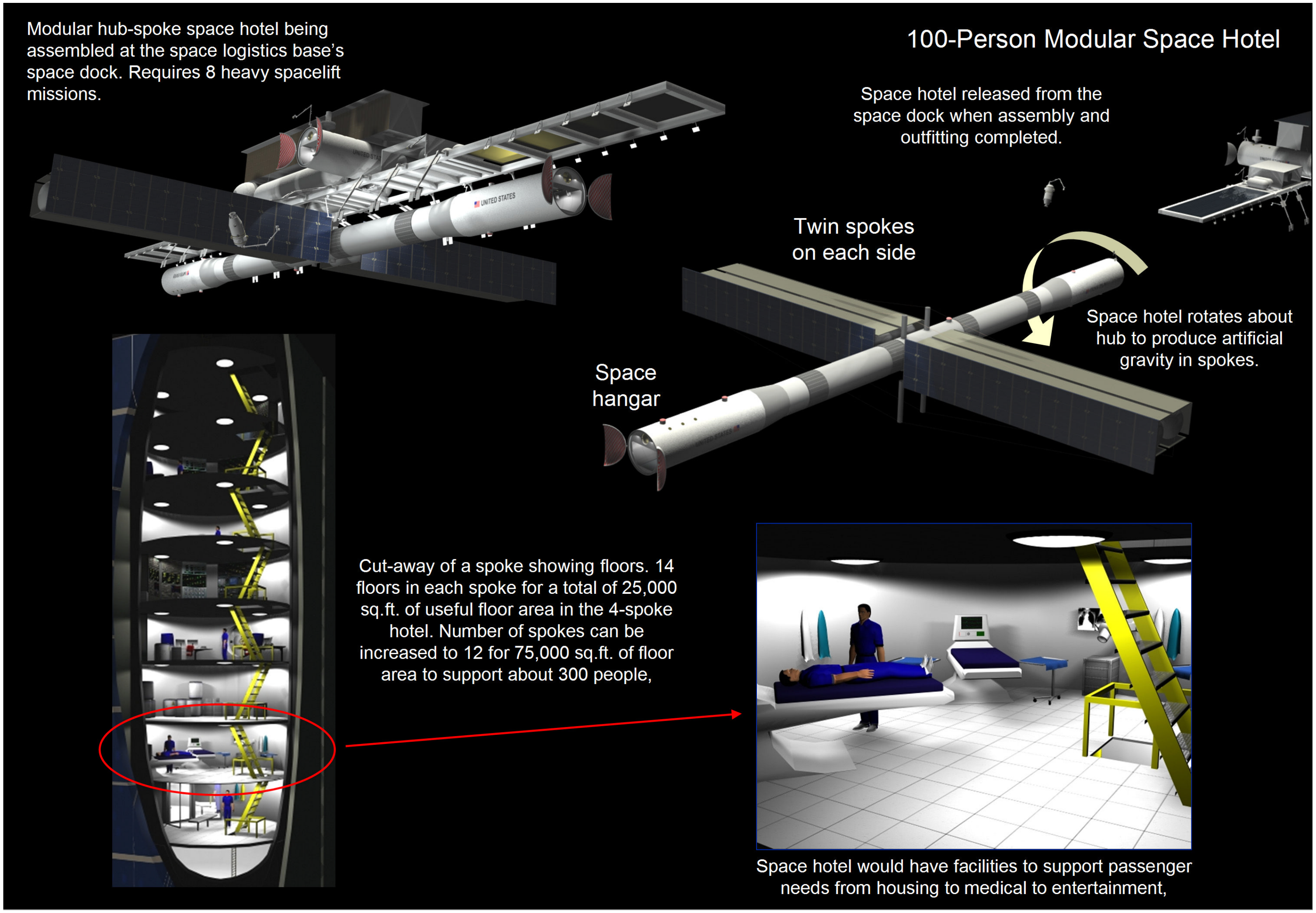

Figure 2: Depicts a modular space hotel being assembled at the space dock from large modules launched using the heavy spacelifter.