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Chapter 15

The Development of Space Station Objectives*

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Introduction

Although Space Station *Freedom* may be one of mankind's highest technological achievements when completed around the year 2000, few people understand the reasons for building it and what it will do. Two questions must be asked to understand a space station—the first is, "What useful things can a space station do in orbit?" and the second is, "What will a space station do for the nation that builds it?"

The answer to the first question consists of the mission objectives that space stations can accomplish. Mission objectives are the functions and roles that space stations perform in orbit. A few prescient individuals developed the basic set of mission objectives between 1902 and 1952. These men—considered crackpots by many—had little public support and even less money, but they were committed to their vision.

The answer to the second question consists of "national objectives" which are the reasons why building a space station is in the nation's best interest. National objectives are the "selling points" most often heard in Congress during

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NASA's space station budget debates, and they are tailored to fit specific political situations and purposes.

The history of NASA is, in part, the search for an acceptable mix of national and mission objectives for a space station project. The history of the development of both kinds of objectives is a fascinating story, beginning with a handful of obscure visionaries and ending with a multi-national, multi-billion dollar investment in an idea whose time has come.

The Search for Mission Objectives

The Pioneers, 1903-1923

The first published account of a space station—of sorts—appeared in the American magazine *Atlantic Weekly* in 1869. The whimsical story "Brick Moon," written by a preacher named Edward Everett Hale, described a 200-foot diameter hollow sphere made out of bricks.[1] It was to be flung into orbit by a giant catapult and used as a navigational aid for sailors. Unfortunately for the Brick Moon's hapless construction crew, the Moon was catapulted a bit early—stranding them in orbit.

Although no one knew it at the time, Hale's "Brick Moon" contained all the basic elements of a space station—it was a man-made object permanently orbiting Earth, it supported life for a crew, and it performed a useful function for the people below. Many more stories followed "Brick Moon" as the new genre of science-fiction caught on in the 19th century, but few people saw through the fiction to the real possibilities that lay beyond.

In 1903, the same year that the Wright brothers flew their airplane over the sands of Kitty Hawk, a brilliant Russian, named Konstantin Tsiolkovsky, published the first scientific treatise to mention the concept of a space station. Tsiol-kovsky's prophetic paper, "Exploring Universal Expanses with Jet Instruments," was largely devoted to mathematically proving that rocket flight was possible, but buried among the equations was this note about the possible use of an manned orbiting rocket: ". . . we may provide for a permanent observatory moving beyond the limits of the atmosphere for an indefinitely long period of time around the Earth, just like our moon."[2] Thus, the first mission objective for a space station was to observe the Earth and heavens from orbit.

Tsiolkovsky continued his visionary work, and, by 1911, he was proclaiming that mankind would eventually leave Earth and colonize the solar system. In the widely read Russian magazine *Aviation Reporter* he stated: "The movement around Earth of a series of rockets fully instrumented to house intelligent beings may serve as a base for further propagation of mankind."[3] Thus, the second

mission objective envisioned for a space station was to be a waystation—or spaceport—for space exploration.

Anyone proposing manned rocket flight in 1903 had to be unusual—and Tsiolkovsky was. A shy genius, who lost his hearing after a childhood bout with scarlet fever, Tsiolkovsky became intrigued by rocketry and spaceflight while reading Jules Verne as a teenager. Mastering mathematics and physics essentially on his own, he managed to secure a teaching job in the provincial town of Kaluga in 1892. At home, after teaching school, he practically invented the entire field of astronautics single-handedly. In 1913, he followed up his earlier space station concept with more details, including a proposal for assembling the station in orbit from spent rockets. By 1923, Tsiolkovsky had made an extensive study of liquid propellants for rockets, created models of interplanetary spaceships, and described closed-loop life support systems for space vehicles. Years later, as his theories and predictions were proven correct, historians named Tsiolkovsky the "Father of Cosmonautics."

Although Tsiolkovsky originated many space station concepts, the Western world did not learn of his work until much later. His publications were printed in Russian, which was not a familiar language to Western scientists, and his remote location in the Russian town of Kaluga prevented contact with the international scientific community—not that they would have embraced his work had they known of it. The first German translations of Tsiolkovsky's work appeared in the late 1920s, but his theories remained virtually unknown to the West until the late 1930s.[4] By then, Western rocket pioneers had independently developed more thorough space station concepts.

The first scientific consideration of space stations in the West is credited to a Romanian, named Hermann Oberth. Unaware of Tsiolkovsky's prophecies, Oberth independently derived the space station concept in his popular 1923 book *Die Rakete zu den Planetenräumen* [Rockets into Interplanetary Space]. In this work, "the sole cornerstone of all later space-travel ideas,"[5] Oberth postulated that space stations would be Earth observatories, communication links, and rocket refueling outposts:

> With their sharp instruments they could recognize every detail on earth and could communicate with earth by using mirrors. They could be of use in geography and ethnology in that they could observe and photograph unexplored lands. . . Their value to military operations would be obvious, whether the space stations are controlled by belligerents or the reconnaissance reports sold for high fees. . . The stations could also contribute much to saving shipwrecked persons and for news services. . . The observation station could also serve as a [rocket] fueling station. . .[6]

In addition, Oberth described in detail how a huge sunlight reflector could be built on a space station to direct light onto Earth to warm cold regions, melt icebergs, and to use as a strategic weapon. Oberth also discussed the possibilities of astronomy from space-based telescopes and zero-gravity research, although he mentioned these in the context of manned rockets and not space stations.[7] In 1929, he revised and reissued his book and added a suggestion that space stations could observe the Earth to provide more accurate weather predictions.[8]

Although met with derision or indifference from traditional-thinking critics, the concepts outlined in Oberth's book fascinated post-World War I German society. The book sold very well and even required additional printings to satisfy public demand. Oberth's success encouraged other scientists to openly discuss the subject, and to publish their own theories on rocketry and spaceflight.

Far from working in the remote provinces of Russia like Tsiolkovsky, Oberth spent many years with rocket enthusiasts in Germany, and his work was widely known among the rocket societies in Europe and the United States. Becoming the second president of the renowned German rocket society,[9] the Verein für Raumschiffahrt (VfR [the Society for Space Travel]), Oberth instructed and inspired many key figures in the history of spaceflight, including Wernher von Braun and Willy Ley.

Rocket Societies Continue the Search: 1920s-1950s

In the 1920s, several rocket societies formed to share information and promote the dream of spaceflight. In the West, the most prominent of these included the American Rocket Society, the British Interplanetary Society, and the German counterpart VfR. As membership in these societies grew in the 1920s and 1930s, space station concepts began to build a small but avid following, led by the young Hermann Oberth. Ideas were shared in the journals of the rocket societies, and, as a result, space station concepts became increasingly sophisticated.

After Oberth's 1923 work, the next historically significant space station mission objective appeared in the VfR's journal *Die Rakete* [the Rocket] in 1928. An Austrian baron, named Guido von Pirquet, proposed an ingenious orbital network of three space stations. The network consisted of a "low" space station in a 475-mile-high orbit and a "high" station in a 3,125-mile-high orbit, serviced by a "transfer" station in a highly elliptical orbit running between the two. This arrangement maximized the advantages of three fundamental kinds of Earth orbits. The low station observed the Earth from a close vantage point, while the high station served as a rocket construction and launching facility for

interplanetary trips. The elliptically-orbiting station efficiently ferried people and supplies between the two stations on a timetable of coinciding orbits.

The orbital network concept was a clever solution to a dilemma von Pirquet faced when pondering how mankind could achieve interplanetary rocket flight. From his rocket efficiency calculations, von Pirquet concluded that direct flights from Earth to the planets would require an impossibly large rocket, so some type of waypoint—a high orbital station—was needed as an intermediate step. Enough materials could be ferried up to this high station from the other two stations to construct a rocket capable of reaching distant planets.[10] Modern rocket technology now allows direct interplanetary flights, but many people still consider a space station to be the preferred place to start a manned interplanetary voyage.[11]

Although Tsiolkovsky, Oberth, and von Pirquet created roles and missions for a space station, they did not work out the various engineering details of the station itself. The first person to do this was a Slovenian army captain and engineer, named Herman Potocnik.[12] Writing under the pseudonym of "Noordung," Potocnik tackled the practical aspects of assembling and operating a space station in *Das Problem der Befahrung des Weltraums* [The Problem of Spaceflight] in 1929. Considered the first "design proposal" for a space station, Potocnik's book added a much needed air of reality to the futuristic concepts of the rocket societies.

Potocnik named his station the *Wohnrad* [Living Wheel], after its wheel-like shape, and its mission objectives of Earth and astronomical observation were drawn from Oberth's previous work. But Potocnik proposed a new mission for space stations—orbital research laboratories. He explained how scientists onboard a space station could experiment with the conditions found in space of zero-gravity, vacuum, and temperature extremes to produce great discoveries for mankind. Potocnik died of tuberculosis soon after publishing his book, but his *Wohnrad* lives on as a very important benchmark in the history of space station concepts.

Despite the rocket societies' best efforts to proclaim the gospel of spaceflight, the American public and scientific community mostly ignored the work of Oberth and the other space visionaries. It was not until 1944, when German V-2 rockets began blasting London and Antwerp, that ordinary Americans showed an interest in rocketry. Suddenly everyone wanted to know about these strange new machines that traveled faster than anything previously imagined.

The most famous author to write for this new audience was a German immigrant to the U.S., named Willy Ley. A writer and founding member of the VfR, Ley was intimately familiar with the theories of Oberth, von Pirquet and the other rocket scientists. As a professional journalist, he was able to describe

the complex theories of rocket scientists in simple terms that ordinary people could understand. His 1944 book, *Rockets*, was an immediate hit with U.S. readers—becoming the bible of space history, and requiring several revisions and over 20 printings to meet demand. Included in his book was an entire chapter about space stations. Ley compiled all the mission objectives proposed up to that time and presented them in his book. For the first time, a reader could find a complete summary of space station missions and roles in one place.

Mission objectives for Ley's space station included the following:

1. Spaceport/waystation for interplanetary travel
2. Astronomical observatory
3. Earth/meteorological observatory
4. Biomedical research in zero-gravity
5. High/low temperature research
6. Vacuum research
7. Radiation research
8. General science.[13]

Ley's popular book influenced a generation of Americans just as they were about to enter the space age. His book closed with the following thought: "The station in space promises many new discoveries. It is not impossible that a single one of them will pay for everything."[14]

Not one year after *Rockets* appeared in bookstores, the first space activity to become profitable was proposed by Arthur C. Clarke, the British Interplanetary Society member and soon-to-be famous author. In a letter to the editors of the British *Wireless World* magazine in February 1945, Clarke suggested using manned space stations to relay radio signals to all parts of the world: "Three repeater stations, 120 degrees apart in the correct [geostationary] orbit, could give television and microwave coverage to the entire planet."[15] In the October 1945 Wireless World, Clarke published a more detailed—and very influential—proposal that, twenty years later, blossomed into the multi-billion dollar global telecommunications industry.

Clarke later joked that he lost a fortune by not patenting his idea, but in the end he explained: "As things have turned out, I can honestly say that I don't give a damn. (Though I suppose that if I had not done well in other fields, by this time I might have been a typical embittered inventor, waving protest banners outside COMSAT headquarters.)"[16]

Today, unmanned geostationary satellites perform the mission that Clarke envisioned for space stations back in 1945. Considering the vacuum tube technology in those days, Clarke felt that it was a good idea to have a crew of

repairmen onboard to maintain the balky radio components. He did not foresee the miniature electronics breakthroughs of the 1960s, that rendered maintenance crews—and space stations—unnecessary for this mission.

Space Stations become a Popular Icon: 1952

In 1952, a classic space station proposal was unveiled in the American *Collier's Magazine*. The author was Wernher von Braun—the former chief engineer of the German V-2 rocket program, who came to the U.S. after the war to lead American efforts in rocketry. Vivid color illustrations of von Braun's 80-man, wagon-wheel shaped station—and a little exposure in the movie *2001, A Space Odyssey*—turned the station into a popular icon.

Von Braun's space station incorporated many of Oberth's and Ley's proposed missions, but it was designed primarily to serve a new mission—an orbital military base. Although by 1952 the idea of orbiting military bases had become an old standby in the science fiction of Robert Heinlein and others, von Braun was the first engineer to seriously propose and design a space station for that role.

Inside the 250 foot diameter rotating station, the crew would perform zero-gravity experiments, observe the Earth, photograph troop movements, and relay military communications. But the primary task of the crew was far more serious—maintaining an arsenal of atomic bombs. Von Braun described the role of the atomic bombs onboard the military station:

> Small winged rocket missiles with atomic war heads could be launched from the station in such a manner that they would strike their targets at . . . any spot on the earth . . . [offering] the most important tactical and strategic advance in military history.[17]

Written while the bitter Korean War was in full swing, Von Braun's message was a warning that the battle lines of the Cold War could soon extend into space.

As with Arthur C. Clarke's space station idea, it was not too long before von Braun's concepts became obsolete, too. The orbital atom bomb concept was superseded by intercontinental ballistic missiles, and the military observation post role was assumed by less expensive unmanned spy satellites.

So ends the early development of space station mission objectives. Working in an environment of indifference and ridicule, the pioneers—Tsiolkovsky, Oberth, von Pirquet, Potocnik, Clarke, and von Braun developed the fundamental mission objectives around which all modern space station concepts are designed: spaceport, observatory, laboratory, communications link, and military

base. By introducing us to what a space station could do, these pioneers provided a tantalizing glimpse of mankind's future. If only the willpower could be summoned to build a space station!

Motivating America: Meeting National Objectives with a Space Station

By 1952, all of the basic space station mission objectives had been developed by a few farsighted individuals working alone or in small groups. A much more coordinated and larger scale effort would be necessary to mobilize the resources to build a space station. To secure the billions of taxpayer dollars required, the American public had to be convinced that a space station was in their best interest. Futuristic mission objectives alone were not appealing enough to sell a space station—Americans had to believe that crucial national objectives would be satisfied. Thus began a 30-year effort to define and link enough national objectives to a space station program, so that the American public would ensure its survival in NASA's budget battles in Congress.

Beat the Soviets: 1957-1969

On October 4, 1957, the Soviet Union successfully orbited Sputnik, the world's first man-made satellite. In the wake of U.S. embarrassment over being upstaged by the Soviet Union, and Cold-War fear that the Soviets might be able to control the "high ground" of space, President Eisenhower and Congress created NASA in 1958. Its primary objective was to establish American leadership in space by demonstrating superior space technology. For most Americans, it was important to win this battle in the Cold War. The "space-race" was on.

One of NASA's first debates, in 1958, was whether to go directly to the Moon, or to go via an intermediate step—a space station. Many NASA engineers believed, as did von Pirquet in the 1920s, that the fuel requirements for a single rocket to take men to the Moon and back would result in a prohibitively large rocket. One logical solution was to start a lunar voyage from an orbiting space station, where a rocket could begin its journey not only free from Earth's atmospheric drag, but also at an advantageous initial velocity of five miles per second. Other engineers felt that an incremental approach to spaceflight was warranted. In NASA planning sessions, held in 1959, the argument was voiced that during a lunar journey, ". . . man and the vehicle are going to be subjected to the space environment for extended periods of time. . . All of these aspects need extensive study. . . [and] the best means would be with a true orbiting space laboratory."[18]

Also, as a civilian research and development agency, NASA wanted to satisfy the scientific community and provide them with a zero-gravity research center. The counter-argument was that a space station was not an end-unto-itself, but merely an unnecessary diversion from the primary goal of interplanetary space travel.

As fate and politics would have it, NASA's debate was silenced on May 25, 1961, when President John F. Kennedy issued his famous challenge to send men to the Moon before the end of the decade. In 1962, Kennedy elaborated on the reasons for this expedition: "Our leadership in science and in industry, our hopes for peace and security, our obligations to ourselves as well as others, all require us . . . to become the world's leading spacefaring nation."[19] By making NASA's lunar program a battlefront in the Cold War, Kennedy ensured that funding for lunar missions would be available for years to come. No such national objective would ever be linked to a space station program.

Throughout most of the 1960s, NASA's budgets were fully funded by a Congress eager to beat the Soviets in the race to the Moon. It was one of those rare and glorious eras when the overwhelming majority of Americans united in common resolve. Naturally, many at NASA assumed that once the business of lunar landing had been accomplished, the public would be eager to continue funding space missions and would support space station development. NASA's studies in the 1960s, therefore, aimed at figuring out how they could build a space station, rather than why they should build one. This philosophy was voiced in the U.S. Air Force's 2nd Annual Astronautics Symposium:

> The ability for man to go where he can and to try to go where he has not yet been is an end in itself needing no justification . . . manned space operations need not be justified by predicting in advance what utilization may be made of it. To be able to go into, and to live and function in space, is sufficient purpose.[20]

By 1962, three NASA centers had undertaken space station studies. The Langley Research Center developed the "Manned Orbital Research Laboratory" (MORL) concept, Marshall Space Flight Center considered turning a Saturn rocket stage into an orbital workshop, and the Manned Space Center (later renamed the Johnson Space Center) developed the "Olympus" space station concept. The purposes of the three concepts were:

1. To see if a space station could be built
2. To determine what a space station could do
3. To determine areas to improve upon for the next space station attempt.

Aside from the national objective of demonstrating American technological superiority, NASA and its contractors gave little thought to promoting more substantive national objectives for the American public to buy into. Indeed, when the Langley Research Center held NASA's first space station symposium, in 1962, to discuss the research of the aerospace community, a litany of mission objectives were proposed for space stations—including many from Willy Ley's list—but not one page of the report is devoted to a discussion of national objectives.[21]

Meanwhile, in 1963, the U.S. Defense Department announced their own space station program, the Manned Orbital Laboratory (MOL). The purpose for the MOL program was never clearly defined, but many believe that it was "to be used primarily for reconnaissance purposes."[22]

Consisting of a cylindrical laboratory between 25 and 41 feet long, MOL supported visits from a pair of astronauts flying a modified version of NASA's two-man Gemini capsule. To the dismay of many in the military, MOL became obsolete in the late 1960s with the arrival of less expensive and more discreet unmanned observation satellites. Small satellites could provide superior autonomous reconnaissance capability without the complex life-support systems that men in space would require. At the same time that strategic observation satellites were being successfully demonstrated, the estimated cost of MOL had tripled from $1 to $3 billion. Faced with these factors, and a war in Vietnam to finance, the U.S. Department of Defense canceled the MOL project in 1969. Since that time, space stations have not been pursued by the U.S. defense community as a means to satisfy American military objectives.

NASA Struggles to Remain Relevant: 1969-1975

During the late 1960s, the Apollo lunar program was well underway, and NASA leadership became more aggressive in getting a space station funded. In 1969, NASA issued contracts for a "Phase B Space Station Program Definition Study" for a 12-man station costing between $8-15 billion with a design life of ten years.[23] Both McDonnell Douglas and Rockwell responded with concepts consisting of cylindrical stations supporting a multitude of scientific and operational activities.

NASA hoped that these Phase B studies would lead to full-scale development, but public interest in NASA's space station projects was low. In contrast to President Kennedy's clearly defined national objectives for lunar missions, neither NASA nor the White House provided sufficient justification to the nation for undertaking this expensive project. Since lunar landings were being accomplished without a space station, and world leadership in space had been

secured, there were no unique national objectives remaining for the space station to satisfy. America had higher priorities to pursue.

As the Apollo program came to an end in the early 1970s, NASA experienced a surprising reversal of U.S. public opinion. In a few short years, NASA had lost funding for further lunar expeditions, the Saturn rocket program, and hope for a "Man to Mars" project. While NASA engineers had been busy building Moon rockets, the rest of America had undergone the cultural upheaval of the '60s and involvement in the Vietnam war. NASA's space plans seemed to have lost its relevance to a generation of Americans more concerned about social issues and global problems, such as war, poverty and overpopulation. With the space-race won, and a war in Indochina to wrap up, the Nixon Administration was not supportive of NASA's space goals either, forcing NASA to fight for funding on the same terms as any other federal agency. The results were budgets in the 1970s about one-half as large as those in the late 1960s.[24]

Coasting on the waning momentum of the space race, NASA was able to pursue one last major manned space effort—Skylab. America's first temporary space station, Skylab's mission objectives were threefold:

1. To validate space station design theories
2. To study the effects of microgravity on humans for an extended time
3. To pursue general scientific goals, such as Earth, celestial, and solar observation, and microgravity research.[25]

Skylab's national objectives were less defined. Certainly Skylab was promoted as a means to sustain U.S. leadership in space between the Apollo and the Space Shuttle programs.[26] Also, many at NASA wanted to return to its original philosophy of building lasting space infrastructure. Skylab seemed to be the logical next step.

From Skylab, NASA learned that well-trained crews were capable of working productively in space for up to three months at a time. Advantages to having men in space were visibly demonstrated when astronauts saved Skylab from disaster by repairing a stuck solar array and adding a heat shield during several space walks. The three crews returned with plenty of advice on how to improve the next generation space station, including making the living quarters more "user friendly," requiring more maintainable equipment, and providing some free time for the crews to unwind after long hours of work. The success of Skylab gave NASA the confidence it needed to pursue more complex space station plans.

Exploring Other National Objectives: 1975-1979

In the mid 1970s, with the Skylab program concluded and Congressional approval of the fledgling shuttle program secured, NASA initiated another round of space station studies. In an effort to become more relevant to a large segment of American society, NASA decided to pursue the more broad and appealing national objective of "solving global problems through research."

In NASA's 1975 "Manned Orbital Systems Concept" (MOSC) study, emphasis was placed on space stations performing "[research] programs directly related to the improvement of life on Earth."[27] Earth observation would increase knowledge in meteorology, climatology, oceanography, and atmospheric phenomena, while research on the behavior of materials in the absence of gravity offered the chance to manufacture new medicines and materials not possible on Earth. By using remote sensing aboard a space station, NASA was quick to point out that nations could be alerted to impending droughts, harmful agricultural practices, and over-development.

When the "energy crisis" emerged as a major national problem in the mid 1970s, NASA began to look at ways that space technology could help solve that problem, too. NASA became interested in a proposal to use gigantic geosynchronous solar-array satellites to generate and beam electric power to Earth. The solar-array satellites required shuttles to launch them, space tugs to position them in orbit, and orbiting "garages" to maintain them. To NASA leaders seeking justification for a space station, a space shuttle, and an orbital transfer vehicle all in one neat package, this concept was most appealing. The MOSC study was dropped, and NASA called for a new "Space Station Systems Analysis Study" (SSSAS) to develop a huge space station complex to provide the necessary "space infrastructure" to support solar power satellites and other large-scale space structures.

The national objectives proposed for the SSSAS project are summarized in McDonnell Douglas' 1977 contractor report to JSC:

1. To serve important needs of man on Earth
2. To advance U.S. preeminence in science and technology
3. To generate an economic return on investment.

To support these objectives, McDonnell Douglas proposed four primary mission objectives:

1. Maintain the satellite power system
2. Build and maintain huge radio communications structures

3. Process materials in space for commercial users
4. Further scientific research.[28]

The three national objectives proposed for SSSAS were difficult to sell to the American public. There was no need to demonstrate U.S. preeminence in science and technology again, since the Apollo lunar landings and Skylab had so recently proven American leadership in space. Also, few believed space stations could be profitable, especially since NASA was having trouble solving fundamental problems with the solar array satellite proposal, such as the staggering cost of orbiting several million square feet of solar cells and the safe beaming of power to Earth. Since no miracle cures or exotic alloys came from Skylab, it was not clear to the average citizen how the SSSAS space station could serve man's important needs, either. Confronted by a bewildering array of missions, but no credible national objectives, the American public never became interested in pursuing the SSSAS concepts, and Congress would not authorize further expenditures.

NASA Takes a New Approach: 1979-1984

Despite earlier failures, in 1979 NASA's Johnson Space Center tried again to arouse public interest in space stations, with another in-house study entitled the "Space Operations Center" (SOC). Although essentially a rehash of SSSAS concepts, the authors of the SOC study showed a significant improvement in linking national objectives to a space station in the minds of many Americans. NASA carefully chose two national objectives for the SOC station:

1. To maintain American leadership in space
2. To motivate young people to pursue engineering and science careers.

These objectives are clearly voiced in a 1980 article:

> If the US is to maintain its leadership in space, continuity in research and development is necessary . . . [also] there is frankly a need for a real goal to maintain the dedication of present participants in the space program and the interest and enthusiasm of young people in space technology in order to motivate their pursuing engineering and science careers.[29]

NASA selected these two national objectives because they would appeal to the majority of Americans. By 1980, the children from the Apollo era had grown up and were having children of their own. Education was a significant concern for these "baby boomer" parents. What better way to justify a space program than

to show it would stimulate children's interest in school? Also, the continual Soviet presence in space aboard their mysterious Salyut space stations, coupled with the U.S. absence in space since the 1975 Apollo-Soyuz mission, clearly proved to Americans, in 1980, that U.S. leadership in space was lagging.

SOC did not lead to a full scale space station effort, but it served as a dress rehearsal for the opening act of the Space Station *Freedom* program. It marked a major shift in NASA's philosophy of how to promote space stations to the public.

In 1981, the Space Shuttle became operational, and NASA leadership wanted to move on and tackle another major space project. A national dialogue on the future of America's manned space program began in earnest. Debate focused on what America wanted from its space program, what it could afford, and what could be achieved. Many agencies, organizations, and U.S. leaders were called upon to form positions on the subject. Public debate was to prove healthy for NASA, and, along with the success of the Space Shuttle, NASA saw its budget and prestige increase significantly. With momentum building, NASA decided to make a major push for a space station, and by this time NASA was ready to talk the language of national objectives.

To lay a firm foundation for justifying the expense of a space station program, NASA created an inter-center Space Station Task Force. Instead of the old NASA pattern of first studying what a space station could do and then how it might be built, the Space Station Task Force asked industry and the scientific community to focus on what American national objectives the space station could satisfy. Many were asked the following question:

> If the United States were to acquire an initial civilian 'space station' complex in low-Earth-orbit in the 1990s, who could use it, how could they use it, what attributes, capabilities, and types of components should it therefore have, what would it cost, when could it become available, and what benefits could its use provide?[30]

The design would be molded around these conclusions. John Hodge, chairman of the Task Force, summed up the philosophy in 1982: "It's easy to design a space station. . . . What's not so easy is putting together all the elements in a design that is useful to the nation and realistic in terms of today's economic conditions."[31]

From the study, three U.S. national objectives were defined:

1. To solve world problems through research
2. To support space infrastructure
3. To serve as a staging base and testbed for Mars and/or lunar missions.

Having successfully convinced a majority of Congress with these three national objectives, President Ronald Reagan encouraged NASA, in 1985, to continue with the development of the space station. Eight missions—essentially Willy Ley's list from 1944—were identified to support the three national objectives. NASA reported them to the Senate Committee on Appropriations in March 1984:

1. An on-orbit laboratory supporting research on a wide range of life, materials, and other science topics, and the development of new technology
2. Permanent observatories for astronomy and Earth remote sensing
3. A facility for microgravity materials processing and manufacture of products
4. Servicing of satellites and platforms
5. A transportation hub to assemble, check out and launch space vehicles
6. An assembly facility for large space structures
7. A storage depot for spare parts, fuel, and supplies for use by satellites, platforms, vehicles, and people
8. A staging base for more ambitious future projects and travel (e.g., a lunar settlement or a human voyage to Mars).[32]

Space Station Freedom, 1985-Present

In 1987, President Reagan and the Congress allowed NASA, for the first time, to sign contracts with major aerospace companies to actually design and build a space station. International participation was solicited, and both the European Space Agency and the Japanese Space Agency promised to contribute a laboratory module, while the Canadian Space Agency pledged to provide robots to perform maintenance and construction tasks outside the modules. Later, in 1993, Russian contributions were considered as well.

Specific design requirements were developed to ensure the space station would support the national and mission objectives previously established by the Task Force. Space Station *Freedom* was underway.

NASA received much support—and also much criticism—for its fledgling station program. Many in the U.S. scientific community complained that the space station would siphon money from research projects at home. Congressmen voiced concern over the projected costs of the station, particularly since NASA had underestimated the Space Shuttle program by billions of dollars. As a result, the space station has undergone numerous concept reductions and design scrubs since its inception in 1987—to the consternation of NASA, as well as its International Partners. National and mission objectives were trimmed. From the list of eight mission objectives put forth in 1984, NASA retained only three, consisting of:

1. General space science research
2. Remote Earth sensing
3. Microgravity research.

National objectives were redefined, promoted extensively, and made official policy in NASA's "Space Station Freedom Strategic Plan" of 1992:

- o To enhance U.S. technological leadership and competitiveness
- o To establish an unprecedented international cooperative science and technology venture
- o To stimulate interest in mathematics, science, and engineering education
- o To provide a source of national pride and inspiration.[33]

In 1993, with increased budget pressures and a new Administration, a novel national objective emerged to save the space station from sagging support in Congress—using the space station as a tool of foreign policy. By buying Russian hardware for the space station, or by paying Russia to launch parts of the space station, many people believe the United States can use it as a channel to provide much needed foreign aid to Russia and help support Russian reforms.

The debate over the future of NASA's space station, and the purposes it should serve, will continue throughout its lifetime, but one thing is certain; in approving the space station program, a large segment of American society has approved, at least for now, NASA's set of national space station objectives.

Space Station *Freedom* incorporates mission objectives nearly 60 years old, and national objectives as old as NASA itself. After trying for over 30 years, NASA has finally found the elusive mix of objectives that fit well with America's political and economic circumstances. Along the way, NASA has learned that expensive space ventures must appeal to the fundamental needs and desires of the American people. As long as the public understands and accepts the basic reasons for undertaking Space Station *Freedom*, they will ensure its survival in the Congressional budget battles of the future. Now, the challenge is up to the engineers of NASA and its partners to put together a space station that lives up to the expectations of America, and of the world.

References

[1]von Braun, W., and Ordway, F., *History of Rocketry & Space Travel*, Thomas Crowell Co., New York, 1966, 1969, and 1975, p. 18.

[2]Tsiolkovsky, Konstantin, Russian journal *Science Survey*, No. 5, 1903. Translation from NASA TT F-243, p. 53.

[3]Tsiolkovsky, Konstantin, Russian magazine *Aviation Reporter*, No. 19, 1911. Translation from NASA TT F-243, p. 81.

[4]Winter, Frank, *Prelude to the Space Age*, Smithsonian Institution Press, Washington, D.C., 1983, pp. 22-23.

[5]Ley, Willy, *Rockets, Missiles and Men in Space*, Viking Press, New York, 1968, p. 101.

[6]Oberth, Hermann, *Die Rakete zu den Planetenräumen* (1923), translation paraphrased from NASA TT F-922, 1965, pp. 93-95.

[7]*Ibid.*, p. 93.

[8]Oberth, Hermann, *Wege zur Raumschiffahrt* (1929), from translation in NASA TT F-622, p. 480.

[9]Winter, p. 37.

[10]Sykora, Fritz, "Guido von Pirquet—Austrian Pioneer of Astronautics," *History of Rocketry and Astronautics*, R. Cargill Hall, ed., *AAS History Series*, Vol. 7-I, AAS Publications, San Diego, 1986, p. 151.

[11]*Civilian Space Stations and the U.S. Future in Space*, Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-STI-241, November 1984, p. 60.

[12]Miller, Ron, "Herman Potocnik—alias Hermann Noordung," *Journal of the British Interplanetary Society*, Vol. 45, pp. 295-296, July 1992.

[13]Ley, Willy, *Rockets - The Future of Travel Beyond the Stratosphere*, Viking Press, New York, 1944, pp. 231-234.

[14]*Ibid.*, p. 236.

[15]Clarke, Arthur C., "Extra-Terrestrial Relays," *Wireless World Magazine*, October 1945, pp. 305-308.

[16]Clarke, Arthur C., *Ascent to Orbit*, Wiley & Sons, Inc., New York, 1984, p. 65.

[17]Von Braun, Wernher, "Crossing the Last Frontier," *Collier's*, March 22, 1952, p. 74.

[18]Logsdon, J., and Butler, G., "Space Station Historical Overview," in *Space Stations and Space Platforms*, Vol. 99 of Progress in Astronautics and Aeronautics series, AIAA Press, New York, 1985, p. 209.

[19]Kennedy, John F., Speech given at Rice University, Sept. 12, 1962, from *The Space Station - An Idea Whose Time Has Come*, Simpson, Theodore, ed., IEEE Press, New York, 1985, p. 260.

[20]Spilhaus, Athelstan, Speech in *Vistas in Astronautics, Volume II*, Int'l Series of Monographs on Aeronautical Sciences and Space Flight, Alperin, M., and Gregory, H., eds., Pergamon Press, New York, 1959, p. 142.

[21]NASA Technical Note D-1504, *A Report on the Research and Technological Problems of Manned Rotating Spacecraft*, 1962, p. 2.

[22]Simpson, Theodore, *The Space Station*, IEEE Press, 1985, p. 32.

[23]Logsdon, p. 227.

[24]*Report of the Advisory Committee on the Future of the U.S. Space Program*, (the Augustine Report), Dec. 1990, U.S. Government Printing Office, Washington, D.C., p. 4.

[25]Gatland, Kenneth, *The Illustrated Encyclopedia of Space Technology*, Harmony Books, New York, 1984, p. 173.

[26]Compton, D., *Living and Working in Space*, NASA SP-4208, Washington, D.C., 1983, p. 1.

[27]Logsdon, p. 234.

[28]*Ibid.*, p. 239.

[29]NASA, Johnson Space Center, "Space Operations Center - A Concept Analysis," from the *Journal of the British Interplanetary Society*, Vol. 33, 1980, p. 419.

[30]*Civilian Space Stations and the U.S. Future in Space*, p. 141.

[31]O'Leary, Brian, *Project Space Station*, Stackpole Books, Harrisburg, PA, 1983, p. 47.

[32]*Civilian Space Stations and the U.S. Future in Space*, p. 60.

[33]*NASA Space Station Freedom Strategic Plan*, 1992, published by NASA Headquarters, 1992, p. 5.

Bibliography

Alperin, M., and Gregory, H., *Vistas in Astronautics, Volume II*, International Series of Monographs on Aeronautical Sciences and Space Flight, Pergamon Press, New York, 1959, 318 pages.

American Astronautical Society, *History of Rocketry and Astronautics, AAS History Series*, Volume 7, Part I, Hall, Cargill, R., ed., AAS Publications, San Diego, 1986, 238 pages.

Bekey, Ivan and Herman, Daniel, editors, *Space Stations and Space Platforms - Concepts, Design, Infrastructure, and Uses*, Volume 99 of the Progress in Astronautics and Aeronautics series of the AIAA, AIAA, New York, 1985, 392 pages.

Braun, Wernher von, "Crossing the Last Frontier," *Collier's*, March 22, 1952, pp. 25-29, 72-74.

Braun, Wernher von, and Ordway, Frederick, III, *History of Rocketry & Space Travel*, Thomas Crowell Co., New York, 1966, 244 pages. Other editions include 1969, 276 pages; 1975, 308 pages; 4th edition, *Space Travel: A History*, Harper & Row, New York, 1985, 308 pages.

Civilian Space Stations and the U.S. Future in Space, Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-STI-241, November 1984.

Clarke, Arthur, C., "Extra-Terrestrial Relays," *Wireless World Magazine*, October, 1945, pp. 305-308.

Clarke, Arthur, C., *Ascent to Orbit*, John Wiley & Sons, Inc., 1984, New York.

Compton, W. David, and Benson, Charles, D., *Living & Working in Space - A History of Skylab*, NASA SP-4208, Washington, D.C., 1983, 449 pages.

Gatland, Kenneth, W., *The Illustrated Encyclopedia of Space Technology*, Harmony Books, division of Crown Publishers, Inc., New York, 1984, 302 pages.

Ley, Willy, *Rockets - The future of travel beyond the stratosphere*, Viking Press, New York, 1944, 287 pages.

Ley, Willy, *Rockets, Missiles and Men in Space*, Viking Press, New York, 1968, 557 pages.

NASA Space Station Freedom Strategic Plan -1992, published by NASA Headquarters, Washington D.C., 1992, 48 pages.

NASA Technical Note D-1504, *A Report on the Research and Technological Problems of Manned Rotating Spacecraft*, Washington, D.C., 1962.

NASA Technical Translation TT F-243, *Works on Rocket Technology*, K. E. Tsiolkovskiy, Washington, D.C., 1965.

NASA Technical Translation TT F-622, *Ways to Spaceflight* (1929), Hermann Oberth, Washington, D.C., 1972.

NASA Technical Translation TT F-922, *Rockets in Planetary Space* (1923), Hermann Oberth, Washington, D.C., 1965.

O'Leary, Brian, *Project Space Station*, Stackpole Books, Harrisburg, PA, 1983, 159 pages.

Report of the Advisory Committee on the Future of the U.S. Space Program, (the Augustine Report), December 1990, U.S. Government Printing Office, Washington, D.C., 59 pages.

Simpson, Theodore, ed., *The Space Station -An Idea Whose Time has Come*, IEEE Press, New York, 1985, 295 pages.

Space Station Freedom Media Handbook, May 1992, NASA, Washington, Technical & Administrative Services Corporation, 1992, 102 pages.

Winter, Frank, H., *Prelude to the Space Age - The Rocket Societies: 1924-1940*, Smithsonian Institution Press, Washington, D.C., 1983, 207 pages.