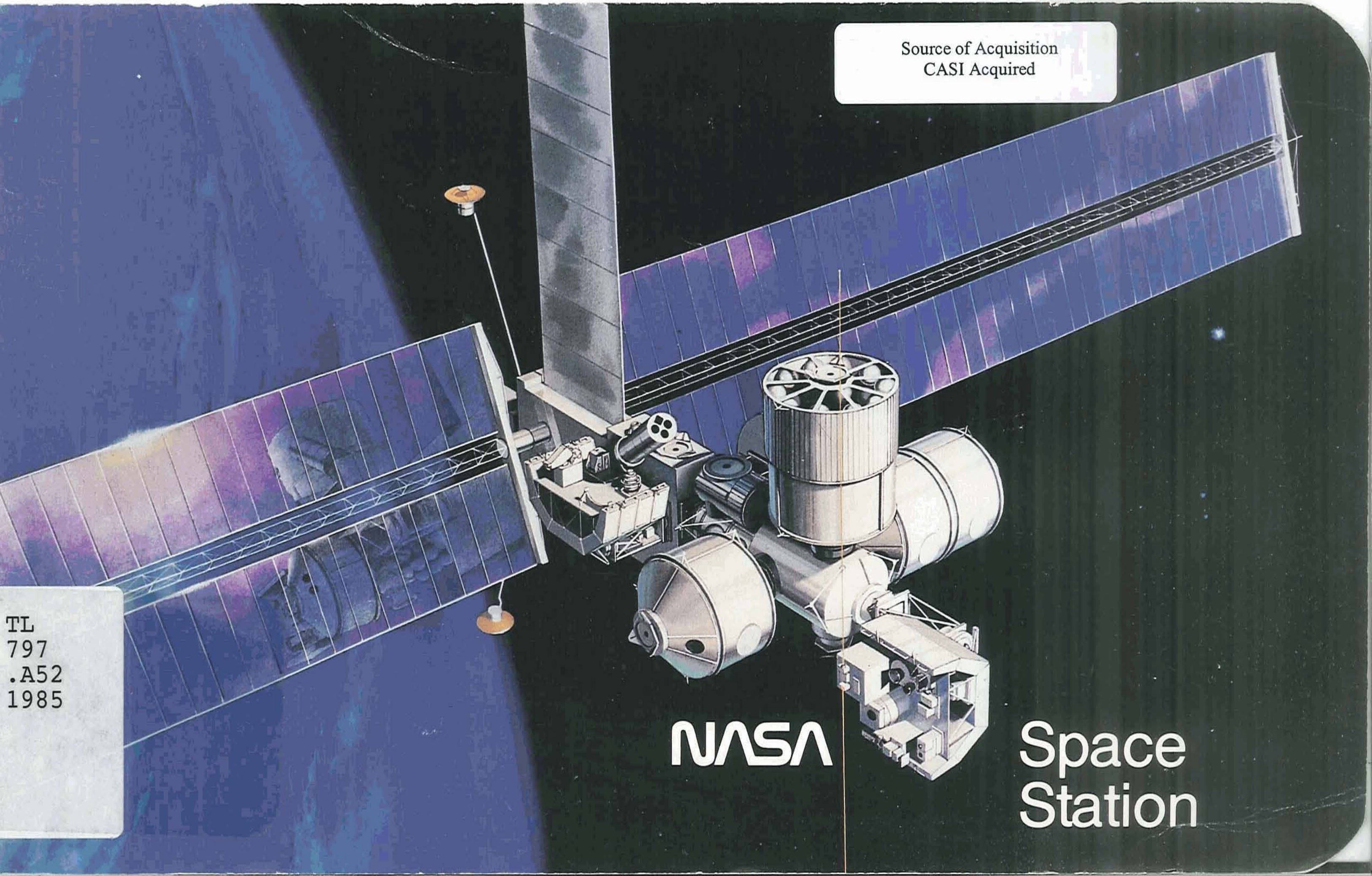

NASA

Space Station

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by
David A. Anderton

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"Tonight I am directing NASA (the National Aeronautics and Space Administration) to develop a permanently manned space station—and to do it within a decade."

With those words, part of the State of the Union message to Congress January 25, 1984, President Ronald Reagan signalled the official start of a bold new space program, essential to maintain the United States' leadership in space during the decade of the 1990s.

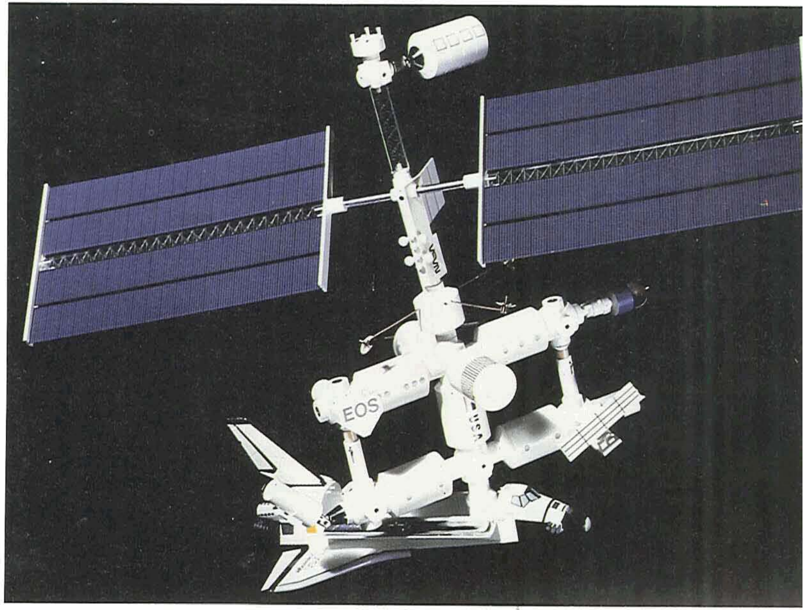
The dreams of centuries and the planning of a quarter-century were, at long last, on the road toward reality. Now, NASA had a Presidential directive to move aggressively again into space by proceeding with the development of a space station, the next logical step in a long sequence of unmanned and manned space flight programs. Further, NASA now had a deadline by which to accomplish that defined goal.

"We can follow our dreams to distant stars," said the President, "Living and working in space for peaceful, economic and scientific gain."

Living the dream

And now, imagine that the year is 1997. The space station has been built in orbit, and has been occupied for several years. Crews have arrived at that way station in space, stayed for a term, and returned to Earth. And now it's our turn. We are on the flight deck of a space shuttle, part of the logistics and transportation system that flies regularly to the orbiting station.

Out of the thousands of stars in the panorama that fills our viewing port, one seems to be growing brighter. It increases in size and brilliance while we watch, and then, almost suddenly, begins to appear different from



This concept of an advanced space station, developed in NASA-contracted studies by McDonnell Douglas Astronautics Company, shows the major characteristics of typical contemporary orbiting base architecture. Cylindrical modules house the crew, scientific experiments and a processing factory for the company's proprietary Electrophoresis Operation in Space (EOS) process. The space shuttle is shown docked at the receiving end of the hub structure.

the surrounding pinpoints of stars. Angular shapes protrude; the first we can discern seems to be a large rectangle, perhaps a solar collector or an antenna. It stands clear of the rest of a geometric cluster now taking shape as we watch.

The bright shape has resolved into a grouping of similar cylinders, joined by a hub-like structure. Closer now, external features are defined sharply by the extreme contrast of light and shadow: antennas, smaller cylinders, rectangular boxes, all looking like an assemblage of some unusual and unfamiliar geometric solid.

And now we are close enough to see the space station clearly, and to notice that there is activity around and aboard the clustered laboratories, workshops and living quarters. One cylindrical module is a repair and overhaul base; its bay is open, echoing the shape of the cargo bay of our shuttle, and secured inside is a recognizable communications satellite, in from orbit for scheduled maintenance.

Two astronaut technicians, space-suited and backpacked, are flying free from an unmanned work platform a few hundred meters distant. They are towing a canister containing data from the unmanned space probe that is parked, for the time being, at the edge of that platform.

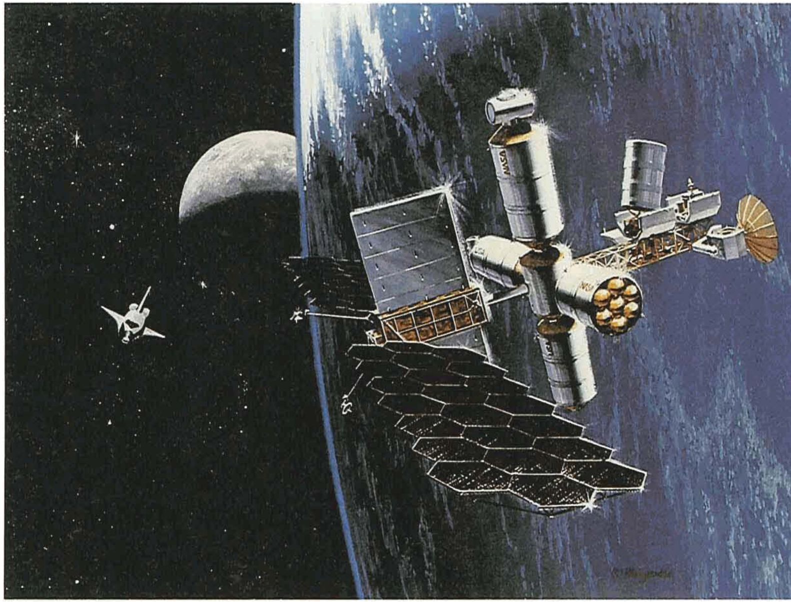
Slowly now, the shuttle begins a curving approach to the cluster. Our pilot initiates a slow roll to position the shuttle docking hatch against a corresponding entrance on the space station. Now, all we can see through the viewing port is stars, and once again we seem alone in the universe. But just meters away is a space station, a permanent base in orbit, and inside is a busy crew. Some of its members are preparing to receive the shuttle, some are working in an adjoining laboratory, and some are off duty and asleep.

The shuttle nudges the station hatch; there is a gentle grating sound and a muffled thump as the hatches dock and lock. We are there. Only a few hours ago we were launched from the pad at the Kennedy Space Center. But it has been years, decades, centuries since Earthlings first began to wonder, and hope, and scheme to get here.

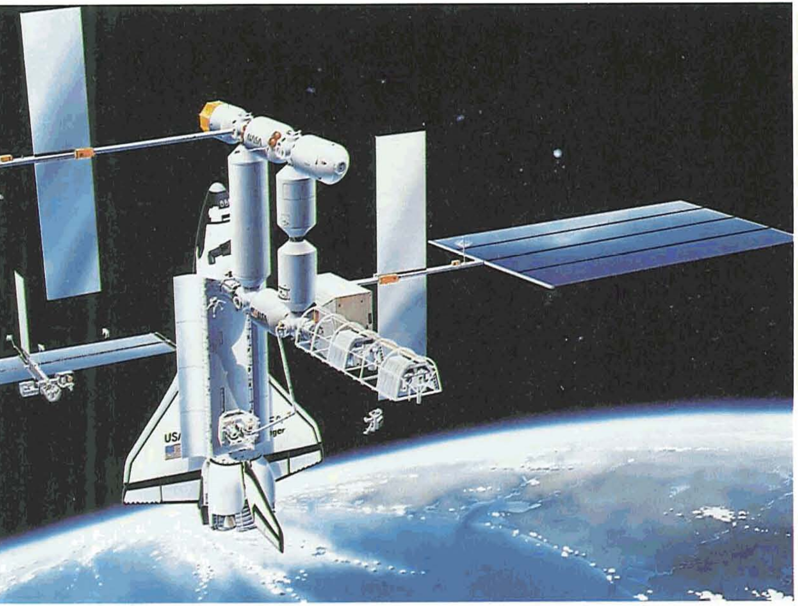
The dreams become concepts

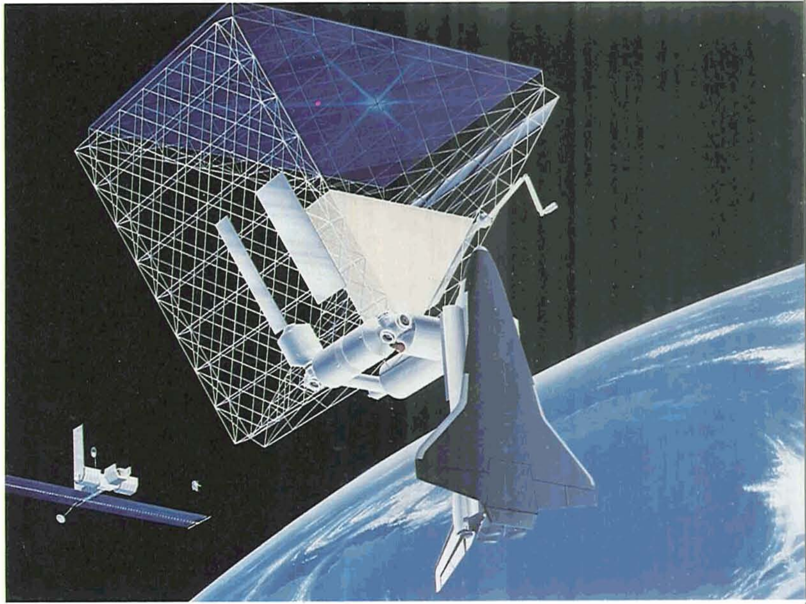
NASA's concepts for a space station are, right now, only concepts. There is much to be done before the envisioned clusters of habitats and laboratories, docking facilities, unmanned platforms and manufacturing plants become lines on paper and components in fabrication.

Literally years have been spent preparing for the detailed studies of the inhabited space station that will begin, now that the Presidential decision has been made to initiate the program. NASA

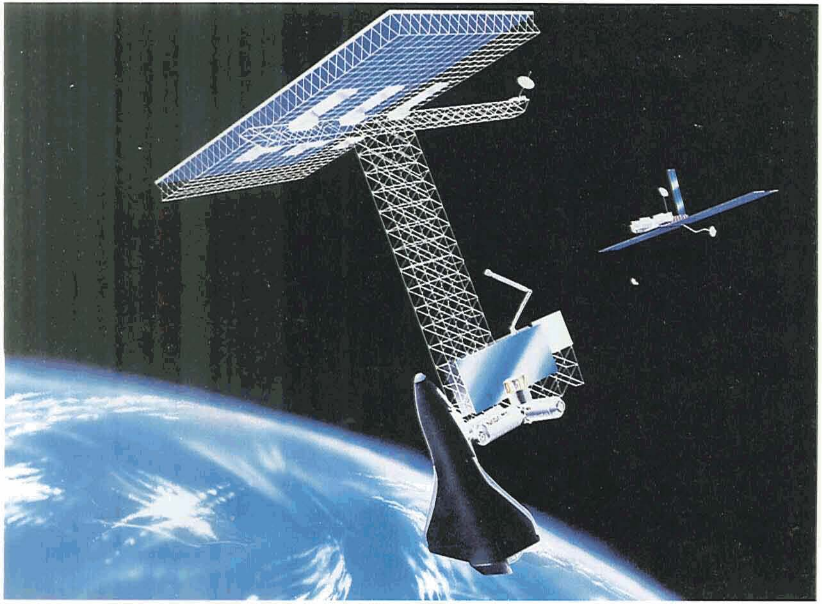


Space station architectural studies by TRW Space and Technology Group, under contract to NASA, produced this concept of an orbiting station.





These three design reference configurations were developed at the NASA Lyndon B. Johnson Space Center to help narrow the possible selections of space station architecture.



and industry contractors have studied the requirements, asked potential users for their inputs, and produced documents to guide the conceptual designs and the hardware designers.

That work was done under the minimal restraints of two broad sets of guidelines, one of management-related matters, the other of engineering-related subjects. From a management viewpoint, the space station effort was to begin with a three-year period for extensive definition of the concept.

Participation in the program would be NASA-wide, with the Johnson Space Center, in Houston, Texas, chosen to lead the effort. Development funding would be requested in the 1987 fiscal year (beginning October 1986); the initial operational date would be in the early 1990s, and the cost to that point would be about $8 billion. Extensive user community participation was scheduled, with industry, other government departments, commercial, scientific and technological interests represented. International participation also was invited, and considered likely.

In the engineering sense, the station would be planned for continuous habitation, depending on the shuttle for initial construction, resupply and crew transfer. Both manned and unmanned elements would be included in an evolutionary design that could grow as required. It was to be operationally semi-autonomous and, in the jargon of computer operators, "user-friendly."

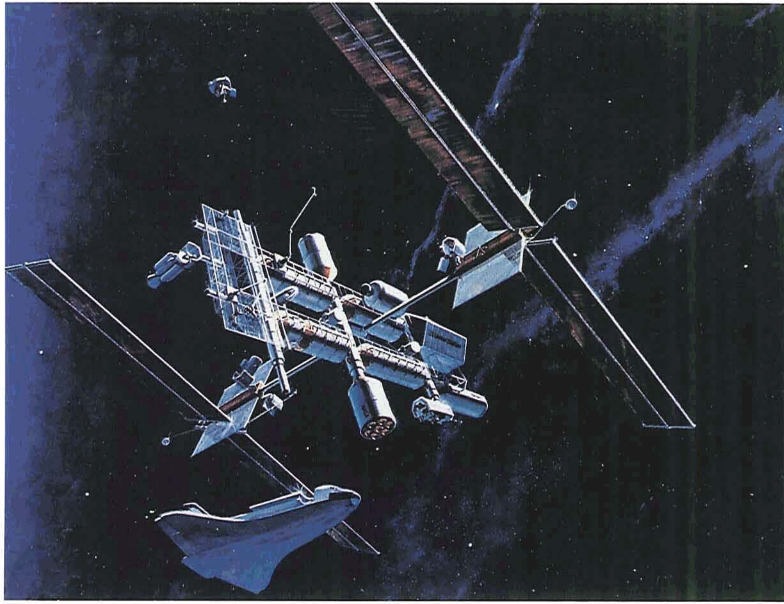
These considerations, earlier thinking within NASA, and mission analysis studies done under contract to industry during the previous years, resulted in a broad outline of station capabilities. It should have room for a crew of six to eight, working in two or three pressurized modules. It should be a versatile station, capable of supporting unmanned scientific experimental platforms as well as manned vehicles for flights into space or different orbits. Initially, the station should be able to service nearby satellites, and would be responsible for some attached payloads. The array should include two unmanned platforms, one in the same orbit as the station itself, and the other in a polar orbit. At some future time, the crew could grow to 12 to 18 members, utilizing four to six pressurized modules for research and technology development projects. The station would be able to send for distant satellites, and retrieve them for on-board servicing. Several unmanned platforms would orbit in the same plane as the station, and a space-based orbital transfer vehicle would be available to support station activities.

Then and now, functionally similar

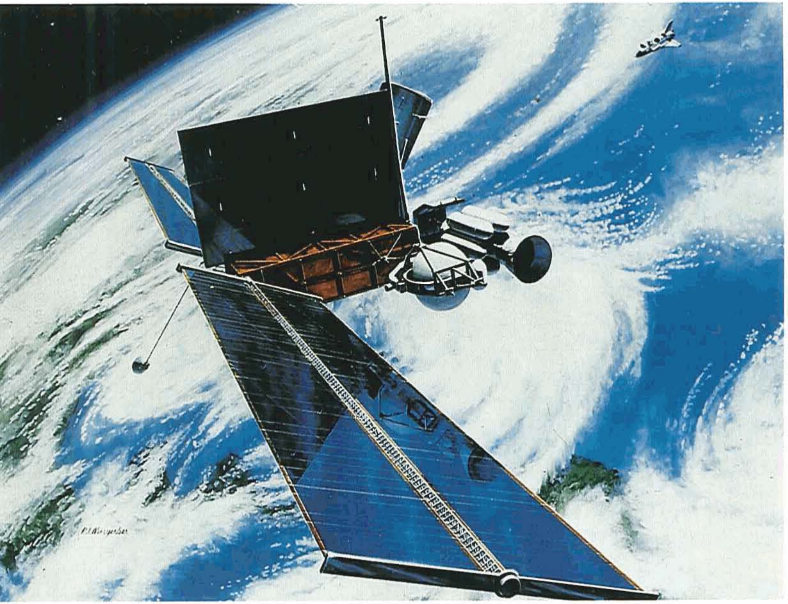
But all space stations resemble each other, whether they were conceived in science fiction a half-century ago or are yet to come from the drawing boards, engineering offices, computers and laboratories of an aerospace corporation. The fundamental design, on which the current studies generally agree, is a functional cluster of geometrically similar cylindrical modules. Each module performs a singular and dedicated task. Expanses of solar collectors dominate the cluster, and secondary assemblies of antennas, industrial or scientific modules give an air of randomness to the whole structure.

NASA studies in-house and under contract to industry have narrowed the focus of the many concepts for an inhabited space station. The current conceptual design favored by NASA planners foresees a cluster of four or five modules for living and work, augmented and supported by a number of separate vehicles. Additionally, there will be attached pallets for science experiments, and co-orbiting unmanned scientific platforms.

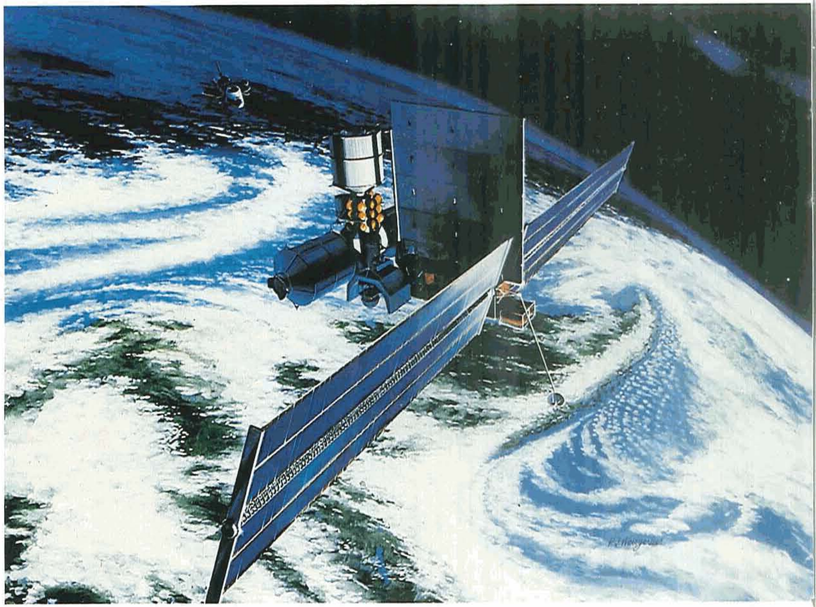
The permanent space base will lie in a low-inclination orbit at 28 degrees to the Earth's equator, and about 400 kilometers (250 miles)



This concept for a later-phase space station consists of dual solar arrays, modules for living and logistics, attached pallets for scientific experimentation, and orbital transfer vehicles. This concept was derived during mission analysis studies conducted for NASA by TRW Space and Technology Group.



An array of two large solar panels and a single radiator at right angles to them is the prominent design feature of this orbiting station concept developed by TRW Space and Technology Group. Partially hidden by the radiator is an orbital transfer vehicle. The shuttle (upper right) ferried the elements of this station into orbit, and continues to make regular runs for resupply and crew transfer.



From another angle, and at another time, the TRW concept shows an unmanned scientific pallet facing towards Earth. Next to it are three modules, two manned for living and experimentation, and the third unmanned, facing upward for logistics support.

above it. From that flight path, the crews and sensors will be able to scan the portion of Earth that lies between about 28°N and 28°S latitudes, an area including slightly more than the torrid zone. All of Europe and the USSR, and most of North America and China, will be out of observable reach.

The space station will be assembled in orbit. Necessary materials and components will be brought to the site in the space shuttle, and astronauts will do the actual building.

Design concept: Clustered modules

The core of the current clustered-assembly concept would be four or five cylinders, each approximately 4.25 meters (14 ft.) in diameter by 7.3 meters (24 ft.) long. Volume of each such cylinder is about 105 cubic meters (3,700 cu. ft.). The weight of this initial station—meaningless in the space environment, but significant in terms of shuttle payload—will be on the order of 36 metric tons.

One of these cylinders would house the crew of six to eight astronauts, with living quarters and amenities comparable to those of the earlier Skylab workshop. Complete and computerized climate control would be a feature of the new space station, with a "normal Earth" atmosphere of mixed nitrogen and oxygen in all areas. Working sections would have a shirt-sleeve environment, sleeping areas would be private and comfortable, and optimized cool temperatures would be maintained in the electronic bays.

Two other modules are scientific laboratories, one of them perhaps dedicated to the study of life sciences, and one most likely serving as a space factory for materials processing. The fourth is a logistics unit, primarily a supply module. There also would be a backup logistics module available, to be brought up fully loaded on a subsequent shuttle flight and traded, intact, with the depleted unit. Presumably, this would be done on the same shuttle flight that brought up a replacement crew, to take over from the crew that had been in space from three to six months.

Joining these modules into a single cluster is one of the functions performed by the multiple docking adaptor. When pressurized, this unit serves as the temporary connection between space station and shuttle.

Module for satellite servicing

An unpressurized module, geometrically similar to the shuttle cargo bay, would serve as a service station for satellites. Repair, overhaul, refurbishing, and perhaps even maintenance of satellites, both scientific and commercial, would be done here. Its equipment would include manipulator arms, like the one installed in the shuttle.

An expanse of solar cells (about 2,000 square meters in area), positioned well clear of the station to allow additions for future power requirements, would be the primary source of energy for the orbiting base. The solar array would generate about 75 kilowatts of electrical power, sufficient to meet the station's initial needs, and would be programmed to move to face the Sun for maximum collection effectiveness. Supporting equipment for electrical power storage, for the station itself, and for the astronauts housed there, would be located in another unit, adjacent to the solar array.

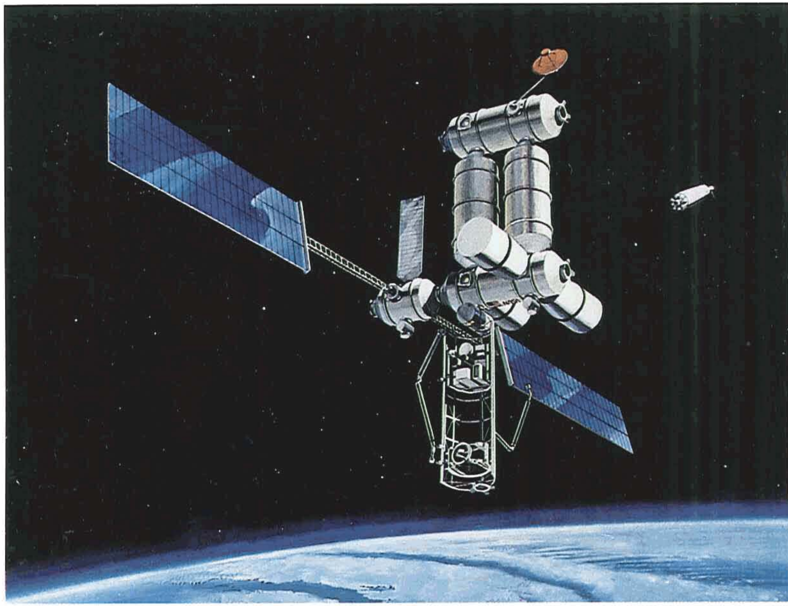
An unmanned propulsion package, designated the Orbital Maneuvering Vehicle (OMV) by NASA, would be based on the station. This vehicle is perceived as a relatively small machine, basically a platform with restraints for its cargo, and a rocket powerplant for propulsion. Its mission is the retrieval of free-flying spacecraft in need of servicing. It would be launched and flown automatically to the satellite, retrieve it, and return it to the open servicing bay of the space station for necessary work.

Two free-flying platforms would be associated with the orbiting base. One of them would fly in the same 28-degree orbit as the space station. Its function would be to carry scientific or commercial research payloads that could operate independently, and that would need only infrequent attention from an astronaut. The other would fly in a 98-degree Sun-synchronous polar orbit, and would be used to look at the Earth through a variety of sensors. This platform, oriented as it would be and operating independently of the space station, would be a logical choice for whatever payloads might be required for Earth resources observations. This polar-orbit platform, because it would be out of reach for servicing by the space station crews and equipment, would be serviced instead either by the space shuttle or by a shuttle-based orbital maneuvering vehicle.

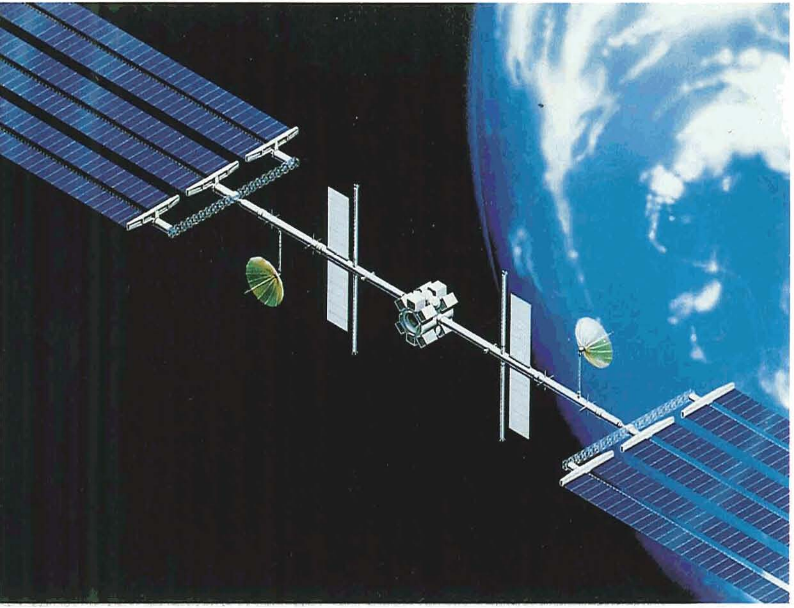
Planners studied a wide variety of scientific missions that could be supported by the space station. Some, already assigned to fly aboard the space shuttle, could profitably be transferred to a space station in permanent orbit. Some could later operate independently in space as one of a number of free-flyers, serviced by station personnel and equipment, but not necessarily associated with the station in a close and parallel orbit.

In general, scientific experiments that are heavily dependent on stabilized and accurately pointed instrumentation require strict control of their environment to avoid the potential presence of destabilizing forces and contaminating substances near the space station. That combination of needs dictates that those experiments be mounted on free-flyers, with the space station serving as the support base, providing servicing and repair as needed.

From a scientific standpoint, the space station would provide advantages for ambitious future missions such as the return of samples from Mars. That kind of mission requires assembly of the flight vehicle in orbit, because of its size and launching requirements.



A mature space station configuration might look like this one, conceived at Rockwell International's North American Space Operations Division as part of contracted NASA studies. Two solar panels provide power. Cylindrical modules are arranged for living and for experimental activity. Prominently featured are the advanced remote manipulator systems for assembly of large structures and the servicing or storage of satellites and instruments. An Orbital Transfer Vehicle (OTV) is shown (upper right) returning to the station after delivering a payload to a higher orbit.



Current plans for space station architecture visualize an evolutionary base, with elements progressively added. The first element likely to be stationed in orbit will be the utility module, consisting of power, communications, thermal and other core systems for the final station. Shown here are the two solar sails, a pair of radiators, two communications antennas, and a central core of equipment and systems.

Cost estimates and timetables

All of this space structure will be developed and emplaced for about $8 billion, according to the latest NASA cost projections. Spending would start modestly enough, with about $100-150 million being the initial increment for definition of the station concept. Follow-on design effort could require about $250 million and then an initial increment of about $1 billion would be needed as the first contracts were awarded for construction of hardware.

Then, following those expenditures, components would be designed, planned for transport to orbit by the shuttle, tested, and shipped on a sequence of outbound ferry flights.

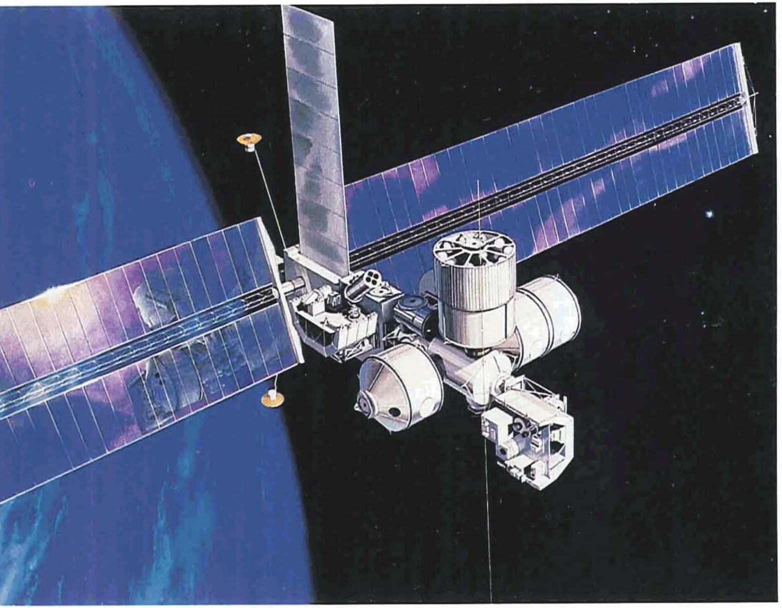
Assembly in orbit would follow, and the station would begin to form. Its solar cells would begin to produce power, and the orbiting base would take on some of the attributes of life.

NASA studies to date indicate that the initial space station assembly could become operational early in the 1990s. It is too soon to guarantee a firm opening day. Lifetime of the initial station is estimated at between 20 and 30 years. Further along in time, NASA foresees the possibility of adding a second orbiting space station, in a polar orbit to meet future requirements. It may seem premature to talk about a second orbiting base, when a first hasn't yet been designed. But early planning is necessary, and the reasons for a second base are compelling. They grow out of the many uses of a single space station.

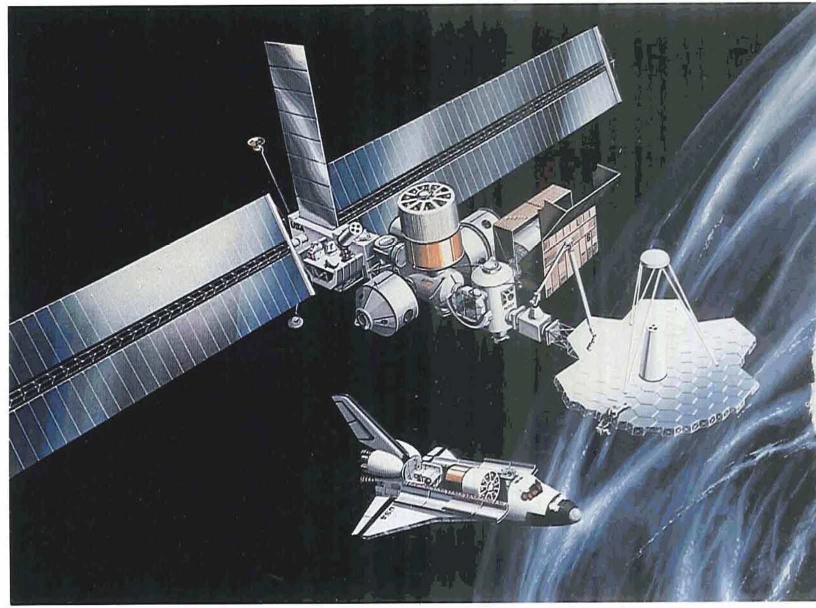
International cooperation in space

One of the ways suggested to broaden the appeal of the space station, and to provide for some cost-sharing of the initial expenses, has been the selling of "condominium rights" to other countries. Under this concept, familiar to urban dwellers and owners of resort homes, a participating nation would pay the cost of its involvement in the space station. This would be above the $8-billion investment of the United States.

NASA discussions with foreign nations and agencies have resulted in interest expressed by a number of them, including Canada, France, Germany, Italy, Japan, and the European Space Agency (ESA). There are a number of reasons for this international interest. ESA has been a continuing participant in the shuttle program, and there have been other past cooperative programs in space. The technological capabilities developed by other nations have positive, constructive contributions to make.



A central airlock joins two habitat modules (left and right) and an unmanned logistics module (upper) in this concept of a space station designed under NASA contract at the McDonnell Douglas Astronautics Co. A rotating pallet for space science and applications payloads completes the cluster of modules.



A large antenna is under construction in this concept of a space station by McDonnell Douglas Astronautics Co., designed under contract with NASA.

But why a space station, anyway?

The most convincing reasons follow from the wide acceptance of the argument that space exploration is today as inevitable as the opening of the West was two centuries ago, or as the exploration of Antarctica became 50 years ago. With that as a given, there appears to be a logical procession, an orderly way to explore space. An initial effort employs small scientific satellites, and expands to manned satellites like Mercury and Gemini. After learning as much as possible with those systems, go to the Moon. Then establish a prototype laboratory in space, like Skylab, and develop a space resupply system, like the shuttle. The next logical step is a permanent orbital space station.

Next, from that base, extend into space. The orbiting base becomes a way station, a transportation node, on the road to the planets. From it, supply trains leave regularly for a permanent scientific base on the Moon, the 21st century counterpart of a base in Antarctica. From the orbiting space base, an in-orbit-constructed spacecraft—mammoth, fragile and spiderly—sets sail for Mars with a human crew readied for the two-year voyage.

Commercialization is a valid reason

Is that too visionary? Then consider a very practical set of reasons. Space possesses extremes of cold and vacuum, coupled with a lack of gravity. There are some high-technology industrial processes that are very difficult to accomplish on Earth, in the presence of gravity, and where vacuums and low temperatures must be achieved expensively by pumps and refrigeration equipment. Would it be at all economical to process materials—pharmaceuticals of exquisite purity, perhaps—by such techniques as electrophoresis (the separation of substances by electrical, rather than gravitational, forces) in space? The answer is yes, and there are industries today ready to do just that.

That's why one of the space station's proposed modules is dedicated to materials processing. That's also why NASA has planned a space commercialization organization which will consider and then propose policies for industrial use of the space station. The market is apparently huge; one NASA official states that it is "...approaching billions of dollars within the next five to seven years." And these figures only refer to new kinds of business, not to the continuing commercial satellite programs.

The NASA official added that new high-technology ventures are the most important programs to consider. One example is the Electrophoresis Operation in Space (EOS) effort pioneered by McDonnell Douglas on shuttle flights, and now augmented by Johnson & Johnson participation. Other areas for commercialization include new applications of existing space technology, and those commercial ventures that would move existing programs and services out of government and into the private sector.

Further, the kind of scientific satellite that can be sent into space is limited by the payload size of available launch vehicles. Suppose that there were no such limit on size, and that a scientific probe could be constructed—by humans, probably—in space, made of the flimsiest materials because they would not be required to withstand the stress of gravity and the launch. Such a probe would be welcomed by the scientific community as a true breakthrough in the exploration of space.

Why an inhabited space station?

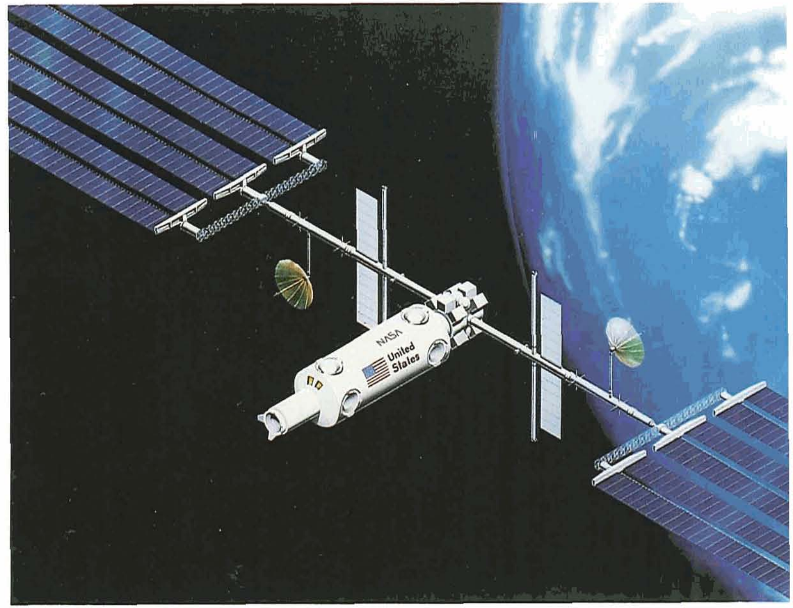
There are definite advantages to having a crew available for observations. The arguments are widely accepted. Humans can exercise judgment, can step in when and if automation has gone awry. They can change observation programs to account for unexpected changes in the observed subject, such as a new volcanic eruption or a solar flare, or to compensate for malfunctioning equipment. And as originators of experiments and observations, humans have no peers. The astronauts of Skylab were able to relay more useful information about the oceans than any of the then-available unmanned devices could do. The astronauts on Spacelab were able to repair scientific equipment and enhance the productivity of the mission itself.

And while it is true that the capabilities of unmanned satellites and probes are absolutely astounding, there are times when the ability to retrieve and repair one would be worth many millions of dollars. Astronauts, based on and working from the space station, can provide that service.

There are intangible reasons for establishing an inhabited space station, reasons of national prestige and pride, the enhancement of national security, and the stimulation of interest in scientific and technical education.

And there are long-range goals that include scientific settlements on the Moon, manned flights to Mars and back and colonies in gigantic space ships.

To put some numbers on many of these, NASA carefully studied a series of possible missions that were feasible, and that could be done most efficiently with the orbiting space station. A preliminary list totalled more than one hundred separate missions, many of them with commercial applications, others for the development of technology, and still others in



The next payload delivered by the shuttle would be a habitat module, shown here attached to the basic utility module.

science. That list of missions alone, said NASA, would occupy the operations of a manned space station for the remainder of this century.

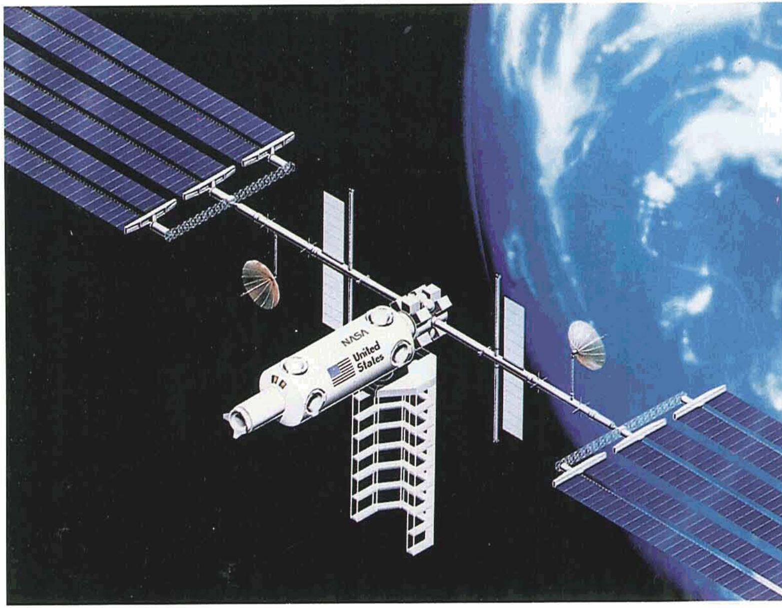
Even Newton thought of a space station

Sir Isaac Newtom defined a series of natural laws governing the motions of matter, and it is to Sir Isaac that historians generally bow when they cite references to early concepts for Earth satellites. In Newton's book that laid the foundations of science, *Philosophiae Naturalis Principia Mathematica,* written in Latin and printed in London in 1687, there appears this passage (from a later English translation) in a section defining centripetal forces, for example, gravity: "And after the same manner that projectile. . .may be made to revolve in an orbit, and go round the whole earth. . ."

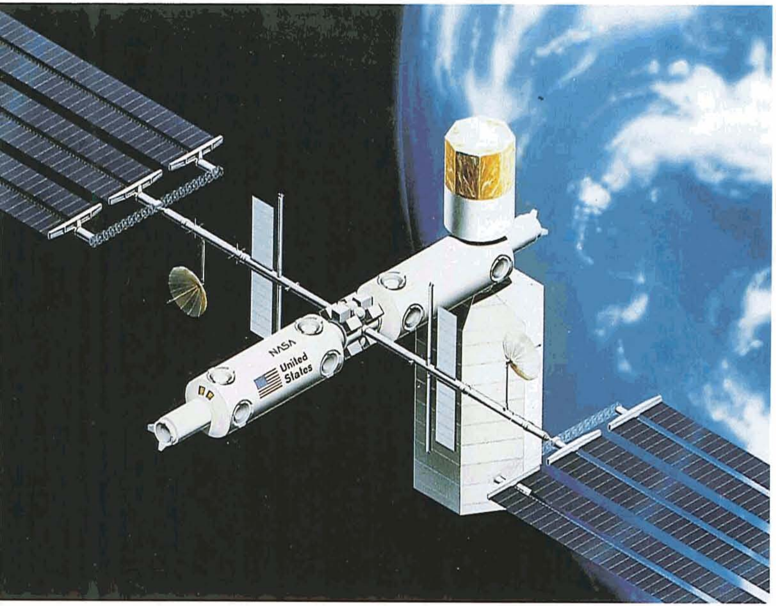
Certainly one of the earliest references to a space station in fiction appeared in a series of three articles in the magazine *Atlantic Monthly* in late 1869. They were written by the Rev. Edward Everett Hale, a Boston clergyman, grandnephew of the Revolutionary War hero Nathan Hale, and the featured orator at Gettysburg the day Lincoln made his immortal address. Hale's title, *The Brick Moon,* gives away the concept. He envisioned a hollow, spherical space station, 200 feet in diameter, to be used to aid navigation. It was to be built of bricks, whitewashed on the outside for higher visibility. Hale suggested that it be fired into place from a gigantic flywheel assembly driven, like a millwheel, by a waterfall. It was typical of many of the early concepts for space flight and space habitations, based on a broad ignorance of anything beyond the writer's experience.

The great Russian space pioneer Konstantin Eduardovitch Tsiolkovskiy described an Earth satellite in a 1911 article in the aviation journal *Vestnik Vosdukhoplavaniya.* He wrote about an imagined arrival in orbit, and of observing the Earth during the two-hour orbital period of the satellite. And he wrote of the great longing that he and every other dreamer about space flight has experienced: "This picture is so majestic, attractive, and infinitely varied that I wish with all my soul that you and I could see it." He never did, and few of us—unfortunately—will.

Hermann Noordung (a pen name for Austrian Imperial Army Captain Potocnik) published *Das Problem der Befahrung des Weltraums* (The problem of space travel) in 1928. It is noteworthy today because Noordung devised a space station layout shaped like, and rotating like, a wheel around a central hub which also was a docking adaptor. The spin was intended to generate pseudo-gravity. Spiral stairwells connected the central hub and the living and working quarters around the rim. A huge parabolic solar collector was to be the source of power; its focused heat ran a steam powerplant.



The third element of the evolutionary space station would be a payload storage and repair bay patterned after the space shuttle's payload bay. This open-sided structure is shown positioned below the habitat module.



An alternate possibility for the space station configuration is to add a second module, for command purposes, and then to install an enclosed space "garage," protecting vehicles while they are being serviced or stored at the base. A logistics payload also has been docked to the command module.

In October 1951, the Hayden Planetariam in New York City held the First Annual Symposium on Space Travel. Members of the editorial staff of *Collier's* magazine were among the attendees; they later convened a scientific symposium of their own, publishing the results as a series of articles. The articles, later expanded into a book, *Across the Space Frontier* (Viking Press, New York, NY, 1952), developed Noordung's concept into an elaborate, 76.2-meter (250 ft.) diameter space station. That spinning wheel, positioned about

1,600 kilometers (1,000 miles) above the Earth in an orbit with a two-hour period, rotated three times per minute to generate a synthetic gravity. Later, the idea and concepts were used by the Walt Disney Studios as the basis for a series of television programs about space flight. The TV images were convincing; space stations might, indeed, look like that.

Everybody's concept of a space station

But it was a movie—Arthur C. Clarke's *2001: A Space Odyssey*—that fixed in many minds the typical space station. Those unforgettable opening scenes, with the space shuttle approaching the massive and slowly spinning spoked toroid, influenced an entire generation who will never again hear Johann Strauss' *An der schoenen, blauen Donau* (The Beautiful Blue Danube) without a sudden recall of that awe-inspiring approach.

The proposed grouping of modules for NASA's 1991 space station in no way resembles the fanciful wheel of *2001*. Conventional wisdom at the time that film was made suggested that artifical gravity would be necessary for long-term habitation. But after NASA's experience in a series of space programs that placed astronauts in an environment almost totally lacking in gravitational attraction, it was concluded that it simply was not necessary to provide the rotational motion, and its concomitant centrifugal force, to simulate Earth gravity.

Instead, today's plans show living and working modules huddled together around a hub, extending feelers and collectors and manipulators into space, and resembling some fanciful robotic spider poised at the center of a web of stars.

Such configuration studies arose from a series of industry contracts issued by NASA in August 1982. Eight major aerospace firms—Boeing, General Dynamics, Grumman, Lockheed, McDonnell Douglas, Martin Marietta, Rockwell, and TRW—were asked to analyze the science, applications, technology development, national security and space operations missions that would either require, or benefit from, a permanent space station in low Earth orbit. They were not asked to design such a station, but they were expected to develop what is called basic architecture—a generalized concept of how such a station could, or might, be designed on a functional basis. The specific shapes could come later. Form, said famed architect Frank Sullivan, follows function.

Basic space-station architecture

The contractor study teams considered the requirements and limitations, and developed individual views of an idealized space station architecture. In April, 1983, they reported the results of their studies. Broadly conceived, an Earth-orbiting permanent space station could be much more than a scientific laboratory and observatory. It could serve as a manufacturing facility, for commercial applications of the derivatives of space science and technology. It could be a transportation node, a place to base payloads and vehicles for processing and launching, and a servicing facility, where those same payloads could be maintained and repaired. It could be an assembly base, to join components of space structures and build the gigantic arrays of sensors, collectors, and supporting equipment required for distant space exploration.

"Were NASA to have (such) a station," said NASA Administrator James M. Beggs, "It could represent a fundamentally new and versatile capability to support activities in space over the next 30 years."

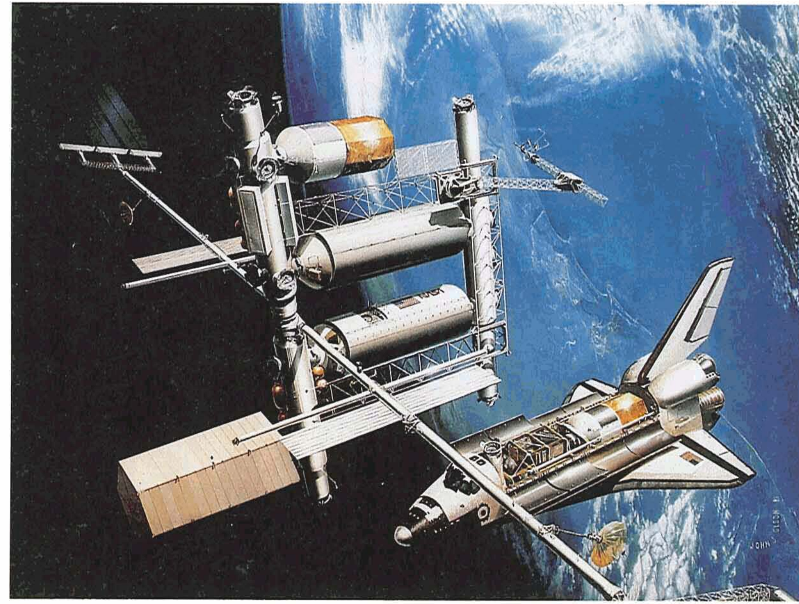
The results of the contracted studies were generally consistent, suggesting an inhabited base station and an unmanned platform in a low-inclination Earth orbit. An orbital maneuvering vehicle was proposed to support space station operations, and a second unmanned platform was suggested for observations from a polar orbit.

The studies agreed that such an orbital base and its supporting vehicles would be capable of performing a wealth of significant and promising missions, including scientific experimentation and research, technology applications, and commercial applications of space technology. Further, the design studies indicated that an evolutionary growth process was desirable, so that a first-step, conservative space station design could easily be carried to, and assembled in orbit by the shuttle system.

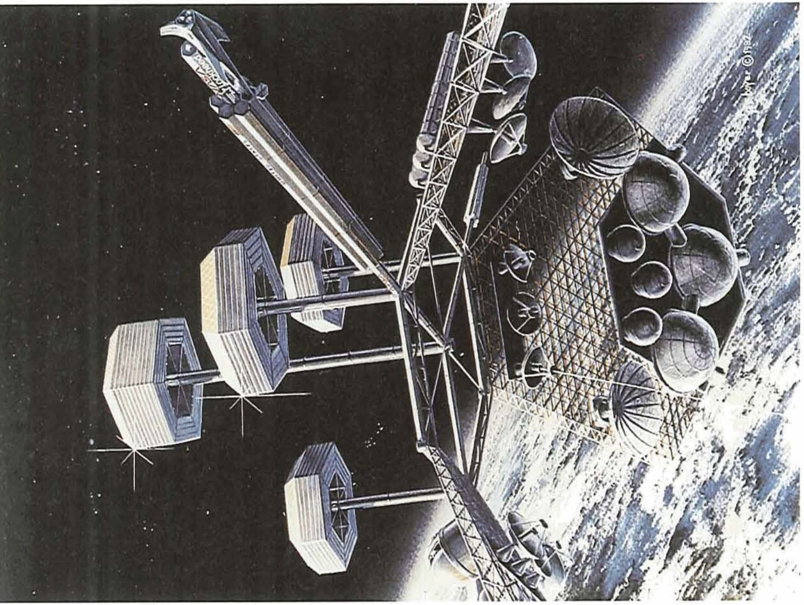
Later shuttle trips could add to that basic structure as needed, so that an eventual orbiting space station could be an elaborate complex of living and working quarters, with satellite servicing and support, commercial processing plants, scientific laboratories, and terminal facilities for space travelers to and from orbit.

Further, studies suggested that the space station should be used as a support and launch base for an orbital transfer vehicle, so that space flights could be made from the base to geosynchronous Earth orbit, and even beyond.

These contractor efforts were paralleled by studies of possible contributions by for-



The space shuttle approaches its dock on the space station, payload bay open and ready for contents transfer to the orbiting base. In this concept by Boeing Aerospace Company the modules are linearly attached by cylindrical passageways, rather than clustered around a central hub.



Space station concept developed at Lockheed Missiles & Space Company features living quarters and control center spun slowly to create artificial gravity (central hexagonal solid). Three zero-gravity modules (surrounding central hexagonal solid) are used for scientific and commercial applications. All are interconnected by a network of pressurized tubes. Each platform has 360-degree line-of-sight communications, without interference from flight paths of shuttles or other space vehicles.

eign organizations to such missions; they were conducted by (and paid by) the European Space Agency, Canada, France, Germany, Italy and Japan.

Also in April, 1983, NASA formed a Concept Development Group (CDG) with the task of integrating the eight contractor studies to produce a basic set of architectural concepts which would be a foundation for follow-on definition of the station itself. The CDG has produced four iterations of the architectural concept process so that the best cost and schedule estimates and goals can be derived.

According to the current time schedule, in 1987 NASA will choose the best possible synthesis of these eight forms and initiate the building of a space station.

Ten years may pass swiftly

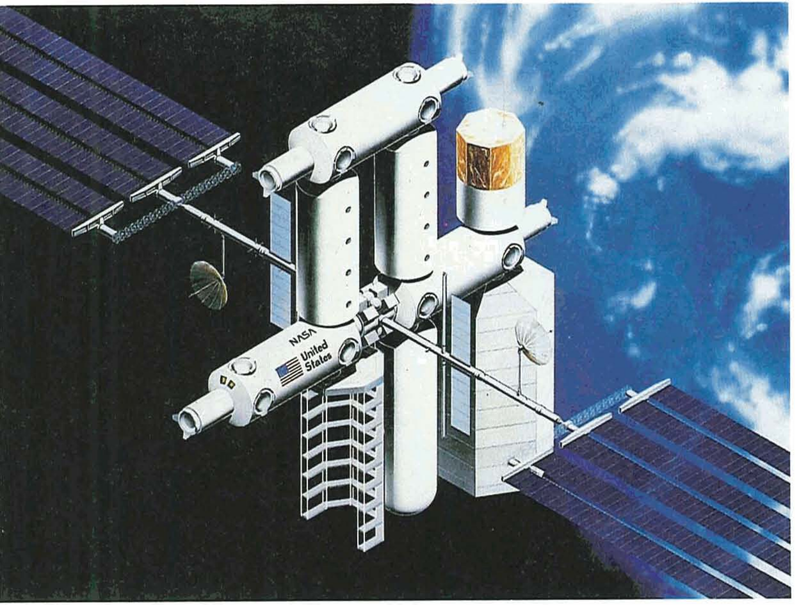
A decade to accomplish that is not too long, even given the extensive experience accumulated over the years of America's space program. NASA, assigned the responsibility for manned space flight programs even before its official 'open-for-business date of October 1, 1958, planned for a deliberate and consistent gathering of the voluminous knowledge required to move boldly and safely into space. That planning was intended to explore and exploit every flight to the utmost, and to schedule experiments and operations that would furnish the experience and knowledge to enable the next step to be taken.

The list of unknowns was formidable. The effects of long-term weightlessness were a major concern, as were other health and fitness considerations. If man were to be placed in space, it was necessary to know how best to send him there, how to safeguard him during his exposure to the new environment, and how to return him safely to Earth.

Project Mercury was the first American probe into the mysteries of manned space flight. Its epochal first suborbital mission, flown by Astronaut Alan B. Shepard, Jr. on May 5, 1961, produced about five minutes of weightlessness, hardly enough time for any quantification beyond Shepard's subjective feelings of pleasantness. What it did prove, beyond further argument, was that the chosen re-entry vehicle design, with its ablating heat shield, was a safe and effective way to return astronauts through the scorching speed of the return to Earth.

By the time John Glenn had accomplished the first U.S. orbital flight, the phenomenon of weightlessness was beginning to yield to understanding. Subsequent flights built on that experience, slow step by slow step, and when the Mercury program ended in May 1963, its primary goal had been achieved. An American astronaut had been flown to, and kept in, orbit for a full day, and then returned safely.

A sequence of ten Gemini flights, with their crews of two astronauts, began in March 1965. The Gemini flights taught much about rendezvous, docking, controlled re-entry, and extravehicular activity. They also showed that astronauts could abide weightlessness for at least two weeks without serious medical problems.



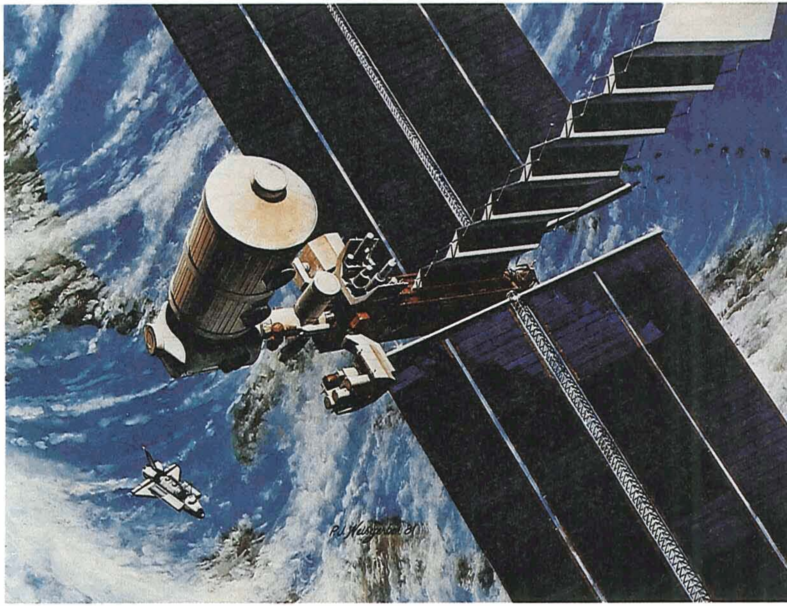
After seven or eight shuttle trips, the space station might look like this concept. Its crew of 8 or 12 would be aboard and operating the station. Each command module now has an attached command center, and bridging the upper two centers is a docking tunnel. The lower structures include the open-sided assembly fixture, a propellant storage tank, and an unpressurized space "garage."

Apollo pioneered lunar exploration

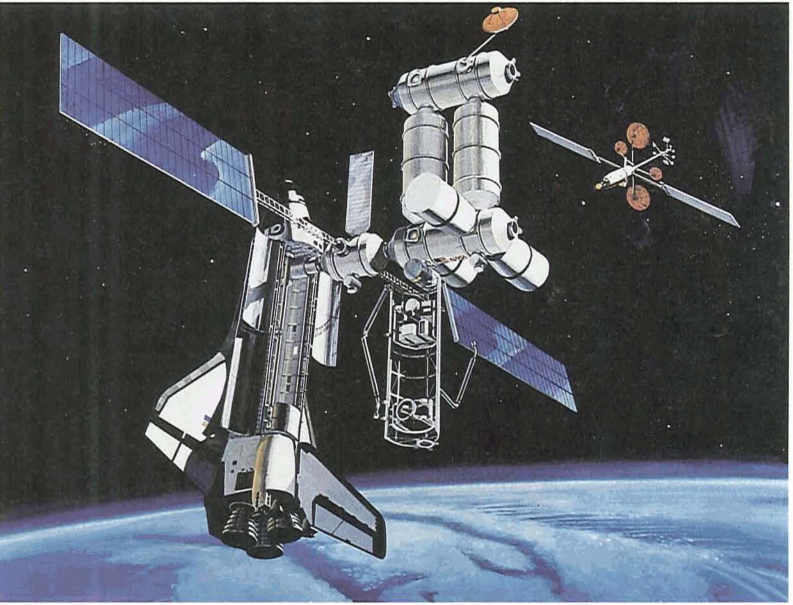
The Apollo program methodically extended those rudimentary space flights to orbiting, landing on, and exploring the Moon. It also showed a watching world the drama of the first human to walk on the Moon. Astronaut Neil Armstrong stepped off the ladder of the lunar module and landed on the Moon's surface on July 20, 1969, achieving a primary goal of the Apollo program. More than three years later, Apollo 17's crew, last of the lunar explorers for a while, returned to Earth in December 1972.

Those pioneering flights to a forbidding environment demonstrated that navigation to and from the Moon could become routine, and that astronauts could land on and explore the lunar surface. Apollo's flights also proved that a permanent, inhabited lunar base was not a wild vision of science-fiction. It had become perfectly feasible, if there were a requirement to build it.

On May 14, 1973, a new spacecraft established itself in low Earth orbit. Damaged during its launch, Skylab seemed doomed to be aban-



This concept evolved from a study of an unmanned space platform performed by TRW Space and Technology Group, under contract to NASA. In this illustration, the space shuttle is shown (lower left) delivering a second pressurized module to the station, to augment its capability to house both crew and scientific payloads.



Relative size of the space shuttle and the space station is emphasized in this picturization of a typical resupply mission. The shuttle is docked, and a communications satellite has been removed from its payload bay and stored temporarily in the open-sided assembly bay, where manipulator arms and astronauts performed the final assembly and checkout. Then, attached to an orbital transfer vehicle, the satellite (upper right) is ferried to a higher orbit.

doned before its first crew arrived to take up housekeeping. But ingenious solutions, devised by NASA engineers, produced a fix that was transported to space and accomplished—not with struggle—by the first Skylab crew. "We fix anything," was their proud claim.

Three times, three crews of three astronauts each made the voyage to Skylab aboard a modified Apollo command module, and returned on the same vehicle. The first crew, after repairing Skylab so that it could be inhabited, stayed there for 28 days. The second crew spent 59 days in orbit. And the third logged 84 days before returning to Earth on February 8, 1974.

The abandoned Skylab continued to orbit for several years and, in 1979, prematurely fell out of orbit toward the Earth and disintegrated in the blazing fires of re-entry.

Skylab built on everything that had been done before in space. It demonstrated that astronauts could live comfortably there for as long as 84 days, could conduct a wide variety of scientific experiments, could conquer weightlessness and orientation problems, could maintain a healthy physique through exercise, and—vital as it was to the success of the Skylab mission—could make major repairs in space. Considering those factors, it appeared that Skylab astronauts had become the prototypes of long-term space station crews.

Routine trips into orbit

Following the Skylab program, the space shuttle (Space Transportation System) began to move toward its initial flights. It was first announced as a concept for a reusable spacecraft in 1968. Four years later, NASA awarded the contract for the shuttle design, development and testing. The heart of the shuttle design is its huge cargo bay, 18.3 meters (60 ft.) long and 4.6 meters (15 ft.) in diameter. It can carry anything from unmanned spacecraft to fully equipped scientific laboratories, and deliver them to an orbit above Earth, remaining there for a week or more while the spacecraft are launched, or while the lab is operating.

The first shuttle flight began April 12, 1981, and ended successfully more than 54 hours later. Since then, a succession of shuttle flights has been completed, with typical flights lasting for eight or more days.

The Space Transportation System (STS) is the most recent program in NASA's space exploration, and it underlines the methodical approach which the agency has followed since the beginning. Mercury and Gemini were pioneering programs, designed to learn the fundamentals of space flight and to define the problems. Apollo was a series of exploration voyages, the equivalent of the great voyages of discovery of the 15th and 16th centuries. Skylab demonstrated that routine operations in space were feasible. And the space shuttle provided the routine access to space.

Now, the space station makes possible the permanent utilization of space, and will be a tremendous stride forward into the future worlds of lunar explorations, of planetary voyages for observation and exploration, and of eventual settlements in space.

And these are not beyond our grasp. A few years after the space station is operational in orbit, it could become the launch site for a new program of lunar expeditions. This time, it would make sense to establish a small habitat on the Moon, so that astronauts could be delivered to the base, stay there for a period of time to conduct their explorations, and return from the lunar surface to the orbiting launch site.

Later, perhaps before the turn of the century, NASA would be able to launch an unmanned scientific mission to Mars which would carry a rover vehicle and a surface sampler to explore that planet.

Thus the inhabited, permanent space station, like its predecessors in the various NASA programs, is not an end to itself, but a way station on a long and exciting outbound journey.

"It is inevitable," said a NASA Advisory Council task force, "That human habitation will eventually extend beyond the confines of the Earth in many ways and on a scale far larger than is currently envisioned. Although it may not now be productive to debate the specific nature of the timing of this most dramatic of human ventures, it is appropriate to use such a venture as a distant goal to guide our search for an understanding of the solar system and to stimulate the further advance of humankind."

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