NASA Wants a Space Station

Proposals range from a multibillion dollar space city to a low-budget platform; but what do the users want?

"We have a highway to space!" astronaut Thomas K. Mattingly proclaimed after the fourth and final test flight of the space shuttle Columbia. And now that the shuttle is officially ready for use, he added, "we need to build the city"—a permanent space station in low earth orbit.

Mattingly is not alone in that sentiment. The National Aeronautics and Space Administration (NASA) as a whole wants that space station very badly. It would be the agency's next major mission, the heir to Apollo and the shuttle. NASA administrator James M. Beggs suggested it as such in his confirmation hearings last year, and since then has been touting the idea at every opportunity. The agency fought for, and obtained, favorable wording for the idea in the Reagan Administration's new space policy (*Science*, 23 July, p. 331). In May a ten-member task force was organized at NASA headquarters to coordinate further planning. And next year the agency hopes to include more than $10 million for space station development in the fiscal year 1984 budget, which goes to Congress in January. NASA estimates the station will ultimately cost some $3 billion to $5 billion, with the initial modules reaching orbit about 1990.

NASA's fervor for the station stems in part from institutional need. Without some kind of new mission the agency sees itself degenerating into a kind of high-tech trucking company, with nothing much to do but launch payloads for other people. But it also stems from a vision of the space station as the logical next step after the shuttle. Agency officials are fond of pointing out that the space station idea came first. The shuttle was conceived in the 1960's simply as a cheaper way of getting up there and back. Now that the shuttle is operational, says deputy administrator Hans Mark, it is time to go back and finish the original plan.

Unfortunately for NASA, however, it is hard to imagine a worse economic climate for proposing a multibillion-dollar space city—especially since a great many people still see every space endeavor in the image of Apollo: massively expensive projects pursued for little else but national glory and NASA's continued existence. Senator William Proxmire gave Beggs a lecture on the subject in hearings last May: "I am concerned that [the space station] will proceed regardless of the real need for such a program because your agency needs it more than the country needs it."

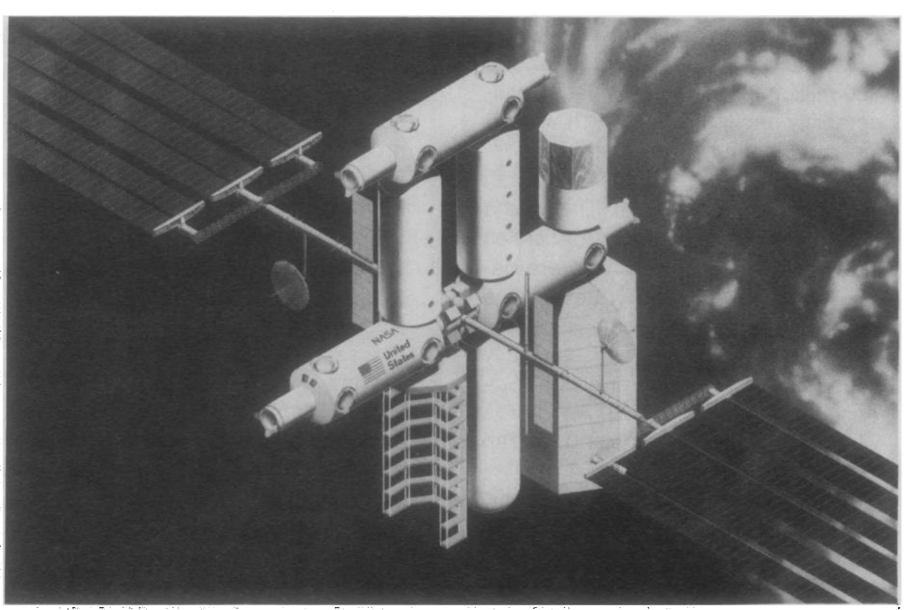
Among scientists, meanwhile, there is a widespread fear that the space station would be another shuttle, with delays and cost overruns that once again savage NASA's science and applications programs. As one high-ranking House staffer puts it, "I think there will be support for the space station as a long-range goal—if NASA doesn't have to give up everything else to get it."

On the other hand, many of these skeptics concede that a modest platform, focused on specific user needs, might prove very useful. It could serve as a research platform in fields such as astronomy, materials science, and remote sensing. With further development it could also serve as a transportation hub for moving communications facilities into geosynchronous orbit, or for launching a new generation of planetary spacecraft. Presidential science adviser George A. Keyworth, who has been highly skeptical of the more ambitious space station concepts, told *Science* that such a low-key, step-by-step approach has a reasonable chance of White House approval.

The question, then, is not whether a space station per se is worth having. A space station should be a tool, not an end in itself. The real question is whether that tool is worth the cost.

The answer seems to be "Yes," although that judgment depends on just how well NASA fits the station hardware to the needs of users. Unfortunately, NASA generated considerable confusion on the matter during the last year, with different segments of the agency advocating very different things.

Broadly speaking, there are two points of view. On the one hand, there are the veteran engineers who remember the glory days of Apollo. They stress the importance of manned operations in space. Their ideas for a space station are epitomized in the Space Operations Center, or SOC, a conceptual design produced by the Johnson Space Center in Houston, Texas. The SOC features habitat and workshop modules for 9 to 12



The Space Operations Center concept

The design includes solar panels, habitat and workshop modules, construction booms, fuel tanks, and spacecraft hangars. All the modules would be brought up by the shuttle and assembled in space.

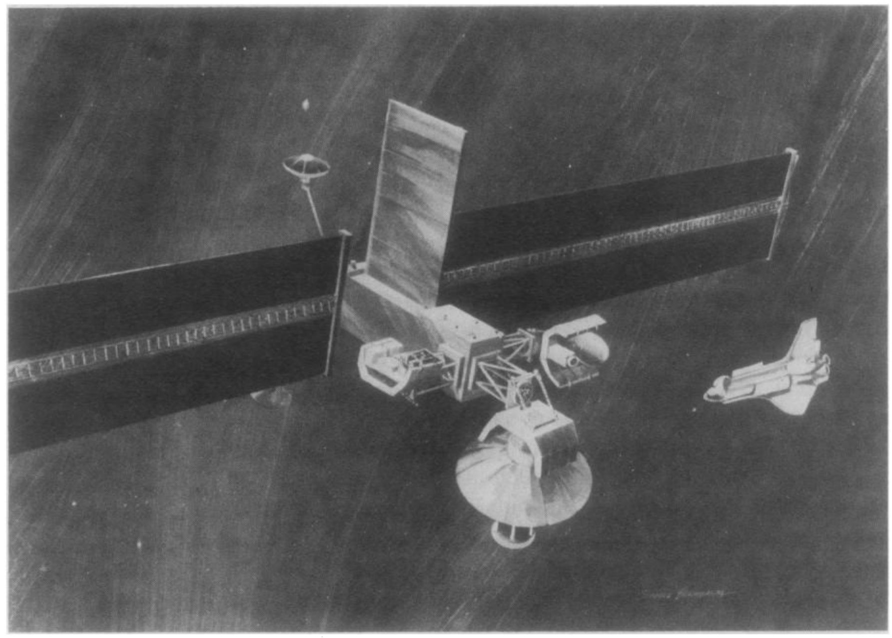
people, construction booms for assembly of antennas and other large space structures, and fuel tanks for a separate Orbital Transfer Vehicle that would take cargo brought up to the station by the shuttle and ferry it into the 35,900-kilometer geosynchronous orbit. SOC would cost about $8 billion over 10 years.

For a while, the Johnson public relations team managed to convince a lot of people that SOC *was* the space station, even though NASA was actually nowhere near a final design. In fact, top agency officials have all but disowned SOC. Space assembly and orbital transfer might be crucial in the 1990's, but in the current economic climate SOC's $8-billion price tag was only giving ammunition to critics of the station. Besides, the emphasis on SOC was obscuring the fact that there are other ways of building a station, ways much more congenial to cost-conscious Washington.

The most prominent example was the Space Platform design produced by Johnson's rivals at Marshall Space Flight Center in Huntsville, Alabama. The platform epitomized the task-oriented point of view of NASA's scientists and applications people. In its simplest, unmanned form, it would be little more than a set of solar panels for power, some internal electronics, and a number of sockets for instrument pallets taken right out of the shuttle payload bay. Manned modules and construction equipment could be added later, if needed. The Huntsville group estimated that the first space platform would cost about $750 million, with replicas costing another $400 million apiece. While such platforms could hardly be called cheap, the Huntsville planners argued that the price would be low enough for NASA to contemplate building several and specializing each to a different purpose.

Back at NASA headquarters, however, Beggs and his associates saw little chance of getting their space station unless they could resolve the confusion and come up with something all the potential users could support. Both the Marshall and the Johnson plans were too specialized, it was felt. Thus, both designs were scrapped, and in May the Space Station Task Force was formed to reconcile the disparate points of view into an all-NASA design.

Task force leader John Hodge seems well aware of NASA's oft-criticized tendency to plunge ahead with hardware development before it thinks much about the users. That impulse prevailed in the shuttle program, he points out, and as a result the agency spent the late 1970's in an embarrassing scramble for customers.



The Space Platform concept

Shown here with the space shuttle in the far background, the platform would essentially just provide power and stabilization for instruments mounted in pallets brought up in the shuttle's payload bay.

It is a prime source of apprehension and skepticism about the station. "So we're trying to take an entirely different approach," he says. "We're saying, To hell with the configurations, what are the requirements over the next 25 years?"

Thus, Hodge is asking eight aerospace companies to take a fresh look at the scientific, commercial, and military missions for a station. Only after the appropriate missions are identified will each of the eight draw up new conceptual designs. "Then you compare them and try to take the best from each," he says. By mid-1983 the results should be in hand and the agency should be ready to begin technology development and trade-off studies.

Some user needs are already fairly clear. A good example is space astronomy. During the past decade, enormous strides have been taken with short-lived satellites such as Uhuru, Einstein, and the Solar Maximum Mission, and the astronomers are hungry for more. Space Telescope, due for launch in 1985, will allow them to study how faint, distant galaxies and quasars began forming in the aftermath of the Big Bang. Solar Optical Telescope (SOT) will ride in the shuttle bay to image the fine structure of flares and sunspots—structure obscured by the atmosphere, but crucial for understanding solar activity, the solar wind, and their impact on the earth. SIRTF, the cryogenically cooled Shuttle Infrared Telescope Facility, will use its freedom from infrared-absorbing water vapor to peer into molecular clouds, where stars are being born, and into the core of our galaxy, where there may be a supermassive black hole (*Science*, 21 May, p. 838).

When the National Academy of Sciences recently made its recommendations on astronomy's needs for the 1980's [the "Field Committee" report (*Science*, 16 April, p. 282)], well over half the programs involved new instruments in space. At the same time, the report strongly endorsed the use of a space platform for astronomy.

"There are few, if any, astronomical missions that would not be better done from a platform than from the shuttle," says committee member Harlan J. Smith, chairman of the astronomy department at the University of Texas, Austin. He points out that instruments mounted in the payload bay will have only about 7 days in orbit before the shuttle's fuel cells run out of power. Then they will have to come home. Compare that to leaving the telescopes on an independent space platform, where they could stay in space for 6 months or a year.

"It's an order of magnitude more exposure time for only a very slight additional cost," says Smith. Thus, more astronomers could use the instruments—astronomers never have enough telescope time—and an instrument like SOT, for example, could monitor the sun continuously for flares and other transient phenomena that it might otherwise miss. Besides, he says, a high-resolution telescope would be more stable on a platform than on the shuttle, where astronauts would shake it slightly every time they moved.

Each payload could be placed on its own free-flying satellite, of course, just as the Space Telescope will be. But each would then have to have its own hardware for pointing, stabilization, communications, heat dissipation, and photovoltaic power. A platform would centralize those functions. William C. Snoddy, deputy director of program development at Marshall Space Flight Center, estimates that a typical scientific payload could operate for 6 months on Marshall's Space Platform at a cost of roughly $30 million—less than one-third as much as the cost on a free-flyer, and some 30 percent less than the cost on the shuttle. (The $30 million includes a portion of the cost of the platform.) Clustering the payloads would also make it easier for visiting shuttle astronauts to top off the cryogens, make repairs, or replace one set of instruments with another. They could service many payloads at once instead of chasing individual satellites all over the sky.

After astronomy, another prime mission for the space station is zero-gravity materials processing. There is already intense interest in both the fundamental science that can be done and in the potential commercial payoff. On the first flight of Spacelab in 1983, for example, the European Space Agency will devote 33 out of 77 experiments to materials science. NASA has an active program centered at Marshall in Huntsville. And private money is beginning to come into the field.

"We want to isolate the effects of gravity so we can better understand fundamental processes," says Lowell K. Zoller, head of the materials science program at Marshall. Six different crystallization processes are used commercially, he points out, and all of them are affected in fundamental ways by gravity. Hundreds of metal alloys have never been made on the earth because the components are immiscible and separate before the melt can cool. There are any number of ideas for making ultrapure materials that never come in contact with a container wall. "We'll need to ferry hundreds of specimens back and forth," says Zoller. "We're really looking forward to the station so we can get a lot of work done instead of one shot at a time."

The most dramatic example of the field's commercial promise is the collaborative effort of McDonnell Douglas Astronautics and the Ortho Pharmaceuticals Corporation division of Johnson & Johnson. During the past 6 years the partners have spent several tens of millions of dollars to develop the techniques of zero-gravity electrophoresis, with the ultimate goal of producing pharmaceuticals commercially in space. Candidates include insulin-secreting beta cells, interferon, epidermal growth factors, growth hormones, and as many as 40 others.

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On the fourth shuttle flight a McDonnell Douglas/Ortho test unit verified that zero-gravity electrophoresis yields 400 times the output and up to 5 times the purity as the same process on the ground. The researchers are jubilant. If subsequent tests continue to go well, a production facility could be in orbit by 1987.

"We see some distinct advantages to having it on a space station," says David Richmond, electrophoresis program manager at McDonnell Douglas. Again, the main problem with the shuttle is its time limitation: "You wouldn't build a factory on Earth twelve times as big as you need just so you could run it for only one month of the year," he says. It would be much better to have a continuous process. And McDonnell Douglas finds significant improvements in cost in using the station instead of a free-flying satellite.

In a third field, communications, a space station would have little direct application because the satellites used for television, direct broadcast, business communications, and the like all occupy geosynchronous orbit, 35,900 kilometers up. The shuttle, and any space station launched and serviced by the shuttle, is limited to a maximum orbital altitude of about 400 kilometers.

But a space station in low earth orbit could still prove useful in an indirect sense. Burton I. Edelson, formerly senior vice president of COMSAT and now NASA's associate administrator for space science and applications, points out that satellite communications traffic is projected to increase by a factor of about 30 between now and the end of the century. "So we will have to make optimum use of every point in the geostationary arc, and optimum use of every frequency," he says.

One solution would be to cluster very large antennas on a platform in geostationary orbit, he says. This would obviously help with overcrowding. Just as important, the large antennas would no longer have to broadcast to a whole hemisphere. Instead they could transmit spot beams, sending one message to California while—at the same frequency—sending something totally different to New York. "It would provide three times the information-carrying capacity for a given investment," says Edelson.

The problem is that the platform he envisions would have a mass of about 5000 kilograms, five times that of the largest communications satellites today. There is no way to launch such a thing directly. So the shuttle will have to bring it up in several loads, says Edelson, and astronauts will have to assemble it in space. "And then because it is precision equipment it will have to be aligned," he says. "Then it has to be mated to the booster that will take it to geosynchronous orbit." All this will require a staging area, and the logical place for that is a space station.

Back at NASA headquarters, Hodge and his task force are faced with the problem of turning these user requirements, and others, into hardware that satisfies everyone. Astronomers, for example, would clearly be happy with a Huntsville-style platform, while the construction of Edelson's antenna farm would require something very much like a SOC.

Moreover, the initial station, however modest, has to allow for growth. "We cannot envision all that we are going to do," says Hodge. One approach might be to drop the idea of a single space station, and instead imagine it evolving into a cluster of structures. At the center would be construction facilities and a manned, SOC-like module, from which astronauts would go forth to service nearby platforms specialized for such uses as astronomy or materials science.

Another problem—and, at the moment, one of NASA's most potent political problems in selling the station—is making sure that the costs can be kept under control. The station does have one key advantage, say agency officials: it is modular. "We are not in a position where we have to go to the President in a very difficult budget year and say, You have to spend so much on a space station," says Hans Mark. "You can spend as much or as little as you want. It just depends on the time scale and the degree of urgency."

Meanwhile, Beggs has been sounding out the Europeans about cooperative financing of the station, with some success. And Major General James A. Abrahamson, head of NASA's Office of Space Flight, says that two groups have already been in contact with him about private financing of a platform for zero-gravity materials work.

Still another question is whether the station should be manned. NASA's belief in "Man in Space" often takes on a mystical quality: "I won't believe it's really a space station unless it's got a man on it," says associate deputy administrator Phillip E. Culbertson. On the other hand, as Wilfred Mellors of the European Space Agency points out, "You don't want the man to be there just to take care of the life support system." The presence of humans on a space station would add greatly to its flexibility, but also to its cost and complexity. NASA needs to do some hard thinking about when humans will really be needed in space and when machines can do just as well.

Then there is the question of the military's role on a space station. NASA, which needs all the support it can get on the project, has been courting the Pentagon actively. "It would be inappropriate to say they're highly enthusiastic," says NASA's Mark T. Nolan, a member of the space station task force. It is a very new idea, after all. "But the Air Force has formed a working group in the Space Division and interest is rapidly picking up."

Nobody is planning for the initial station to carry weapons, he adds. The details are classified, but in the near term the military missions on a station would tend to look a lot like the civilian applications: development of large antennas, for example, or satellite repair. So doing both on the same station should not be difficult.

In the longer term, however, the Air Force is very interested in such things as space-based lasers and particle beam weapons. Should they prove workable, and should the Air Force want to deploy them on a space station—and it is not at all clear that such a thing would be sensible—the compatibility problem would become severe, Nolan says. For one thing, private companies such as McDonnell Douglas and Ortho would hardly want to put their production module on a military target. For another, the Pentagon would hardly want to allow visits by foreign nationals, which would seem to preclude international participation in the station. One obvious solution, if the money were available, would be to build separate stations for military and civilian uses.

Does the United States really need a space station? In the last analysis the question is not technical, but political. As political scientist and space historian John Logsdon of George Washington University points out, "The only reason to build a space station is if there is a national decision that space is worthwhile—and that the space station is the best way to do the things you want to do."—M. MITCHELL WALDROP

Is Hepatitis B Virus a Retrovirus in Disguise?

Among the many features shared by the hepatitis B viruses and the retroviruses is a reverse transcription step in the viral life cycles

Until recently, reverse transcription, the copying of RNA into DNA, was thought to be an exclusive property of the RNA-containing retroviruses. Within the past year or so that view has changed. The discovery of processed genes (*Science*, 28 May, p. 969) strongly suggests that mammalian genes may also be copied from RNA. And now, there is evidence for a reverse transcription step in the life cycle of human hepatitis B and related animal viruses, which have DNA as their genetic material.

In the June issue of *Cell*, Jesse Summers and William Mason of the Institute for Cancer Research in the Philadelphia suburb of Fox Chase reported that during the replication of the genome of duck hepatitis B virus (DHBV) the first of the two DNA strands to be synthesized is copied from an RNA template, not a DNA template. The second strand is then copied from the first.

Although this is the first direct demonstration of reverse transcription in the life cycle of a DNA-containing virus, the finding was not unexpected. Several parallels between the hepatitis B viruses and the retroviruses have emerged during the past few years. In fact, Summers and Mason propose that the hepatitis viruses, despite their DNA genomes, are very similar to the retroviruses. This raises the possibility that the hepatitis B viruses, which have been linked to an increased incidence of liver cancer both in man and animals, may be carcinogenic in the same way as the retroviruses, which are known to cause animal cancers.

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The resemblance of the hepatitis virus genome to the DNA formed during retroviral infections was one of the reasons that Summers and Mason began looking for evidence of reverse transcription in the hepatitis life cycle. "There is a clear analogy between the genome structure of the hepatitis viruses and the provirus of a retrovirus," Summers says. "It made us wonder if the hepatitis viruses were synthesized in the same way."

When a retrovirus infects a cell, its RNA genome is copied by the viral enzyme reverse transcriptase to form a single strand of DNA, the minus strand as it is called. (The single-stranded RNA of the viral genome is designated "plus.") The minus strand is then copied to form the complementary plus DNA strand, thus producing a double-stranded DNA molecule, the provirus. This is linear and is flanked on each end by long terminal repeats (LTR's), a repeated sequence a few hundred base pairs in length.

Synthesis of the provirus may involve the formation of a circular DNA intermediate consisting of a complete minus strand and a growing plus strand. Although this molecule has not been isolated, its existence is predicted on the basis of what is known about proviral synthe-

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