Japan: space power of the 21st century

Marsha Freeman reviews the ambitious programs of a nation with a great vision of space exploration.

"The 21st century will see the development of the Moon and Mars. . . . Japan has already developed almost to the same level as other countries, and I think in the 1990s our country will join in these international programs," stated Dr. Nobuki Kawashima, a leading Japanese space scientist, in an Aug. 31, 1986 speech in Virginia.

Dr. Kawashima, who is a professor of physics at the Institute of Space and Astronautical Science (ISAS) in Tokyo, was a project participant in the electron beam experiment aboard the U.S. Space Shuttle in 1983. His institute leads all the space science research in Japan. Dr. Kawashima was addressing a conference of the International Caucus of Labor Committees, the philosophical association founded by Lyndon LaRouche, as a participant on a panel of scientists discussing the Moon-Mars missions of the next millennium.

The Space Shuttle Challenger accident on Jan. 28, 1986, and the resultant stand-down of the Shuttle program for two years, have thrown the space programs of U.S. allies into a state of uncertainty. The nations of Western Europe and Japan have depended upon the Shuttle program to provide them with a launch capability for large payloads, but more importantly, with access to the only manned space program in the Free World.

The Japanese have been developing and launching their own rocket systems for a number of years, and have larger vehicles already under development. But Japan is now faced with the prospect of relying less on the American manned space and interplanetary programs, and this will likely accelerate the development of its own space capabilities.

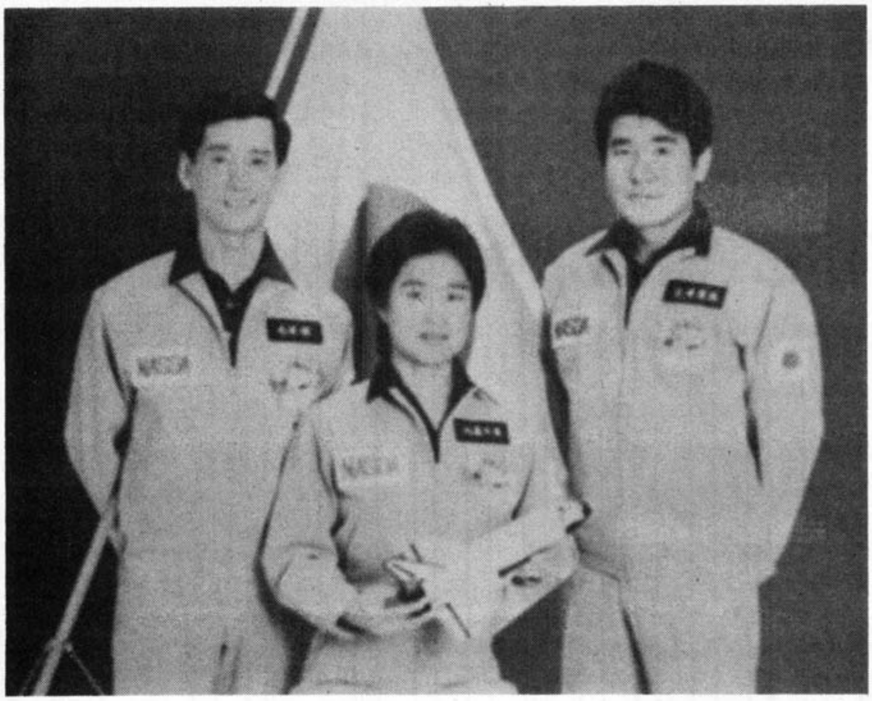
Prospects for the future

On Aug. 13, two weeks before Dr. Kawashima's speech in the United States, Japan joined the small and prestigious group of space-faring nations, which includes the United States and the members of the European Space Agency: It successfully launched its first rocket with engines using liquid hydrogen fuel. The new large H-I rocket, which gives Japan the capability to orbit larger commercial-sized satellites, also opens Japan's pathway to interplanetary exploration.

As Dr. Kawashima explained, the first Japanese lunar mission will be conducted by his institute in 1990. The MUSES satellite will be a lunar fly-by, and will utilize lunar gravity to "kick off" and fly by the Moon. One year later, the National Space Development Agency of Japan (NASDA), which specializes in space applications and large launch vehicles, will do the first launch of a larger Japanese-designed and built H-II rocket.

"At present," stated Dr. Kawashima, "Japan's space development budget is only $800 million, which is very small when compared with the automobile industry and other big industries. . . . At this moment, we cannot say that space development is an industry in Japan; but I think that in 1990, space development will become one of the industries in Japan."

But, he stressed, "1990s space development cannot be done by one country. The programs become bigger and bigger, so we need international collaboration." He pointed to the recent international effort of six spacecraft, from Japan,



Above: Dr. Nobuki Kawashima. Left: Japanese astronauts (from left) Dr. Mamoru Mohri, professor of nuclear engineering; Dr. Chiaki Naito, cardiovascular surgeon; and Dr. Takao Doi, an expert in hydrodynamics. One of them will perform experiments aboard the U.S. Spacelab/Space Shuttle.

the U.S.S.R., the European Space Agency, and the United States, which made up the Halley's Armada, and said that this "international collaboration was very successful."

In the past, Dr. Kawashima explained, his scientific institute has been reluctant to conduct large-scale international collaboration programs. "One reason is that we are not so used to it, and the other is that when we do such a large-scale international program, then things like the Challenger accident, as an example, affect many factors which we cannot control."

"The majority of our people like to have their own launch vehicle," he stated, but after the 1990s, programs such as lunar exploration "can't be done by one small university organization." According to Dr. Kawashima, the reluctance to plan large cooperative missions "is now changing."

Dr. Kawashima outlined the perspectives of Japan's lunar exploration program. He explained that although "the Apollo project was very successful, in some sense it was said that the Moon had been explored very extensively; this was on the Moon's surface, and only where Apollo landed. But actually, the explored spots on the Moon are very small, when compared with the whole surface of the Moon—it's only a local point."

"For 21st-century lunar base construction," he continued, "it is important to explore the whole surface of the Moon, so that we can find where will be the best place to construct the lunar base."

The institute is considering three possible lunar exploration mission options for the middle of the next decade. The first option is a penetrator mission. This "would make seismic observations of the Moon and determine the existence of a metal core there," Dr. Kawashima said. Because the Moon has 14 days of daylight, and then 14 days of night, and no atmosphere, it is very cold at night, and very hot during the day, he explained. This makes thermal control very difficult for instruments on the surface, but "the penetrator, one meter below the surface, would be where the temperature does not change very much."

Second, a polar orbiter would do a "global survey of the Moon and its material composition, which would also tell us about the origin of the Moon." Both of these lunar programs would depend upon the use of the M-3S-III rocket, which has not been approved yet for development by ISAS.

A lander would be a third lunar mission option, but for that, a significantly larger launch vehicle would be required. "What will be the ideal lunar mission in the mid-1990s?" Dr. Kawashima asked. In addition to the lunar polar orbiter and penetrators, a powerful rover would be required "to confirm the results from the lunar orbiter."

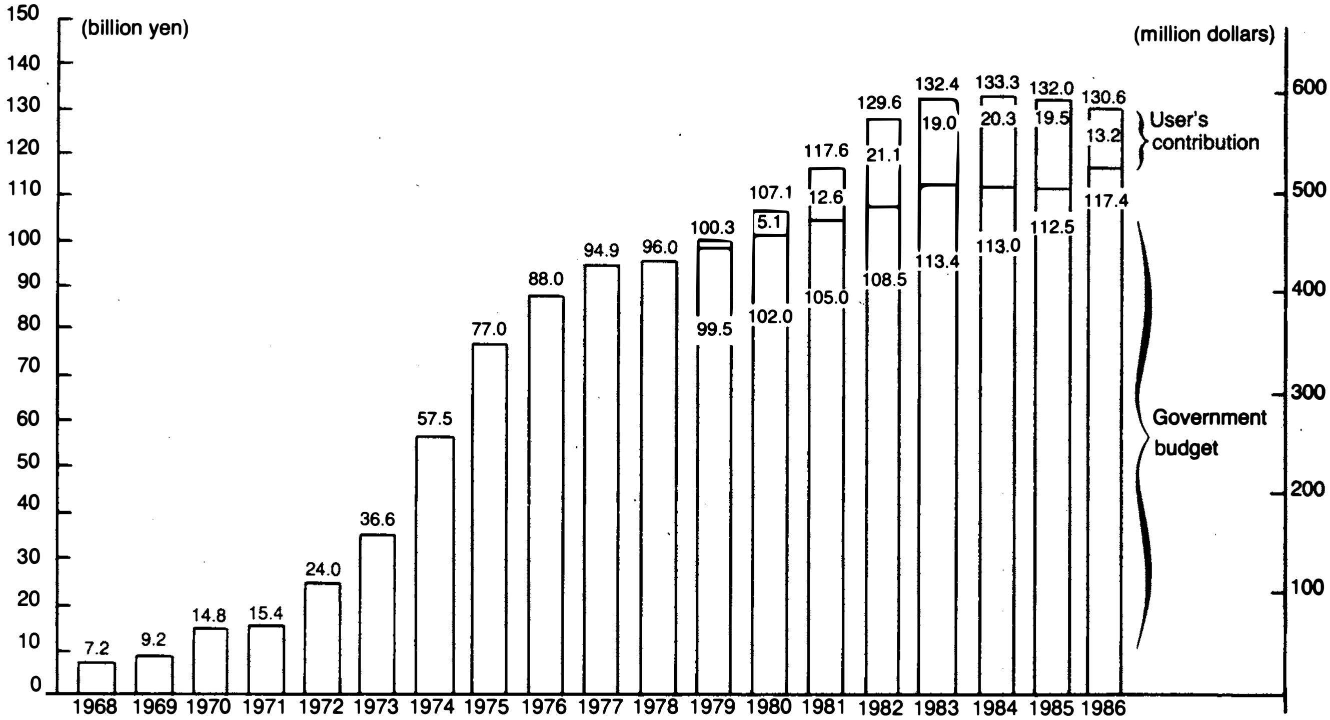
All of the missions, however, should be "a step to other planetary exploration," he said. The technology would be used also for the "further planets, and other bodies in the Solar System."

Closing the space gap

In his brief presentation, Dr. Kawashima could only touch on some of the history of the space program in Japan. We present here a more detailed review of this remarkable program, which is the third-largest in the world.

The Japanese space program had quite modest begin-

FIGURE 1
Budget for Japan's space activities



Government funding for space development in Japan increased steeply over the 1970s. More recently, government funding has been flat, but user fees from industry have increased, as more commercial satellites are being launched by the government.

Note: When these calculations were made last year by the National Space Development Agency of Japan, a dollar equalled approximately 240 yen; as we go to press, the dollar has fallen to about 156.

Source: National Space Development Agency of Japan

nings. In 1955, ISAS, which was then a part of the University of Tokyo, participated in the scientific research conducted for the International Geophysical Year. Japan launched the tiny "pencil" rocket, which was a suborbital sounding rocket. The pencil rocket stood 9 inches tall, and weighed 6.7 ounces!

ISAS, which is responsible for Japan's space science and exploration activity, upgraded the pencil rocket and then in 1963 began development of the M (Mu) series of solid-fueled rockets, for suborbital scientific experiments, which attained an altitude of 850 km. In 1970, ISAS launched the first Japanese satellite, using its solid-fueled L-4S-5 rocket vehicle. This was the first satellite launched in Asia, beating the Chinese by about two months, and Japan became the fourth nation in the world to launch a satellite. But unlike the United States and the Soviet Union, Japan did it with a rocket that hadn't first been developed as an intercontinental ballistic missile.

In 1969, Japan made the decision to accelerate the development of both larger launch systems and new satellite technologies, to be able to orbit space applications satellites, and established the National Space Development Agency of Japan. NASDA's primary focus is to develop the practical applications of space technology in communications, weather, remote sensing, and direct broadcast.

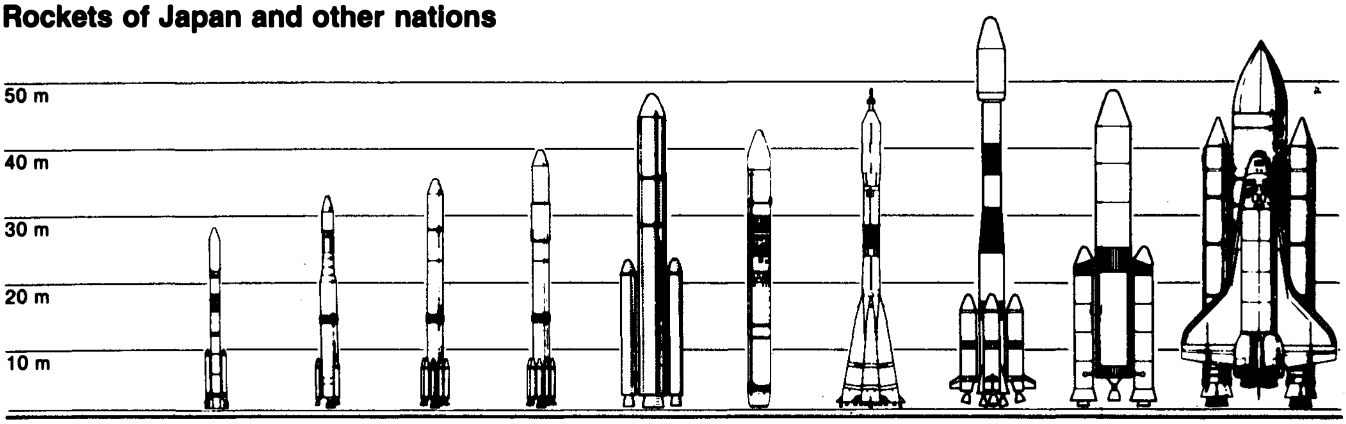
With the establishment of NASDA, and the decision to develop rocket technology, Japanese policymakers had to make a fundamental decision. The United States had already landed men on the Moon, and Japan was at least 15 years behind other industrialized nations in space.

Rather than begin from scratch and build their own large rockets themselves, the Japanese decided to license the U.S. Delta rocket technology, to get a head start. Japanese satellite manufacturers also bought either entire satellites, or crucial components, from the United States. Though this certainly saved years of development time, it also had its drawbacks.

The first NASDA rockets were the N-I and N-II, which are capable of placing 286 and 770 pounds of payload into geosynchronous orbit, respectively. On Feb. 23, 1977, the first Japanese satellite was put into geosynchronous orbit by an N-II rocket, and Japan became the third space party in the world to launch a satellite into this orbit with its own rocket.

The second-generation N-II began operations in 1981,

FIGURE 2
Rockets of Japan and other nations



Rocket name	M-3SII (ISAS)	N-I (NASDA)	N-II (NASDA)	H-I (NASDA)	H-II (NASDA)	CZ-3 (CHINA)	A-2 (U.S.S.R.)	ARIANE 4 (ESA)	ARIANE 5 (ESA)	Space Shuttle (U.S.A.)
Total weight (t)	61	90	135	140	258	–	–	460	500	2,041
Payload capacity into LEO*1 (kg)	670	1,200	2,000	3,000	8,000	5,000	–	8,000	15,000	29,500
Payload capacity into GEO*2 (kg)	–	130	350	550	2,000	–	–	2,200	4,000	2,400 (using upper stage)

ISAS = Institute of Space and Astronautical Science
NASDA = National Space Development Agency of Japan
ESA = European Space Agency

*1 LEO: Low Earth Orbit
*2 GEO: Geostationary Earth Orbit

Source: National Space Development Agency of Japan

but is still 50% based on U.S. technology. The N series of rockets has two stages using liquid petroleum-based fuels, and a solid-fueled third stage. They also use solid rocket boosters.

Drawbacks to reliance on the U.S.

The licensing agreement signed with the McDonnell Douglas Company prohibited Japan from launching another country's satellites with its N rockets. In addition, the Japanese suffered failures in two communications satellites in 1979 and 1980, due to malfunctions of U.S. launcher technology. Japanese space officials are not even allowed to disassemble and check the systems before they fly, and are required to launch without confirmation checks.

There have also been specific areas in which the United States has refused to transfer the technology, such as in inertial guidance systems for launchers. This forced the Japanese to design their own system, which is used on the N-II rocket.

The use of the U.S. Delta technology has also limited Japan to very brief launch seasons per year. This means that NASDA can launch only four rockets annually, since the large Japanese fishing industry is concerned that falling solid rocket boosters, which are jettisoned into the ocean, will adversely affect fishing around the island. NASDA has been restricted to launches in January-February and in August-September.

The Japanese-designed H-II rocket, however, will not face the same problem, because the rocket boosters will fall off more than 300 miles out to sea, which is well beyond the 120-mile line established by the fishermen.

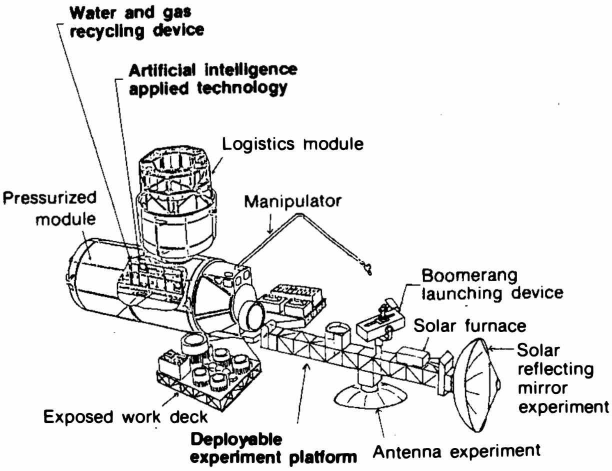
In an interview in March 1985 in *Aerospace America,* Nobuyuki Arino, managing director of TRW Overseas in Tokyo, gave another example of the problems created by dependence on U.S. technologies. "At the time that Toshiba was developing the broadcast satellite, one of the key technologies that Japan wanted was a three-axis attitude-control system, but due to governmental constraints, General Electric could not transfer the technology to manufacture a suitable one, so they delivered a black box." The Japanese were forbidden to look inside.

"I think that phase one of U.S.-Japan space relations has been completed," Arino commented. "Japan's student role in learning about advanced technology is over. . . . In the final analysis, Japan will develop its own technology. It is just a matter of time. So rather than let Japan become isolated or a bitter long-range competitor, why not build cooperation so that we do not go in opposite directions in the future?"

The decision of whether to use U.S. technology to make up time, or develop indigenous Japanese systems that would

FIGURE 3

Technologies on the space station experimental module



The Japanese Experiment Module for the U.S. space station will be a multi-billion dollar facility, comprised of the pressurized module for the astronauts, an open exposed work area, and a top-side logistics module to store supplies.

Source: Science & Technology in Japan

take longer but make Japan more independent, was a difficult choice. In the August-September 1982 issue of *Space World* magazine, Dr. Hiroshi Uda, the director of NASDA's Tsukuba Space Center, commented on the fear in Japan of "wasting time" and ultimately failing by doing the research themselves.

"We should have many experiences of successful and unsuccessful events through our space projects. Unsuccessful events can give us new ideas for next-generation successes. But our space projects receive much assistance from the United States and we have no unsuccessful events except Ayame 1 and 2. So, from the investment viewpoint, our space projects are very effective. But, basically, we are losing the chance to get our own technologies and testing, and ideas for the future."

Dr. Uda did not hesitate to add that if Japan is to both catch up to other world space programs, and develop its own space technologies, the space budget will have to grow dramatically. Since the government funding for space is tied to the increase of the GNP in Japan, the slowed pace of recent economic growth has slowed the increases in funding for space.

Reforming space policy

Since that interview in 1982, however, space policy in Japan has developed along with the technology. By the early 1980s, corporations interested in launching communications and other commercial satellites gave the Japanese government a choice: Either accelerate the development of the larger H-II rocket, or the companies would go to the U.S. Space Shuttle or the European Ariane to get their satellites into orbit.

The government responded by accelerating the development schedule for the first Japanese-engineered and built rocket, the H-II. This $800-million-plus program, which will result in the first H-II launch in about 1992, will give industry a commercial-sized launch capability.

In 1982, the Science and Technology Agency of Japan, which oversees NASDA, and the Space Development Council, which directly advises the prime minister, started a review of the space program, and in 1984, an updated space policy was promulgated by the government. The *Outline of Japan's Space Development Policy* states, "Japan has to develop its own technological resources so that it will be able to carry out various space development activities steadily in the future."

The *Outline* presents 15-year goals for the program, in order "to keep Japan's level of science abreast with international standards, to contribute to the intellectual progress of mankind, and to promote the development of science and its application in ways suitable to Japan." The goals include advancement in satellite communications; astronomical observation scientific satellites; experiments in space in materials science and life sciences; generic satellite technologies such as standardization and improved performance; launch vehicle development, leading to the use of the H-II rocket; and the consolidation of space activities, including the reinforcement of national research and university work, international joint projects, and increased public information.

The role of industry

In contrast to the United States, Japanese industry plays an important role in promoting national space policy. In 1980, the powerful Ministry for International Trade and Industry (MITI) established an advisory body for space industrial development. It estimated that space will be a $4.5 billion industry for Japanese manufacturers by the mid-1990s, comparable in size to the radio and television manufacturing industries at that time.

MITI recommended that Japan's space industry "aim at the world market." In 1981, sales from space-related industry in Japan had reached $480 million, with 20% of that from the export of communications equipment. At the time, the head of NASDA remarked, "If we decide to save money now, our descendants may hold a grudge against us." In 1981, Japan was already spending five times as much on its space program as Great Britain.

The major corporations in Japan have formed a number of private space marketing organizations, which make the aggressive French commercial space effort look pale by comparison. In February 1985, forty-one companies formed the Japan Space Utilization Promotion Center, funded at 6 million yen per year, and projected to be spending 60 million yen by 1988.

They are now designing a space experiment data base for use by industry, and are conducting surveys of space experiments for the space station. In May 1986, the Space Technology Corporation was established by six companies and the Japan Key Technologies Center to carry out industry-funded research on materials processing in space. These companies will participate in experiments planned for the German D-2 and D-3 Spacelab missions on the Shuttle.

The Institute for Unmanned Space Experiment Free Flyer was set up in April 1986 by 13 corporations to finance the building of an unmanned orbiting platform. The three-ton facility will be released into space by the Shuttle, carry out experiments, and be returned by the Shuttle for ground analysis every two to three months.

As Japan's own technologies for communications and remote sensing have moved into operational use, industry has taken over the management and marketing of these services. In the future, Japan's participation in the NASA space station will open the door to the creation of new materials in space, and new technologies important to industry. MITI itself is now involved in space station planning, and one can only assume that Japan's upcoming H-II rocket, and its commercial space technology, will challenge the rest of the world's space-faring nations, for a share of the international marketplace.

The importance of space

There is a very practical reason why Japan has focused a significant effort on independently developing space capabilities: It is a nation of islands, with more than half a million people who live in such remote areas that they cannot receive conventional television transmission. In addition, Earth and ocean remote sensing from space provides the most efficient means for looking at the country's dispersed land and the surrounding ocean.

Since 1979, Japan has been directly receiving and processing U.S. Landsat remote-sensing data, according to a NASDA agreement with NASA. The Remote Sensing Technology Center of Japan distributes the data throughout the country. In 1980, Japan hosted a United Nations seminar on remote sensing, and holds annual training courses for the 13 members of the U.N. Economic and Social Committee for Asia and the Pacific, in satellite communications and remote-sensing data analysis.

In 1987, NASDA plans to launch the first operational Japanese remote sensing satellite, the Marine Observation Satellite, MOS-I. This satellite will observe the ocean in visible light, near infrared radiation, and microwave. It will measure the color, temperature, and surface features of the ocean, ocean currents, water vapor in the atmosphere, clouds, ice floes, and the generation of "red tides." It will give scientists information that will prevent weather-related and other natural disasters, locate fishing and ocean resources, and provide surveillance of coastal regions. It will be Japan's first domestic Earth observation satellite.

It has been estimated that using the MOS-I data will reduce the total fuel consumed by offshore Japanese fishing fleets by 10%-20%, as the satellite can map the distribution of chlorophyll for fish food, and improve weather watches.

For land remote sensing, the Japanese will orbit the Earth Resources Satellite, ERS-I, in about 1990. It will be their heaviest-yet satellite, weighing in at over 3,000 pounds. ERS-I will include active sensing technology using a synthetic aperture radar, which will use microwaves bounced off the land to determine the fine relief of the surface, and provide all-weather, day-and-night coverage.

ERS-I has been jointly developed with MITI, and in 1984, Japan started preparing the establishment of the Technology Research Association of the Resource Remote Sensing System under MITI, to promote the use of the data. The RRSS has 13 members, including the heads of oil companies, and it is directed by the president of Mitsubishi Electric Corporation.

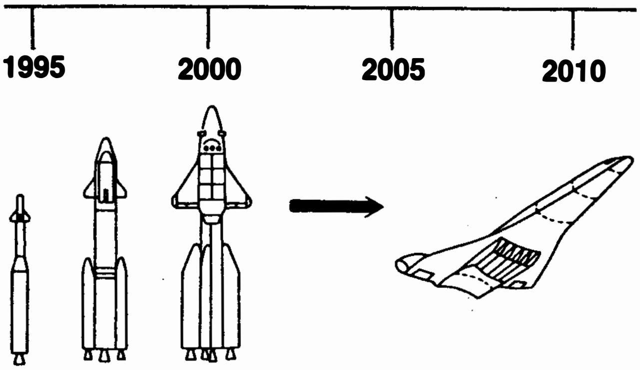
Meteorological observation from space is especially important in the Pacific, where there are few other observation points available for large stretches of ocean. So far, Japan has launched three meteorological satellites, which are used for daily forecasts and typhoon warnings.

The weather data received is used throughout Asian/Pacific countries, including Australia. In 1989, a fourth satellite will be launched, to replace an older one, and incorporate more sophisticated sensing technology.

The first domestic communications satellite launched in Japan was at the end of 1977. In 1983, this system was upgraded with the launch of two more satellites, for communication in an emergency, and with remote islands. As has been the case in nearly every particular area, the Japanese may not have launched the first communications satellite in the world, but they have deployed the latest technology, as they piggybacked the United States in overall launch systems and satellite technology.

The Communications Satellite-I (CS-I), launched in 1977, was the world's first k-band frequency system. This operates in the billions of herz range, and though the United States began doing research into using this higher frequency band for communications during the Nixon administration, the

FIGURE 4
Japanese concepts of space shuttle development



Japanese designers have begun preliminary testing of small reusbale space shuttle models. They plan to develop a small spacecraft by the year 2000, which would be launched on the H-II rocket, and perhaps join with the U.S. to develop an aerospace plane by the year 2010.

Source: Government of Japan

research program has been canceled and restarted three times since then. CS-III, scheduled to be launched in 1988, will be the world's first to use more efficient gallium arsenide solar cells as the primary power source.

In 1982, Nippon Electric Company completed a plant in Yokahama, for the mass production of satellites. It can produce four major satellites in the one-ton class simultaneously, and will build the MOS-I ocean satellite as its first one.

Direct broadcast communication technology is very important in Japan, where people in cities with tall buildings, and in remote or mountainous areas, cannot receive regular television signals. The satellite's signal is received by an antenna dish. In April 1978 Japan orbited the world's first direct broadcast satellite, and two more went up in 1984 and earlier this year.

Frontier space exploration

Unlike in the United States, where just one agency, NASA, oversees the development of launch vehicles, applications technology, and space science, in Japan the Institute for Space and Astronautical Science oversees space science work alone. Over its 30-year history, ISAS has participated in space science research using its own small rockets, making contributions in radio astronomy, study of the aurora on Earth and plasma waves in space, solar radiation, the atmospheric structure around the Earth, and other fields.

In 1985, however, Japan entered the field of planetary exploration for the first time, with two satellites they launched themselves, called Sakigake (Pioneer) and Planet-A. The Planet-A spacecraft came within 150,000 km of the coma of Halley's comet, and showed a periodicity in brightness of this outer shell of the comet. Changes in the speed of the ions of the solar wind, and other observations, verified for scientists that indeed the comet does release heavy particles, such as water molecules, from its nucleus.

ISAS has a continuing series of one scientific satellite launcher per year, and plans to launch the ASTRO-C in 1987 to observe x-ray sources in the central core of galaxies. As mentioned above, the MUSES sources in the central core of galaxies. As mentioned above, the MUSES satellite, in 1990, is planned as a lunar fly-by; Japan is also participating in a number of highly complex international space science efforts.

The decision facing the institute now, is whether to give up its traditional insistence that Japanese science missions be launched only by the small satellites built at the institute—which would eliminate the possibility of any large-scale lunar or planetary exploration—or whether to work with NASDA, and use the upcoming larger rockets to push forward on the space frontier.

Putting man into space

The first launch of the U.S. Space Shuttle Columbia, in April 1981, generated tremendous excitement in Japan. According to reports from Japanese scientists with whom I was speaking by phone the day the Columbia landed, nearly everything in Japan's cities came to a standstill, as people rushed off the streets, into stores or other facilities with televisions, to watch this great achievement.

The success of the Space Shuttle opened up for Japan, Western Europe, Canada, and other U.S. allies, the first-ever opportunity to send their own experiments and scientists into space. On Sept. 1, 1983, aboard the Space Shuttle Challenger, an experiment was conducted to answer a question suggested by a high school student in Japan: "Can it snow in space?"

The Japanese newspaper *Asahi Shimbun* sponsored a contest to design an experiment to be flown in a Getaway Special canister on the Shuttle, and the apparatus designed by Nippon Electric produced the first artificial snow in space. The snow "flake" was not six-pointed, but round, and provided important insight for scientists interested in producing crystals in microgravity.

In November 1983, on the first Spacelab mission, the SEPAC particle accelerator, designed and built at ISAS in Japan, was flown aboard the Shuttle, to observe the interaction of charged particles injected into the space plasma from the spacecraft, along the magnetic field line of the Earth.

The First Materials Processing Test (FMPT), originally scheduled for this year, will now be flown aboard the Shuttle in about 1990. This facility contains 34 experiments, of which 22 are in materials processing, and the rest are in the life sciences. For this mission, a Japanese payload specialist will be aboard; out of the 533 applicants, 3 are now undergoing training, and one will fly on the mission.

FMPT will make use of acoustic levitation in a furnace, where material is processed while suspended by sound waves. In another experiment, ultrafine particles will be produced from a vaporized metal in a rare gas atmosphere, to study the way nuclear formation of heavy metals takes place. Scientists believe this process of the formation of metals is closely related to the formation of planets.

In the life sciences, one experiment will examine the effect of microgravity on the differentiation of bone cells, and their regulatory mechanisms in chicken eggs. These results will provide important data for scientists studying the effect of the lack of gravity on animal reproduction in space.

The three Japanese payload specialists, all of whom are scientists, are now in training at the Tsukuba Science Center, and will transfer to the NASA Johnson Space Center for training, as their flight approaches. The Japanese plan to make full use of the Space Shuttle, as it is available, but the real thrust Japan will take into the manned space program, will be with the mid-1990s U.S. space station.

When President Reagan announced the space station initiative in 1984, he asked NASA Administrator James Beggs to offer major participation in the program to the other space-faring nations of the Free World. Though the final design of the station is still being determined, the European Space Agency and Japan have both made a commitment to provide a laboratory module for the facility.

The Japanese Experiment Module (JEM) will be built by Japanese industry, and though it will be an international facility like the rest of the station, it will provide tremendous access to Japanese science and industry to the new environment of space. JEM is an ambitious facility, which includes not only the pressurized module for experiments, but also an attached logistics module for extra supplies and to hold samples, and an open or exposed facility to test new materials, and perhaps for astronomy experiments. The module will be a multibillion-dollar investment, and the largest international space venture yet for Japan.

According to Dr. Obayashi, who heads the special committee for the space station under the Space Activities Commission, the importance of the project is that "Japan will be assuming responsibility in an important global project; it will foster new scientific skills; there will be an expansion of space science experiments and probes; it will serve as a stimulus to education and economic development, and will pave the way for the establishment of space colonies in the 21st century."

In the next century

The Japanese fully plan to join the United States and Europe in manned space operations of their own, in the next century. The H-II rocket, operational in the early part of the next decade, will give Japan the ability to deliver about 18,000 pounds of payload to low-Earth orbit, and about 6,000 pounds to geosynchronous orbit.

But it can also take about the same 6,000 pounds to the Moon, about 4,000 pounds to Venus or Mars, and 1,000 pounds to orbit Jupiter. The second stage of the H-II will have larger engines, using liquid hydrogen, than are on the H-I, and will be capable of restarting once in orbit. Two large solid rocket boosters will be used to augment the first-stage liquid hydrogen engines, similar to the Space Shuttle configuration.

The Japanese are building a new launch pad at the Tanegashima Space Center, and are spending about 200 billion yen per year for the H-II development.

In addition to being capable of taking small payloads outside of Earth orbit, the H-II could be used as a transport vehicle to the space station, similar to the capabilities of the European Ariane V, which will also be deployed in the early 1990s.

On top of the H-II, again like the Ariane V, could also sit a small reusable space shuttle or space plane. Japanese engineers have been working on space shuttle-type technology development since 1978, at the National Aerospace Laboratory. This has included research in new composite materials, hypersonic wind tunnel testing of vehicle designs, reusable rocket engines, ultra-high-temperature-resistant materials, and optimum shape design.

According to the summer 1986 issue of the magazine *Science and Technology in Japan,* which is published by the Science and Technology Agency, the Advanced Space Shuttle Transportation System program in Japan is conducting research in aerodynamics, heat protection, navigation and guidance control, and air-breathing engine technologies.

The same magazine reveals an even more interesting project: "If a non-permanently manned 'self-reproductive' system is set up on the Moon, or on a planet, the infrastructure is bound to grow, and it will become possible to take advantage of its economic potential in the near future. When this happens, large investments in the Moon are expected."

They suggest that a lunar industrialization scenario might consist of delivering a miniaturized, fully automated robotic manufacturing plant, which uses the materials found on the Moon. "When the automated machinery has produced sufficient materials for a man-controlled infrastructure extraterrestrially, mankind will be able to emigrate into space."

The drawback is the size of automated factories already in existence on Earth (at least, in Japan). If the machinery were miniaturized to one-eighth its normal size, the magazine imagines, it would make it economically feasible to transport such a system to the Moon! These systems "could also be used on Mars, the Martian moons, the asteroids, or on any other heavenly body."

This project could be carried out with investments on the scale of the Apollo program, the magazine posits, and "has the potential to change everyday life. . . . This field could be a path for Japan, as one of the industrially advanced countries, to make a contribution to world development."

It is clear that Japanese leaders see their nation making a major contribution to the scientific, economic, and space frontiers of the next century. The world would be quite a different place, if policy planners in the United States looked at the prospects of the U.S. program with the same kind of optimism as the Japanese look at theirs.