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Japan's space policy aims high, despite late start

Their approach, far from what many think, is not based on copying others, but applies fundamental scientific breakthroughs. A report from Marsha Freeman and France's Philippe Jamet.

The near-cancellation by the United States of Space Station Freedom last June posed in stark relief the fact that the European and Japanese space programs are dependent on American manned efforts. Only the U.S. and the Soviet Union can transport people into space. Only those two nations have built facilities and launched them into Earth orbit, for men to live and work in space. Would the end of Freedom mean the end of our allies' manned space programs?

This was not an easy question for the leaders of the Japanese space program to consider. Focused on the basic economic rebuilding of their country after the Second World War, the Japanese were late-comers in the space arena. The series of rocket launchers they have used, up until now, has been largely technology licensed from American manufacturers.

But in the past decade, the leadership of Japan initiated a series of science projects, and space programs in particular, to set a more independent path.

Like the Europeans and Canadians, the Japanese are "buying" their way into manned space flight by sending their astronauts and equipment on the U.S. Space Shuttle, and hopefully later, on Space Station Freedom. They are training a corps of astronauts, developing the technology and hardware for living and working in space, gaining the experience they will need for future projects, and advancing their basic science as well as applied technology by standing on the 35-year-old foundation laid by both the United States and the Soviet Union.

But in the next century, the Japanese will begin to have operational space systems that will be less dependent upon others. Although they have had technical difficulties developing the advanced liquid hydrogen engines for their next-generation H-II rocket, which recently suffered a freak accident with the first fatality in the Japanese space program, it is the first indigenously designed and produced launch vehicle in their program.

When Space Station Freedom is in orbit, the Japanese plan to fly their unmanned robotic Hope mini-shuttle to dock with it to deliver supplies, equipment, and materials for the crew. Developed by Japanese companies and research laboratories, Hope (H-II Orbiting Plane) will lead to a larger, manned vehicle, which will complement deliveries of men and supplies to Freedom by the U.S. Shuttle and the French-designed Hermes spaceplane.

Under construction now is the Japanese Experiment Module (JEM), which will be one of the attached laboratories of Freedom. With the experience gained from designing and building the JEM, Japan will be in a position in the future to design and construct its own space stations.

Over the past few years, Japanese companies have pulled together small teams of engineers and visionary thinkers to begin to design colonies and cities in space. They are well aware that the nexus of economic growth potential by the middle of the next century will not be in Asia, but should be the rest of the Solar System! Development of lunar construction materials and techniques, using indigenous resources on the Moon and Mars, and examining the organization of societies under such hostile and unusual circumstances, have all been under study.

The Japanese started their space program later than the other major spacefaring nations. As in other scientific fields, however, they aim to catch up and overtake the competition, and have set upon a well thought-out and deliberate course to do so.

Comparing Japan and Europe

A look at the astonishing evolution of the Japanese space program offers an opportunity to compare the approach of Europeans, and especially the French, to Japan's. If we judge Japan's space program in the light of "hard facts," without guessing at its ultimate evolution, it would appear that the program, for the moment, remains at a lower technological level than Europe's, even though Japan has launched or contracted for launch more satellites than the Europeans. Such a conclusion would be somewhat misleading.

There is a wide divergence in the strategies taken by Europe and Japan for the medium-term future. For example, Europeans put their emphasis on developing launch vehicles, such as the Ariane 5P, to capture a market share for launching heavy commercial satellites at the end of the century. By contrast, the Japanese, with their expertise in electronics, highlighted a "satellite-driven" program, which utilized increasing miniaturization to decrease the weight of research and commercial satellites. Relying on the fact that progress in electronics and computer miniaturization could open up a whole generation of compact, highly sophisticated satellites, Japan was the first to make plans for a plant devoted entirely to producing advanced communications satellites.

As a result of the "satellite-driven" approach, the Japanese launcher H-II—latest in a generation of a family of rockets designed to place satellites into geostationary orbit—will only be able at best, beginning 1993-94, to launch two satellites of 2 tons, whose present performance compares to the AR44L version of the European Ariane 4 launcher (4.4 tons), which will be superseded about 1995-96 by the Ariane 5P. The new European launcher will be able to place into geostationary orbit, simultaneously, two 2.6 ton satellites, and in a later version 6.7-6.8 tons. These performances leave it a comfortable safety margin of more than 2 tons with respect to the Japanese competitor, and a bit less than that if, as is expected in Tokyo, it evolves toward better performance by the addition of liquid fuel boosters. In that case, the utilization by Ariane 5P of the upgraded Vulcain engine, called Mark 2, for its first stage, would allow the Europeans to add yet another ton.

Another technological choice brought about by the Japanese in propulsion—which is not without immediate problems for them to solve—could also push back the effective deployment date for the H-II. Following the development of the H-I launcher, which allowed them to bring on line a liquid hydrogen engine beginning in 1986, the Japanese have chosen to integrate into the H-II, and to develop for this purpose, a liquid fuel engine with performance comparable to the HM60 Vulcain, called LE7, whose expected thrust was 120 tons, as against 110-115 for the European engine developed by the SEP. Another version of the Japanese engine, called the LE7A, which is expected to utilize a liquid oxygen/liquid petroleum fuel mix, has the advantage of offering a better ratio of mix than the LE7 and of setting the Japanese engine designers onto a new road, which their American and European colleagues are still hesitating to take. In contrast to the European engine based on the techniques of derived flow, in utilizing the concept of integrated flow, which is more difficult to achieve over time and is already used for the main engines in the American Space Shuttle, the Japanese are running up against delicate problems in overcoming this technological hurdle: Recently an LE7 engine exploded at the test site, and a number of attempts that had earlier achieved minimum results were also affected by cracks in the turbine blades and the destruction of the turbo-pump casing.

At present, Japanese engineers are turning toward a solution which consists of reducing the thrust and pressure of the LE7, which will make it heavier and reduce its carrying capacity. Therefore, it seems uncertain that the future H-II rocket could in fact carry two 2.2-ton satellites into geostationary orbit, as the officials at Japan's National Space Development Agency (NASDA) were hoping, and that the test flight initially planned for 1993 could take place as expected. The initial aim of putting it into operational service over 1994-95 will probably have to be pushed back to 1997-98, and, even at that point, the H-II will not be able to compete with the upgraded versions of the Ariane 5P, which will go beyond putting 6.5 tons into geostationary orbit. As a consequence of this, the launching of the Japanese experimental satellites VEP and ETS-6, the scientific satellite SFU and the weather satellite GM5 will have to be set back the same amount of time.

Despite the problems that exist, it would be inappropriate for Europeans to underestimate the Japanese space program, which is more extensive than generally supposed, and to poke fun at the technological difficulties which can be overcome at the cost of a few years' delay in the development of their programs. It would be equally inappropriate to make *a priori* judgments about the ultimate development of the Japanese space program in the light of criteria that European and American "experts" have incorrectly used in the past to evaluate Japan's science and technology policies. There is no dearth of examples; it is almost a cliché that Japanese science policy is motivated only by considerations of applied research that looks exclusively to the short term. Just as false are the ideas which hold that the Japanese are, more than anything, "copiers," endowed with an exceptional ability to seize part of the market in discoveries made by others; these ideas bear no resemblance to the deeper reality of Japan, which is not merely a model of "reactivity."

The reality of Japanese science policy

On closer examination, Japan's scientific and technological research reveals itself to be quite different from the image

Since 1985-86, Japan has invested a great deal of money in research programs in microgravity, in collaboration with the United States, often through Japanese private firms. Here, a Japanese astronaut uses U.S. NASA facilities to train for weightlessness.

given it by the frantic European proponents of liberal economics.

Even if the first steps in development were involved in copying and bore a similarity to the efforts of developing countries, seeking to pay for imports of brain-power and know-how, the successes Japan achieved in domains as diverse as steel-making, electronics and microprocessors, computers, optics and photography, and automotive technologies, are not properly due to "certified exact copies" of imported patents which the Japanese industrialists exploited with more alacrity than those who produced them. In fact, an exhaustive examination of the industrial policies developed in Japan over 20-odd years shows, quite the contrary, that success should be properly attributed to long-term planning and to an astonishingly persistent collaboration between the public and private sectors.

More astonishing yet, an analysis of the foundation for these successes shows that in large part they were the fruits of basic research that was not always closely tied to applied research programs. For example, 15 or more years ago, Sony was able to develop a color cathode ray tube for television reception, thanks to purely fundamental research whose objectives could not have been further from the development of television in itself. This research was carried out in Sony's own laboratories and not in public laboratories financed by the state.

In other areas, such as the process for manufacturing the basic element of electronics and computers, very large-scale integration circuitry, precision mechanics, optical electronics, robotics, high-grade steel, fiber optic communications, biotechnology, aquaculture, and high-speed ground transport, Japanese advances are more than anything a result of research carried out in Japan. To be convinced of that, one has only to consult the figures for patents registered in various places throughout the world, or to go to the National Institute for Industrial Patents in Paris to find the startling number of patents registered there from Japan. In other domains, where the Japanese situation still used to appear to be a few years "less good" than in the United States or Europe—e.g., biotechnology, life sciences, or materials processing—Japan has already recouped the difference; and its biotechnology research project "Human Frontier," one of whose unspoken objectives is to attract foreign expertise, upsets European and American authorities no end.

In areas such as hydroponic agriculture (Kiowa Corp.), Japanese advances are considered "alarming" by some competitors and, insofar as the promising arena of long-distance energy transmission by laser or microwave is concerned, the Japanese, thanks to work by their Institute for Space and Astronautical Science (ISAS) and the Japan Electrotechnical Laboratory, are closing in on their nearest American competitor, Raytheon, which up to now enjoyed an absolute monopoly on this type of research, with the important advantage of benefiting from SDI contracts. These two areas of research obviously have long-term applications for ambitious "distant future" programs such as colonization of the Moon, asteroids, and Mars.

For all of the examples that we have just mentioned, it is remarkable to note that their success is largely due to a policy of encouraging research by the Ministry of International Trade and Industry (MITI), whose main role—rather than to stifle other players through superannuated bureaucratic practices—is principally to anticipate technological developments far ahead of time and to prepare for the ensuing economic changes. Deploying a "Council for Industrial Technologies," MITI organizes standing study groups on "breakthrough" subjects, comprising experts from practically every area of research and industry. When one area seems to be a breakthrough area or one wrongly neglected by competitors in other countries, MITI, after having financed complementary studies from some of the country's 200 think tanks—e.g., the Nomura Research Institute—convenes a roundtable of the department heads for "strategy and perspectives" of the principal industrial groups and proposes common long-term programs, in which the product of research is shared among the different actors, before progressively being moved into the arena of innovations. Nearly 40% of the research contracts financed or encouraged by MITI have to do with fundamental or basic research, and not with applied research, as is so often believed in the West.

It is quite useful to consider how the very specific form of Japanese social organization favors the rapid dissemination of fundamental and basic research into applied research, development, and innovation. Numerous Western experts have remarked how much better the same fundamental and applied research in Japan had been adapted to the same structures, but also estimate that the Japanese model is difficult to transpose to exactly that degree, for specific socio-organizational reasons.

Japan's industrial and technological success must be thought of as the result of a long-term effort which was often undertaken without its importance being well understood in Europe or the United States. Hence, while the Japanese R&D effort in 1955 represented only 1% of the global financing of the other five scientific powers—U.S.A., Soviet Union, Great Britain, France, and Germany—the same figure had gone to 15% in 1988 and now reaches nearly 18%.

The *White Book* commissioned by the Japanese government in 1987 is very revealing about Japan's scientific ambitions. One learns from it that Japan counts more researchers and engineers than all countries in Western Europe combined; that Japan is right on the heels of the United States when it comes to the per capita ratio of scientists and engineers; that it puts out 25 high-quality popular scientific journals, as compared to 5 or 6 in France, and that there is even a best-selling weekly that devotes two-thirds of its coverage to science and technology. Compare that to sales in Europe of rags and pulp publications!

Can Japan's success in science and technology policy be translated into space programs?

Certainly an ambitious space program ought to be the object of specific treatment, and the recipes for success obtained in one place cannot automatically be translated, even where there are similarities in two different science programs, such as space and energy independence, or development of nuclear power stations.

As for the Japanese space program proper, it is necessary to document its extraordinary growth since the end of the 1960s: minuscule in 1968 at $49.6 million, the space budget reached $638 million in 1976, at a time when it was totally dependent on high-cost imported American technologies, and rose to the level of France's National Center for Space Studies (CNES) in 1989, at somewhere around $1.1 billion. Since then, as a result of the present reduction in available credit in France, it is highly probable that the Japanese space budget has gone higher than France's. Presently Japan's space effort has a budget of $1.24 billion, compared to $12.3 billion for the United States, and $6 billion for the Soviets—figures of course, that only apply to the civilian budget—and $4.9 billion for Europe. As a ratio of the Gross National Product, the Japanese space budget surpassed Europe (0.04% compared to 0.07%), and the plans of Japan's Commission for Space Activities (SAC), which advises the government, already show that the Land of the Rising Sun expects to multiply this figure by several orders of magnitude between now and the end of the century, to the extent that a number of large industrial groups are integrating space matters into their long-term strategies for the next 15 years.

Whereas Japan has already stood out in the past in its research into microgravity, it is interesting to note that the Japanese are already becoming interested in lunar colonization; in fact, the Japanese Muses probe was the only such probe sent toward the Moon since the end of the Apollo program, and a second, upgraded probe is planned for 1997. The Japanese have succeeded with little foreign help in mastering liquid fuel propulsion, in deploying a system similar to the French Onera. The National Space Laboratory carries out research, through public and private funding, for the development of a passive, initially unmanned mini-shuttle (i.e., without its own propulsion system) the Hope, which would use a version of the H-II launcher and operate on a concept similar to the Hermes shuttle.

Even more ambitious are the laboratory's researches into air-breathing engines, and studies carried out with NASDA—one of the two Japanese space agencies, along with ISAS more oriented toward scientific programs—on the concept of a Rocket Plane. In the first version of this two-stage concept, making use of eight LE7A engines for the first and one LE7 for the second, the rocket could put 12-15 tons into low orbit and automated installations for manufacturing in microgravity. A later version, based on the same first stage and a recoverable, winged hybrid second stage, could put up to 30 tons into orbit toward the year 2005, during a period when the Europeans will still be using the Ariane 5P/Hermes system.

Given the number of players involved in the project—the two official commissions SAC and Science and Technology Agency (STA), the technical services of four ministries, the specialized subsidiaries of *all* the major industrial groups of the country—and the expected rise in R&D expenses permitted by the considerable profits amassed by the industrial sector over 20 years, it is clear that the Japanese space program is called upon to play a major role in the 21st century. It is worthwhile to recall that SAC is in the process of bringing the government bit-by-bit to accept, over and above the development of new concepts for launchers acquired over a long time, two of the projects it holds most dear: a totally independent Japanese space station and a permanent base on the Moon.

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