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Japan's Participation in the U.S. Space Shuttle Program: Achievements and Lessons in Space Policy*

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Abstract

In the aftermath of the Apollo 11 moon landing, the United States invited western countries, including Japan, to participate in its "post-Apollo" space program, which consisted of two main elements, the "Space Shuttle" and the "Space Station." However, because the United States had decided to develop the Space Shuttle essentially on its own in 1972, Japan decided to participate in the Space Shuttle program in the field of utilization in 1974. This marked the beginning of Japan's participation in international space cooperation efforts and also led to Japanese human spaceflights after the 1990s. This article reexamines the relationship between Japan's space activities and the U.S. Space Shuttle program from the beginning to the end, from the perspective of Japan-U.S. diplomatic history. It should be concluded that Japan's participation in the U.S. Space Shuttle program was a success in space policy because Japan became one of the advanced countries in space efforts by participating in the program and later in the International Space Station (ISS) program.

Introduction

Japanese human space activities had been supported by the U.S. Space Shuttle program until the program ended with the 135th and last mission of the *Atlantis* in July 2011. Seven Japanese astronauts had flown on a total of thirteen Space Shuttle missions since September 1992. At the same time, Japan has also participated from the beginning in the International Space Station (ISS) program, originally called the U.S. Space Station program in the 1980s. Because Japan has never had its own human spaceflight program, its involvement in human

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spaceflights has essentially been limited to the Space Shuttle and ISS programs.[1)]

The origin of this course of Japanese human spaceflights can be traced back to the Japan-U.S. space relations during the 1970s. Around 1970, the United States announced its "post-Apollo" space program and invited western countries, including Japan, to participate in the program. The post-Apollo program consisted of two main elements, the "Space Shuttle" and the "Space Station." Although the United States decided in January 1972 to develop the Space Shuttle basically on its own, Europe and Canada nevertheless participated in the development of various components. However, Japan decided to participate not directly but indirectly in the international cooperation efforts in September 1974. In other words, Japan decided to participate in the Space Shuttle program in the field of utilization. The Japanese Space Experiments with Plasma (later Particle) Accelerators (SEPAC) were conducted on board the "Spacelab" of the Space Shuttle in November 1983 and March 1992. This cooperation in space science experiments led to Japanese human spaceflights. Japanese astronaut Mamoru Mohri was the first Japanese person to take part in a human spaceflight of the Space Shuttle; he went into space on board the *Endeavour* in September 1992. Thus, Japan's participation in the U.S. Space Shuttle program was one of Japan's main space activities until more recently.

This article reexamines the relationship between Japan's space activities and the U.S. Space Shuttle program from the beginning to the end, from the perspective of Japan-U.S. diplomatic history.[2)] In particular, it analyzes why and how Japan could not participate directly in the program in the beginning, but could participate afterward in its utilization such as by conducting space science experiments and human spaceflights, by making the most of the important related documents and previous studies that existed in both countries.[3)] Such an

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1) Apart from the Space Shuttle and ISS programs, Japanese journalist Toyohiro Akiyama flew to the Russian *Mir* space station on board its *Soyuz* spacecraft in December 1990, which was the first Japanese human spaceflight.

2) This article is also a revised and expanded version of the following: Hirotaka Watanabe, "U. S. Space Shuttle Program and Japanese Space Activities during the 1970s," presented at the 24th International Symposium on Space Technology and Science (ISTS), Miyazaki, Japan, 30 May-6 June 2004.

3) For the history of Japanese space policy, see John M. Logsdon, "Learning from the Leader: The Early Years of Japanese-U.S. Space Relations" (Washington, DC: Space Policy Institute, George Washington University, 1998), Joan Johnson-Freese, *Over the Pacific: Japanese Space Policy into the Twenty-First Century* (Dubuque, IA: Kendall/Hunt, 1993), Kazuto

examination and analysis have not fully been done until now.

First, this article gives an outline of Japan-U.S. space relations during the 1960s as the background of the U.S. invitation to Japan to participate in its post-Apollo program. Next, it examines the policy-making process of the Space Shuttle program as an example of international space cooperation in both the United States and Japan. Then, it describes how Japan participated in the Space Shuttle program in the field of utilization while it formulated the first "Outline of Japan's Space Development Policy" in March 1978 and participated in the U.S. Space Station program, later renamed the ISS program, after the 1980s. Finally, this article summarizes the space policy achievements and lessons of Japan's participation in the U.S. Space Shuttle program, and gives some suggestions for the future Japanese human spaceflight program.

Japan-U.S. Space Relations during the 1960s[4)]

It can be said that the Japan-U.S. space relations started in the early 1960s when Japan sent a mission to the United States to investigate its space activities. However, as Japan was already investing in the research and development of rockets to acquire independent access to space, there was limited space cooperation; Japan only received data from U.S. satellites.

In the late 1960s, the issue emerged in Japanese government and industry as to whether Japan should import foreign space technology to make practical use of space through communications and meteorological (weather) satellites sooner than

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Suzuki, "Administrative Reforms and the Policy Logics of Japanese Space Policy," *Space Policy*, Volume 21, Number 1, 2005, pp. 11-19, Yasunori Matogawa, "Looking Ahead: Half a Century of Space Activities in Japan," in P. V. Manoranjan Rao, ed., *50 Years of Space: A Global Perspective* (Hyderabad: Universities Press, 2007), pp. 137-171, and Hirotaka Watanabe, "The Evolution of Japanese Space Policy: Autonomy and International Cooperation," *History of Rocketry and Astronautics: Proceedings of the Thirty-Ninth History Symposium of the International Academy of Astronautics, Fukuoka, Japan, 2005, American Astronautical Society (AAS) History Series,* Volume 36 (San Diego, CA: Univelt, Inc., 2012), pp. 271-295.

4) For more details, see Hirotaka Watanabe, "Japan-U.S. Space Relations during the 1960s: Dependence or Autonomy?" *History of Rocketry and Astronautics: Proceedings of the Thirty-Seventh History Symposium of the International Academy of Astronautics, Bremen, Germany, 2003, AAS History Series*, Volume 34 (San Diego, CA: Univelt, Inc., 2011), pp. 261-277, and Yasushi Sato, "A Contested Gift of Power: American Assistance to Japan's Space Launch Vehicle Technology, 1965-1975," *Historia Scientiarum*, Volume 11, Number 2, 2001, pp. 176-204.

would otherwise be possible. At the same time, the United States was trying to control Japanese rocket development through both international cooperation and control of technical exports. Although Japan prolonged its decision between dependence and autonomy in space technology, its final decision to receive the first space technology transfer from the United States was based upon the factors of diplomacy, security, domestic politics, and economy as well as technology.

The two countries concluded in July 1969 "The Exchange of Notes concerning the Cooperation in Space Exploitation between Japan and the United States of America."[5] According to the agreement, any technology or equipment transferred from the United States to Japan would be used solely for peaceful purposes, would not be transferred to third countries, and would be used for any systems compatible with the International Telecommunications Satellite Consortium (INTELSAT) agreements. Concretely, the agreement would cover unclassified technology and equipment up to the level of the *Thor-Delta* vehicle systems, exclusive of reentry and related technology. The contents of the agreement symbolized the U.S. policy toward international space cooperation, which was that the United States should advance such international space cooperation as would contribute to U.S. foreign policy, security, and the economy.

Around the same time, Japanese space organizations were arranged more functionally. The Space Activities Commission (SAC) was established in August 1968, and the National Space Development Agency (NASDA) was established in October 1969. SAC took charge of setting Japanese space policy under the Prime Minister. Under the supervision of SAC, NASDA took charge of practical space applications, while the Institute of Space and Aeronautical Science (ISAS), established as a national academic organization in February 1964, was responsible for scientific space research.

In February 1970, Japan succeeded in launching its first satellite *Ohsumi* by the *Lambda 4S* rocket, which had both been developed by ISAS. However, according to the 1969 Japan-U.S. agreement, NASDA space activities were dependent on U.S. space technology during the 1970s. Although it took a fairly long time to change its space programs, Japan announced in October 1970 that NASDA would stop the Q and N rocket programs, under which Japan would develop the rockets on its own, and start the new N-I rocket program, under which Japan would develop the rocket by introducing U.S. space technology. Thanks to

5) The Japan Aerospace Exploration Agency (JAXA), "Space Law," full text available at <http://stage.tksc.jaxa.jp/spacelaw/world/1_09/09.E-1.pdf>. Accessed 20 November 2015.

the space technology transfer, NASDA succeeded in launching the first N-I rocket in September 1975 and the first Japanese geostationary satellite with the third N-I rocket in February 1977. Japan thus became the third country to launch geostationary satellites, following the United States and the Soviet Union.

The history of Japan-U.S. space relations during the 1960s, from the standpoint of Japan, was marked by the shift from autonomy to international cooperation or dependence. To save both time and money, Japan adopted the strategy of "identifying the leader in technological capability and learning as much as possible from its accomplishments, then building on that learning to develop a strong indigenous technology base."[6)]

U.S. Policy-Making Process

The Space Shuttle program first appeared as a major part of the U.S. post-Apollo space program in the Space Task Group report in September 1969.[7)] The post-Apollo program consisted of the "Space Shuttle," the "Space Station," the "Space Tug," and human Mars expeditions. The Space Shuttle would provide low-cost transportation between the surface of the Earth and a space station in low-Earth orbit. The Space Tug would be a transfer vehicle between different Earth and lunar orbits. The Apollo program to go to the moon was exclusively of the United States, by the United States, and for the United States; in a change of policy, the Space Task Group report recommended that U.S. post-Apollo efforts should be advanced through international participation and cooperation.

Armed with the Space Task Group report, during late 1969 and early 1970, National Aeronautics and Space Administration (NASA) Administrator Thomas O. Paine visited Europe, Canada, Australia, and Japan for initial discussions on cooperative opportunities in the U.S. post-Apollo program. The reactions to Paine's proposals were varied. While Europe and Canada indicated that they were interested in making contributions to the program, Australia and Japan were rather negative.[8)]

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6) John M. Logsdon, "U.S.-Japanese Space Relationships at a Crossroads," *Science*, Volume 255, 17 January 1992, p. 297.

7) The Space Task Group, *The Post-Apollo Space Program: Directions for the Future,* September 1969, reprinted in John M. Logsdon, et al. eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume I: Organizing for Exploration* (Washington, DC: NASA SP-4407, 1995), pp. 522-543.

8) For more details on international cooperation in the post-Apollo program, see John M. Logsdon, "The Development of International Space Cooperation," in John M. Logsdon, et al.

Just after Paine's tour, however, President Richard M. Nixon provided in March 1970 only a very guarded endorsement of future space activities.[9] Gradually, NASA found that the White House and Congress had no intention of approving all programs recommended by the Space Task Group, and some in the White House were far less enthusiastic about cooperation in large hardware programs than were Paine and the Space Task Group.[10] Therefore, NASA dropped its hopes for Mars expeditions and then for the Space Station program, and decided to concentrate on gaining approval for developing a two-stage, fully reusable Shuttle as its major program of the 1970s. With the post-Apollo program reduced, Paine resigned from NASA, and James C. Fletcher, President of the University of Utah, was named the new NASA Administrator in September 1970.

Meanwhile, the United States was discussing with western countries, especially Europe, their participation in the Space Shuttle program. Although the United States intended to extend international space cooperation, it wanted to maintain the U.S. monopoly in two areas of space activities: launch vehicles for sizable payloads and communications satellites for INTELSAT.[11] These issues were the same when it came to extending Japan-U.S. space cooperation. Consequently, discussions between the United States and European countries made very little progress.

In May 1971, the Office of Management and Budget (OMB) indicated that NASA's approved budget would remain constant at its Fiscal Year 1972 level of $3.2 billion for most of the duration of the Space Shuttle program. The budget forced NASA to study and re-evaluate the Space Shuttle designs offering the maximum capability for the minimum overall and annual development costs. NASA tried every possible means during 1971 to justify the development of the Space Shuttle. NASA developed a rationale emphasizing the Shuttle's utility for performing a variety of roles related to unmanned space missions for NASA, the Department of Defense (DOD), intelligence agencies, other countries, and

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eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume II: External Relationships* (Washington, DC: NASA SP-4407, 1996), pp. 5-10.

9) The White House Press Secretary, "The White House, Statement by the President," 7 March 1970, reprinted in Roger D. Launius, *NASA: A History of the U.S. Civil Space Program* (Malabar, Florida: Krieger Publishing Company, 1994), pp. 216-221.

10) Logsdon, "The Development of International Space Cooperation," p. 6.

11) Logsdon, "The Development of International Space Cooperation," pp. 7-8.

commercial users.[12] In particular, NASA focused on making the Space Shuttle design meet all DOD requirements such as the ability to launch payloads, and having a high cross-range capability—the ability to maneuver on re-entry to either side of the vehicle's ground track. Thereby, the Space Shuttle would be for both civilian and military use.

In the summer of 1971, NASA adopted an orbiter with external, expendable hydrogen and oxygen tanks. While this change saved development costs, it also meant that the Shuttle would never be truly inexpensive since costly components would be thrown away with each use.[13] Moreover, NASA and its contractors prepared an elaborate economic analysis of the cost-effectiveness of the Space Shuttle. In October 1971, Mathematica, Inc., a firm headed by the distinguished economist Oskar Morgenstern, reported to NASA that the concepts of the Thrust Assisted Orbiter Shuttle (TAOS) with external hydrogen and oxygen tanks and a 60 x 15 ft payload bay had emerged as the most preferred system and represented an approach that practically assured NASA of a reusable space transportation system with major objectives achieved.[14] In a 22 November memorandum to the White House, NASA made its "best case" argument for going ahead with the Shuttle.[15] Although these arguments seemed to be persuasive, the struggle continued between NASA and OMB over the Shuttle's size, payload capability, and costs. Therefore, NASA carried its argument beyond the OMB staff to the top policy advisers at the White House.

To NASA's pleasant surprise, President Nixon approved the development of the full-size Space Shuttle with a 60 x 15 ft payload bay on 3 January 1972. Two days later, President Nixon announced that the United States should proceed at once with an "entirely new type of space transportation system." This was the Space Shuttle. President Nixon decided to approve the development of the Space Shuttle for the following reasons: the political impact of human spaceflight, new military capabilities, and the short-term employment impacts of a Shuttle go-ahead

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12) John M. Logsdon, "The Decision to Develop the Space Shuttle," *Space Policy*, Volume 2, Number 2, 1986, p. 104.

13) Logsdon, "The Decision to Develop the Space Shuttle," p. 107.

14) Klaus P. Heiss and Oskar Morgenstern, "Factors for a Decision on a New Reusable Space Transportation System," 28 October 1971, reprinted in Logsdon, *Exploring the Unknown, Volume I*, pp. 549-555.

15) James C. Fletcher, "The Space Shuttle," 22 November 1971, reprinted in Logsdon, *Exploring the Unknown, Volume I*, pp. 555-558.

in states critical to the President's re-election in 1972.[16] However, the Space Shuttle that the President approved was drastically different in design and estimated cost from what NASA had hoped to develop.[17]

After the Space Shuttle finally gained approval as a U.S. post-Apollo program, the discussions between the United States and Europe progressed little by little. Since U.S. civilian and military space endeavors would rest on the Space Shuttle during the 1980s, the United States did not want European countries to cooperate in the development of the Space Shuttle orbiter itself. In September 1973, a U.S.-European agreement on the terms for the cooperative development of the "Sortie Can," not the technologically more challenging "Space Tug" or parts of the Shuttle orbiter itself, was achieved.[18] The Sortie Can, later renamed the "Spacelab," would be a pressurized laboratory inside the Shuttle's payload bay. This agreement came in the context of a package deal that also committed European countries to developing their own launch vehicle and to beginning work on a maritime communications satellite.[19] The United States compromised on these points, though it wanted to maintain its monopoly in the field of launch vehicles and communications satellites.

In contrast, the negotiations between the United States and Canada proceeded relatively harmoniously.[20] It was agreed in July 1975 that Canada would be responsible for developing the Remote Manipulator System, later known as "Canadarm," used on board the Space Shuttle.

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16) Logsdon, "The Decision to Develop the Space Shuttle," p. 119.

17) For further details on the development of the Space Shuttle, see, T. A. Heppenheimer, *The Space Shuttle Decision, 1965-1972: History of the Space Shuttle, Volume I* (Washington, DC: Smithsonian Institution Press, 2002), and Ray A. Williamson, "Developing the Space Shuttle," in John M. Logsdon, et al. eds., *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program, Volume IV: Accessing Space* (Washington, DC: NASA SP-4407, 1999), pp. 161-193.

18) T. A. Heppenheimer, *Development of the Space Shuttle, 1972-1981: History of the Space Shuttle, Volume II* (Washington, DC: Smithsonian Institution Press, 2002), pp. 57-65, and Arnold W. Frutkin, "Government Level Negotiations on Sortie Lab," 9 May 1973, reprinted in Logsdon, *Exploring the Unknown, Volume II*, pp. 85-87.

19) Logsdon, "The Development of International Space Cooperation," pp. 8-9.

20) Heppenheimer, *Development of the Space Shuttle, 1972-1981*, pp. 271-273, and Andrew W. Frutkin, "Canadian Interest in Remote Manipulator Technology to be Used with the Space Shuttle," 3 April 1972, reprinted in Logsdon, *Exploring the Unknown, Volume II*, pp. 48-49.

Japanese Policy-Making Process

Soon after Japan concluded the Exchange of Notes for space technology transfer with the United States, NASA Administrator Paine visited Japan on the last leg of his tour around various western countries to explain the U.S. post-Apollo space program. On 3 March 1970, he had meetings with the Japanese delegation, which consisted of SAC members, the presidents of ISAS and NASDA, and some officials from related agencies such as the Science and Technology Agency (STA). The important points of the U.S. proposals on its post-Apollo program are summarized as follows.[21)] First, the United States would extend international cooperation to advance space exploitation and utilization for the human race. Second, the United States would be planning the "Space Shuttle" and "Space Station" programs as the main elements of its post-Apollo program. Finally, the United States would like Japan to participate in the meetings hereafter to discuss the concepts of the two programs.

There were active questions and answers between the two sides.[22)] First, the Japanese side asked whether the United States would supply Japan with some high technology in the post-Apollo program, though the 1969 Japan-U.S. agreement imposed restrictions on the level of supplied technology. The U.S. side answered that it would be the best way for Japanese scientists, engineers, and industry to participate directly in the post-Apollo program from the beginning, if Japan wanted to acquire such high technology. The Japanese side also asked whether their cooperation in the post-Apollo program might involve establishing an international institution such as INTELSAT. The U.S. side answered that the way to cooperate had not been decided and would depend on future meetings. Finally, the Japanese side asked to what extent the United States had discussed the post-Apollo program with other western countries. The U.S. side answered that some European countries had indicated their strong interest in the Space Shuttle program.

At the Japan-U.S. meetings, NASA Administrator Paine did not necessarily expect an immediate response from the Japanese side because the post-Apollo program itself was just in the conception phase. Still, it was a great surprise to Japan that the United States was proposing such large space programs to Japan

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21) Toki Hachifuji, *Uchukaihatsu SeisakuKeiseino Kiseki [The History of Space Development Policy Formulation]* (Tokyo: International Communications and Culture Association, 1983), pp. 160-161.

22) Hachifuji, *The History of Space Development Policy Formulation*, pp. 161-164.

because both countries had just concluded an agreement to extend their space cooperation in July 1969. In any case, Japan responded to the U.S. invitation by establishing under SAC the "Special Committee on the Post-Apollo Program," which consisted of members from SAC, related agencies, academia, and industry in July 1970.[23)] Japan also began sending a delegation to the post-Apollo meetings in the United States. However, Japanese space policy-makers seemed to be in no hurry to decide how Japan would participate in the post-Apollo program because it was more important for them to set forth a new rocket program according to the 1969 Japan-U.S. agreement.[24)]

The Special Committee submitted to SAC its interim report in April 1971, several months later than scheduled.[25)] The report stated mainly how matters were standing with the post-Apollo program. First, the U.S. approach to international cooperation in its post-Apollo program was that each participant should bear its own expenses necessary to develop its own part of the program. Second, the Space Shuttle program entered the next phase of design proposals after conception. Third, it was still difficult for Japan to conclude how it would participate in the post-Apollo program. The progress of the post-Apollo program in the United States was rather fluid and behind schedule. In addition, it was difficult for Japan to coordinate the international cooperation with its domestic programs, for example, the development of new launch vehicles and satellites, in terms of budget and human resources as well as technology itself. Japan was barely able to follow the discussions on the post-Apollo program.

In Japanese industry, the "Space Activities Promotion Council (SAPC)," established in June 1968 in Keidanren (Japan Federation of Economic Organization),[26)] had a strong interest in the post-Apollo program and sent a mission, including officials from related agencies such as STA and NASDA, to the

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23) The Research Coordination Bureau, the Science and Technology Agency (STA), Japan, *Uchukaihatsu Iinkai Geppo [The Space Activities Commission (SAC) Monthly Report]*, Number 6, August 1970, p. 3.

24) The Record of the Proceedings of the Japanese Diet, "The Special Committee for the Promotion of Science and Technology" on 2 and 24 April, 15 May, and 7 September 1970. Available at <http://kokkai.ndl.go.jp> (in Japanese). Accessed 20 November 2015.

25) Hachifuji, *The History of Space Development Policy Formulation*, pp. 164-165.

26) Keidanren (Japan Federation of Economic Organizations), *Space in Japan 1978-1979* (Asahi Evening News: Tokyo, 1979), pp. 120-122. The *Space in Japan* series were prepared under the editorial supervision of the Research Coordination Bureau, the Science and Technology Agency (STA), Japan.

United States and Europe in June 1971. As early as August of the same year, the report was announced.[27] The report indicated that the U.S. post-Apollo program would certainly accomplish some form of international cooperation. Europe was still positive about its participation. There would be every possibility of Japan's participating in the Space Station and Space Tug programs in the conception phase, but only a small possibility of participating in the Space Shuttle program in the design proposal phase. The report stressed that Japan was far behind Europe in collecting information on the post-Apollo program.

The SAPC report prompted the Special Committee to establish a working group to draft Japan's concrete plans in the post-Apollo program. The working group was expected to issue the report by around the summer of 1972. However, it was not until June 1973 that the group finished the report. It noted that Japan should participate in the post-Apollo program in the form of not developing but utilizing the Space Shuttle and its Sortie Can.

Through the working-group report, the Special Committee submitted to SAC its final report in May 1974.[28] The United States had basically decided on the development of the Space Shuttle by itself in January 1972, and Europe had decided to participate in the development of the Spacelab (Sortie Can) in September 1973. The final report stated the necessity and possibility of Japan's participation in the post-Apollo program. First, Japan would be able to contribute to international cooperation in space science and technology by participating in the post-Apollo program. Second, since the United States had decided to develop the Space Shuttle by itself and Europe had decided to develop the Spacelab in the post -Apollo program, Japan should participate in the program by utilizing the Space Shuttle and the Spacelab for space science and medicine experiments. Third, to coordinate its participation in the post-Apollo program with its domestic programs, Japan should extend its participation by developing its own modules and sending its own astronauts.

Since SAC approved the final report by the Special Committee, the report became the Japanese government policy for the post-Apollo program. In September 1974, four and a half years after the U.S. invitation, Japan finally replied to the United States that Japan would participate in the Space Shuttle program in the field of utilization.[29] Compared with Europe and Canada, it took a

27) Hachifuji, *The History of Space Development Policy Formulation*, pp. 165-167.

28) Hachifuji, *The History of Space Development Policy Formulation*, pp. 167-169.

29) Hachifuji, *The History of Space Development Policy Formulation*, p. 169.

much longer time for Japan to decide how it would participate in the post-Apollo program.

In those days, Japan lacked a long-term, comprehensive vision for its space activities and had little understanding of the international situation concerning space activities. In addition, Japan had not yet cultivated sufficient economic, scientific and technological strength to participate in the multilateral space cooperation effort. After all, in terms of Japan-U.S. relations, Japan had to choose "one" bilateral international cooperation effort—the development of launch vehicles and satellites with the help of U.S. space technology, which would lead to autonomy in the future—over "the other" multilateral international cooperation effort—the direct or substantial participation in the U.S. Space Shuttle program.

First Outline of Japan's Space Development Policy

With its decision on the post-Apollo program, Japan was able to concentrate on the development of new launch vehicles and satellites, based on the 1969 Japan-U.S. agreement.[30)] Simultaneously, however, Japan did not give up participating in such cooperative international space efforts as the post-Apollo program. In September 1973, Japan participated in the U.S. *Skylab* program by proposing materials experiments utilizing microgravity. Moreover, in February 1977, the Space Experiments with Plasma, later Particle, Accelerators (SEPAC), which had been proposed by ISAS Professor Tatsuzo Obayashi and his associates, were adopted as some of the experiments to be done on board Spacelab 1 by NASA and the European Space Agency (ESA). ESA was practically established in April 1975. SEPAC was subsequently carried out in November 1983 and March 1992.[31)]

In the late 1970s, Japan also worked on formulating its long-range space policy. SAC announced the first "Outline of Japan's Space Development Policy"

30) For more details, see Hirotaka Watanabe, "Japanese Space Policy during the 1970s: A Road to Autonomy by Modifying the Japan-U.S. Space Cooperation Agreements," *History of Rocketry and Astronautics: Proceedings of the Forty-Fifth History Symposium of the International Academy of Astronautics, Cape Town, South Africa, 2011, AAS History Series*, Volume 42 (San Diego, CA: Univelt, Inc., 2014), pp. 153-180.

31) For further details on discussion over Japan's specific participation in the Space Shuttle program such as SEPAC, see the Record of the Proceedings of the Japanese Diet, "The Cabinet Committee" on 11 April 1973, and "The Special Committee for the Promotion of Science and Technology" on 10 April 1975. Available at <http://kokkai.ndl.go.jp> (in Japanese). Accessed 20 November 2015.

(hereafter, "Outline") in March 1978.[32] It was a comprehensive report, which stated the basic policies and programs of Japan's space activities for the next fifteen years. It emphasized both the long-term vision of Japan's space activities and the involvement in international cooperation efforts.

The "H-II" rocket, which would be a completely domestic rocket, was first named in the Outline. The H-II rocket would be developed to bear Japanese space transportation and especially, to support human space activities in the 1990s. An indication of Japan's participation in the U.S. Space Station program was also described in the Outline. In the section on "International cooperation," it was stated that "Japan will play a suitable role by participating actively in such programs as the second phases of the Space Shuttle and large-scale Space Station for the sake of efficient space development of the world."[33]

Regarding the "experiment instruments to be carried by the Space Shuttle" for the next fifteen years, the Outline stipulated as follows:

> With regard to instruments used for experiments on board the Space Shuttle, such as a unit that can perform the necessary experimental functions, or a laboratory, those instruments for experiments concerning the production of materials, life science, engineering, and other scientific purposes will be developed initially. These will be followed by experiments concerning the construction of a pilot plant for materials processing and manufacturing, a space power station, a space laboratory, and other large structures. Further, when Japan develops an independent manned spacecraft, the Space Shuttle will be used for the purpose of preliminary development and testing of the manned spacecraft.[34]

Regarding the "manned support techniques" for the next fifteen years, the Outline stated as follows:

> Manned space activities by Japan will be developed first by relying on manned spacecraft of the United States. The first project will be planned for around 1983, and manned operational techniques are to be acquired while carrying out experiments mainly on material processing. These will be followed mainly by the development of application techniques concerning fittings and instrumentation. With regard to Japan's own

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32) *SAC Monthly Report*, Number 27, April 1978, pp. 8-16. For the English version, Keidanren, *Space in Japan* 1978-1979, pp. 188-200.

33) Keidanren, *Space in Japan 1978-1979*, p. 189.

34) Keidanren, *Space in Japan 1978-1979*, p. 192.

manned support techniques, sufficient research and surveys will be carried out later, and only after the technical feasibility has been established will development be planned.[35)]

The Outline embodied exactly what Japan learnt from the U.S. invitation to its Space Shuttle program. Japanese efforts to respond to the invitation deepened its understanding of the international situation concerning space activities and also made it recognize the importance of having a long-term vision of space activities. Moreover, Japan learnt the lesson that it should not miss the opportunity to participate in international space programs. The Outline meant that Japan's space activities in the next fifteen years would be supported by the U.S. Space Shuttle program.

Japanese human space activities and Shuttle[36)]

As early as March 1978, the National Aerospace Laboratory (NAL), under the jurisdiction of STA, started to study the methodology for selecting and training Japanese astronauts as Payload Specialists (PS) who would conduct experiments on board the Space Shuttle.[37)] Also in August 1978, SAC started to draw up the "First Material Processing Test (FMPT)," which would be conducted by astronauts on board the Space Shuttle.[38)] The target year of launch was 1984. SAC publicly sought ideas and selected thirty-four suggestions out of 103. Twenty-two of the suggestions concerned materials experiments, using microgravity in the production of new materials, while twelve were life science experiments, such as investigating how fish would be affected by space sickness.

The cooperation on *Skylab* and the preparation for space experiments on board the Space Shuttle led to Japanese human spaceflights. In January 1983, immediately after his inauguration, Japanese Prime Minister Yasuhiro Nakasone visited the United States to improve Japan-U.S. relations by showing that he shared the same understanding of international affairs as the United States. In the press release following their meetings, U.S. President Ronald W. Reagan remarked as follows:

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35) Keidanren, *Space in Japan 1978-1979*, p. 192.

36) For more details about Japanese human space activities, see JAXA, "The Space Shuttle and Japan's Manned Space Activities," 5 December 2011, available at <http://global.jaxa.jp/article/special/spaceshuttle/index_e.html>, "History of Japan's Manned Space Activities," available at <http://iss.jaxa.jp/astro/history_e.html>, and "Japanese Astronaut Biographies," available at <http://iss.jaxa.jp/en/astro/biographies/>. Accessed 20 November 2015.

37) Hachifuji, *The History of Space Development Policy Formulation*, pp. 302-303.

38) Hachifuji, *The History of Space Development Policy Formulation*, pp. 304-306.

> During our wide-ranging consultations we discussed our intention for extensive and fruitful cooperation in space. I presented the Prime Minister with a plaque containing the flags of our two nations which were flown together on the first flight of the space shuttle *Columbia*. I'm pleased to announce today that I have offered Prime Minister Nakasone—and he has accepted—the opportunity for Japanese participation in our shuttle program, including an invitation for a Japanese specialist to be a part of the space lab mission in 1988. Both the Prime Minister and I look forward to continuing our efforts together in the peaceful use of the vast expanses of space.[39)]

In November 1983, NASDA called for some candidates for Payload Specialists (PS) on board the U.S. Space Shuttle to conduct the first materials experiments in the late 1980s. Three people, Mamoru Mohri, Chiaki Mukai, and Takao Doi, were selected as the first generation of Japanese astronauts in August 1985. Around the same time, Japan decided not only to invest in a totally domestic rocket, "H-II," to acquire independent access to space, but also to participate in the U.S. Space Station program to promote international space cooperation, which was another post-Apollo program and later renamed the ISS program.[40)]

Because of the delay in the Space Shuttle program after the *Challenger* accident in January 1986, it was not until September 1992 that Japanese astronaut Mohri conducted the first Japanese human spaceflight on board the Space Shuttle *Endeavour* as a PS. During the FMPT mission, he conducted thirty-four space experiments proposed by Japanese researchers in the fields of materials and life science. Since then and until completion of the last mission in the Space Shuttle program in July 2011, seven Japanese astronauts had flown on a total of thirteen Space Shuttle missions. The history of Japanese human spaceflight can be categorized into three phases.[41)]

In the first phase, Japan learnt about the space environment through space

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39) "Remarks of the President and Prime Minister Yasuhiro Nakasone of Japan Following Their Meetings," 19 January 1983, reprinted in Chihiro Hosoya, et al., eds., *A Documentary History of U.S.-Japanese Relations, 1945-1997* (Tokyo: University of Tokyo Press, 1999), pp. 1028-1030.

40) For more details on Japan's decision on the H-II rocket and the Space Station program, see Hirotaka Watanabe, "Japanese Space Policy during the 1980s: A Balance between Autonomy and International Cooperation," *Acta Astronautica*, Volume 68, Issues 7-8, April-May 2011, pp. 1334-1342.

41) JAXA, "History of Japan's Manned Space Activities," available at <http://iss.jaxa.jp/astro/history_e.html>. Accessed 20 November 2015.

experiments. Through FMPT mission STS-47 conducted by astronaut Mohri in September 1992 and the Second International Microgravity Laboratory (IML-2) mission STS-65 conducted by astronaut Mukai in July 1994, Japan acquired basic knowledge for transporting humans to space and conducted research and development of technologies needed for space experiments utilizing microgravity.[42)]

In the second phase, Japan accumulated technology through robotics, for example, rendezvous and robot arm operations, and Extravehicular Activities (EVA). To prepare for assembling and operating the ISS, Japanese astronauts were allowed to become Mission Specialists (MS). An MS is an all-round astronaut who operates Shuttle systems or performs EVA as well as payload operations; a PS conducts space experiments utilizing the special payloads on board the Shuttle. Astronaut Koichi Wakata was the first Japanese MS; he flew on Space Shuttle mission STS-72 in January 1996. He operated the robot arm and recovered the Japanese Space Flier Unit (SFU). Subsequently, astronaut Takao Doi became the first Japanese astronaut to conduct an EVA during the STS-87 mission in November-December 1997.

In the third phase, Japan contributed to the ISS program through the participation of Japanese astronauts in its assembly and operations. The ISS assembly began in November 1998. Astronaut Wakata flew aboard the STS-92 mission in October 2000, the seventh ISS assembly flight, and participated in the ISS assembly by operating the robot arm. After the delay in the Space Shuttle program after the *Columbia* accident in February 2003, astronaut Soichi Noguchi flew on board the "Return to Flight" mission STS-114, which tested and evaluated the new procedures for flight safety in July 2005. He conducted three EVAs as a lead spacewalker.

Japan developed the Japanese Experiment Module called *Kibo*, a facility that enabled up to four astronauts to work simultaneously on experiments. Astronaut Doi flew on Space Shuttle mission STS-123, which delivered the first element of *Kibo*, the Experiment Logistics Module-Pressurized Section (ELM-PS), to the ISS in March 2008. During the mission, he installed the ELM-PS on the ISS using the Space Station Remote Manipulator System (SSRMS). He was the first Japanese astronaut to enter the first Japanese ISS module in orbit. Subsequently in June 2008, astronaut Akihiko Hoshide flew to the ISS on mission STS-124. He installed

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42) STS stands for the Space Transportation System, which is a name for NASA's Space Shuttle program.

Kibo's Pressured Module (PM) on the ISS using the SSRMS. Finally, astronaut Wakata installed the final two components of *Kibo*: the Exposed Facility (JEM-EF) and the Exposed Section (JEM-ES) at the ISS in July 2009. He became the first Japanese astronaut to stay at the ISS for four and a half months, from March to July 2009. Finally, the last Japanese astronaut on board a Space Shuttle mission was Naoko Yamazaki. She was on board Space Shuttle *Discovery*, mission STS-131, in March 2010. She supported the mission's primary tasks by operating both the Shuttle Remote Manipulator System (SRMS) and the SSRMS.

Thus, Japan acquired almost all of the available technology and know-how related to human space activities, except that related to its own human spacecraft and launch vehicle, by participating in the Space Shuttle and ISS programs, and it contributed to overcoming the two Space Shuttle accidents with the United States.

Conclusion

The Space Shuttle program was the product of the first multilateral cooperation in human space activities. However, the negotiations were never easy for all participants. In the end, the United States developed the Space Shuttle itself, while Europe and Canada developed its components, the Spacelab and the Remote Manipulator System, respectively. In other words, Europe and Canada participated in the Space Shuttle program as developers from the beginning, but Japan participated in the program later as a user of the program.

Shortly before the United States invited western countries to participate in its post-Apollo program, the United States and Japan jointly decided in 1969 to extend their space cooperation. Therefore, both countries may have shared the view that it was not that important for them to cooperate in the post-Apollo program, and Japan could not afford to participate actively in the program because of its cost, time, and human resources. However, it took too much time, more than four years, for Japan to decide whether it would participate in the program. At that time, the United States itself was discussing what the Space Shuttle would be like. Its policy-making process was extremely bureaucratic and top-down. In contrast, the process in Japan was consensus-building and bottom-up. The bottom-up approach often took a lot of time. In addition, Japan lacked a long-term, comprehensive vision for its space activities and had little understanding of the international situation of space activities.

In policy-making processes in both the United States and Japan, domestic factors were more influential than international ones. The United States limited international cooperation in the Space Shuttle program to such components and utilization in order to maintain the U.S. monopoly in space activities. However, Japan decided to give the highest priority to the development of launch vehicles and satellites, rather than to its participation in the post-Apollo program.

During the 1970s, the U.S. post-Apollo program enabled Japan to learn about space activities underway in both the United States and Europe, to self-examine its own space activities, and to gain an understanding of international cooperation in space activities. Therefore, Japan did go ahead with its participation in the Space Shuttle and Spacelab programs as a "user," though not as a "developer or maker." What did the U.S. Space Shuttle program mean in terms of Japan's space activities? The space policy achievements and lessons of Japan's participation in the program can be summarized as follows.

First, in terms of political and diplomatic significance, Japan was able to enhance its international status as an advanced country in space efforts and to strengthen Japan-U.S. relations. While Japan developed the N-I, N-II, and H-I rockets by introducing U.S. technology, and later the H-II rockets with its own technology, it was able to acquire almost all the available technology and know-how related to human space activities by participating in the Space Shuttle program. Therefore, Japan has achieved a balance between autonomy and international cooperation in its space activities.

Second, in terms of economic significance, the Japanese space industry was fostered by the participation in the Space Shuttle program. How much did Japan spend to participate in the program? How much did it cost to launch a Space Shuttle flight? The average cost per launch over the life of the U.S. Space Shuttle program from 1981 to 2011 was about 1.5 billion U.S. dollars.[43] Roughly speaking, the average cost per astronaut on the Space Shuttle was about 250 million U.S. dollars, as one launch usually carried six astronauts. On the other hand, the average cost per astronaut on board the Russian *Soyuz* was about 60 million U.S. dollars.[44] However, Japan never paid the United States directly because Japanese astronauts' flights on board the Space Shuttle were not commercial endeavors, but rather "bilateral space cooperation." Therefore, we cannot determine how much Japan actually spent to participate in the Space

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43) Roger Pielke, Jr. and Radford Byerly, "Correspondence: Shuttle Programme Lifetime Cost," *Nature*, Volume 472, Number 7341, 7 April 2011, pp. 38. Available at <http://www.nature.com/nature/journal/v472/n7341/full/472038d.html>. Accessed 20 November 2015.

44) "Space Shuttle Retirement Leaves Russia Grinning," *The Daily Yomiuri* (now *The Japan News*), 7 April 2010, p. 3.

Shuttle program. However, the cost should be checked, calculated, and analyzed for our future space activities.

Third, in terms of social significance, Japanese people became more familiar with space itself because it was well known that Japanese astronauts were flying in space and Japan's experimental devices were being used on board the Space Shuttle. The Space Shuttle program greatly inspired Japanese children, younger generations, scientists, and engineers. However, the social influence should be fully examined from the standpoint of not only quality but also quantity for our future space activities.

Fourth, in terms of scientific and technological significance, Japan was able to acquire almost all available technology and know-how related to human space activities, except that related to its own human spacecraft and launch vehicle, by participating in the Space Shuttle program. For example, the methods of selecting and training astronauts, the support and health management of astronauts in space, and the development and operation methods for space laboratory equipment. This technology and know-how enabled Japan to develop its module for the ISS program.

Consequently, it should be concluded that Japan's participation in the U.S. Space Shuttle program was a success in space policy because Japan consequently became one of the most advanced countries in the field of space activities by participating in the program and later in the ISS program. However, one important lesson could be the cost-effectiveness. Japan needs to calculate its participation cost and preserve the records for future generations. Another lesson could be that Japan's participation in the U.S. Space Shuttle program resulted in too much dependence on the United States in the field of human spaceflight. In order to maintain the status of a space-advanced country in the future, Japan will have to ultimately decide whether it should advance its technology and know-how related to human space activities, including its own human spacecraft and launch vehicle, or give them up when the ISS program is terminated after 2024.