Chapter 8
International Competition and Cooperation

When the United States was building its civilian space program, political competition with the Soviet Union acted as a goad to enhance U.S. technological capabilities, especially in space. In part, U.S. officials worried that the Soviet Union's successes in launching large spacecraft demonstrated its ability to field ballistic missiles capable of landing nuclear weapons on the United States. The demonstration of U.S. technological leadership by leading in civilian space activities soon became an important part of U.S. motivation for any proposed new activity.[1] In 1%1 the Kennedy administration and the 85th Congress took U.S. leadership a step farther by funding a program that soon established across-the-board preeminence in space activities. Not only did the United States demonstrate its preeminence in activities involving human crews, it established strong programs in planetary exploration, meteorological satellites, and land remote sensing. The United States also spearheaded the development of the communications satellite industry, which today is still the only fully commercial space enterprise.[2]

Beginning in the 1970s, other nations, especially Japan and the European countries, have been demonstrating their increasing capabilities in space technology. They are now able to challenge the United States in space applications and in certain areas of space science.[3] As a result, the United States has seen the steady loss of its position as the dominant supplier of space-related goods and services in the world market. Hence, the grounds of competition have shifted away from political competition for global status to economic competition with our traditional allies. America's challenge for the 1990s and beyond will be the construction of effective mechanisms to enhance the U.S. economic position.

Despite the strong competitive foundation, the U.S. space program has also had a long history of encouraging cooperative activities.[4] During the 1960s, the 1970s, and even into the early 1980s, the United States organized cooperative activities — in part to enhance its leadership position. Under those circumstances, most U.S. cooperative efforts were generally unequal partnerships in which the United States could set the foundation and terms of the cooperative venture. In part, the United States could do so because the Soviet Union offered little competition for cooperative programs. The secretive nature of its space program, and the relatively immature level of its technology made the Soviet Union unable to offer much of interest to technologically advanced potential partners.

Although the capacity of the countries of Europe and Japan to challenge U.S. firms means that they will likely continue to gain market share for commercial goods and services, it also means they make more effective partners in cooperative ventures. In some areas of technology other countries lead; hence the United States would gain technologically from cooperating. For most cooperative projects, the combination of skills each party would bring would greatly enhance the project's outcome.

The Soviet Union's continuing experience in supporting a human presence in space on the ***Salyut*** and ***Mir*** space stations, in launching a variety of launch vehicles, and its long-term interests in planetary exploration, coupled with much

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[1] Indeed, the role of leadership is codified in the National Aeronautics and Space Act of 1958 (Public Law 85-568). "The aeronautical and space activities of the United States shall be conducted so as to contribute materially to.... The preservation of the role of the United States as a leader in aeronautical and space science and technology... (42 U.S.C. 2451, Sec. 102c(5)).

[2] Numerous communications satellites have also been built for civilian government uses.

[3] U.S. Congress, Office of Technology Assessment, *International Cooperation and Competition in U.S. Civilian Space Activities*, OTA-ISC-239 (Washington, DC: U.S. Government Printing Office, 1985), ch. 4.

[4] The National Aeronautics and Space Act of 1958 mandates international cooperation (42 U.S.C. 2451, Sec. 102 c(7)).

greater openness about its space activities, now make it a potentially attractive partner for cooperative science and technology projects.[5] The Soviet Union is also seeking to attract partners for commercial ventures and is willing to arrange highly competitive terms for such cooperation. The political advantages of competing with the Soviet Union in space have greatly diminished, and are being replaced by a growing realization that cooperation would help support the Soviet Union's transition to a market economy, and assist Soviet political stability as it experiments with democratic reform. On the other hand, the current Soviet economic crisis affects its ability to fund space activities and may make it difficult for Soviet scientists to engage in large cooperative projects.

As space projects grow in cost and technological complexity, the need for efficient, cost-effective use of resources argues for an international division of labor. During the 1990s, the United States faces the challenge of developing new cooperative mechanisms, based on the new global economic and political realities. That challenge will require U.S. policymakers to alter significantly modes of thinking that derive from the era of the cold war. For example, in future cooperative projects with the United States, Japan and Europe are likely to require increasingly greater voice over the terms of the project. For the Mission from Planet Earth, the United States will have to resolve the apparent tension between its wish to carry out ambitious, and costly, projects on its own and the attraction of seeking foreign participation in order to: 1) reduce costs for each participant, 2) increase overall technological capabilities, 3) expand its opportunities for involvement in wider variety of disciplines, and 4) extend its political influence. The United States will also have to consider the opportunity that cooperation in U.S.-led projects gives for our partners to increase their competitive posture.

COMPETITIVE CONCERNS

How the United States invests in its space program will affect other segments of the economy. Investments made in technologies that could spur industrial development and increase America's international competitiveness would be most welcome in today's economy.[6] As noted earlier, during the 1990s and into the next century, the United States is unlikely to have any competitors in sending human crews to the Moon and Mars. However, we can expect other nations, including Canada, France, Germany, and Japan, to have a strong interest in developing the technologies required for robotics spacecraft and probes. Many of these technologies have a close relationship with increasing productivity in the manufacturing and service sectors.

Although the United States invented robots and still leads in many areas of research, in other countries robotics technologies have assumed a greater role in the economy. Canada, France, Germany, Italy, and Japan,[7] in particular, have targeted automation and robotics (A&R) technologies for development for industrial and governmental use. In some areas, such as manufacturing,[8] their efforts well exceed U.S. capabilities.

Several OTA workshop participants expressed concern that the U.S. space program has not invested adequately in A&R technologies. Canada, France, Germany, and Japan have implemented programs that direct investment on A&R space technologies toward the common goal of supporting their industrial base.

[5]U.S. Congress, Office of Technology Assessment, *U.S.-Soviet Cooperation in Space*, OTA-TM-STI-27 (Washington, DC: U.S. Government Printing Office, July 1985), ch. 4.

[6]U.S. balance of payments to the rest of the world make the United States the world's greatest debtor nation.

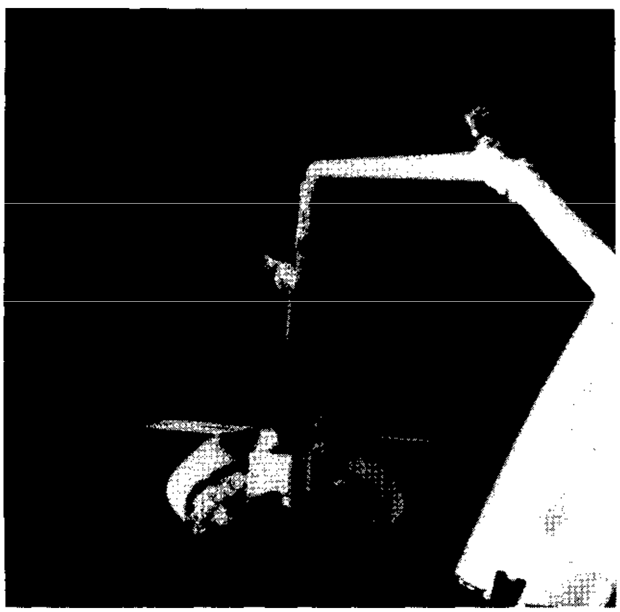
[7]Andrew Tanzer and Ruth Simon, "Why Japan Loves Robots and We Don't," Forbes, Apr. 16, 1990, pp. 148-153; William L. Wittaker and Takeo Kanade, *Space Robotics in Japan* (Baltimore, MD: Japanese Technology Evaluation Center, 1991).

[8]See, e.g., the series of articles on the impacts of robotics on manufacturing in the special issue of *Technological Forecasting and Social Change*, vol. 35, April 1989.

Canada

Canada has used its involvement in the space shuttle system, for which it provided the Canada Arm, and the space station, for which it is providing the Mobile Servicing System and Special Purpose Dextrous Manipulator, to build its capabilities in A&R. The Canadian A&R program has three integrated elements that are focused toward one common goal: the development and implementation of the robotic system for space station *Freedom.*[9] *They* are divided into three phases:

- *Near Term (baseline) –* Mobile Servicing Sy em and Spec a Pu po e Dext ou Ma n pu a o Canad an objec ve n ude he deve opmen and mp emen a on of a o bo c y em ha wi mee he ba e ne e quirements for the space station during assembly, maintenance, and operations.
- Mid *Term –* Advanced Technology Program. Canadian objectives include the enhancement of the basic robotic system with higher performance capabilities to support its future growth. Examples of such technologies include real time collision prevention and avoidance, and advanced vision. The additional capability should lead to reduced costs and increased crew productivity.
- *Far Term –* Strategic Technologies in Automation and Robotics. Canadian objectives include: 1) the development of strategically important A&R technologies for potential incorporation into the Canadian Mobile Servicing System over its lifetime by contracting out research to industry; and 2) the support of national economic development through encouraging commercialization of the developed technologies.



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Europe

Germany, Italy, and France have expressed considerable interest in developing robotics technology for use in space. For example, the German Aerospace Research Establishment (DLR) is building the Space Robot Technology Experiment, ROTEX, which will fly in the next German Spacelab mission (D-2) aboard the space shuttle, scheduled for 1992. ROTEX is a small, six-axis robot that will be used to verify an array of robotic tasks in space. It is designed to perform a variety of preprogrammed tasks, but also under control of astronauts and by remote control from Earth, using 3-dimensional stereo computer graphics and stereo television. ROTEX will:[10]

- verify joint control under microgravity;
- demonstrate and verify the use of ROTEX handcontrollers;

[9] NASA Advanced Technology Advisory Committee, "Advancing Automation and Robotics Technolgy for the Space Station Freedom and for the U.S. Economy," Technical Memorandum 103851 (Moffett Field, CA:Ames Research Center, National Aeronautics and Space Administration, May 1991), app. C.

[10] G. Hirzinger, J. Dietrich, and B. Brunner, "Multisensory Telerobotic Concepts for Space and Underwater Applications," *Proceedings of the Space and Sea Colloquium,* European Space Agency, Paris, France, Sept. 24-26, 1990, pp. 151-61.

- demonstrate and verify the use of human-machine interfaces that also allow for tele-operation from Earth; and
- verify the execution of a variety of tasks in space, e.g., making plug-in connections, assembly, and catching free-flying objects.

DLR is also working on lightweight robots and on a variety of A&R methods to increase productivity in space. It expects many of these methods to have Earthbound applications.

Robotics experts at the French space agency, Centre National D'Etudes Spatiales (CNES), are exploring the potential for an "automatic planetary rover," and have established partnerships with other French laboratories working on both terrestrial and undersea mobile robots.[11] The program is in its early stages and is focused on developing robotic devices for scientific exploration of Mars: sample analysis, establishment of geophysical profiles, and deployment of autonomous stations, for possible Mars deployment in A.D. 2000.

Japan[12]

Japan has especially targeted A&R for research & development investment, as it expects these technologies to provide increased productivity in a variety of areas. It also expects to reduce its operations costs for crew-carrying missions by employing A&R technologies, as well as create A&R devices for robotic missions. The National Space Development Agency (NASDA) funds the Space Robot Forum, a group that brings together members from government, industry, and academia to recommend directions for space robotics. It has urged the development and extensive use of so-called third-generation robotics systems that operate with little human intervention.[13]

Japan is developing a first-generation, 9.7-meter-long robot arm for use with its Japan Experimental Module (JEM) for the international space station Freedom. It will carry a smaller arm and gripper at the end to provide greater dexterity. The Forum has suggested developing a space station in the 21st century that would be operated by robots controlled from Earth.

Japan has also expressed interest in exploring the Moon and exploiting lunar resources. Individuals at the Japanese space agency, NASDA, have examined the potential for developing a lunar base, using lunar materials for construction.[14]

COOPERATIVE OPPORTUNITIES

As noted in an earlier OTA report, "U.S. cooperative space projects continue to serve important political goals of supporting global economic growth and open access to information, and increasing U.S. prestige by expanding the visibility of U.S. technological accomplishments. "[15] A return to the Moon and an exploration of Mars present a range of possible cooperative activities with other nations. Because the costs for intense planetary exploration are likely to be very high, international cooperative activities could reduce U.S. costs and increase the U.S. return on its investment for exploration. A well-conceived cooperative program could also establish the United States as a leader in exploration.[16] A broadly based cooperative exploration program

[11] Denis J.P. Moura, "Automatic Planetary Rover: The French Mars and Lunar Rover Preparatory Program," CNES briefing charts, March 1991.

[12] William L. Wittaker and Takeo Kanade, *Space Robotics in Japan* (Baltimore, MD: Japanese Technology Evaluation Center, 1991).

[13] First-generation robotic devices would work largely by teleoperation. Second-generation devices are those that do simple tasks on their own; third generation robotic devices would be nearly autonomous. William L Wittaker and Takeo Kanade, "Japan Robotics Aim for Unmanned Space Exploration," *IEEE Spectrum*, December 1990, p. 64.

[14] T. Iwata, "Technical Strategies for Lunar Manufacturing," IAA-88-588, Presented at the 39th Congress of the International Astronautical Federation Meeting, Bangalore, India, Oct. 8-15, 1988.

[15] U.S. Congress, Office of Technology Assessment, International *Cooperation and Competition in Civilian Space Activities*, op. *cit.*, footnote 3, p. 7.

[16] John M. Logsdon, "Leading Through (operation," *Issues in Science and Technology*, summer 1988, pp. 43-47.

with varied levels of participation, whether it was primarily robotic or employed human crews, would also enable the United States to encourage less developed countries to enhance their own science and technology base. However, cooperative projects must be carefully structured to keep costs within bounds. Otherwise, the numerous management interfaces and the differences in cultures may vastly increase total costs for a project.[17]

In the past, most of the National Aeronautics and Space Administration's (NASA) cooperative activities have been bilateral, in large part because bilateral cooperation is much simpler and therefore less costly to manage than multilateral cooperation.[18] They have also generally been bounded in time. Yet increasingly the size and duration of projects have led to the need for a more flexible position. While some projects are appropriate for a bilateral approach, others, because of their size, complexity, or duration, may require a multilateral approach.

Even if, for international legal purposes, the individual agreements are better arranged between pairs of nations, the day-to-day interactions are likely to be multilateral, rather than bilateral in scope. For example, although the agreements of the United States with Canada, the European Space Agency (ESA), and Japan concerning Freedom are bilateral agreements, in designing, building, and operating the space station, representatives of the four parties must meet and coordinate with each other primarily as a group in order to carry out their business most efficiently. Hubble Space Telescope also requires continuing management interaction among the nations involved.[19]

The need for a broader level of cooperation has led to several suggestions for an umbrella organization or mechanism to coordinate and manage large, international space projects.[20] Such suggestions have always had to face the concern that the ensuing bureaucratic arrangements could become extremely complicated and that individual nations could begin to lose control over their own projects. They could also lead to high overall program costs related to need to involve more organizations, each with its own agenda and scientific goals, in the process. The multilateral Inter-Agency' Consultative Group (IACG) has been suggested as a possible model for future cooperative ventures because it was able to circumvent these drawbacks.[21]

Prior to the passage of Comet Halley through the inner solar system in 1986, the ESA, Japan, the Soviet Union, and the United States formed the IACG to coordinate their efforts to observe Comet Halley from space (box 8-A). The IACG organization was deliberately kept informal and simple in order to minimize bureaucratic impediments and to focus on scientific tasks. It operated on the understanding that the IACG would serve only in an advisory capacity to the member agencies. In addition, there would be no exchange of funds and minimal technology transfer.[22]

The IACG provides an attractive model because it is relatively simple, and because it scored a major success in the Halley encounter. Each cooperating entity brought a particular strength to the joint project in the form of a spacecraft or

[17] The fate of the Mars Observer Visual and Infrared Mapping Spectrometer is particularly instructive. Removed from the Mars Observer payload in order to save money, it was later resurrected to fly on the Soviet Mars '94 mission as a joint U.S./Soviet/French/Italian effort. It became overly complicated and the U.S. financial share of the project eventually grew greater than the original instrument would have cost on Mars Observer. The United States eventually had to cancel its involvement, deeply disappointing U.S. scientists and international partners alike. Steven Squyres, Cornell University, 1991.

[18] "NASA prefers bilateral relations over projects that might involve three or more countries or organizations." U.S. Congress, Office of Technology Assessment, *UNISPACE '82: A Context for International Cooperation and Competition, OTA-TM-KC-26* (Washington, DC: U.S. Government Printing Office, March 1983), p. 68.

[19] Joan Johnson-Freese, *Changing Patterns of International Cooperation in Space* (Malabar, FL: Orbit Book Co., 1990), ch. 9.

[20] Ibid.

[21] Kenneth S. Pedersen, "The Global Context: Changes and Challenges," *Economics and Technology in U.S. Space Policy*, Molly Macauley (cd.) (Washington, DC: Resources for the Future, 1986), pp. 173-198.

[22] Joan Johnson-Freese, *Changing Patterns of International Cooperation in Space* (Malabar, FL: Orbit Book Co., 1990), ch. 15.

Box *8-A–The Inter-Agency Consultative Group (IACG)*

Delegates from the European Space Agency (ESA), Japan, the Soviet Union, and the United States met in Padua, Italy, in 1981 to discuss ways of coordinating their efforts to observe Comet Halley from space. E.A. Trendelenburg, director of scientific programs for ESA and Roald Sagdeev, director of the Space Research Institute of the Soviet Union had earlier urged that those nations with Comet Halley projects could maximize their scientific return by working directly together rather than through a broad-based organization, such as the International Committee on Space Research (COSPAR). Other officials agreed and formed the IACG to coordinate their efforts to observe Comet Halley from space.

The IACG's initial meeting resulted in three working groups that met as often as necessary to generate recommendations related to the flight projects and to allocate specific tasks before, during, or following the Halley encounter. Although the United States sent no probe to the comet, in cooperation with the International Halley Watch, it provided critical positional data on the Comet and the space probes. In order to give the European Giotto space probe the best possible chance to image the nucleus of Halley, accurate observations of both the comet and the probe were necessary. The United States used the Deep Space Network to track the two Soviet Venera probes as they passed by Halley on March 6 and 9, 1986, on their way to Venus.[1] The resulting observations enabled scientists to reduce considerably the positional uncertainty of the comet's path, and made it possible to guide ESA's Giotto accurately into the outer part of Comet Halley. Representatives from all organizations involved met regularly to coordinate their activities, yet the United States at that point had no formal cooperative agreement with the Soviet Union.*

[1]This was called the Pathfinder concept.

[2]Indeed, Roald Sagdeev, former director of the Soviet Institute of Space Sciences, once quipped that "during the Halley observations, the United States acted as subcontractor to the European Space Agency" in supplying data about Venera's position.

SOURCE: Joan Johnson-Freese, ***Changing Patterns of International Cooperation in Space*** (Malabar, FL: Orbit Book Co., 1990), ch. 15.

equivalent capability; the result from the whole was much greater than the sum of its individual parts. The IACG, which began as an experiment, is continuing and will focus on cooperating in space science. One of the reasons it worked well is that cooperative ventures with few interfaces are much easier to arrange and manage.

The United States might wish to cooperate on a wide variety of projects related to the exploration of the Moon and Mars.[23] The extent to which the IACG or an organization modeled after it would be successful for such purpose, would depend in part on whether it could maintain simplified management interfaces. Of greater importance is the question of who the potential partners might be.

At the present time, the only countries to demonstrate a strong interest in sending human crews to Mars are the United States and the Soviet Union. No other country has the launch vehicles or other infrastructure necessary to land crews on the Moon. In large part, they have not invested in the means to launch and support human crews because other countries have different economic and political goals. However, Japan has an active program to study the Moon with robotic instruments,[24] and European scientists within ESA have studied the scientific opportunities for exploring Mars[25] and the Moon.[26] The Soviet Union is planning a robotic exploratory mission to Mars in 1994 and considering a later sample return mission to Mars. The Soviet missions are

[23]Bruce C. Murray, "Can Space Exploration Survive the End of the Cold War?" The ***Planetary Report***, May/June 1991.

[24]Shigebumi Saito, "Japan's Space Policy," ***Space Policy,*** August 1989, pp. 193-200.

[25]European Space Agency, ***Mission to Mars: Report of the Mars Exploration Study Team*** (Paris, France: European Space Agency, January 1990).

[26]The European Space Agency report is now in progress.

aimed in part at preparing the way to send humans to Mars sometime in the next century. The Soviet Union has for years contemplated launching a lunar orbiter[27] and has studied the potential for returning a lunar sample from the farside of the Moon, but has no mission under planning. Hence, based on demonstrated interest, the strongest opportunities for the United States to initiate cooperative projects for at least the next decade would be on robotic ones. All three major entities–ESA, Japan, and the Soviet Union might be interested in participating.

During the early part of the next century, cooperation with the Soviet Union on sending human crews to and from Mars might also be attractive,[28] if the Soviet Union can survive its current economic and political crises,[29] and the United States can resolve its own economic difficulties. Given the high costs of supporting human crews in space and Japan's and ESA's experience with space station ***Freedom,*** Japan and the European countries might be highly resistive to such cooperation for many years.[30]

The following examples illustrate the range of potential projects that might be possible:

- ***Life sciences research —*** Cooperating on life sciences work with the Soviets could be highly fruitful for both parties. Soviet scientists have collected considerable data on the reactions of humans to the space environment.[31] However, in the past they were reluctant to share life sciences data, in part, because the data were considered militarily sensitive. Soviet scientists are now able to share more of their data on weightlessness and other life sciences issues. NASA is now cooperating with the Soviet Union in a variety of life sciences areas, including standardization of measurements, use of U.S. equipment on board ***Mir,*** and exchange of biological specimens.[32] The two countries could extend their opportunities to collect high-quality long- and short-term reactions to the space environment by agreeing to fly astronauts and cosmonauts on each others' space vehicles.
- ***Astronomy from the Moon —*** Making astronomical observations from the Moon might be an especially fruitful area in which to cooperate, at a variety of levels. The major space-faring nations also have strong programs in astronomy and would likely have an interest in cooperating on designing and placing observatories of various sizes on the Moon. In order to keep initial efforts as simple as possible, it might be possible for each participating entity to design and build its own telescope, each with different capabilities. Such a program could even involve countries that lack an independent means to reach the Moon. For example, it could involve countries of Eastern Europe that have the scientific expertise to do serious astronomical research but lack the rockets and money to launch their telescopes.
- ***Small rovers on the Moon or Mars —*** Several small rovers could be sent on a single launch. In a cooperative program, each cooperating entity could build its own small rover, perhaps specialized to gather specific data. Here again, each country could con-

[27] Nicholas L. Johnson, The *Soviet Year* in *Space 1990* (Colorado Springs, CO: Teledyne Brown Engineering, February 1991), pp. 123-124.

[28] "Senior Soviet Space Officials Outline Plan for Joint Mars Mission," *Aviation Week and Space Technology,* Nov. 19, 1990, p. 67; Burton I. Edelson and John L McLucas, "U.S. and Soviet Planetary Exploration: The Next Step is Mars, Together," *Space Policy,* November 1988, pp. 337-349.

[29] "Aggressive Soviet Space Program Threatened by Budget, Policy Changes," *Aviation Week and Space Technology, Mar.* 18, 1991, pp. 153-154.

[30] The many delays and restructuring of space station *Freedom have angered our* Partners.

[31] A.D. Egorov, A.I. Grigoriev, and V.V. Bogomolov, "Medical Support on Mir," *Space, vol. 7, No. 2,* April/May 1991, pp. 27-29.

[32] A 1987 agreement established a Joint Working Group in Space Biology and Medicine, which shares data acquired on Mir and the Space Shuttle.

tribute according to its own capabilities. If one small rover failed, its failure would not interfere with the ability of the others to succeed.

- ***Use of Soviet Energia* —** As Western experience with the Soviet space program grows and confidence improves, the United States could envision closer cooperation with the Soviet Union. For example, the Soviet Union possesses the world's only heavy-lift launch vehicle, capable of lifting about 250,000 pounds to low-Earth orbit. It has offered to make ***Energia*** available to the United States for launching large payloads. In the near term, the Soviet offer could assist in developing U.S. plans to launch large, heavy payloads, e.g., fuel or other noncritical components of a Moon or Mars expedition. If these cooperative ventures succeeded, they could be extended to include the use of Energia to launch other payloads, perhaps even a joint mission to the Moon or Mars.

- ***Cooperative network projects* —** Europe and the United States are both exploring the use of instrumental networks on Mars to conduct scientific exploration. Each cooperating entity could contribute science payloads, landers, or orbiting satellites to gather data for a joint network project.

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