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# U.S.-European Cooperation in Space Science: A 25-Year Perspective

John M. Logsdon

*Summary.* In the past 25 years, the National Aeronautics and Space Administration has engaged in a range of cooperative activities in space with other countries and international organizations, most of the scientific interactions being with Europe. The character of U.S.-European cooperation in space science is changing as a result of the increased maturity and level of space capability which Europe is bringing to the partnership; the consequent addition of a competitive dimension to the relationship; the increasing cost of space science missions; and the relative scarcity of funds available for space science. A number of issues flow from the current situation, but in general the outlook is for continued productive cooperation between the United States and Europe in space science.

In the 25 years that the United States has had a government space program, international cooperation has been one of its major themes. An objective of the National Aeronautics and Space Act of 1958, which was the charter for the civilian space program and which established the National Aeronautics and Space Administration (NASA), was "cooperation by the United States with other nations and groups of nations in work done pursuant to the Act and in the peaceful applications thereof" (*1*). Armed with this legislative mandate, with presidential and congressional support for a U.S. civilian space program which emphasized openness and scientific objectives, and with already existing patterns of cooperation in space science, NASA has since its inception conducted an active program of international partnership.

In space perhaps more than in most areas of international science, it has been the policies and initiatives of a government agency and its top officials, rather than those of the scientific and technical community, which have established the U.S. attitude toward cooperative undertakings. Although NASA's international programs have involved the Soviet Union, Canada, Japan, and various developing countries, its primary cooperative partner has been Europe—both individual European countries and the various European space organizations which have existed over the past two decades. Table 1 suggests the dominance of U.S.-European interactions in the overall record of NASA's most important cooperative programs.

The U.S.-European partnership in space science has been, on the whole, remarkably successful, in terms of cooperation both between the United States and individual European countries and between the United States and Europe's multilateral space science agencies: the European Space Research Organization (ESRO) and its successor the European Space Agency (ESA). Projects such as Ariel (United States–United Kingdom), Helios (United States–Federal Republic of Germany), Infrared Astronomical Satellite (United States–United Kingdom–Netherlands), International Ultraviolet Explorer (United States–United Kingdom–ESA), and International Sun–Earth Explorer (United States–ESA) are just a few of the major scientific undertakings which have benefited from U.S.-European collaboration. This record of success must be kept in mind in evaluating any past and current stresses in the cooperative relationship.

As the U.S. space program enters its second quarter-century, there are significant changes in U.S.-European cooperation; the major reasons for these changes include: the increased maturity and level of space capability which Europe is bringing to the partnership; the consequent addition of a competitive dimension, both in scientific and economic terms, to the relationship; the increasing cost of space science missions; and the relative scarcity of financial resources available on both sides of the Atlantic for space science.

Last fall saw the first flight of Spacelab, an orbital facility for manned scientific experimentation which was developed by Europe at a cost of approximately $1 billion; Spacelab is designed only for use with the U.S. space shuttle and reflects the intimate character of continuing U.S.-European collaboration. At the same time, Europe has developed its own launch capability in the Ariane series of expendable boosters and is using the autonomous capability not only to launch its own spacecraft but also to compete with the space shuttle for other launch contracts. European countries are also developing satellites for Earth observation and communications and exploring the potential of space manufacturing, with the objective of competing with the United States for economic payoffs from space.

Further scientific cooperation in space between the United States and Europe will occur in this mixed context of collaboration and competition. The state of that cooperation is vigorous, as both the United States and Europe continue the fascinating adventure of exploring the nature of the solar system and the cosmos which is made possible by space technology.

John M. Logsdon is director of the Graduate Program in Science, Technology, and Public Policy, George Washington University, Washington, D.C. 20052.

### Origins of U.S. Cooperative Programs

As the late Homer Newell, one of the U.S. pioneers in space science and an early and strong advocate of international cooperation in space, has noted, "with roots in the International Geophysical Year, which had already generated a lively interest in the potential of satellites for scientific research, one might argue that the appearance of an international component in the NASA space science program was inevitable" (*2*). The International Geophysical Year, organized under the sponsorship of the International Council of Scientific Unions (ICSU), was an 18-month (July 1957 to December 1958) effort involving 66 countries, some 60,000 scientists, and the expenditure of hundreds of millions of dollars; both the Soviet Union and the United States agreed in 1955 to launch scientific satellites as part of IGY activities.

There was in place at the very start of the space age, therefore, a nascent international community of scientists who saw space technology as providing exciting opportunities for extending and expanding their investigations. This community was quick to press NASA to keep its program open to international involvement. The pressure was congenial, since one reason the United States had decided to house its major space activities in a separate, civilian government agency was to present to the world an image of peaceful intent and open style; this was in deliberate contrast to Soviet space activities, which were controlled by the military services and conducted with great secrecy. There were those in 1958 who argued that the U.S. space program should be under military control and not opened to international cooperation because "the tools of space research—rockets, radio, radar, guidance, stabilization—were all common to both the military and to science. Even the scientific objectives . . . were of interest and possible value to the military" (*3*, p. 5). Added to this "dual use" character of space technology and some areas of space science was the role of space achievement as an area for superpower political competition, particularly after the United States launched the Apollo program in 1961. Thus scientific activity involving the use of space systems took place in a highly charged political and military environment. By carefully defining the conditions under which cooperative activities would be initiated and carried out, NASA was able to conduct an international program which has been relatively free from distortion for political purposes and from limitations because of military sensitivities. Even so, with respect to space cooperation "a clear duality dogs both the history and the prospects of international partnerships" (*3*, p. 6).

### NASA Guidelines and Objectives for International Cooperation

When NASA announced to ICSU's Committee on Space Research (COSPAR) in March 1959 that it would assist COSPAR members in launching scientific experiments and satellites, the agency had already under development a set of policy guidelines for such cooperation. Those guidelines have survived periodic reexamination and remain in force today. They reflect "conservative values" (*3*, p. 32) with respect to the conditions under which cooperation is desirable; shaping those values were both the recognition of the political significance of space activities and the strong personalities of individuals such as Newell and Arnold Frutkin, who directed NASA's international program from the agency's earliest months until the mid-1970's.

The essential features of NASA guidelines are (*4*, p. 18):

- Cooperation is on a project-by-project basis, not on a program or other open-ended arrangement.
- Each project must be of mutual interest and have clear scientific value.
- Technical agreement is necessary before political commitment.
- Each side bears full financial responsibility for its share of the project.
- Each side must have the technical and managerial capabilities to carry out its share of the project; NASA does not provide substantial technical assistance to its partners, and little or no U.S. technology is transferred.
- Scientific results are made publically available.

A key feature of NASA's cooperative efforts is that "while NASA has international programs, it does not fund *an* international program." Rather, "funding for international projects must come out of the NASA program offices," and "for an international approach to a project to be undertaken it must not only contribute to achieving the goals of the interested program office, but it must be considered to be among the best approaches to achieving these goals (*5*, p. 68). This emphasis on technical soundness and scientific merit has been a consistent feature of the U.S.-European cooperation over the past 25 years, whatever other objectives are sought through such cooperation. As one perceptive analysis notes, "although NASA recognizes possible political benefits from achieving utilitarian goals, NASA's cooperative programs are justified almost entirely on technical and scientific grounds, both within and outside" the agency (*4*, p. 49). The objectives of NASA's international programs can be grouped as shown in Table 2.

While the priority given to these various objectives has varied with time and mission opportunity, at the core has been a policy that permitted this country's closest allies to become involved in the U.S. space effort. Indeed, some have criticized NASA for making possible such participation, at minimal cost, in an effort paid for almost entirely by U.S. taxpayers: "benefit, know how and opportunity were shared to an extent that was entirely unprecedented where an advanced technology was involved, particularly one with such strong national security implications" (*6*, p. 74).

### Evolution of U.S.-European Cooperation in Space Science

During the "golden age" of the U.S. space program, from the beginning of the Apollo buildup in 1961 through its peak in the 1965–1966 period, NASA's international activities grew rapidly along with the rest of the agency's efforts. Before the first Apollo 11 moon landing in July 1969, nine European spacecraft had been launched by the United States, and substantial momentum had built behind European involvement with the United States in space experimentation. This momentum has carried through to the current day, but, as one top-level participant has commented, "when resources abound and opportunities are plentiful, a cooperative attitude abounds. . . . When the resources and opportunities shrink, . . . altruism takes a back seat and . . . scientists take a more selfish view of cooperation" (*7*, p. 38).

Several factors have influenced the evolution of U.S.-European space cooperation in the period since 1970. In no particular order of importance, they are:

- Shrinkage in the NASA budget overall in the post-Apollo era. The space science budget came under particular pressure as the share of overall resources going to shuttle development increased. This meant fewer science missions and more competition among U.S. scientists to get their experiments on the missions which were approved.
- A broadening of NASA's interna-

tional program to encourage European participation, not only in science missions, but also in developing large space systems including manned space flight elements.

- Evolution of the 11-member European Space Agency, founded in 1975, into an effective entity. ESA has carried out a successful science program of its own and has managed several space applications projects and two major hardware development programs, Spacelab and Ariane. The national space programs of France, Germany, Italy, the Netherlands, and the United Kingdom, with differing emphasis, are also vigorous.
- More recently, growing concern in the United States that cooperative undertakings in space, including space science, could serve as vehicles for unwanted transfer of militarily or economically sensitive U.S. technology to other countries.

While Europe has continued to cooperate with the United States, it has also become a formidable competitor in various categories of space applications and in some fields of space science. Europe is now a very capable actor in space, and it could become more difficult for the United States to develop cooperative projects on its preferred terms. While the United States remains the partner of choice for ESA and individual European countries, existing and potential cooperation with the Soviet Union and Japan provides an alternative. There is now the possibility of a global division of labor and cost in space science, and this makes the task of planning and getting agreement for major space science projects both challenging and full of opportunities.

There has been an undercurrent of ambivalence among U.S. space scientists and NASA managers about European involvement in NASA missions, whatever the stated policy. For one thing, "always the U.S. side was slightly constrained by fear that foreign collaborators . . . might not fulfill their commitments." This concern had diminished over time; "in the few cases where serious delays occurred, as in the Solar Polar project, it was more often the United States that was responsible. . . . Had NASA personnel not been susceptible to the then universal belief that other nations necessarily lagged behind the United States in technological capability, the policy of collaboration in space matters could almost certainly have been more rewarding" (*6*, p. 71). For another, when foreign experiments have been selected by NASA, some U.S. scientists have raised the question of whether the foreign experiment was selected over a competing U.S. experiment on the basis of merit or whether it was selected because it would be provided to NASA free of charge (*7*, pp. 38–39). Another reservation with respect to foreign participation has been that "by selecting a high-technology experiment, the United States encourages development of the industrial base in the foreign country which will contribute to a decreased United States competitive position in world trade" (*7*, p. 39). Yet another concern is that management of a U.S. space science project is greatly complicated by the need to integrate the experiments or other contributions from a foreign partner.

Table 1. Patterns of international cooperation, 1958 to 1983, including past and currently approved cooperative projects (*17*).

| Participant | Cooperative spacecraft projects | Experiments with foreign principal investigators |
|---|---|---|
| Total | 38 | 73 |
| Total, Europe | 33 | 52 |
| European Space Agency | 8 | 1 |
| France | 2 | 17 |
| Federal Republic of Germany | 7 | 11 |
| United Kingdom | 7 | 18 |
| Italy | 6 | 1 |
| Netherlands | 2 | 3 |
| Spain | 1 | |
| Belgium | | 1 |

While growing European capability has muted concern about the first of these factors, it has also created healthy competition among all space scientists for access to orbit and beyond for their experiments. European scientists have always been able to propose experiments on U.S. missions, but U.S. scientists are only now gaining a reciprocal opportunity to serve as principal investigators for experiments on ESA missions.

A major attempt to engage Europe with NASA's technology development efforts took place in the 1969–1973 period, as NASA itself sought to gain presidential and congressional approval of an ambitious post-Apollo program of manned space flight. The negotiations on European participation in the program were much more political in character than prior (and subsequent) negotiations on cooperative undertakings in space science. This post-Apollo experience, perhaps justifiably, has left a lingering "bad taste" in Europe. NASA's objective was "to stimulate Europeans to rethink their present limited space objectives, to help them avoid wasting resources on obsolescent developments [a reference to European plans to develop an independent launch capability], and eventually to establish more consider-

Table 2. Objectives of NASA's international programs.

*Scientific/technical*

"Increasing brainpower working on significant problems and expanding scientific horizons by making space an attractive field for research" (*4*, p. 17).

Shaping the development of foreign space programs to be compatible with the U.S. effort "by offering attractive opportunities to 'do it our way' " (*4*, p. 50).

Through such influence, limiting funds available in other countries for space activities which are competitive or less compatible with U.S. interests.

Obtaining unique or superior experiments from non-U.S. investigators.

Obtaining coordinated or simultaneous observations from multiple investigators.

Increasingly, making available opportunities for U.S. scientists to participate in space science missions of other countries or regions.

*Economic*

"By sharing leadership for exploring the heavens with other qualified space-faring nations, NASA stretches its own resources and is free to pursue projects which, in the absence of such sharing and cooperation, might not be initiated" (*18*); NASA estimates getting over $2 billion in cost savings and contributions from its cooperative programs over the past 25 years (*5*, p. 69).

"Improving the balance of trade through creating new markets for U.S. aerospace products" (*4*, p. 17).

*Political*

Creating a positive image of the United States; "the U.S. program of cooperation in space reaches a scientific, technical, and official elite in the struggle for minds" (*3*, p. 73).

Encouraging European unity; the U.S. space program "lends itself admirably to cooperation with multilateral institutions in Europe" (*3*, p. 78).

Reinforcing the image of U.S. openness in contrast to the secrecy of the Soviet space program; "when NASA was organized . . . the keystone of Government space policy was to give dramatic substance to the claim of openness—and, at the same time, to seek credibility for the nation's assertion that it entered space for peaceful, scientific purposes. This was done . . . most importantly, by inviting foreign scientists to participate extensively and substantively in space projects themselves" (*6*, p. 70).

Using space technology as a tool of diplomacy to serve broader foreign policy objectives.

able prospects for future international collaboration on major space projects'' (*8*).

A basic problem in this case was that NASA could not deliver what it was promoting in Europe. NASA's post-Apollo ambitions included a space station and a fully reusable space shuttle, and the agency continued to solicit European involvement in these programs even when their approval by the President was very uncertain. Indeed, within the United States NASA tried to use the prospect of cost-sharing with Europe as a selling point for approval of these programs. When only the space shuttle remained as a potential program, NASA encouraged Europe to consider developing both components of the shuttle orbiter and a separate major project, a reusable orbital transfer vehicle called a space tug. However, NASA was forced to withdraw these offers at the last minute when the Air Force, whose support was needed for shuttle approval, objected to European development of essential elements of the Space Transportation System; when concerns regarding excessive transfer of propulsion technology were raised; and when some in NASA became concerned about the safety implications of placing a cryogenically fueled tug in the shuttle payload bay. Finally, NASA offered Europe the comparatively simple and less expensive task of developing a ''research and applications module'' to fit into the shuttle payload bay; this is what became the Spacelab project.

By this time, Europeans were rather skeptical about NASA overtures, but they (particularly Germany) had also become so eager to embark on manned flight activities that they agreed to develop the Spacelab system under what in hindsight have been seen as unfavorable terms; the first set of flight hardware, developed with European funds, was to be transferred to NASA, and after an initial joint NASA-ESA mission which included flying a European payload specialist, Europe was to pay for future shuttle-Spacelab flights. NASA agreed to buy a second set of flight hardware from Europe, but ''a significant segment of the European space community believes that the United States is getting the lion's share of the benefits from Spacelab'' (*9*).

European space officials have described themselves as ''stupid'' in accepting the U.S. terms for involvement in its post-Apollo program and believe that such acceptance stemmed from lack of confidence in European capabilities and from a belief that only through cooperation with the United States could those capabilities be improved. Now, having brought both Spacelab and Ariane to success, Europe has much more confidence in its ability to chart its own future in space and it will be a more demanding participant in negotiations with the United States over cooperative ventures (*10*).

European confidence in the United States as a cooperative partner was shaken in the spring of 1981 when the United States announced, without prior consultation with its European partners, that it was canceling a U.S. spacecraft which was part of a two-spacecraft International Solar Polar Mission (ISPM). This withdrawal caused vigorous protests not only from European space officials but also from representatives of foreign ministries (*11*). In this case, ''NASA's success in international participation became a political liability'' (*5*, p. 69); NASA was forced to reduce funding in a major space science mission, and all three existing large missions—the Space Telescope, the Galileo mission to Jupiter, and the Solar Polar mission—had major European involvement.

There is general agreement that the ISPM affair was handled clumsily, and both the United States and Europe have moved beyond it, although European officials are not beyond using U.S. guilt over the incident as a bargaining chip in U.S.-European negotiations on future collaboration.

In summary, U.S.-European cooperation in space has become a much more complex enterprise in the last 10 years as both U.S. and European space efforts matured. While the balance sheet in that enterprise remains strongly on the positive side for all participants, competition and conflict have joined collaboration as hallmarks.

## Current Issues in U.S.-European Cooperation

The major U.S. science missions now approaching launch, the Space Telescope and the Galileo spacecraft to Jupiter, have major participation by Europeans, and it is anticipated that there will be continuing cooperation as the United States and Europe begin new missions. The following are some of the issues which will influence the development of that cooperation.

*Closer coordination and collaboration in planning and conducting space science efforts*. The task of maximizing the scientific payoff from the resources available in the United States and Europe (and other countries) for space research is perhaps the key continuing issue in this area. The United States, ESA, and various European countries are all fully capable of undertaking major space science missions on their own, but with limited funds available on both sides of the Atlantic, there is a need to develop a coordinated approach to space science which recognizes the benefits of cooperation and the realities of competition. To date, attempts to do this have primarily involved negotiations from government agency to government agency. There are regularly scheduled meetings between the heads of NASA and ESA and between the space science directors of the two agencies.

The most recent NASA-ESA space science planning meeting took place in June 1983, and the issues addressed exemplify the problems and potential of a coordinated approach to future space science undertakings (*12*). Three areas of cooperation were discussed: (i) infrared astronomy, (ii) solar terrestrial research, and (iii) planetary exploration. In the first of these areas, in essence the United States and ESA ''agreed to disagree.'' The issue under discussion was the next step beyond the highly successful U.S.-Dutch-British Infrared Astronomical Satellite (IRAS) launched in early 1983. Both the United States and ESA have developed future mission concepts, and the two approaches are not compatible. The meeting noted both ''NASA's strong interest in collaborating to develop a single major international infrared space telescope facility'' (presumably based on the U.S. mission concept) and ''the firm commitment of ESA'' to its mission. Recognizing that ''the difference in orbit and launch vehicle restrict any major hardware collaboration,'' NASA and ESA agreed to coordinate the planning for the separate missions to maximize their complementarity and overall scientific return, but also for the time being abandoned hope of a joint mission.

By contrast, an examination of the large number of missions under study in the United States, Europe, and Japan in the area of solar terrestrial physics identified ''considerable merit in considering a joint . . . mission''; NASA and ESA established a working group, which will also include Japan, to ''look for joint missions which can satisfy the main scientific requirements in a cost-effective way.'' Similarly, NASA and ESA agreed in the planetary exploration area ''to identify mutually beneficial opportunities for cooperative missions.'' In particular, the two agencies are to study a joint

Saturn-Titan probe mission for a 1992 launch. Planetary exploration is one of the areas of international scientific cooperation agreed on at the Versailles-Williamsburg series of summit meetings and is also the focus of attention of a working group of the National Academy of Sciences and the European Science Foundation. A cooperative Saturn-Titan mission, if feasible, would thus be politically as well as technically significant.

Another example of the benefits of a coordinated approach to mission planning in a particular area of science is found in the U.S.-German interaction in x-ray astronomy. A large community of investigators has developed to use the data produced by NASA's High Energy Astronomical Observatory. However, there would be a data gap of a number of years before the next mission in x-ray astronomy were it not for the existence of a German project called *Roentgensatellit* (ROSAT). The United States and Germany in 1982 signed a Memorandum of Understanding for close collaboration in this mission, thus ensuring continuity in the field for U.S. as well as European scientists (*13*).

There is a growing need for the United States, Europe, Japan, Canada, and perhaps eventually the Soviet Union and other space-capable states to work together in space science, from the early stages of developing a mission concept to the joint funding and conduct of various missions. Because of its dominant position in space activities in the free world, the United States in the past has been largely able to shape such collaboration to its own objectives. This situation no longer obtains, and there could be a difficult period of adjustment for this country as the new reality of partnership among relative equals becomes the standard pattern. It may prove advantageous for NASA to engage the U.S. scientific community more intimately in developing its international programs; this could minimize international misunderstandings and perhaps blunt nonproductive and expensive competition. In space science, as in many other areas, the United States is adjusting to the recognition that it cannot be first in everything.

*Involvement of non-NASA scientists in shaping international cooperation.* "At present, ideas for joint international endeavors are primarily developed at formal meetings between representatives of the various governments. . . . There is a need for a more effective forum which would enable space scientists and managers to exchange ideas informally (*14*). While NASA plans its science programs in close consultation with the external science community, including the Space Science Board (SSB) of the National Academy of Sciences, there is little tradition of SSB involvement in international space science matters. The National Academy is the U.S. member in COSPAR, but that forum has little apparent influence on national space programs. Of course, informal interaction among space scientists in various countries interested in similar scientific problems is a major source of project proposals in both the United States and Europe.

The nearest European equivalent to the SSB is the Space Science Committee (SSC) of the European Science Foundation. This committee has a small budget and has not developed close ties with the European Space Agency. Nevertheless, the SSB and SSC held joint workshops in 1976, 1978, and 1983, and some consideration is being given to establishing standing SSB-SSC working groups in selected areas of space science.

In a separate development, at the initiative of the heads of the European Science Foundation and the National Academy of Sciences, a joint SSB-SSC working group on planetary exploration has been established. The U.S. side of this group is composed mainly of individual scientists who are closely related to NASA's Solar System Exploration Committee.

All these developments may represent initial steps in opening up the process of planning U.S.-European cooperation in space science to more structured participation of nongovernment scientists. As scientific competition among those working in space becomes increasingly international, such involvement may be required to reach agreement on how to coordinate or cooperate in research on major scientific problems.

*Access for U.S. experimenters to European science missions.* If Europe is to approach parity in influencing the direction of progress in various areas of space science, there must also be a mutuality of opportunity for U.S. and European scientists to participate in the resulting activities. NASA has from the start opened its "Announcements of Opportunity" to all free-world scientists, but ESA and individual European countries have limited access to their scientific missions to European scientists, at least as principal investigators. This policy may have been defensible as a means of developing a European space science community, but NASA is now demanding reciprocity of access. Germany has already indicated its willingness to comply. For the ESA mission to Halley's comet, *Giotto*, nine of the ten experiments have U.S. coinvestigators (a total of 33 individuals); ESA has agreed in principle to open up its future missions to U.S. principal investigators, and a NASA-ESA committee is now studying how best to implement that agreement.

*Increasing militarization of space activities.* Space technology had its origin in military missile and satellite programs, and there has been continuing attention to ensuring that the international programs of NASA do not provide access to militarily sensitive technology. Now the major U.S. launch system is the space shuttle, which is a national capability used for NASA, Department of Defense, and non-U.S. missions. In this context, "classified operations will be a necessity and are bound to lead to a more restrictive atmosphere, less conducive to international cooperation; tending to lead in the same direction . . . are developments in detector technology and in active atmospheric-magnetospheric experimentation" (*7*, p. 40). It is well beyond the scope of this article to discuss the increasing military interest in various uses of space technology, but if the Department of Defense budget for space, which is already larger than NASA's, continues to grow, there is likely to be an impact on international space science. One possibility is increased international cooperation on defense applications of space among the United States and its North Atlantic Treaty Organization allies. Other areas of scientific collaboration have been able to coexist with military interest in the same scientific area and its underpinning technologies, and this duality has been present in space from the beginning; nevertheless, the changing context of space activity must be of concern to those interested in promoting open international cooperation in space science. In particular, several members of ESA are neutral states which could object to being involved in cooperative activites with the United States which had any hint of military overtones.

*Impact of space shuttle on scientific cooperation.* The space shuttle is an extremely capable launch system and short-term orbital platform. It offers scientists an environment much different from any previously available in which to design and operate their experiments; there is even the chance to accompany them into orbit. Europe has recognized the shuttle's potential and is designing systems for its own and cooperative space activities which can only be used with the shuttle. These include Spacelab and an ESA-developed unmanned free-flying platform called *Eureca*, scheduled

for a 1987 launch. As the shuttle, Spacelab, and other systems become more familiar to scientists, there will emerge innovative ways to take advantage of these new capabilities.

However, U.S. and European scientists will also share a common problem as they plan their missions for the Space Transportation System; because it is a manned system, the requirements for qualifying payloads to go aboard it and for supporting those payloads with documentation are both demanding and expensive, especially in comparison to similar requirements for unmanned launches. When European scientists began to plan for the use of Spacelab, for example, they "were really shocked by the requirements for testing and documentation and the associated cost of those requirements" (*9*). Europe is continuing to find it difficult to afford to use elements of the Spacelab system for its experiments; the result is that "continuous use of Spacelab by those who built and financed it is not likely" (*15*). Whether the shuttle will prove to be a crucial asset for those planning future science missions or a source of costs which limit the number of missions that are affordable is yet to be determined, but the impact of the shuttle is of crucial importance to U.S. and European space scientists alike.

*Possible U.S.-European collaboration on space station.* The U.S.-European interaction over a European role in NASA's major post-Apollo programs has colored the whole of transatlantic cooperation in space over the past decade. Similarly, outcome of the just-beginning interactions over European participation in NASA's proposed space station program may affect the overall prospects for European-U.S. collaboration over the next decade or more. This impact could have several dimensions. (First, of course, NASA must get approval to begin such a program.) Europe has been following NASA's planning for the space station quite closely and has carried out parallel studies of options for European participation; in essence, NASA and ESA are already traveling together down a path that could lead to a major European role in an evolving station effort. This early and close involvement is quite different from what occurred in the post-Apollo period and signifies how close the U.S. and European outlooks on space have become.

If, after this start, something intervened to make large-scale collaboration on station development impossible, there would certainly be a ripple effect on other areas of cooperation. On the other hand, a joint decision to move ahead with significant collaboration on the space station would cement the increasingly intimate relationship between the planning and conduct of U.S. and European space activities. While there would still be economic competition and rivalry over scientific achievement, they would occur within a broader cooperative framework.

One rationale for developing a space station and associated infrastructure is to create a research facility in Earth orbit. Just as the existence of the space shuttle and Spacelab will define the conditions for most space science missions in the coming decade, so would the availability of permanent orbital facilities condition the conduct of space science in the 1990's. Thus, it is important to the space science community that any space station which is developed be a congenial base for its experiments, and pressure from U.S. and European space scientists will be important in ensuring that that is the case.

## Conclusion

Kenneth Pedersen, NASA Director of International Affairs, has commented that "international space cooperation is not a charitable enterprise; countries cooperate because they judge it in their interest to do so" (*16*). This observation can be extended to the level of individual space scientists; in the 25 years since scientific experiments in outer space became feasible, U.S. and European scientists have found it increasingly in their individual and mutual interest to carry out much of their activity on a cooperative basis. NASA's policies have encouraged and facilitated such cooperation; one result has been the nurturing of a vigorous space science community in Europe as well as the United States.

That community today recognizes the high stakes involved in maintaining effective communication and cooperation across national borders; this appears the only way for space science to thrive. The simple missions have already been flown, resources for space science are scarce, and a coordinated approach to the planning, funding, and conduct of complex science missions makes eminent sense. New ways may be needed to allow space scientists to join with the government organizations through which they function in a collaborative enterprise of cosmic discovery, but in general the outlook for international space science in the coming decades is one of great promise and excitement.

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