Section II-7 partnerships

NASA's space science program exists within a much larger research and technology context that spans the globe. In some areas space science leads the pace of innovation, and in others it benefits from efforts and investments of others. Our pace of discovery is quickened by contributions from other U.S. Government agencies, U.S. universities and industry, and scientific collaborators around the world.

Other NASA Enterprises

Partnerships with other NASA Enterprises are essential to the Space Science Enterprise strategy. For example, the Space Science Enterprise works with the Human Exploration and Development of Space (HEDS) Enterprise to provide information essential to future human exploration and development of the Solar System. This includes scientific information about likely human destinations such as the Moon and Mars, surveys and characterization of space resources, and evaluation of space radiation hazards. The partnership with HEDS also involves using Enterprise missions to test technologies for human exploration of space and planetary environments.

HEDS, in turn, provides the Space Science Enterprise opportunities to accomplish investigations that would otherwise be impractical. For example, the Space Shuttle flies science payloads such as telescopes to study the ultraviolet universe, sub-satellites to study the solar corona and the origin of solar wind, and cosmic dust collection experiments. The International Space Station will provide further opportunities for these and other types of investigations. Ultimately, some of the most important and complex science goals, such as understanding the possible origin and evolution of life on Mars, will be addressed by human explorers. Indeed, answering questions of this magnitude may prove to be a significant part of the rationale for human exploration. Moreover, ambitious future space observatories may depend on human assistance in assembly, maintenance, and upgrading; the history of the Hubble Space Telescope provides brilliant examples of this synergy.

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The Space Science, Earth Science, and new Biological and Physical Research Enterprises are jointly developing a program in Astrobiology, a new multidisciplinary research field that studies the origin and distribution of life in the universe, the role of gravity in living systems, and Earth's atmosphere and ecosystems.

Our studies of the Sun, the near-Earth space environment, Earth's middle and upper atmosphere, and other planets are also of interest to the Earth science community. For example, variations in solar radiation and particle emission cause variations in Earth's atmos-

phere. The study of other planets, particularly Venus and Mars, is another avenue to understanding why Earth is capable of sustaining life, and how global change processes might operate in other planetary settings.

The Aerospace Technology Enterprise also makes important contributions to the Space Science Enterprise. For example, aeronautics expertise at Ames Research Center supports the SOFIA airborne observatory program.

Our education and outreach programs are carried out in close collaboration with the Office of Human Resources and Education and the Office of Equal Opportunity Programs to ensure that space science initiatives complement existing activities and support NASA's overall programs in these areas.

Other U.S. Government Agencies

The National Science Foundation (NSF) has many programs that support or enhance NASA space science missions. NSF-supported ground-based research on the Sun, the planets, and the universe contribute to the intellectual foundations of many NASA space science flight missions. NASA and NSF jointly fund planet search programs. NSF is also responsible for U.S. scientific activities in the Antarctic. NSF, the Smithsonian Institution, and NASA collaborate on the search for, collection, distribution, and curation of Antarctic meteorites. NASA and NSF have a joint program to use Antarctica as an analog for the space environment in developing long-range plans for Solar System exploration. NASA also uses Antarctica for a future generation of very long-duration balloon missions. There are close ties between NASA's astrobiology programs and NSF's Life in Extreme Environments (LEXEN) program.

The Department of Energy (DOE) similarly has a wide range of programs that support NASA space science activities. DOE has developed and supplied the radioisotope thermoelectric generators (RTGs) that have enabled a wide range of Solar System exploration missions—from Apollo to Viking to Voyager, as well as the Galileo and Cassini-Huygens missions to the outer planets. DOE has developed instruments and sensors for NASA's space science missions, particularly through its Los Alamos and Lawrence-Livermore Laboratories. DOE and NASA have jointly studied a mission to place high-energy particle detectors in space aboard satellites and the International Space Station, and the agencies are working together on the Gamma Ray Large Area Space Telescope (GLAST). Data from DOE missions also support the International Solar Terrestrial Physics program.

For its part, the Department of Defense (DOD) has been a major developer of high sensitivity, large-area infrared detector arrays needed for many space science missions. These and technology for large-area deployable optical systems are important for future large telescopes in space. Through its Naval Research Laboratory (NRL), DOD has contributed instruments to space science missions such as the Compton Gamma Ray Observatory (CGRO) and the Solar and Heliospheric Observatory (SOHO). In another area, NASA and DOD cooperated on the Clementine mission, a DOD-led joint mission that surveyed the Moon. Space science, in turn, contributes to some DOD objectives. For example, research on solar flares, coronal mass ejections, solar energetic particles, and the terrestrial middle/upper atmosphere and magnetosphere is important for DOD command, control, and communications systems. DOD and NASA have established a partnership for expanded cooperation on the space environment.

In addition, NASA cooperates with the National Oceanic and Atmospheric Administration (NOAA) and DOD by providing data used for forecasting and understanding the space environment. This effort is part of an interagency (NASA, NSF, NOAA, DOD, DOE, Department of the Interior [DOI]) national space weather program. NASA also works closely with the U.S. Geological Survey of the Department of the Interior and the National Institute of Standards and Technology (NIST, Department of Commerce).

The formation of technology development partnerships is an important goal of the Space Science Enterprise. DOE, DOD, and other agencies such as NOAA share many needs and capabilities with NASA, and NASA works closely with them to identify opportunities for synergistic technology development.

In the education area, NASA works with NSF and the Department of Education to use space science missions and programs to contribute to science, mathematics, and technology education and to share the excitement of space science discoveries with the public. For example, we worked closely with the Department of Education's Gateway to Educational Materials Consortium to develop an online resource directory for space science education products.

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Universities

From NASA's very beginning, universities and university scientists have played a central role in the planning and implementation of space science. University scientists serve on NASA study teams and on key advisory committees that lay out long-range goals and objectives, strategies, and priorities for space science. University scientists develop new approaches for making critical measurements, serve as principal investigators for flight investigations, and carry out the laboratory, theoretical, and computational studies required to interpret data returned from space science missions.

Universities exist to create new knowledge and to transmit it. The intellectual environment of universities encourages innovation. Thus, university scientists carry out basic space science research and other long-term research needed to investigate underlying principles that form the foundations of new technology. Universities have the principal responsibility for ensuring the steady stream of highly trained and motivated people needed to assure the future vitality of the Space Science Enterprise. Space science programs are also significant contributors to the ongoing development of scientists and engineers to meet larger national needs. Support from NASA flight projects and research grants programs is an important contributor to maintaining the infrastructure that permits this university participation.

The trend towards smaller, more frequent, and lower cost missions, together with the advent of advanced communications and information systems technologies, has allowed universities to take on greater responsibility for the design, development, and operation of entire missions rather than just the development of individual instru-

ments on larger NASA-developed missions. Easier electronic access to archived data and new policies that place science data in the public domain as soon as possible are helping scientists and students at a wide range of institutions, including colleges and smaller universities, to participate in the analysis of space science data.

For these reasons, the Space Science Enterprise is committed to a long-term partnership with our universities and their community of scientists and students.

Industry

Industry has made and will continue to make significant contributions to the planning, development and implementation of space science missions and research programs. Industry has played a critical role in the design, engineering, manufacture, construction, and testing of both large and small space missions; in the design, development, testing, and integration of advanced instruments; and in the development of advanced spacecraft, instrument, mission operations, and information system technologies. Many industry capabilities have been developed for commercial applications with DOD or NASA core technology support. The resulting extensive space industry infrastructure is available for use for space science purposes. The establishment of partnerships with industry allows space science to benefit from the experience and capabilities of the industrial sector.

> The Space Science Enterprise is committed to the long-term support of university research and to continuing to work closely with university scientists and students.

As noted earlier, universities are now partnering with industry to assume full responsibility for the design, development, and operation of entire missions. With the more frequent flight opportunities now being provided through the Explorer, Discovery, and New Millennium programs, such partnerships are likely to play an even more important role in the Space Science Enterprise in the future. The reliance on the identification, development, and utilization of advanced technology to dramatically lower instrument, spacecraft, and mission operations costs requires strong partnerships between industry and the Enterprise. Strong partnerships are also important for facilitating the transfer of NASA-developed technology to industry and thereby realizing the commercial potential of these technologies and contributing to the long-term capability and competitiveness of American industry.

Other Nations

The quest for knowledge does not recognize national boundaries. Scientific expertise and capabilities are today more than ever distributed among many nations. Common interests and limited resources virtually dictate that nations cooperate in the pursuit of common goals. Further, the Space Act specifically mandates a leadership role for NASA in promoting international cooperation in space research. For all of these reasons, international cooperation is a fundamental aspect of virtually all Space Science Enterprise programs.

In some cases, other agencies and nations contribute to NASA-led missions. Foreign collaborators can join with U.S. teams to propose on NASA's competitive announcements, and foreign agencies can negotiate to stake out roles in U.S. strategic missions outlined in this and future plans. To support participation of U.S. investigators on foreign missions, the missions-of-opportunity option in Explorer and Discovery solicitations allows U.S. researchers to compete for funding to provide instrumentation or other contributions to missions developed by other countries or agencies.

International coordination of strategic planning poses a challenge, but one that merits continuing attention. Each agency, whether the European Space Agency or the numerous national agencies with which the Enterprise collaborates, has its own policies, planning cycles, funding processes, and scientific and technical priorities. The cooperative environment is characterized by a complex, but healthy, blend of competition and cooperation. But there is a general recognition, which NASA shares, that the opportunities for discovery outstrip the technical or financial resources of any individual player. As a result, we are continuing to work to better understand the goals and capabilities of our current and future partners, and we expect continuing progress in maximizing all parties' returns on space science investment through cooperative approaches to space research.

The Student-Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment (STARSHINE) satellite leaves the cargo bay of the Space Shuttle *Discovery* near the completion of the STS-96 mission. The stowed Canadian-built remote manipulator system (RMS) arm is visible in the foreground.