May 5, 2016 IG-16-020

NASA's International Partnerships: Capabilities, Benefits, and Challenges

NASA OFFICE OF INSPECTOR GENERAL

MESSAGE FROM THE INSPECTOR GENERAL

The Space Act of 1958 that created NASA identified the need to cooperate with "nations and groups of nations" in aeronautical and space activities as one of the Agency's primary mission objectives. To this end, NASA currently manages more than 750 international agreements with 125 different countries, the flagship being the International Space Station, which after 15 years in low Earth orbit is expected to continue operating until at least 2024.

These collaborative efforts have enhanced space-related knowledge through sharing of capabilities, expertise, and scientific research while cultivating positive working relations between nations. Moreover, as NASA missions become more complex and costly, it will be difficult for the Agency to achieve its ambitious goals without leveraging international partnerships, particularly for human exploration in deep space.

This report examines NASA's efforts to partner with foreign space agencies. We identified the space-related interests of more than a dozen space agencies around the world, examined their technical and financial capabilities, identified potential barriers to cooperation, and suggested possible ways to minimize those barriers. The observations we present are based on our analysis of information we received from NASA and firsthand from its foreign partners as well as information from studies prepared by NASA, our office, the Government Accountability Office, and other research, educational, and advisory organizations.

In sum, we found that NASA faces significant challenges to its use of international partnerships. First, the process of developing agreements with foreign space agencies requires approval from the Department of State, which often takes many months, if not years, to complete. Second, U.S. export control regulations can hinder dialogue between NASA and its partners, causing frustration with project planning and implementation and reducing the competitiveness of the U.S. space industry. Third, the lack of strong, centralized international space coordination groups and restrictions on the number of NASA employees who are permitted to attend international conferences make dialog between NASA and its partners more difficult. Finally, both the U.S. political process and geopolitical realities complicate NASA's efforts to expand international partnerships, particularly with the Russian and Chinese space agencies.

Although we make no formal recommendations in this report, we discuss three actions raised by partners NASA may wish to consider to help improve international cooperation: (1) streamline information sharing about opportunities for cooperation, (2) increase opportunities to share Agency test facilities, and (3) adopt successful past practices.

Paul K. Martin
Inspector General

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BACKGROUND

INTRODUCTION

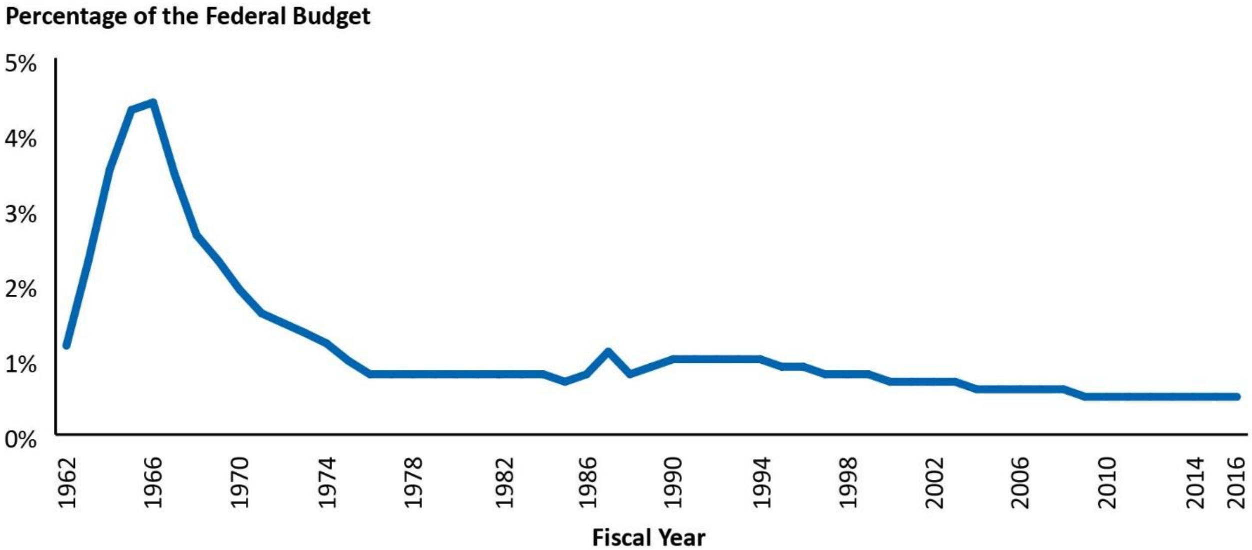
In October 1957, the Soviet Union took the world by surprise when it launched Sputnik, mankind's first artificial satellite. The United States responded with the Apollo Program, which landed astronauts on the Moon 12 years later. While NASA's initial history was characterized by rivalry with the Soviet Union, since then the Agency has significantly expanded cooperative efforts with other nations' space agencies. The resulting international partnerships have included collaborations with Russia, European nations, Japan, and Canada, particularly on development and operation of the International Space Station (ISS or Station).[1] In addition to nurturing relationships between the United States and these countries, such collaborative efforts have provided NASA with access to capabilities, expertise, and resources that have aided Agency projects. As NASA's missions become more complex and expensive, particularly as the Agency seeks to send humans to Mars and other deep space destinations, international partnerships will only grow in importance.

In the early 1960s, the U.S. space program enjoyed substantial support from the President and Congress, with NASA's annual budget increasing from $500 million in 1960 to $5.2 billion just 5 years later.[2] Since then, NASA's share of the Federal budget has significantly decreased. Peaking in 1966 during the Apollo Program at 4.4 percent, by 2015 NASA received only 0.5 percent of the overall Federal budget. Figure 1 illustrates NASA's funding profile as a percentage of the Federal budget between 1962 and 2016.

[1] For a full list of abbreviations, please see Appendix V.

[2] Converted to fiscal year 2016 dollars, NASA's 1965 funding of $5.2 billion would equate to approximately $39.13 billion.

Figure 1: NASA's Funding as a Percentage of the Federal Budget, 1962–2016



Source: Office of Management and Budget.

A number of factors affect partnerships between NASA and foreign space agencies, including the space policy goals and financial and technical capacities of individual countries, the U.S. Government's review process for international agreements, U.S. export control laws, and domestic and international politics. In this review, we examined the technical and financial capabilities of selected international partners, lessons learned from previous cooperative efforts, potential barriers to cooperation, and possible ways to minimize those barriers. We interviewed officials from NASA and the French, German, Indian, and Japanese space agencies, as well as the European Space Agency (ESA).[3] In addition, we developed a detailed questionnaire and received responses from the Australian, Argentinian, Brazilian, Canadian, Italian, South Korean, Spanish, Ukrainian, and United Kingdom space agencies.[4] The findings we present in this report are derived from our interviews, the questionnaire responses, and information gathered from reports and studies prepared by NASA, our office, the Government Accountability Office (GAO), and other research, educational, and advisory organizations. The scope and methodology are discussed in Appendix VI.

EVOLUTION OF NASA'S INTERNATIONAL COLLABORATION ACTIVITIES

The launch of Sputnik in the midst of the Cold War rivalry between the Soviet Union and the United States fueled passage of the National Aeronautics and Space Act of 1958 (Space Act), which established NASA as the United States' civilian space agency.[5] Among other things, the Space Act empowered NASA

3 As of 2016, ESA is comprised of 22 member states: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom.

4 We did not receive responses from the Mexican, Russian, and South African space agencies.

5 51 U.S.C. § 20113(e) (2010).

to enter into international agreements and directed the Agency to "make every effort to enlist the support and cooperation" of the international community in its endeavors.[6]

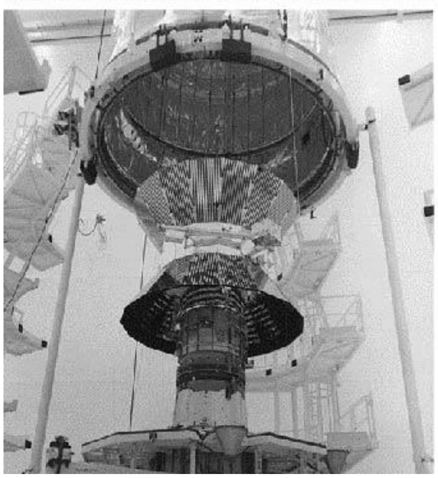
1960s

Soon after passage of the Space Act, NASA entered into bilateral agreements with France, Germany, Italy, and the United Kingdom to cooperate on space science research, satellites, and sounding rocket launches. As early as 1961, NASA and France's Centre National d'Etudes Spatiales – one of Europe's oldest space agencies – had formal agreements enabling French scientists to launch payloads on U.S. rockets and work alongside NASA personnel at Agency Centers (see Figure 2). By 1962, NASA was collaborating with 55 nations on space-related projects, including satellites, sounding rockets, and ground-based work in meteorology and communications.[7] In addition, foreign researchers were working with NASA, foreign engineers and technicians were training at NASA Centers, and foreign students were studying in American universities under NASA sponsorship.

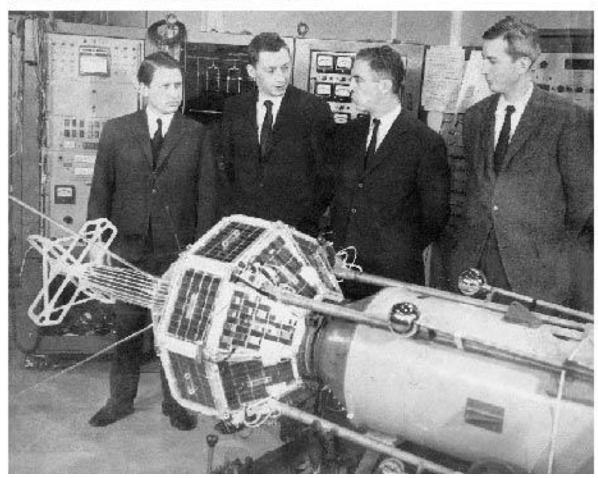
The most ambitious international project during this early period was Helios, the first U.S.-German interplanetary mission, which would go on to send two separate probes to the Sun to study the interaction between the Earth and the Sun (see Figure 2). The United States contributed two launch vehicles and several experiments to Helios, while the Germans built the probes.[8] At the same time, NASA was collaborating with Japan on sounding rocket firings to compare results from American and Japanese instruments that measured the temperature and density of electrons in Earth's ionosphere.

Figure 2: Photos of NASA's Early Collaboration with France and Germany

NASA Integration of FR-1 French Satellite



NASA-German Helios Project



Source: NASA.

[6] 51 U.S.C. § 20102(d)(7), 51 U.S.C. § 20115, and 51 U.S.C. § 20164 provide NASA with authority related to foreign governments and entities.

[7] Sounding rockets carry instruments designed to take measurements and perform scientific experiments during suborbital flight. Since 1959, NASA-sponsored space and Earth science research projects have used sounding rockets to test satellite and spacecraft instruments and to provide information about the Earth's atmosphere and radiation environment, the Sun, stars, and galaxies.

[8] The first Helios probe was launched in December 1974.

By the end of the 1960s, an increasing number of international projects prompted NASA to develop several principles to guide the Agency's collaboration with foreign space agencies:

- Partners negotiate and supervise joint projects through a designated governmental body.
- Cooperation is undertaken on a project-by-project basis.
- Cooperation should be mutually beneficial and scientifically valid.
- Partners will not exchange funds; each will be responsible for its own contribution.
- Partners will not exchange technical or managerial expertise.
- Scientific results will be made available to researchers of all nations involved.

These principles continue to guide NASA's collaborative efforts today.

1970s

By the mid-1970s, after the end of the Apollo Program in 1972, NASA's budget dropped to less than 1 percent of the Federal budget where it has remained ever since except for a one year period in the late 1980s and the first half of the 1990s.[9] During this decade, NASA cooperated with 94 countries and international organizations on a variety of projects. Most significant were NASA's partnerships on two undertakings that laid the groundwork for future collaboration – the Spacelab Project and the Apollo-Soyuz Test Project (see Figure 3). Spacelab was a $1 billion ESA-built, NASA-operated laboratory housed in a Space Shuttle cargo bay and used to conduct experiments in microgravity during Shuttle flights.[10] First established in 1973, the partnership between NASA and ESA used a barter agreement with no exchange of funds and a "plug-and-play" approach to construction, meaning the Spacelab was constructed as a compilation of modules, trusses, and platforms at different facilities and then integrated on the ground before launch. The Spacelab Project operated through 1998 and laid the foundation for the ISS.

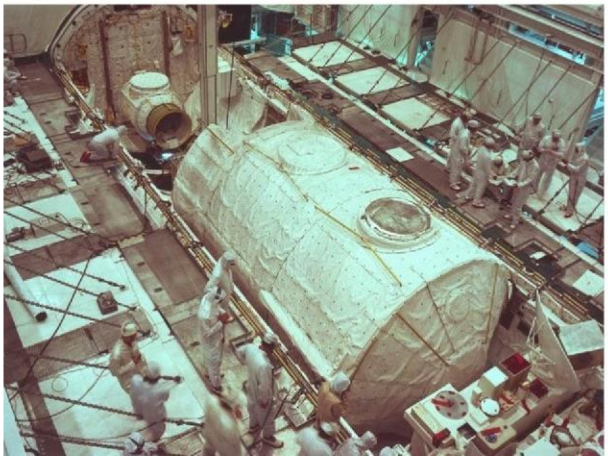
The 1975 Apollo-Soyuz Test Project, the first joint U.S.-Soviet Union space flight, was intended as a symbol of détente between the Cold War rivals. The two countries developed compatible rendezvous and docking systems that enabled the United States' Apollo and the Soviet Union's Soyuz vehicles to dock with each other in orbit. Although the Apollo-Soyuz project had political support in both countries, differences in the organization and engineering styles of the two space agencies and national security concerns provided unique challenges that were ultimately overcome.

[9] NASA's budget in 1987 and 1990–1994 grew to more than 1 percent of the overall Federal budget due in part to an increase in Space Shuttle flights and the launch of the Hubble Space Telescope.

[10] At the time, ESA had 11 member countries: Belgium, Denmark, France, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, and West Germany. All except Sweden participated in the Spacelab Project.

Figure 3: Photos of NASA's Collaboration with ESA and the Soviet Union

Integration of Spacelab-1 at Kennedy Space Center



Onboard Apollo-Soyuz

Source: ESA (left photo) and NASA (right photo).

NASA also collaborated with India on a third important partnership during this period – a project that used a NASA satellite to broadcast educational programs directly to televisions in rural India.

1980s

By the 1980s, NASA had more than 1,000 active agreements with more than 100 countries. The hallmark of international cooperation during this period was establishment of the Space Station Freedom Program. In his 1984 State of the Union address, President Ronald Reagan challenged NASA to build a space station and to invite other countries to join in the endeavor. Ultimately, the Program involved NASA and partners from 12 other countries, including Canada, Japan, and some ESA member countries, with the goal of maximizing partners' technological contributions and sharing costs. However, following U.S. budget cuts, cost growth, technical issues, and the partners' interest in including Russia as a major contributor and partner, the Program was de-scoped in 1993 and replaced with the ISS Program.

1990s

The end of the Cold War and dissolution of the Soviet Union in the early 1990s coincided with increased space-related cooperation between NASA and Russia. A 1992 agreement to exchange astronauts and cosmonauts and fly Space Shuttle missions to the Mir Space Station signaled a turning point in U.S.-Russian space cooperation and led to Russia joining the ISS partnership.[11]

Since 1994, the United States has partnered with Canada, ESA, Japan, and Russia and expended more than $81 billion to develop, construct, and operate the ISS. In addition to U.S. contributions, Canada, ESA, and Japan each made significant hardware contributions to the ISS:

- Canada contributed Canadarm, a remote controlled mechanical arm.

[11] Russia's Mir Space Station operated for 15 years in low Earth orbit from 1986 until 2001.

- ESA provided the Columbus Orbital Facility and the Automated Transfer Vehicle used to transport cargo to the Station.
- Japan provided the Japanese Experiment Module and the H-II Transfer Vehicle, a cargo transportation vehicle.

In addition, Russia provided critical service, control, docking modules, and crew and cargo transportation vehicles without which the ISS could not function. Although its dependence on Russian technology raised concerns at the time regarding technical reliability and the political and economic effects of the partnership, the ISS has served as a template for NASA's international efforts.

2000s and Beyond

The beginning of the 21st century saw the first crew of astronauts and cosmonauts occupy the ISS. Since November 2000, more than 200 men and women from 17 different countries have lived aboard the Station. This unprecedented multinational partnership has created a unique research facility in which to conduct experiments in a weightless microgravity environment. In addition, NASA views the ISS as an important stepping stone on the path of human exploration to destinations beyond low Earth orbit. The first photo in Figure 4 shows the completed ISS in 2011, and the second shows the ISS's Canadarm grappling the Japanese H-II Transfer Vehicle in August 2013.

Figure 4: Photos of the ISS

Completed ISS

Japanese Cargo Vessel Arrives

Source: NASA.

Other international projects during this period included the Rosetta, Global Precipitation Measurement (GPM), and Surface Water and Ocean Topography (SWOT) missions. Rosetta is a robotic space probe built by ESA with contributions from its member states and NASA. Launched in 2004, Rosetta was the first mission to rendezvous, follow, and deploy a lander to the surface of a comet. The GPM mission is an international network of satellites launched in February 2014 to measure precipitation in the Earth's atmosphere and provide a reference standard for precipitation measurements from space. While GPM was developed primarily by NASA and the Japanese space agency, the space agencies of several other countries, including France and India, launched research and operational satellites as part of the mission. In addition, the European Organization for the Exploitation of Meteorological Satellites, an intergovernmental organization that supplies weather and climate-related satellite data to the national meteorological services of member and cooperating states, launched the Meteorological Polar Orbit satellite. The SWOT mission is a joint project between NASA and the French space agency to undertake the first global survey of Earth's surface water, observe the details of ocean surface topography, and measure how water bodies change over time. Planned for launch in 2020, the SWOT mission will address two key issues: (1) the variability of fresh water resources and (2) how ocean circulation affects climate.

Crewed Mission to Mars

U.S. leaders have proposed Mars as a destination for astronauts for more than 3 decades. However, NASA and other international partners cite a number of factors that make a crewed mission to Mars particularly difficult, including its complexity, enormous costs, and the related scientific, technological, and safety challenges. NASA's current goal is to execute a crewed mission to Mars in the 2030s. In October 2015, NASA announced a three-phase plan for human exploration of Mars. During the first phase, NASA will test technologies and advance human health and performance research by conducting research aboard the ISS. In the second phase, NASA will advance and validate capabilities by conducting transportation and habitation operations in cislunar space.[12] Finally, in the third phase, the Agency will undertake human missions to the vicinity of Mars before eventually landing on the planet's surface.

The National Research Council (NRC) has pointed out that given its expense and technical challenges, international collaboration will be an essential component of any human mission to Mars. Specifically with respect to expense, the NRC stated in 2014 that due to the scale of a crewed mission to Mars "contributions by international partners would have to be of unprecedented magnitude to defray a significant portion of the cost."[13]

While human flight to Mars remains decades away, NASA and other countries have launched more than 40 unmanned missions to Mars since 1960, including landing four rovers on the planet's surface. Mars robotic exploration missions provide good examples of multiple countries participating in a joint effort. For example, the Mars Curiosity Rover has sensors provided by 5 different countries and involvement by 13 countries. In 2014, NASA entered into an agreement with the French space agency to study the Martian interior in order to determine its structure and composition.

Officials from NASA and the French Space Agency Sign Mars Agreement (February 10, 2014)

Source: NASA.

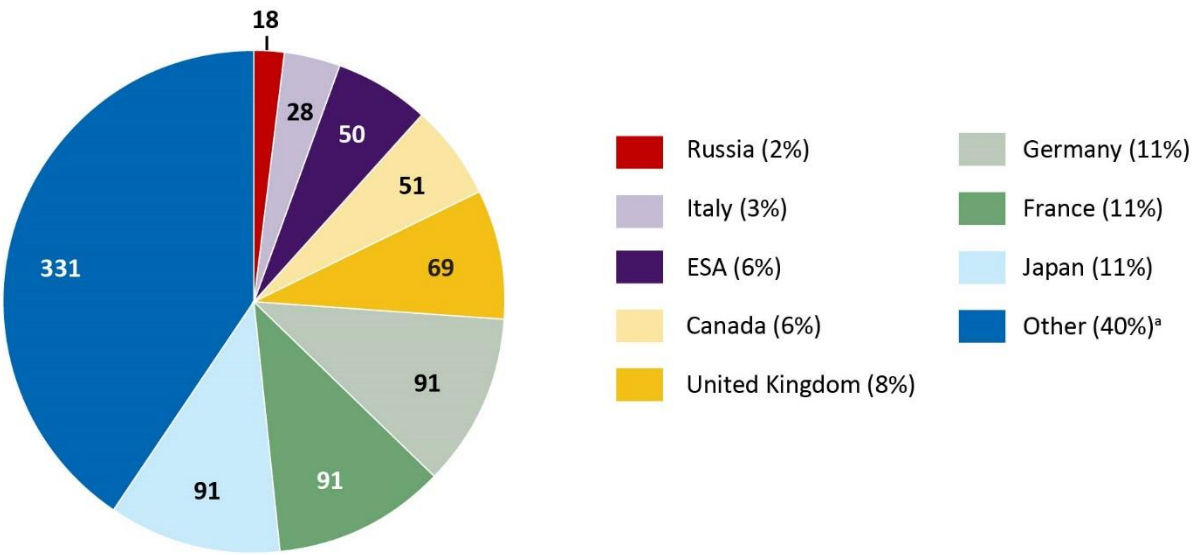
[12] Cislunar is the area of space outside Earth's atmosphere and extending out just beyond the Moon's orbit.

[13] NRC, "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" (2014).

PARTNERSHIPS

In 2014, NASA had 820 active agreements with 125 countries.[14] The scope and subject matter of these agreements ranged from exploring the properties of aerosols with a small African country to billion-dollar commitments to Russia to transport U.S. astronauts to the ISS on Russian rockets.[15] As shown in Figure 5, approximately 60 percent of these agreements were with eight partners: Canada, ESA, France, Germany, Italy, Japan, Russia, and the United Kingdom. The other 40 percent involved a variety of countries, including Australia, Brazil, China, India, South Korea, and Ukraine.[16] NASA officials told us they continue to work to engage other, nontraditional partners such as India, South Korea, and the United Arab Emirates in support of Agency science objectives.

Figure 5: Number of Active International Agreements by Country for 2014



Source: NASA's System for International and Interagency External Relations Agreements Database.

Note: Percentages may not add to 100 percent due to rounding.

[a] For ease of reference and to accurately reflect the total number of agreements, the "other" category includes four active agreements that had multiple signatories, including Canada, ESA, France, Japan, and Russia.

Of the active international agreements NASA had in 2014, 240 focused on space science, 140 on Earth science, 140 on exploration and transportation, and 26 related to the ISS. The remaining 274 agreements related to a wide variety of other subjects.

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[14] The number of active agreements varies at any given point in time. As of April 2016, NASA had more than 750 active agreements.

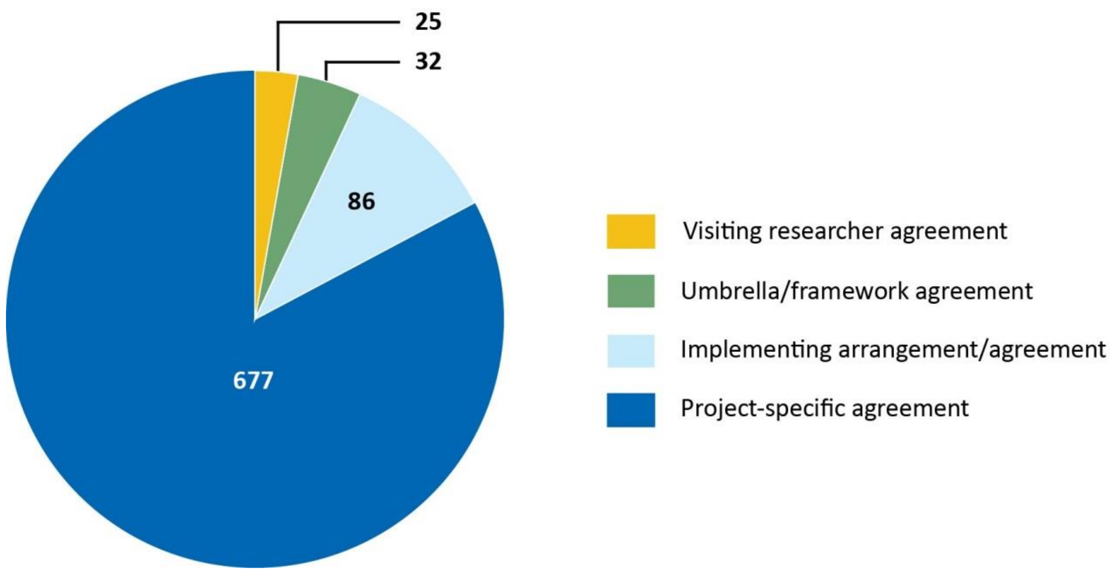
[15] The 1998 intergovernmental agreement on the ISS designated Russia as one of the countries providing crew transportation to the Station. According to the agreement, transportation will be done on a reimbursable basis. The monetary exchange of funds between the United States and Russia was later prescribed in a contract.

[16] Since 2011, NASA's appropriations legislation has restricted the Agency from using funds to "develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company." Consolidated and Further Continuing Appropriations Act, 2012, Pub. L. No. 112-55, 112th Cong., § 539(a). In accordance with this provision, NASA's collaborations with China are limited and must follow a certification process to gain approval; currently, NASA has only one active agreement with China.

NASA's international agreements may be governed by either U.S. or international law. Many countries agree to use U.S. laws as the legal basis, and 444 of NASA's 820 active agreements with international partners are executed pursuant to U.S. law, while the remaining 376 are governed by international law.

When entering into international partnerships, NASA utilizes several different types of agreements: framework agreements (framework), implementing agreements, visiting researcher agreements, and project-specific agreements. Frameworks establish a legal framework for future cooperation between NASA and a foreign space agency. Implementing agreements build on frameworks and provide additional details relating to a specific project. Visiting research agreements allow individuals or universities to work with NASA on specified projects or research. Project-specific agreements relate to a particular project or mission. Project-specific agreements accounted for 83 percent of all active agreements in 2014, with the other three agreement types accounting for the remaining 17 percent. Figure 6 shows the types and number of NASA's active international agreements in 2014.

Figure 6: Types of Active International Agreements in 2014



Source: NASA's System for International and Interagency External Relations Agreements Database.

Coordination Groups

The United States and NASA are members of several international coordination groups or forums designed to facilitate cooperation in space between countries, including the United Nations Committee on the Peaceful Uses of Outer Space (Outer Space Committee). The Outer Space Committee was created in 1959 to "review the scope of international cooperation in peaceful use of outer space" by developing multinational programs, increasing the dissemination of technical information, and studying legal problems arising from the use of outer space. The Office for Outer Space Affairs implements the Outer Space Committee's decisions and facilitates intergovernmental discussions between other United Nations' committees and subcommittees and assists developing countries in advancing their space technology.

In addition to the Outer Space Committee, NASA participates in international conferences that meet on an annual or semiannual basis, including the International Astronautical Congress. Organized by the International Astronautical Federation, the International Astronautical Congress is held in a different country each year and offers space agencies and private entities an opportunity to discuss space-related topics and facilitate potential partnerships. For example, NASA and India entered into an agreement relating to Earth science and established a Mars exploration working group at the 2014 Congress in Toronto, Canada. NASA also signed a cooperation agreement with the Israel Space Agency at the 2015 Congress in Jerusalem, paving the way for future joint missions and scientific data exchanges.

NASA is also a member of the International Space Exploration Coordination Group, a voluntary association of 15 space agencies whose goal is to exchange plans in space exploration and encourage collaboration in order to "strengthen both individual exploration programs and the collective effort."[17] The member space agencies conduct much of their coordination through working groups, including the Exploration Roadmap Working Group and the Technology Working Group. In 2007, the International Space Exploration Coordination Group released a comprehensive document outlining international objectives and efforts in space exploration.[18] The Group also published the Global Exploration Roadmap in September 2011 (updated in August 2013) that articulated the eight goals of the collective space agency community:[19]

1. Develop Exploration Technologies and Capabilities
2. Engage the Public in Exploration
3. Enhance Earth Safety
4. Extend Human Presence
5. Perform Science to Enable Human Exploration
6. Perform Space, Earth, and Applied Science
7. Search for Life
8. Stimulate Economic Expansion

Science Missions

One of the principal means by which NASA engages the science community is through the NRC. Established in 1916 by the National Academy of Sciences, the NRC conducts decadal surveys that provide NASA with the consensus of the science community regarding areas of future study in astronomy, astrophysics, Earth science, planetary science, and solar and space physics. These surveys look 10 or more years into the future and provide NASA with a prioritized list of research areas, observations, and notional missions.

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[17] International Space Exploration Coordination Group, "About ISECG"; http://www.globalspaceexploration.org/wordpress/?page_id=50 (last accessed March 22, 2016). In addition to NASA, the members are ESA and the Australian, Canadian, Chinese, French, German, Indian, Italian, Japanese, Russian, South Korean, Ukrainian, United Arab Emirates, and United Kingdom space agencies.

[18] International Space Exploration Coordination Group, "The Global Exploration Strategy: The Framework for Coordination" (April 2007); https://www.nasa.gov/pdf/296751main_GES_framework.pdf (last accessed March 3, 2016).

[19] International Space Exploration Coordination Group, "The Global Exploration Roadmap," (September 2011, updated August 2013); https://www.nasa.gov/sites/default/files/files/GER-2013_Small.pdf (last accessed March 3, 2016).

The NRC completed its first decadal survey for Earth science in January 2007 at the request of NASA, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey.[20] The 2007 report recommended the Federal Government work with the private sector, academia, the public, and international partners to renew "its investment in Earth-observing systems and restore its leadership in Earth science and applications" and cited 15 new missions as top priorities for NASA (see Table 1). An updated decadal survey for Earth science is underway and expected to be published in 2017.

Table 1: NASA Missions Recommended in NRC's 2007 Earth Science Decadal Survey

Mission	Mission Description	Cost Estimate (Fiscal Year 2006, Dollars in Millions)
Fiscal Years 2010–2013		
Climate Absolute Radiance and Refractivity Observatory (CLARREO)	Solar and Earth radiation	$200
Soil Moisture Active Passive (SMAP)	Soil moisture and freeze thaw for weather and water cycle processes	300
Ice, Cloud, and land Elevation Satellite-2 (ICESat-2)	Ice sheet height changes for climate change diagnosis	300
Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynl)	Surface and ice sheet deformation for understanding natural hazards and climate	700
Fiscal Years 2013–2016		
Hyperspectral Infrared Imager (HyspIRI)	Land surface composition for agriculture and mineral characterization	300
Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS)	Day/night, all-latitude, all-season carbon dioxide column integrals for climate emissions	400
Surface Water Ocean Topography (SWOT)	Ocean, lake, and river water levels for ocean and inland water dynamics	450
Geostationary Coastal and Air Pollution Events (GEO-CAPE)	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	550
Aerosol-Clouds-Ecosystems (ACE)	Aerosol and cloud profiles for climate and water cycle	800
Fiscal Years 2016–2020		
Lidar Surface Topography (LIST)	Land surface topography for landslide hazards and water runoff	300
Precision and All-Weather Temperature and Humidity (PATH)	High frequency, weather temperature, and humidity soundings for weather forecasting	450
Gravity Recovery and Climate Experiment (GRACE-II)	High-temporal-resolution gravity fields for tracking large-scale water movement	450
Snow and Cold Land Processes (SCLP)	Snow accumulation for freshwater availability	500
Global Atmospheric Composition Mission (GACM)	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	600
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	650

Source: NRC.

[20] NRC, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" (January 2007).

AUTHORITY AND POLICY

The Space Act provides NASA with broad authority to engage in international collaboration by entering into agreements with foreign entities, including cooperative agreements and Space Act Agreements.[21] In the context of international agreements, Space Act Agreements may be reimbursable, that is, NASA receives funds in exchange for its services, or nonreimbursable, meaning parties exchange goods or services but no funds.[22] In addition, NASA uses two types of Space Act Agreements exclusively in the context of the ISS – barter agreements and offset agreements. In barter agreements partners exchange goods or services to meet their support commitments for the Station. For example, Japan pays for much of its common systems operating costs with deliveries of supplies and equipment via the Japanese H-II Transfer Vehicle.[23] In offset agreements, a partner provides in-kind contributions to satisfy a financial obligation. Using an offset agreement, ESA is providing NASA with the Orion Multi-Purpose Crew Vehicle service module for Exploration Mission-1 scheduled to launch no later than November 2018 as an offset to meet part of its responsibility for ISS common system operations costs.

NASA policy outlines the Agency's process for the initiation and development of projects involving international cooperation.[24] Pursuant to the policy, NASA may engage in international cooperation if said cooperation will "significantly enhance technical, scientific, economic, or foreign policy benefits" and the project is within the known scientific, technical, and budgetary capabilities of the cooperating partners, with each partner financing its own contributions. All NASA international partnerships must (1) clearly define the division of responsibilities between NASA and the cooperating partner, (2) take into account the need to protect against unwarranted transfer of technology, (3) demonstrate a specific benefit to NASA or the United States, and (4) be established in a formal written project or program agreement that specifies the responsibilities of each partner. NASA's Office of International and Interagency Relations (OIIR) is tasked with coordinating partnership efforts.[25]

OIIR is also responsible for processing international agreements and ensuring the agreements are compliant with the Case-Zablocki Act. The Case-Zablocki Act requires Federal agencies to obtain approval from the Department of State's Office of Space and Advanced Technology for international agreements that are legally binding under international law and involve significant obligations for the United States.[26] The Department of State (State) uses five criteria to determine whether an international agreement is governed by the Act: (1) identity and intention of the parties, (2) significance of the arrangement, (3) specificity of the parties' responsibilities, (4) necessity for multiple parties, and (5) the format of the agreement.[27] With regard to agreement significance, the Act states that minor or trivial undertakings, even if couched in legal language, are not considered international agreements and

[21] Space Act Agreements establish a set of legally enforceable promises between NASA and another party with the goal of enhancing the Agency's ability to advance cutting-edge science and technology.

[22] NASA policy prohibits the use of funded Space Act Agreements with foreign entities.

[23] Common systems operating costs include the cost of transporting cargo and crew to and from the ISS.

[24] NASA Policy Directive 1360.2B, "Initiation and Development of International Cooperation in Space and Aeronautics Programs (Revalidated on August 28, 2014)" (April 16, 1999).

[25] OIIR leads NASA's international relations; negotiates cooperative and reimbursable agreements with foreign space partners; provides management oversight and staff support to NASA's advisory committees, commissions, and panels; and manages the NASA Export Control Program and foreign travel by NASA employees.

[26] U.S. International Agreements; Transmission to Congress, 1 U.S.C. § 112b (December 17, 2004).

[27] 22 C.F.R. § 181.2 (2006).

that when deciding the level of significance the entire context of the transaction and the expectations and intent of the parties must be taken into consideration. If the Case-Zablocki Act applies, the agreement must be approved through the Circular 175 (C-175) interagency review process for which State's Office of Space and Advanced Technology is responsible. At NASA, OIIR coordinates the Agency's compliance with the C-175 review process. We discuss this process in further detail in Chapter 3 of this report.

State's Office of Space and Advanced Technology is also responsible for ensuring that U.S. space, science, and technology activities support the nation's foreign policy objectives and enhance its space and technological competitiveness. The Office oversees treaty-level agreements, including the 1998 Intergovernmental Agreement on the ISS, and manages the interagency coordination and approval for all civil space-related international agreements involving the Department of Energy, the Federal Aviation Administration, NASA, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the U.S. Geological Survey.

Export Control Policies and Regulations

A key aspect of international cooperation is the exchange of project information and technology between partners. Any such exchange is required to comply with U.S. export control regulations, which define an export as the "transfer of anything to a foreign person or foreign destination."[28] U.S. export controls are principally governed by two sets of regulations: the International Traffic in Arms Regulations (ITAR) and the Export Administration Regulations (EAR). The ITAR is administered by State and governs "defense articles," including launch vehicles and certain types of spacecraft, and defense-related services and information. Defense articles or services are described by category on the U.S. Munitions List, which is governed by the ITAR. If an item or information falls under one of the categories on the Munitions List and is not otherwise exempt, the exporter generally must obtain a license for the item. The ITAR also restricts exports depending on destination, particularly with countries for which the United States maintains an arms embargo, such as Iran and North Korea.

Administered by the Department of Commerce, the EAR governs "dual-use" items that have both military and commercial application, such as certain commercial global navigation satellite systems. Similar to the ITAR, the EAR has its own list of regulated exports known as the Commerce Control List. Five factors govern restrictions under the EAR: (1) classification of the item on the Commerce Control List, (2) country of ultimate destination, (3) ultimate end-user, (4) ultimate end-use, and (5) type of transaction, including methods of contracting and financing. The EAR also contains somewhat broader exemptions than the ITAR.

In 2009, President Barack Obama announced a comprehensive review of the U.S. export control process in an effort to reform the system by increasing protections for more sensitive national security items while reducing unnecessary barriers to exporting less-sensitive items. This review resulted in several categories of items being revised and transferred from the ITAR's U.S. Munitions List to the EAR's Commerce Control List, including several technologies routinely used by NASA and aerospace contractors. This change, approved by Congress in 2013, is expected to reduce the number of licenses required for many NASA projects.

[28] NASA Procedural Requirements 2190.1B, "NASA Export Control Program" (December 27, 2011), p. 31.

The NASA Authorization Act of 2010 calls for export control policies "that protect the national security of the United States while also enabling the United States and its aerospace industry to undertake cooperative programs in science and human space flight in an effective and efficient manner and to compete effectively in the global market place."[29] More than 20 years ago, NASA was one of the first Federal agencies to establish an agency-wide export control program. NASA's Export Control Program, administered by the Export Administrator at NASA Headquarters, is designed to safeguard U.S. technology and ensure compliance with U.S. export control regulations. In addition, each NASA Center has both an attorney designated to handle the legal aspects of export control (Export Counsel) and a Center Export Administrator responsible for directing the Center's export control staff. With regard to certain international projects, NASA policy requires that project managers create Technology Transfer Control Plans, which are internal documents designed to identify a program's potential export control vulnerabilities and provide guidance on mitigating those vulnerabilities. Export Administrators may also appoint Export Control Representatives within a directorate or program to assist with export determinations and review. In April 2015, NASA's Export Administrator completed a comprehensive Export Control Program Operations Manual that provides detailed guidance to all NASA entities involved in the export control process.

Geopolitical Landscape

Although NASA is by nature a scientifically and technologically focused agency, from the very beginning its missions and operations have been closely entwined with geopolitics. For example, over the past 50 years, U.S.-Russia relations in aerospace have evolved from direct competition to close cooperation in construction and operation of the ISS. Nevertheless, diplomatic relations between the United States and Russia are volatile and the state of that relationship at various times over the past 5 decades has affected cooperative efforts between the two countries. For example, in response to the ongoing conflict in Ukraine, the United States imposed economic sanctions on Russia and curtailed official government-to-government contacts and meetings. While key NASA activities with the Russian space agency have continued during this period, including those related to operation of the ISS and several science-related missions, other cooperative efforts such as wind tunnel testing, a Venus mission study, and Siberian forest research have been suspended or terminated.

Geopolitical realities have also led to limits on NASA's relationship with the Chinese space agency. China's space agency has made significant progress in recent years when it became the third country – after the United States and Russia – to successfully return a lunar orbiter to Earth after landing a rover on the moon. However, NASA is significantly constrained from engaging in cooperative partnerships with China due to concerns about the country's human rights record, espionage activity, and lack of separation between its military and space efforts. These concerns were further exacerbated by a 2015 cyberattack against Office of Personnel Management databases that many attribute to Chinese hackers.

[29] National Aeronautics and Space Administration Authorization Act of 2010, Pub. L. No. 111-267, 111th Cong., § 2(15) (2010).

Since 2011, NASA's appropriations legislation has contained a provision forbidding the Agency from using any of its funds to "develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company."[30] Under this guidance, NASA can cooperate with China only if the Agency certifies that the proposed activity "pose[s] no risk of resulting in the transfer of technology, data, or other information with national security or economic security implications to China or a Chinese-owned company."[31] NASA has certified only four low-level activities with China in the past 5 years: (1) exchange of respective lunar science mission information, (2) reactivation of cooperative activities in space geodesy, (3) coordination of Earth observation data products for glacier characterization in the Himalaya region, and (4) collaboration in basic air traffic management research.

[30] Consolidated and Further Continuing Appropriations Act, 2012, Pub. L. No. 112-55, 112th Cong., § 539(a) (2011).

[31] Consolidated and Further Continuing Appropriations Act, 2012, Pub. L. No. 112-55, 112th Cong., § 539(c) (2011).

CHAPTER 1

Space Agencies' Goals and Capabilities

NASA and its international partners share a series of common goals, but the timing and prioritization of the partners' preferred research and exploration projects may not align with NASA. Moreover, although foreign agencies have demonstrated and emerging technical capabilities, adequate funding is the key driver for meeting common goals. While NASA's annual budget is significantly larger than the budgets of other members of the international space community, partnerships with foreign space agencies may enable NASA to obtain instruments or technologies from other space agencies to enhance missions. This chapter examines the goals, objectives, and capabilities – financial and technical – of NASA and the 14 space agencies we interviewed or surveyed. We also discuss the technical and financial capabilities of China and Russia.[32] (See Table 2.) Additional detail about each agency can be found in Appendixes I and II.

Table 2: Select International Partners and Associated Space Agencies

International Partner	Space Agency/Acronym
Argentina	National Commission on Space Activities (CONAE)
Australia	Commonwealth Scientific and Industrial Research Organization (CSIRO)
Brazil	Brazilian Space Agency (AEB)
Canada	Canadian Space Agency (CSA)
China	China National Space Administration (CNSA)
ESA	22 member states[a]
France	Centre National d'Etudes Spatiales [National Center for Space Studies (CNES)]
Germany	German Aerospace Center (DLR)
India	Indian Space Research Organization (ISRO)
Italy	Agenzia Spaziale Italiana [Italian Space Agency (ASI)]
Japan	Japan Aerospace Exploration Agency (JAXA)
Russia	Roscosmos State Corporation (Roscosmos)
South Korea	Korea Aerospace Research Institute (KARI)
Spain	National Institute for Aerospace Technology (INTA)
Ukraine	State Space Agency of Ukraine (SSAU)
United Kingdom	United Kingdom Space Agency (UK Space Agency)
United States	National Aeronautics and Space Administration (NASA)

Source: NASA Office of Inspector General.

[a] The 22 member states of ESA are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom. Canada takes part in some projects under a cooperation agreement.

[32] We do not discuss the goals and objectives of the Chinese or Russian space agencies in detail because we did not interview or otherwise obtain information from officials of those agencies.

Goals and Objectives

In its most recent Strategic Plan completed in 2014, NASA identified three overarching goals:

1. Expand the frontiers of knowledge, capability, and opportunity in space.
2. Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.
3. Serve the American public and accomplish our mission by effectively managing our people, technical capabilities, and infrastructure.[33]

For each of these goals, NASA included a number of more specific objectives, such as expanding human presence to Mars and other parts of the solar system and advancing aeronautics research to improve the safety and sustainability of global aviation.

We surveyed 14 of NASA's international partners, either in person or through our questionnaire, about their goals and objectives and compared them to those of NASA.[34] A summary of that comparison is shown in Table 3.

Table 3: Crosswalk of NASA's Goals with Goals of Selected Space Agencies

NASA	Argentina	Australia	Brazil	Canada	ESA	France	Germany	India	Italy	Japan	South Korea	Spain	Ukraine	United Kingdom
Strategic Goal 1: Expand the frontiers of knowledge, capability, and opportunity in space														
Objective 1.1: Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration				•	•	•[a]	•[a]	•	•	•	•	•		•
Objective 1.2: Conduct research on the ISS to enable future space exploration, facilitate a commercial space economy, and advance the fundamental biological and physical sciences for the benefit of humanity				•	•	•	•		•	•			•	•
Objective 1.3: Facilitate and utilize commercial capabilities to deliver cargo to the ISS					•					•			•	

[33] Published in 2014, NASA's Strategic Plan details the vision, mission, goals, and objectives of the Agency.

[34] We did not include the Chinese or Russian space agencies in this comparison because we did not interview or otherwise obtain information from officials of those agencies.

NASA	Argentina	Australia	Brazil	Canada	ESA	France	Germany	India	Italy	Japan	South Korea	Spain	Ukraine	United Kingdom
Objective 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather		•				•	•			•				
Objective 1.5: Ascertain the content, origin, and evolution of the solar system and the potential for life elsewhere				•	•	•	•	•			•	•		•
Objective 1.6: Discover how the universe works, explore how it began and evolved, and search for life on planets around other stars		•			•	•	•		•					•
Objective 1.7: Transform NASA missions and advance the U.S. capabilities by maturing crosscutting and innovative space technologies	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Strategic Goal 2: Advance understanding of Earth and develop technologies to improve the quality of life on our home planet														
Objective 2.1: Enable a revolutionary transformation for safe and sustainable U.S. and global aviation by advancing aeronautics research							•			•	•	•		
Objective 2.2: Advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Objective 2.3: Optimize Agency technology investments, foster open innovation, and facilitate technology infusion, the greatest national benefit	•	•	•	•						•	•	•	•	
Objective 2.4: Advance the U.S. science, technology, engineering, and mathematics education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets	•	•		•										•

NASA	Argentina	Australia	Brazil	Canada	ESA	France	Germany	India	Italy	Japan	South Korea	Spain	Ukraine	United Kingdom
Strategic Goal 3: Serve the American public and accomplish our mission by effectively managing our people, technical capabilities, and infrastructure														
Objective 3.1: Attract and advance a highly skilled, competent, and diverse workforce; cultivate an innovative work environment; and provide the facilities, tools, and services needed to conduct NASA's missions		•	•	•			•	•	•		•	•		•
Objective 3.2: Ensure the availability and continued advancement of strategic, technical, and programmatic capabilities to sustain NASA's mission		•		•	•			•	•		•			
Objective 3.3: Provide secure, effective, and affordable information technologies and services that enable NASA's mission			•	•										
Objective 3.4: Ensure effective management of NASA programs and operations to complete the mission safely and successfully			•				•			•		•		•

Source: NASA Office of Inspector General.

[a] Both France and Germany only engage in human exploration through ESA due to the level of investment and scientific returns.

We found 10 of the 14 agencies share NASA's goal of expanding human presence to Mars and other parts of the solar system. In addition, many of the 14 agencies have common short-term objectives for conducting research on the ISS to facilitate this goal. However, three large agencies – ESA, France, and Japan – reported that it may be difficult for them to participate in human exploration missions beyond low Earth orbit while either committed to supporting ISS operations or until the way ahead is determined and their responsibilities for such missions become clearer. As a result, some agencies are focusing their resources on robotic rather than human exploration missions to deep space. For example, India launched the Mars Orbiter spacecraft in November 2013 to observe the physical features of the Red Planet and study the Martian atmosphere. Similarly, ESA landed the unmanned Philae spacecraft on a comet in 2014 as part of its Rosetta mission with the goal of following the comet on its journey through the inner solar system and measuring the increase in activity as the comet's icy surface is warmed by the Sun.

Almost every international partner we surveyed indicated they place a high priority on understanding the Earth's environment and are therefore supporting projects that focus on the climate, the planet's radiation belts, and the changing environment. For example, NASA and Japan partnered on the Global Precipitation Measurement mission, which is providing observations of worldwide precipitation every 3 hours to help advance understanding of the Earth's water and energy cycles and improve forecasting of extreme weather events. Similarly, NASA worked with Germany on the Gravity Recovery and Climate Experiment (GRACE) mission, which launched in March 2002 and uses two identical spacecraft to map variations in the Earth's gravity field and provide information about the distribution and flow of mass within the Earth and its surroundings.[35]

Finally, international partners indicated a high priority in developing space capabilities that benefit their citizens and on which their domestic industries can build. For example, Japanese officials noted that it has been increasingly difficult to fund space endeavors that do not provide an immediate and tangible benefit to Japanese citizens in a way similar to communications, weather, and navigation satellites built in Japan.

TECHNICAL AND FINANCIAL CAPABILITIES

International collaboration taps into the technical and financial resources of multiple countries to increase the scope of projects beyond the capabilities of individual participants. These partnerships give nations the opportunity to participate in major projects they otherwise could not have accomplished on their own. For example, Canada contributed the Alpha Particle X-ray Spectrometer to NASA's Mars Curiosity Program, which landed on Mars in 2012.[36]

We examined the technical and financial capabilities of 17 space agencies – NASA, the 14 international partners we surveyed, and the Chinese and Russian space agencies – and categorized each agencies' technical capabilities as "demonstrated" or "emerging." For the purposes of our analysis, a demonstrated capability is one the agency has previously performed or demonstrated, while an emerging capability is one the agency has begun to develop but has not demonstrated fully. We grouped the technical capabilities into seven broad categories:

- **Aeronautics** – includes capabilities associated with vehicles traveling through the air, such as NASA's studies in hypersonic propulsion, Germany's capabilities in propulsion technology, and South Korea's work on advanced unmanned aerial vehicles and rotorcraft.
- **Beyond planet Earth exploration** – includes missions to the Moon, Mars, and other planets or celestial bodies, such as Australia's in situ resource utilization work; development of lunar orbiters by China, India, and Japan; ESA's Exobiology on Mars (ExoMars) mission; France's

[35] Due to an uneven distribution of mass inside the Earth, the planet's gravity field is not uniform. The GRACE mission will map out the precise location and size of the "lumps" in the gravity field, enabling greater understanding of the Earth's structure. Additionally, GRACE will monitor the mass and location of water as it moves around on the surface of the Earth, cycling between the land, oceans, and polar ice caps.

[36] The Alpha Particle X-ray Spectrometer is a lightweight instrument for determining the major and minor elemental composition of Martian soil, rocks, and other geological materials at the landing sites.

emerging capabilities with on-orbit storage, transfer, and measurement of cryogenic propellants; and the United Kingdom's work on lunar science.[37]

- **Earth science** – consists primarily of satellites and instruments designated for the study of Earth, such as Italy's work on remote sensing.[38]
- **General science and technology** – is a broad category consisting of capabilities that do not readily fall into the other seven areas, such as Australia's work on radio astronomy, Japan's and South Korea's developments in nanotechnology, and Spain's development of payloads.
- **Human space exploration** – encompasses all capabilities relating to human travel in space, such as astronaut training programs in Canada, ESA, Japan, and Russia, and Germany's developments in closed loop life support technology.
- **Launch systems** – includes rockets that launch payloads or spacecraft into space, such as Japan's cryogenic propulsion stage developments and launchers and associated launch sites developed by Brazil, ESA, Japan, and South Korea.
- **Space-based technology** – includes technologies developed for use in space, such as Ukraine's work on technologies to monitor objects in low Earth orbit from space and work by Argentina and France on satellites and space technologies.

Technical Capabilities

As shown in Table 4, the space agencies displayed a wide range of emerging and demonstrated technical capabilities. All 17 agencies demonstrated capabilities in the general science and technology category and 15 of the 17 in the space-based technology category. In the Earth science category, 12 agencies demonstrated capability, while 5 show emerging capability. For example, Japan has demonstrated Earth science capabilities in high-definition optics, while the United Kingdom has emerging capabilities in Earth observation technology. In addition, in the beyond planet Earth exploration category, 14 agencies exhibited demonstrated or emerging technologies. China and India have shown they can build and launch lunar orbiters and Germany is demonstrating emerging capability with precise landing technology. Finally, 11 agencies exhibited capabilities in human space exploration, including demonstrated success by ESA, Germany, Italy, and Japan with pressurized space modules and Canada's emergent work in medical autonomy.[39] ESA also has demonstrated capabilities with flight service modules, as exemplified by its barter arrangement with NASA to provide the service module for the scheduled 2018 launch of Exploration Mission-1 and hardware components for Exploration Mission-2.

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[37] In situ resource utilization is the collection, processing, storing, and use of materials encountered in the course of human or robotic space exploration that replace materials a mission would otherwise bring from Earth. Examples include rocket propellant, life support gases, reactants for power production systems, or materials for manufacturing spare parts or planetary surface infrastructure.

[38] Remote sensing systems operate by sending laser pulses into the atmosphere and recording the backscattered light using telescopes with sensitive photodetectors.

[39] Canada's autonomous medical care system is intended to provide medical support to crews on long duration missions. The system is designed to provide the combined clinical expertise of an emergency room physician, psychologist, occupational therapist, and family physician.

Table 4: Demonstrated and Emerging Technical Capabilities for Selected Space Agencies

Technical Capability	Country or Space Agency																	Total Demonstrated	Total Emerging
	Argentina	Australia	Brazil	Canada	China	ESA	France	Germany	India	Italy	Japan	Russia	South Korea	Spain	Ukraine	United Kingdom	United States		
Aeronautics								●			●	x	●	●			●	5	1
Beyond planet Earth exploration		x		●	●	●	●	●	●	●	●	●	x	●		●	●	12	2
Earth science	●	x	x	●	●	●	●	●	●	●	●	●	x	x	x	●	●	12	5
General science and technology	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	17	0
Human space exploration		●		●	●	●	●	●	x	●	●	●					●	10	1
Launch systems	x		x		●	●	●		●		●	●	●		x	x	●	8	4
Space-based technologies	●	x	●	●	●	●	●	●	●	●	●	●	●	●	x	●	●	15	2

Source: NASA Office of Inspector General.

Note: ● denotes a demonstrated capability and **x** an emerging capability.

We found that two of NASA's three strategic goals – (1) expand the frontiers of knowledge, capability, and opportunity in space and (2) advance understanding of Earth and develop technologies to improve the quality of life on our home planet – align with the current capabilities of the selected international partners.[40] However, the driving factor behind reaching those goals and maximizing technical capabilities is the financial capability of foreign agencies.

Financial Capabilities

NASA has the largest budget of all space agencies – $18 billion in fiscal year 2015.[41] However, when comparing space agency budgets as a percentage of a country's gross domestic product (GDP), NASA ranks third behind Russia's Roscosmos and Germany's space agency with a ratio of GDP to budget of 0.099 percent as compared to Russia's 0.182 percent ratio and Germany's 0.110 percent ratio, when ESA contributions and non-ESA budgets are combined. Table 5 compares the 2015 budgets for selected agencies with their country's 2015 estimated GDP.

[40] The third goal – serve the American public and accomplish our mission by effectively managing our people, technical capabilities, and infrastructure – is more specific and subjective, and therefore harder to quantify based on the technical capabilities identified.

[41] NASA was appropriated a budget of $19.3 billion in fiscal year 2016.

Table 5: Selected Space Agency Budgets and GDP

Country or Agency	Dollars in Billions			Percent	
	2015 Agency Budget		2015 GDP[a]		
Argentina	$0.20		$563	0.035%	
Australia	0.06		1,252	0.005	
Brazil	0.25		1,904	0.013	
China[b]	5.00		11,212	0.045	
ESA[c]	4.97		18,843	0.026	
	Agency Budget Excluding ESA Contribution	Agency Budget Including ESA Contribution		Percent Excluding ESA Contribution	Percent Including ESA Contribution
Canada	0.34	0.36	1,615	0.021	0.022
France	1.38	2.31	2,470	0.056	0.093
Germany	2.84	3.74	3,413	0.083	0.110
Italy	0.17	0.62	1,843	0.009	0.033
Spain	0.11	0.26[d]	1,230	0.009	0.021
United Kingdom	0.12	0.48	2,853	0.004	0.017
India	1.12		2,308	0.049	
Japan	1.28		4,210	0.030	
Russia	2.15		1,176	0.182	
South Korea	0.42		1,435	0.029	
Ukraine	0.02		85	0.022	
United States	18.01		18,125	0.099	

Source: NASA Office of Inspector General.

[a] 2015 GDP information is based on estimates from the International Monetary Fund.

[b] The budget for China is an estimate drawn from information provided by OIIR. Actual budget information is not publicly available.

[c] The ESA data includes Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom. The GDP for ESA was calculated by adding the GDPs for each member state. For the six countries that contribute to ESA but also have separate space budgets – Canada, France, Germany, Italy, Spain, and the United Kingdom – we also show budget and percentage data including and excluding their ESA contributions. Canada takes part in some projects under a cooperation agreement.

[d] Spain's contribution to ESA is not funded through its space agency, but through the Center for the Development of Industrial Technology.

NASA and its international partners cooperate in a variety of large and small missions with varying technical and financial capabilities. For example, of NASA's 17 major Earth science missions currently in orbit, 10 involve international cooperation.[42] As shown in the following case study, the joint NASA, ESA, and Italian Cassini-Huygens mission represents a successful large-scale international planetary science mission.

[42] Because its mission extends beyond Earth science, we did not include the ISS in this category.

CASE STUDY: THE CASSINI-HUYGENS MISSION

Launched in 1997, the Cassini-Huygens mission includes the Cassini orbiter, which orbits Saturn, and the Huygens probe, which carried six instruments and landed on Titan, Saturn's largest moon. Cassini completed its primary mission in June 2008, but has been extended twice. The most recent extension includes a series of close passes between the innermost rings and the planet followed by planned entry into its atmosphere in September 2017, which will destroy the spacecraft.

"Europe therefore views any prospect of a unilateral withdrawal from the cooperation on the part of the United States as totally unacceptable. Such an action would call into question the reliability of the U.S. as a partner in any future major scientific and technological cooperation."

- Jean-Marie Luton (director general of ESA), June 14, 1994

The technical development effort for the mission was extremely difficult, earning a 96.8 percent complexity rating from the Aerospace Corporation. The United States, 16 European countries, and more than 5,000 scientists and engineers have participated in designing, building, flying, and collecting data from the mission. NASA's Jet Propulsion Laboratory built and manages the Cassini, while ESA built the Huygens probe and Italy provided the mission's communication antenna. The orbiter's 12 science instruments included two European-built instruments along with extensive international collaboration on each science team. The probe's six instruments were each developed by different international teams.

The total original cost of the Cassini-Huygens mission was about $3.26 billion, including $1.4 billion for pre-launch development, $422 million for the launch vehicle, and $809 million for operations and tracking the orbiter and probe. The United States contributed $2.6 billion (80 percent), ESA $500 million (15 percent), and Italy $160 million (5 percent). Although the cost of the mission was over 10 times higher than the $287 million average cost of a NASA planetary science project in the 1990s, development cost growth decreased by 4.2 percent. Program officials were able to manage instrument costs through a resource exchange approach that allowed teams to trade mass, power, data rate, and budget. As a result, all instruments were built and delivered on time and the overall cost of the science payload grew by less than 1 percent.

Artist's Concept of Cassini Orbiting Saturn

Source: NASA/Jet Propulsion Laboratory.

Even so, the mission went through a series of reviews and re-scoping and became a contentious international issue when NASA Administrator Dan Goldin considered cancelling it in 1994. In an article for The Planetary Society, Mission Manager Charles Kohlhase wrote the following: "With many countries participating in this great mission, none of us could imagine Goldin taking this drastic step and damaging our country's relationship with the Europeans. To our joy, on June 14, 1994, Jean-Marie Luton (then director general of ESA) sent a powerful letter to Vice President Al Gore, with copies to the [United States] Secretary of State, key office directors, and of course Dan Goldin." The letter concluded with a paragraph Kohlhase described as having saved Cassini from the budget axe: "Europe therefore views any prospect of a unilateral withdrawal from the cooperation on the part of the United States as totally unacceptable. Such an action would call into question the reliability of the U.S. as a partner in any future major scientific and technological cooperation."

CHAPTER 2

Cost Implications for International Space Projects

Although international projects tend to be larger in size and scope, more complex, and more expensive overall, average cost growth for unmanned and robotic projects in which NASA collaborated with foreign space agencies was lower than average in comparison to both NASA-only projects and projects in which NASA worked with other Federal agencies. In contrast, the ISS experienced significant cost growth and schedule slippage during its 21-year development; however, this was not necessarily due to the international nature of the Station. The fact that numerous countries contributed to building and maintaining the ISS is one factor that may have contributed to the mission's longevity and ability to persevere in the face of significant cost increases and schedule slippage. The ISS development experience has aided NASA and the international partners in establishing a series of "ground rules" regarding international collaboration that may prove useful in future joint endeavors, including human exploration of Mars.

Cost Sharing and Reduced Cost Growth on Unmanned and Robotic Projects

At our request, the Aerospace Corporation (the Corporation) examined data from more than 90 NASA projects launched between 1989 and 2015.[43] This analysis revealed that average cost growth for unmanned and robotic projects involving other space agencies – such as the Magnetospheric Multiscale (MMS) and the Gravity Recovery and Climate Experiment (GRACE) missions – was lower than the average growth in both NASA-only projects and projects in which NASA worked with other Federal agencies.[44] This is particularly noteworthy given that international projects tend to be larger in size and scope, more complex, and more expensive overall. For example, according to the Corporation's data

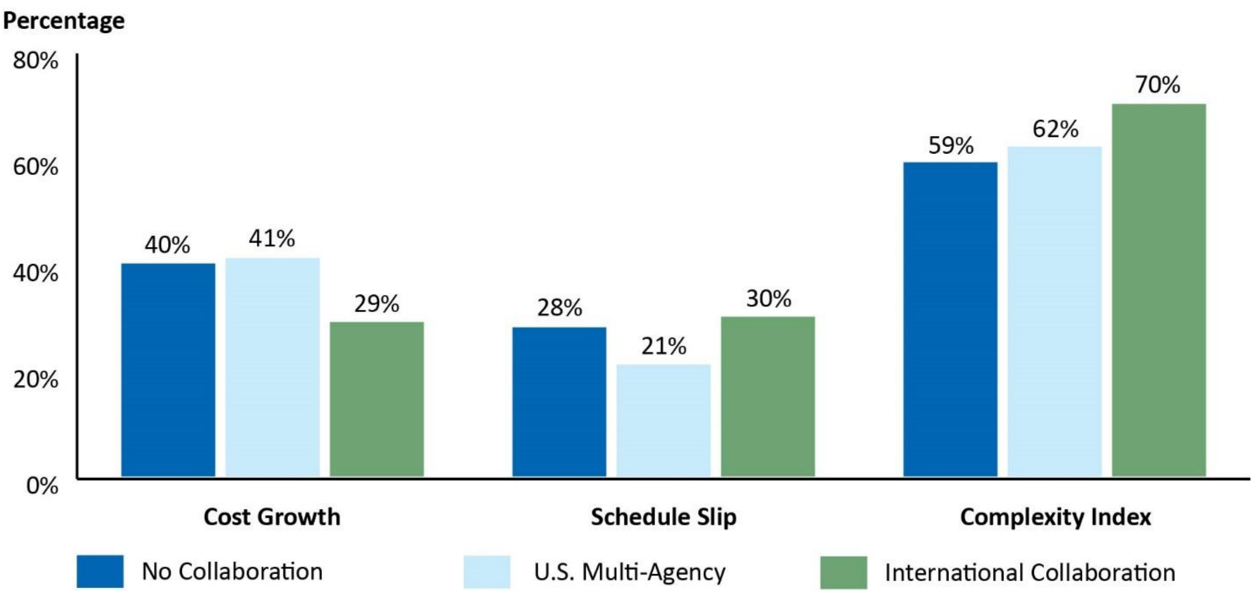
[43] The Aerospace Corporation is a nonprofit organization that operates a federally funded research and development center. The projects examined included NASA planetary, near-Earth, and Earth-orbiting spacecraft, as well as other U.S. Government satellite systems but did not include manned spacecraft such as the ISS.

[44] The Corporation provided similar information for an NRC report, "Assessment of Impediments to Interagency Collaboration on Space and Earth Science Missions" (2011). Based upon the information available at that time, the NRC report concluded that international collaboration led to more cost growth than projects with no collaboration or U.S. multiagency projects. However, when we asked the Corporation to update that information for this review, the combination of a more stringent classification method for what was considered an "international" project and the addition of projects begun or completed since issuance of the 2011 NRC report resulted in the opposite conclusion – that projects with international collaboration actually experienced less cost growth. The Magnetospheric Multiscale mission investigates magnetic reconnection, that is, the process by which the Sun and Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other.

the average developmental cost for missions involving only NASA was $380 million while missions with international partners averaged $454 million.[45]

The Corporation concluded that NASA's international unmanned and robotic missions experienced an average of 29 percent cost growth during the development phase compared to 41 percent for multiagency projects and 40 percent for projects with no collaboration.[46] In addition, the international unmanned and robotic missions had a slightly larger schedule slip – 30 percent – compared to 21 percent for U.S. multiagency projects and 28 percent for projects with no collaboration. (For details on how the Corporation classified missions, see Appendix III.) The Corporation also rated the projects' technical complexity and found international missions were, on average, more complex (70 percent) than both U.S. multiagency missions (62 percent) and those with no collaboration (59 percent). Although one might expect more complex projects to experience greater cost growth, the Corporation's analysis showed this was not the case for international projects. Figure 7 compares the cost, schedule, and complexity of projects with international collaboration with those involving U.S. multiagency participation or no collaboration.

Figure 7: Cost and Schedule Growth and Complexity Indexes During Development for Selected Projects



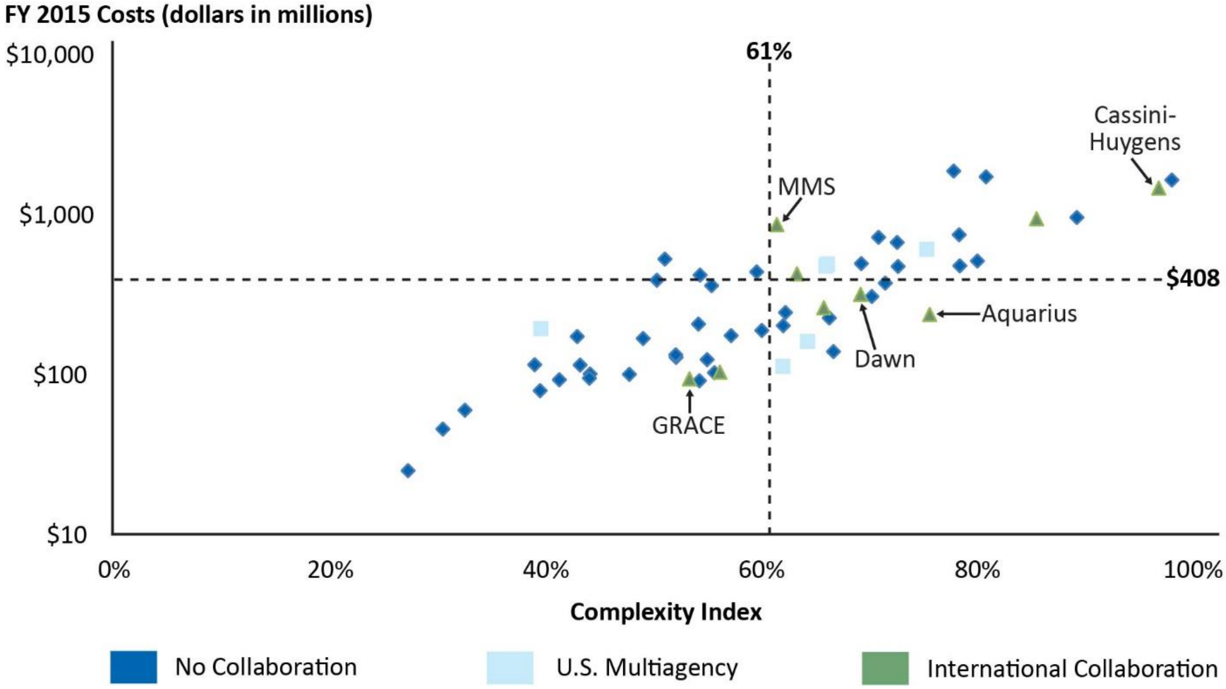
Source: NASA Office of Inspector General presentation of the Corporation's data.

Figure 8 shows the relationship between cost and complexity indexes of multiagency, international, and NASA-only projects. Of particular note, international projects tend to be more complex and expensive compared to NASA-only projects. For example, the Cassini-Huygens mission is a high-cost/high-complexity international mission that experienced little cost growth. For further information about the Cassini-Huygens mission, see the case study discussed in Chapter One of this report.

[45] Average developmental cost for U.S. multiagency projects was $494 million. (Averages are in nominal dollars.)

[46] Cost growth as discussed in this chapter pertains only to increased NASA cost and does not reflect cost growth that may have been experienced by partners.

Figure 8: Complexity of U.S. Multiagency Developments, International Collaborations, and No Collaboration versus Development Costs in Fiscal Year 2015 Dollars



Source: NASA Office of Inspector General presentation of the Corporation's data.

ALTHOUGH ISS EXPERIENCED SIGNIFICANT COST GROWTH AND SCHEDULE DELAYS, INTERNATIONAL PARTNERSHIPS CONTRIBUTED TO ISS PROGRAM STABILITY AND PROVIDED COST SHARING MODEL FOR FUTURE COLLABORATIONS

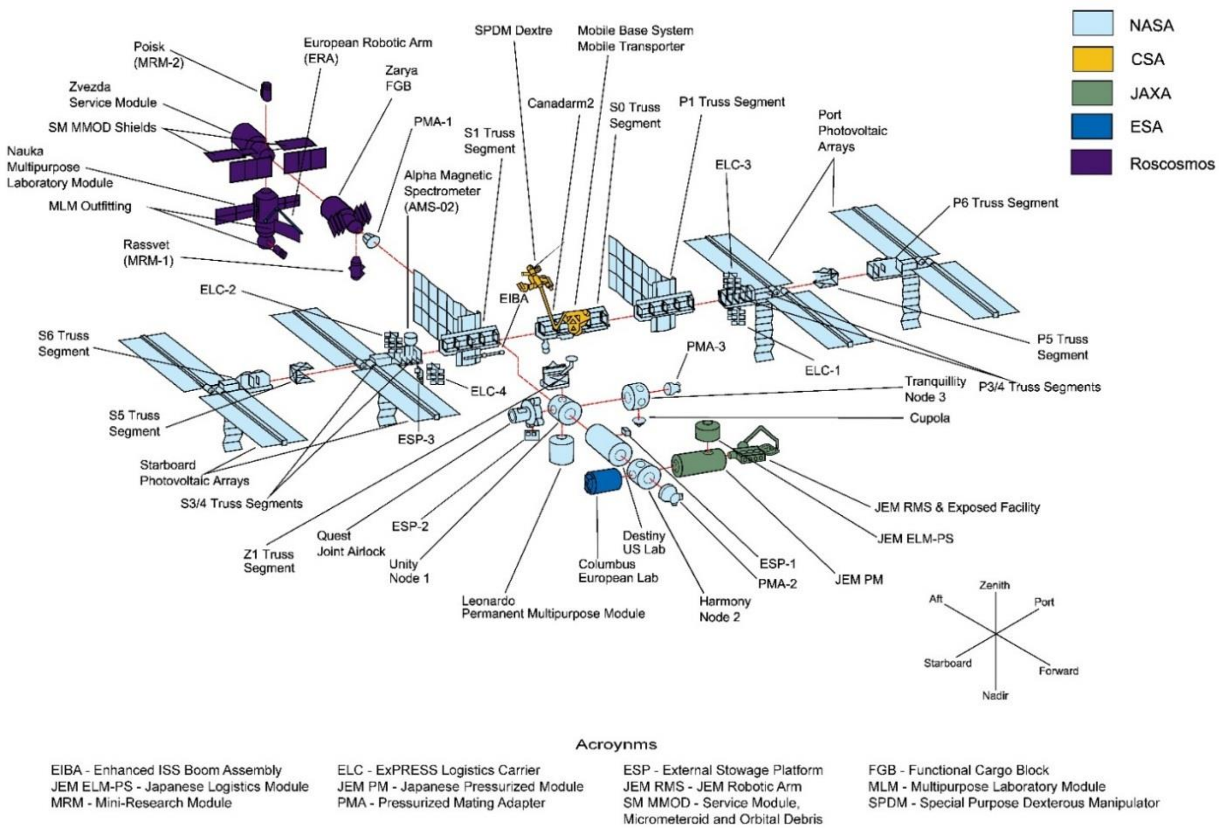
Although not necessarily due to the international nature of the project, the ISS experienced significant cost growth and schedule slippage during its 18-year development. NASA originally estimated in 1993 that assembly of the Station would be complete by 2002 at a total cost to the Agency of $17.4 billion. However, construction was not fully completed until 2011 at a total cost to NASA of over $37 billion including operations and research costs.[47] At the same time, NASA's international partners spent an additional estimated $24 billion – $12 billion from Russia, $5 billion each from ESA and Japan, and

[47] The original estimate of $17.4 billion to assemble the ISS, and the actual cost of over $37 billion do not include the associated Space Shuttle flights to assemble the ISS. Costs expended in the development of the ISS's predecessor, Space Station Freedom are also not included.

$2 billion from Canada – for ISS construction.[48] Through fiscal year 2015, NASA has spent approximately $81 billion for ISS development, operations, research, associated Space Shuttle flights, and cargo and crew transportation.[49] While NASA and its international partners share the Station's common systems operating costs, the United States provides approximately $3 billion in annual funding and pays for more than 75 percent of the shared costs of maintaining the portion of the ISS that NASA operates – also known as the U.S. Orbital Segment.

To date, more than 80 countries have contributed to ISS construction and maintenance and/or have utilized the Station's laboratories. Figure 9 shows the portions of the ISS built by the various partners.

Figure 9: Space Agency Contributions to ISS Construction



Source: NASA Office of Inspector General presentation of ISS Program information.

Note: CSA refers to the Canadian Space Agency and JAXA refers to the Japanese Space Agency.

[48] Funding from international partners was in accordance with the bartering agreements in place. The exchange of funds has been very infrequent under the ISS Program, such as the direct payments to Russia for crew transportation.

[49] Of the $81 billion spent through fiscal year 2015, Space Shuttle flights for assembly of the ISS constitute $30.7 billion. We validated construction and development, operations, and research costs; however, the actual cost of Shuttle flights is less certain. For example, Section 202 of the NASA Authorization Act for fiscal year 2000 (Pub. L. No. 106-391) established general cost limitations on the ISS and Space Shuttle programs and capped Shuttle costs at $380 million per launch. However, in August 2001 the GAO determined actual costs were closer to $759 million per launch. GAO, "NASA: International Space Station and Shuttle Support Cost Limits" (GAO-01-1000R, August 31, 2001). We used the GAO estimate (adjusted for inflation) in our cost calculation.

Throughout NASA's history, extensive cost growth and schedule delays have threatened continuation of some projects. For example, NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) Program – operated in cooperation with Germany – was threatened with cancellation for the second time in its history in March 2014 due to a 300 percent cost increase and 13-year delay in development and what some considered to be insufficient scientific contributions.[50] NASA's fiscal year 2015 budget proposal reduced funding for SOFIA by $75.1 million from the previous year and indicated that unless additional partners were identified to share the Program's $80 million annual operating costs, SOFIA would be put into storage. Subsequently, NASA made two attempts to attract additional partners, but no new partners had expressed interest. In the end, Congress funded the Program in fiscal year 2015 and it was not cancelled.

Despite the occasional threat of cancellation, international participation may help shield projects from this fate even if they prove more costly than originally anticipated. As discussed in the Cassini-Huygens case study, the influence of foreign partners can sway project funding decisions. Similarly, despite significant budget overruns and schedule delays, the ISS Program has continued and was extended twice beyond its original end date of 2013. As of March 2016, NASA plans to operate the Station until at least 2024, and three of the four international partners – Canada, Japan, and Russia – have agreed to participate in the extended mission.

The experience of NASA and its partners on the ISS led to establishment of several ground rules regarding international collaboration. Beginning with the first joint efforts with the United Kingdom in 1962, NASA collaboration with foreign space agencies has followed a model under which each country designates an agency to negotiate and supervise joint efforts, no funds are exchanged between agencies, project agreements are quite specific, and research results are published. According to NASA officials, the principle of no exchange of funds is particularly important because it decouples U.S. and foreign budgetary processes.

ISS Common System Operations Costs

The ISS is divided into two segments – the Russian Orbital Segment and the U.S. Orbital Segment. The U.S. Orbital Segment is comprised of hardware from NASA, ESA, and the space agencies of Canada and Japan. While the four agencies share the U.S. Orbital Segment's common system operations costs (see Figure 10), Russia alone is responsible for the operating costs of the Russian Orbital Segment.[51]

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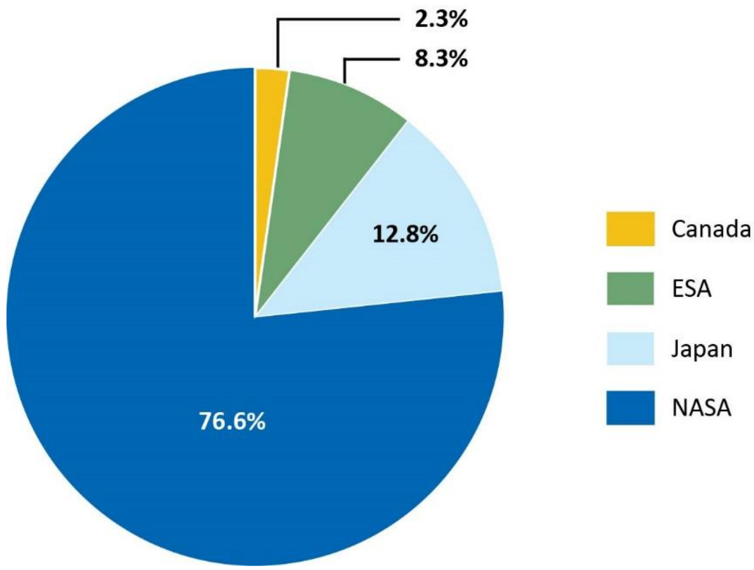
[50] SOFIA – a Boeing 747 aircraft modified to serve as an airborne observatory to study the universe in the infrared region of the electromagnetic spectrum – took 17 years to develop and cost $1.1 billion. As part of the agreement, Germany is expected to pay 20 percent of overall operating costs. The Program experienced significant cost increases and schedule delays during development before reaching full operational capability in February 2014. The baseline for the cost estimate and associated 300 percent cost increase was from 1997.

[51] Russia retains use of 100 percent of its laboratory modules and external payload sites.

Figure 10: Share of ISS Common System Operations Costs



Source: NASA Office of Inspector General presentation of ISS Program information.

Beginning in 1998, Memoranda of Understanding between NASA and its partners have established a direct link between the allocation of resources and the financial responsibilities of the partners, stating:

> NASA, [ESA] and the other Partners will equitably share responsibilities for the common system operations costs or activities . . . attributed to the operation of the Space Station as a whole . . . [Roscosmos] will be responsible for the share of the common system operations costs or activities corresponding to the operation of the elements it provides. NASA, ESA, the [Government of Japan] and CSA [Canadian Space Agency] collectively will be responsible for the share of common system operations costs or activities corresponding to the support of the operation of elements they collectively provide using the following approach: each will be responsible for a percentage of common system operations costs or activities equal to the percentage of Space Station utilization resources allocated to it . . .[52]

In addition to common system operations, each partner is also financially responsible for costs or activities attributed to operating and sustaining the functional performance of the ISS flight and ground elements it provides.

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[52] Memorandum of Understanding Between the National Aeronautics and Space Administration of the United States of America and The Russian Space Agency Concerning Cooperation on the Civil International Space Station, January 29, 1998. Memorandum of Understanding Between the National Aeronautics and Space Administration of the United States of America and The European Space Agency Concerning Cooperation on the Civil International Space Station, January 29, 1998. Memorandum of Understanding Between the National Aeronautics and Space Administration of the United States of America and The Canadian Space Agency Concerning Cooperation on the Civil International Space Station, January 29, 1998. Memorandum of Understanding Between the National Aeronautics and Space Administration of the United States of America and The Government of Japan Concerning Cooperation on the Civil International Space Station, February 24, 1998.

A partner's percentage of common costs is directly tied to their utilization of the Station. As construction on the ISS was completed, research became the Station's main focus and is the primary benefit countries obtain for their contributions to Station operations. Each partner conducts experiments using the onboard facilities, and in recent years, utilization for these purposes – as measured by crew time, for example – has increased significantly. Table 6 shows the percentage of user accommodations and utilization resources allocated to each partner on the U.S. Orbital Segment.

Table 6: Allocation of ISS Research Facilities and Resources

U.S. Orbital Segment Research Facilities	Percentage of Partner Allocations			
	United States	Canada	ESA	Japan
U.S. laboratory, external sites	97.7%	2.3%	0%	0%
European Columbus Orbital Facility	46.7%	2.3%	51.0%	0%
Japanese Experiment Module	46.7%	2.3%	0%	51.0%
Utilization resources	76.6%	2.3%	8.3%	12.8%

Source: NASA Office of Inspector General presentation of NASA and international partners' Memoranda of Understanding information.

Bartering System

The Memoranda of Understanding state that the partners should seek to minimize an exchange of funds and instead provide a service or capability. For example, ESA and Japan have provided supplies and research materials with their cargo transportation vehicles – the Automated Transfer Vehicle and the H-II Transfer Vehicle – in order to cover their shares of the Station's common system operations costs. Furthermore, when the continued production of ESA's Automated Transfer Vehicle beyond 2014 became cost prohibitive and it needed to be retired, NASA and ESA reached an agreement in which ESA agreed to provide the Orion Multi-Purpose Crew Vehicle service module for Exploration Mission-1 and other hardware components for Exploration Mission-2 to meet its obligation for common system operations costs.

Despite the relative success of the barter system in ISS operation, some of the partners we surveyed expressed concern that the arrangement has proven inflexible when partners experience funding challenges. In a rare instance, one partner entered into a bilateral arrangement with NASA to reduce its share of Station common system operations costs. The partner negotiated with NASA to cede a percentage of crew utilization time, upmass, and crew flight opportunities in exchange for reducing its portion of shared costs.[53] However, instances like these are uncommon, and the terms agreed to in the Memoranda of Understanding have remained relatively stable over time.

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[53] Upmass is the delivery of supplies and equipment to the Station, while downmass is return of equipment and experiments to Earth and/or disposal of waste.

ISS Cost Sharing in Perspective

The ISS is an example of a technically and politically complex program that utilize partner contributions – astronauts, ground facilities, launch services, and other items and services – to develop, operate, and sustain a multi-decadal, multinational effort. However, Canada, ESA, and Japan spend significant portions of their space budgets on maintaining the ISS, and according to officials from these agencies, they struggle with securing significant funds for a Mars exploration mission while that obligation continues. While the partners recognize human exploration missions have the potential to generate significant technological and scientific developments, they also point to the significant funding demands of such missions and the often lengthy periods of time they take to produce tangible returns such as scientific discoveries or the application of the new technology to everyday lives. Concerns such as these may affect the willingness and ability of foreign space agencies to participate in deep space human exploration missions and instead lead them to shift focus to areas with higher and timelier returns on investment, such as Earth science and lunar missions.

CHAPTER 3

Challenges to International Partnerships

We identified four issues that complicate NASA's relationships with international partners and present possible barriers to expanding such partnerships. First, the process of developing agreements with foreign space agencies requires approval from State and can often take many months, if not years, to complete. Second, NASA and its partners must comply with complex U.S. export control regulations that can delay cooperative efforts and inhibit the exchange of technical information. Third, a lack of strong, centralized international coordination groups and restrictions on the number of NASA employees who may attend international conferences make dialogue between NASA and foreign partners more difficult. Finally, both the U.S. political process and geopolitical realities complicate NASA's efforts to expand international partnerships, particularly with the Russian and Chinese space agencies.

AGREEMENT PROCESS OFTEN LENGTHY

The procedure NASA follows for reviewing, negotiating, and approving international agreements – known as the C-175 process – requires coordination with the interagency community, approval by State, and is rarely completed within established timeframes. The result can be project delays and uncertainty for both NASA and its partners. Ten of the 15 space agencies we surveyed cited agreement processing time as a factor that complicates collaboration with NASA. It can take many months of negotiating between NASA and its partners before an agreement is finalized. Moreover, we found that a limited number of State Department staff, and in particular only one legal officer, is assigned to review NASA agreements. In an effort to expedite the process, State and NASA have agreed upon standardized implementing agreements under existing frameworks that allow for a 2 week processing period. NASA currently has frameworks with 12 foreign partners and is working toward frameworks with 5 others.

C-175 Process

The C-175 process is intended to ensure proper exercise of the treaty making powers of the Federal government. Pursuant to the process, State must approve agreements with foreign governments that meet the criteria set forth in the Case-Zablocki Act.[54] In determining whether an agreement is governed by the Act, State applies five criteria: (1) identity and intention of the parties, (2) significance of the

[54] U.S. International Agreements; Transmission to Congress, 1 U.S.C. § 112b (December 17, 2004).

arrangement, (3) specificity of the parties' responsibilities, (4) necessity for multiple parties, and (5) the format of the agreement.[55] If the Act applies, the agreement must go through the C-175 process. State approval is not required for international agreements that are "not significant" or are governed by U.S. law.

OIIR is the NASA office responsible for coordinating the C-175 process with State. Generally, OIIR receives a request from a NASA Mission Directorate or Center to work with a foreign partner and prepares a proposed agreement for internal review by the applicable program office, the Chief Financial Officer, General Counsel, export control officials, and other relevant offices. After obtaining all internal concurrences, OIIR prepares a C-175 package for submission to State. The package consists of (1) an action memorandum addressed to the Assistant Secretary of State's Bureau of Oceans and International Environmental and Scientific Affairs requesting authority to proceed, (2) a draft of the proposed agreement, (3) a draft information memorandum for the Under Secretary of State for Space and Science Technology, and (4) e-mails addressed to any other Federal agencies that may need to review the request.

A State action officer is assigned to handle all NASA agreements, as well as agreements involving the Department of Energy, the Federal Aviation Administration, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the U.S. Geological Survey. Upon receipt of a package from NASA, the action officer verifies the completeness of the package, determines if it needs an interagency review, and makes any necessary edits to the action memorandum. The action memorandum, draft agreement, and associated documents are circulated through several State offices as well as the Office of Science and Technology Policy in the White House, the Office of Management and Budget, the Office of the U.S. Trade Representative, and any other U.S. Government departments and agencies that have interest in the matter.[56] When all clearances are received and any changes cleared with the originating agency, the action officer modifies the action memorandum as necessary and submits the draft agreement to the Assistant Secretary for signature. According to federal guidance, the officer should complete this initial review process in 20 days.[57]

Approved packages are then returned to OIIR, which now has the authority to negotiate and conclude the final agreement with the partner. Once the partners have agreed to terms, OIIR resubmits the agreement to State for final approval. Thereafter, any substantive changes to the agreement, including extensions, generally must go through a new C-175 process. Figure 11 outlines the C-175 process.

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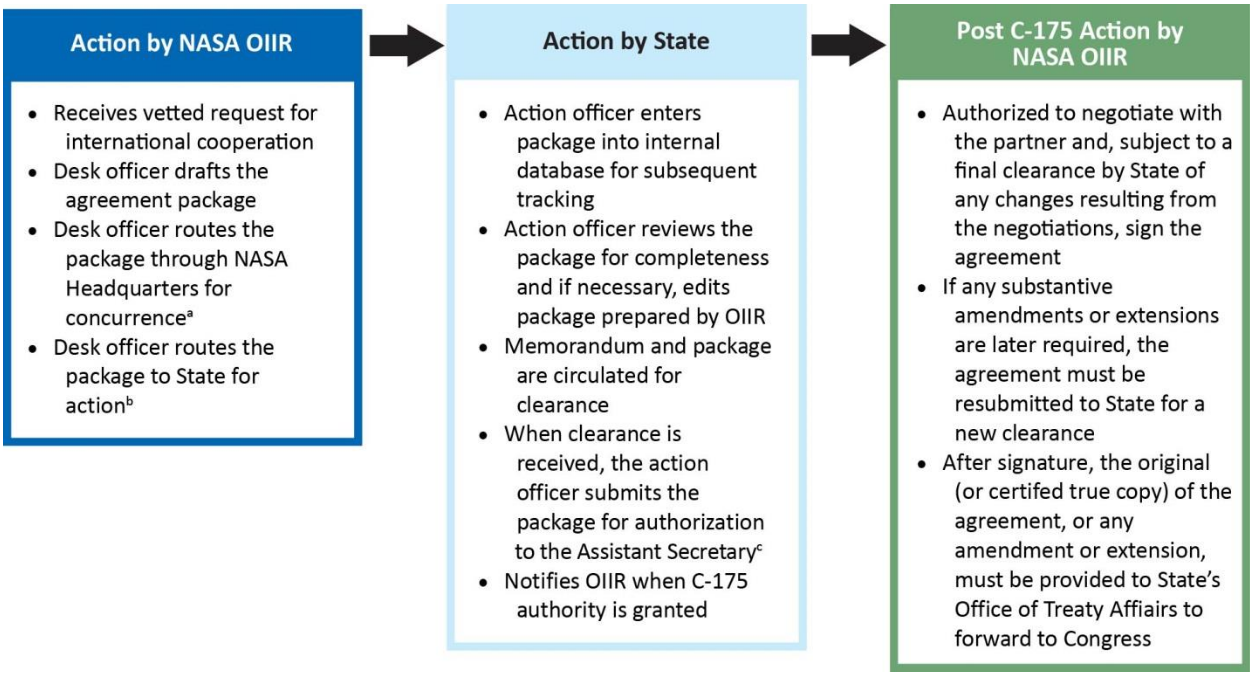
[55] Identity and intention of the parties includes whether the parties intend for the agreement to be governed by international law.

[56] Within State, the C-175 packages are reviewed by the Assistant Legal Adviser for Treaty Affairs, the Assistant Legal Adviser for Oceans and International Environmental and Scientific Affairs, the Assistant Legal Adviser for the particular geographic region, and the country and regional affairs desks of the appropriate regional bureau, among other offices.

[57] 22 C.F.R. § 181.4, Consultations with Secretary of State.

Figure 11: C-175 Process



Source: NASA Office of Inspector General presentation of NASA and State C-175 guidance.

[a] This includes a review by, among others, the OIIR Programmatic Lead, OIIR Division Director, Export Control Office, Program points of contact, other Mission Directorate officials, the Chief Financial Officer, and the Office of General Counsel.

[b] The package consists of an action memorandum addressed to the Assistant Secretary of the Bureau of Oceans and International Environmental and Scientific Affairs requesting authority to negotiate, conclude, or negotiate and conclude an agreement; a draft of the proposed agreement; an information draft memorandum for the Under Secretary for Space and Advanced Technology; and an e-mail for other Federal agencies that need to review the agreement. State reviews these documents for initial agreement approval.

[c] According to Federal guidance, the initial review process should be completed in 20 days.

Initial State Review Rarely Occurs in 20 Days

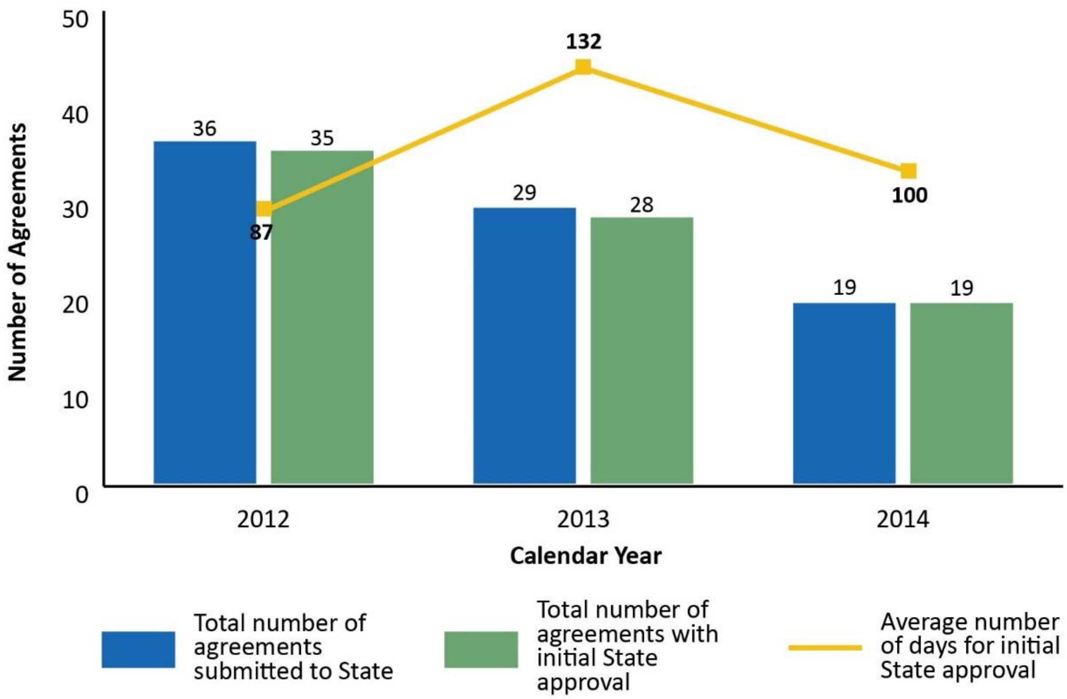
Although guidance states the initial review process should take no more than 20 days from NASA's submission of the C-175 package, State rarely meets this timetable.[58] From January 2012 through December 2014, OIIR submitted 84 agreement packages to State for review through the C-175 process. Two of these agreements – one of which had been awaiting approval for 681 days as of September 3, 2015 – had not received initial approval at the time of our field work.[59] Of the 82 approved packages, only 4 received initial approval within the 20-day timeframe. On average, the number of days to obtain initial approval exceeded the 20-day timeframe by 67 days in 2012, 112 days

[58] 22 C.F.R. § 181.4(c).

[59] The agreement waiting 681 days for approval is a proposed framework with Spain. We were informed that the delay was caused by other, higher-priority agreements. The second package awaiting review terminates agreements with Chile, France, and Spain relating to landing sites for the Space Shuttle, which NASA stopped flying in 2011.

in 2013, and 80 days in 2014.[60] Figure 12 shows the average number of days for initial approval from 2012 through 2014.

Figure 12: Average Number of Days for Initial State Approval, 2012–2014

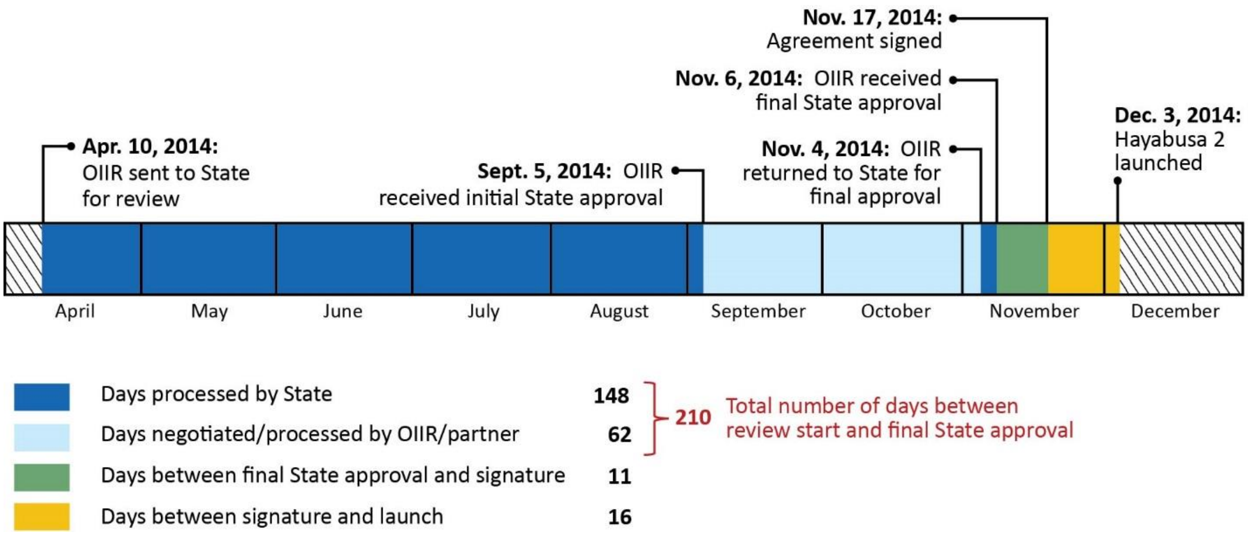


Source: NASA Office of Inspector General presentation of OIIR information.

One project that experienced a lengthy delay for initial State approval was Hayabusa 2, a cooperative mission between NASA and Japan to explore an asteroid, retrieve fragments, and return them to Earth. NASA sent the agreement package to State on April 10, 2014, but the package was not approved until 148 days later on September 5, 2014. After approximately 2 months of negotiating the final agreement, OIIR returned the package to State for final approval on November 4, 2014, which State granted 2 days later. The agreement was then signed on November 17, 2014, approximately 2 weeks before the mission launched. According to OIIR, the Hayabusa 2 agreement was complicated and therefore required extra time for negotiations. To keep the project moving forward while they waited for initial approval, NASA and Japan entered into an interim agreement governed by U.S. law that permitted planning work but did not address the actual launch and mission operations. Japanese officials told us the delay in obtaining initial approval did not cause significant issues for the mission, although they believed approval should have been granted sooner and pointed out it took much longer to work out the agreement with NASA than it does for agreements with commercial contractors. Figure 13 shows the timeline of State's approval process for Hayabusa 2.

[60] The calculation includes only the average number of days for initial approval for calendar years 2012 through 2014 because those years are complete. The average number of days for initial State approval from 2012 through 2014 was 87, 132, and 100, respectively.

Figure 13: Number of Days for State Approval of the Hayabusa 2 Agreement Package



Source: NASA Office of Inspector General presentation of OIIR information.

See Appendix IV for additional information on the timeline for initial approval of NASA agreements submitted to State between 2012 and 2014.

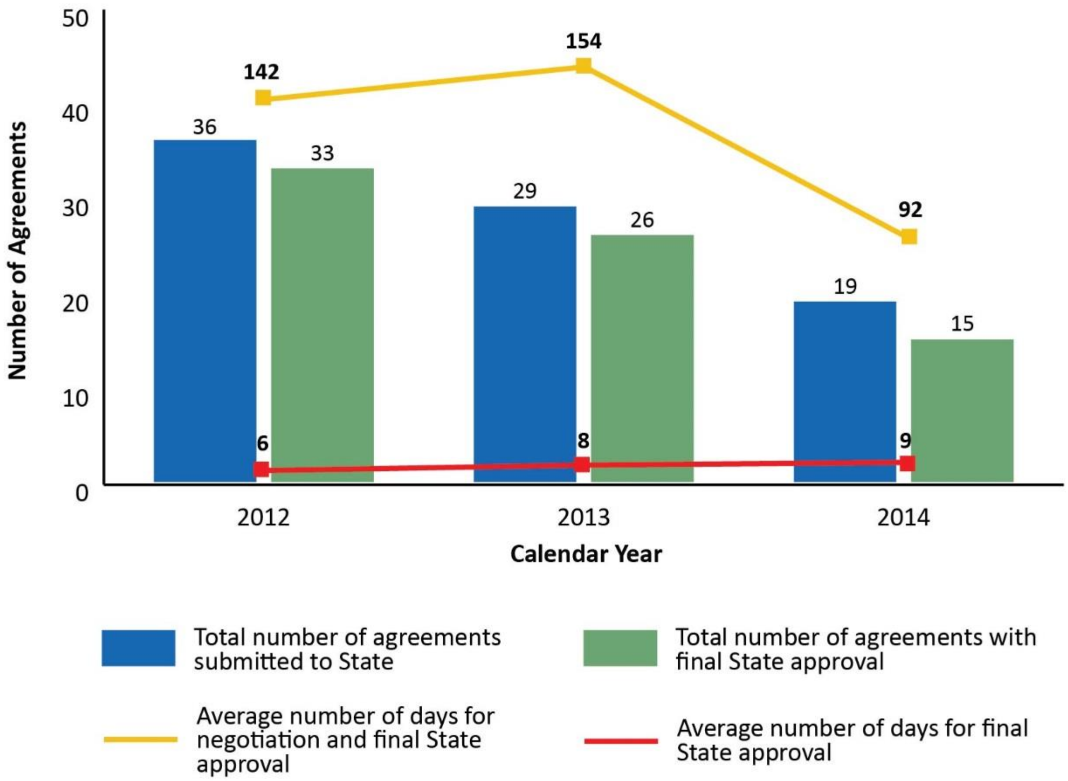
Negotiation Process to Secure Final Agreement Can be Lengthy

Once State approves NASA's initial C-175 package, the Agency is free to negotiate and finalize the agreement with its partners. The amount of time for negotiating and finalizing an agreement varies greatly depending on the nature and complexity of the agreement. Some agreements can be negotiated in very little time, while others take more than a year. For example, an interim agreement with ESA for the Jupiter Icy Moons Exploration mission that did not commit either NASA or ESA to actual development, took 2 days to negotiate, but negotiations for a different agreement with ESA for the Smart Sensor Inter-Agencies Reference Testbench continued for 440 days before final State approval.[61]

Typically, State reviews and approves final agreements relatively quickly, ranging on average from 6 to 9 days in the period we examined from 2012 through 2014. Of the 84 agreements NASA submitted to State during that period, 74 had received final approval at the time of our review. Figure 14 shows the average number of days for negotiation and final State approval for 2012 through 2014.

[61] The Jupiter Icy Moons Exploration mission is planned for launch in 2022 and arrival at Jupiter in 2030. It will spend at least 3 years making detailed observations of Jupiter and three of its largest moons: Ganymede, Callisto and Europa.

Figure 14: Average Number of Days for Negotiation and Final Department Approval, 2012–2014

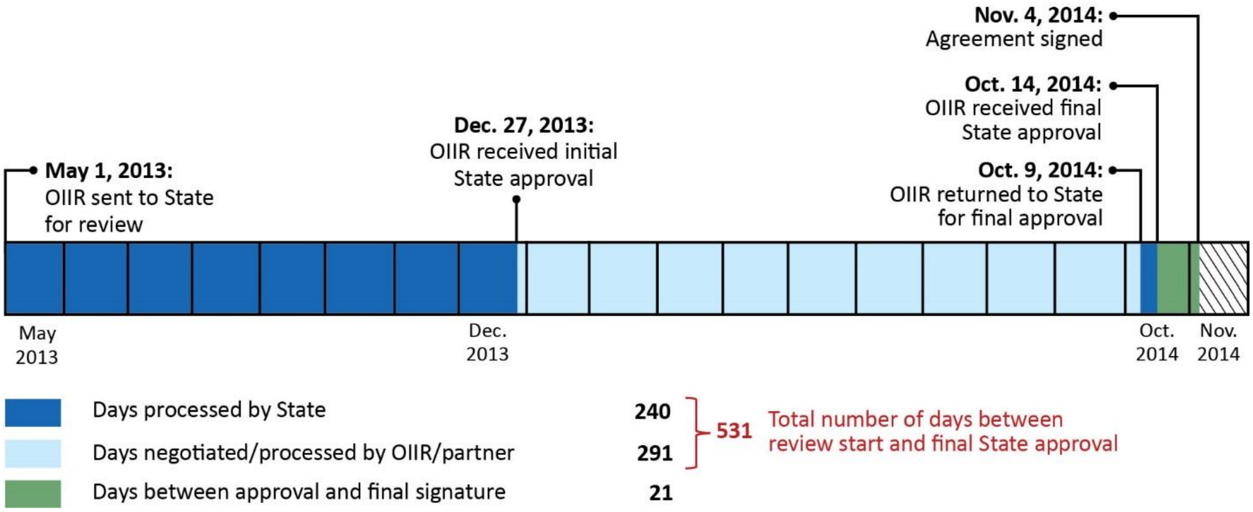


Source: NASA Office of Inspector General presentation of OIIR information.

Note: These figures are approximate because we were provided complete data for only 27 of the 33 agreements that received final approval in 2012, 22 of 26 agreements in 2013, and 14 of 15 agreements in 2014.

Not surprisingly, more complex projects often required more time to negotiate. For example, NASA and the German space agency negotiated for approximately 10 months before finalizing the implementing agreement for the InSight (Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) mission, which intends to place a lander on Mars in 2018 to study the planet's deep interior. Several international partners are involved in the development of the specialized instruments the mission will use. In fact, technical challenges relating to an instrument the French space agency is providing have caused NASA to delay the launch from 2016 to at least 2018. NASA submitted the initial agreement package for the mission to State on May 1, 2013, and received approval on December 27, 2013. NASA returned the package to State for final approval on October 9, 2014, and State granted final approval 5 days later. Figure 15 depicts the timeline for the InSight agreement process.

Figure 15: Number of Days for State's Final Approval of InSight Agreement Package



Source: NASA Office of Inspector General presentation of OIIR information.

Lengthy periods to negotiate and receive State approval can delay projects for months if not years. According to an ESA representative, reaching final agreement for the Jupiter Icy Moons Exploration mission has taken so long that the planning phase of the mission expired. Although this has not affected the planned launch date of 2022, extended planning due in part to agreement processing and procurement arrangements have reduced the mission's schedule margin. The Jupiter Icy Moons Exploration mission is a complex, Jupiter-bound mission that will include 10 instruments developed by scientific teams from 15 European countries, Japan, and NASA. NASA's contributions include an ultraviolet imaging spectrograph, a radar for icy moon exploration, and a particle environment package. The Agency sent the agreement package for a Memorandum of Understanding between NASA and ESA to State for initial approval on January 16, 2015, and the agreement package for an implementing agreement between NASA and Sweden on March 18, 2015. State granted initial approval for the packages 115 and 43 days later, respectively. As of November 9, 2015, NASA had been negotiating the final Memorandum of Understanding with ESA for 182 days and the agreement with Sweden for 193 days. Although NASA committed to this mission in early 2013 and had been working closely with ESA throughout the process, OIIR told us the length of the negotiation period was not unusual given the mission's complexity and the number of partners involved.

Factors that May Contribute to Lengthy Processing Times

We found that several factors may contribute to lengthy processing times of international agreements: (1) limited staff at State to process the agreements, (2) the requirement that all substantive modifications and extensions of existing agreements go through a separate C-175 review, (3) a tendency by State to view all NASA agreements as significant and therefore requiring review, and (4) NASA's manual process for internal review of agreement packages.

State Department Staff

We found that a limited number of staff, and in particular only one legal officer, is assigned to review NASA agreements. In addition to its NASA duties, State's Office of Space and Advanced Technology also reviews international agreements from the Department of Energy, the Federal Aviation Administration, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the U.S. Geological Survey. From 2012 through 2015, these agencies submitted 33 agreements to State for review. While State recognizes that the limited size of its staff dedicated to processing NASA agreements is one factor that has slowed the C-175 process, officials told us competing priorities prevent them from assigning additional staff to this task.

Separate Review for Modifications and Extensions

Federal regulation requires all extensions and substantive amendments to existing international agreements to undergo a separate C-175 review.[62] During 2014, NASA had 376 active agreements governed by international law, some of which may require modifications and/or extensions and therefore C-175 reviews. OIIR representatives told us NASA's partners view this process as unnecessarily rigid in that it fails to accommodate minor, routine modifications such as extensions that do not result in significant changes to the underlying agreement.

Characterization of All NASA Agreements as Significant

Federal regulation provides that minor or trivial undertakings, even if couched in legal language, are not considered "significant" and therefore do not require a C-175 review. State has the authority to determine whether a particular agreement qualifies as significant, and over the last 5 years, it has deemed all NASA agreements governed by international law significant. However, prior to this period, State did determine some agreements to be insignificant and thus not in need of a C-175 review. We reviewed 20 agreements submitted to State in 2014, and found that 4 agreements State determined to be significant may in fact be considered insignificant. Although this number is small, the time consuming nature of the C-175 process has acted as a barrier to receiving more requests. To this point, one large foreign space agency stated they try to work on smaller projects with space agencies other than NASA due to the amount of work and time required to gain approval.

NASA's Internal Review

NASA's internal, paper-based review process for agreement packages may also contribute to processing delays. Before an agreement package is submitted to State for approval, it is routed through NASA Headquarters for concurrence. This process involves review by at least seven NASA offices. Furthermore, the agreement package is hand-delivered to each office, adding processing time and making it harder for staff to track progress. Center and partner representatives indicated that a lack of communication with Headquarters and of a centralized OIIR database to track packages makes it difficult for a Center to monitor the status of agreements, leading to uncertainty regarding the timeframe for agreement approval.

[62] 22 C.F.R. § 181.2.

Frameworks: An Initiative to Streamline Agreement Processing

NASA and State acknowledge the agreement approval process takes too long and have taken steps to streamline the process. For example, State has established a 2-week processing period for implementing agreements established under existing frameworks. NASA has utilized framework agreements since the 1990s to establish standard legal language for activities involving the peaceful use of space and set the terms and conditions for implementing agreements between NASA and a foreign space agency. NASA executes frameworks when there is an identified need by a partner, a legal capacity issue regarding a partner, or a clear benefit to NASA. Table 7 shows the factors NASA considers in determining whether to enter into a framework agreement with a foreign partner.

Table 7: Factors Considered When Determining Whether to Execute a Framework

Factor	Description
Volume of agreements	Number of agreements NASA has with a particular partner at any given time
Partners	Number of different partners within a given country NASA works with, whether the partners are government organizations, and whether the partners can legally bind their government to an agreement
Utility of a framework	Whether the type of cooperation is unique and/or complicated
Type of agreements needed	Whether agreements not governed by international law can be used
Impact to existing agreements	Impact a framework may have on a given partner and whether existing agreements will have to be revised to conform to the framework

Source: NASA Office of Inspector General presentation of OIIR information.

NASA has established frameworks at the government level, and in cases where a foreign space agency has legal capacity to make binding international commitments, at the agency level as well. As of February 2016, NASA had established frameworks with 12 countries and is working on frameworks with 5 others. Table 8 gives the current status of countries or space agencies with frameworks.

Table 8: NASA Frameworks

Established Frameworks[a]	Frameworks in Progress[b]
Argentina Brazil Canada France German space agency Israel space agency Indian space agency Italy Norway Russia Ukraine Sweden	**Brazil** – new framework to replace existing framework signed in 1996; awaiting ratification in Brazil **Japan** – in negotiation between the U.S. and Japanese governments for several years **South Korea** – in negotiation between the U.S. and South Korean governments **Spain** – in C-175 review **Vietnam** – in negotiation between the U.S. and Vietnamese governments

Source: NASA Office of Inspector General presentation of OIIR information.

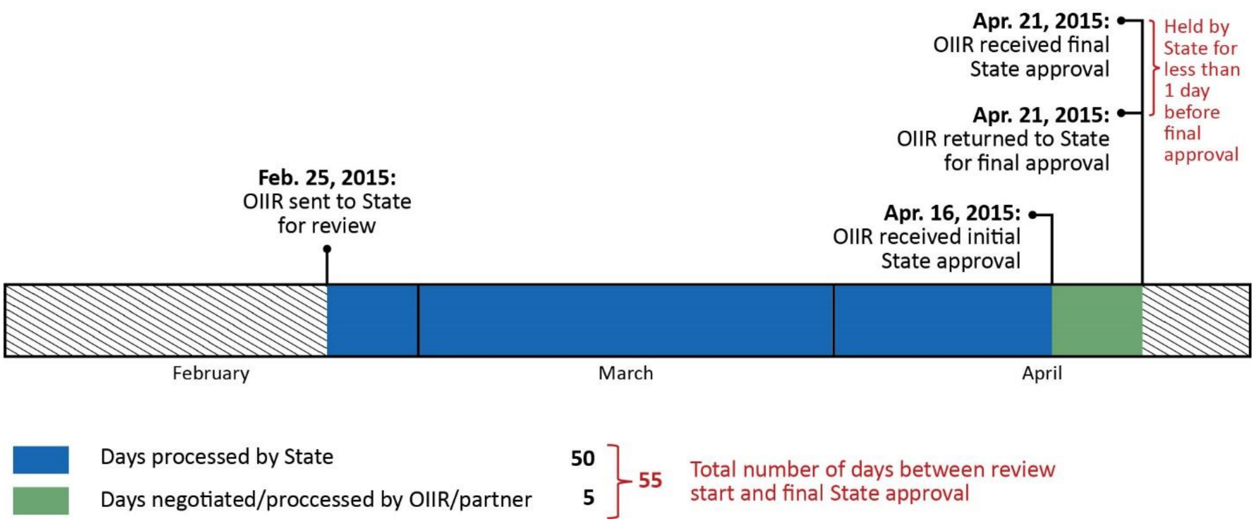
[a] Includes agreements that had not expired, been denounced by the parties, replaced or superseded by other agreements, or otherwise terminated as of the specified date.

[b] Includes agreements in various stages of negotiation and review.

At State's suggestion, NASA sought and received in June 2014 a modified approval process for new implementing agreements or extensions to existing implementing agreements with each of the countries and agencies with whom NASA has established frameworks in place, with the exception of Canada and Russia. Although this process still requires NASA to submit an implementing agreement to State for approval, it sets a 2 week timeframe for the action officer to obtain all necessary clearances and approvals and to issue guidance to OIIR that allows negotiations with the partner to proceed. While OIIR and State officials said they are hopeful this change will reduce processing times, too few implementing agreements have been submitted to date to assess its overall effect. We are aware of two instances in which the 2 week timeframe was not met. In one instance, an implementing agreement for aeronautics research with Germany had received initial State approval after 105 days.[63] In another case, State took 50 days to approve the implementing agreement for the Interface Region Imaging Spectograph with Norway (see Figure 16).

[63] The agreement was submitted to State on March 18, 2015, and received initial approval on July 1, 2015.

Figure 16: Number of Days for State Approval of the Interface Region Imaging Spectrograph Agreement Package



Source: NASA Office of Inspector General presentation of OIIR information.

Establishing a framework agreement is time consuming, and this type of agreement is not suitable for all of NASA's international partners. For example, frameworks do not make sense if NASA does not intend to expand cooperation beyond the current agreement or can use an agreement governed by U.S. law that does not require a C-175 review. Nevertheless, some partners with which NASA does not have or is not working toward a framework have expressed interest in establishing one. For example, ESA has proposed a possible framework to the Agency and is currently refining its proposal to specify the areas such a framework might cover.

We believe OIIR should consider establishing frameworks with additional countries. Although it takes time to establish framework agreements, the benefit is reduced time for approval of implementing agreements going forward. In addition, NASA should engage State in a discussion regarding determinations of agreement significance as a potential way to reduce the number of agreements that must go through the C-175 process. Internally, OIIR should increase the timeliness of its internal review process and consider establishing an electronic tracking system.

Export Control Restrictions Complicate the Exchange of Information Between NASA and Foreign Partners

A key aspect of international cooperation is the exchange of project information and technology between partners. Any such exchange is required to comply with U.S. export control regulations, which define an export as the "transfer of anything to a foreign person or foreign destination."[64] U.S. export controls are principally governed by two sets of regulations: the ITAR and the EAR. The ITAR is

[64] NASA Policy Requirement 2190.1B, "NASA Export Control Program" (December 27, 2011), p. 31.

administered by State and governs “defense articles,” including launch vehicles and certain spacecraft. The EAR governs “dual-use” items that have both military and commercial application, such as Global Navigation Satellite Systems. To transfer items or technologies covered by the ITAR or the EAR, organizations are generally required to obtain a license from either State or the Department of Commerce.

Thirteen international partners who responded to our survey identified U.S. export control regulations as a challenge to international cooperation, with one agency labeling the ITAR as “the largest inhibitor of technical exchange.”[65] Similarly, six of the seven NASA project managers we interviewed told us export control regulations have a detrimental impact on NASA projects involving foreign partners. According to the foreign partners and project managers, export control regulations affect project schedules, communication between NASA and its partners, and increase project costs.

Impact of Export Control Regulations on Partner Exchange

According to NASA project managers and international partners, U.S. export control regulations affect collaborations with foreign partners in three primary ways. First, ensuring compliance with export control regulations is time-consuming. NASA and its contractors are required to obtain licenses to export certain items and information, and some projects involve multiple pieces of equipment or technical information that require separate licenses. For example, NASA missions such as the GPM and the James Webb Space Telescope (JWST) tend to have up to five ITAR licenses each. It can take 6 months to obtain a license. In addition, NASA’s contractors use Technical Assistance Agreements to regulate communication of technical information to foreign entities. Technical Assistance Agreements, which also must be approved by State, can take up to 6 months to process. GPM, a smaller mission, has between 20–30 agreements, while larger projects such as the JWST can have 200 or more.

Second, U.S. export control regulations can impede communication among foreign partners. For example, the JWST, GPM, and MMS project teams described instances in which foreign partners experienced hardware complications NASA personnel knew how to solve. However, due to export control regulations and licensing delays, the project teams could not share their knowledge with the partners. Even if the regulations allow for the transfer of information or technology, they are complex, and project teams may mistakenly believe a particular transfer is not permitted. For example, there was an incident with the SOFIA Program in which a representative of the German space agency gave a technical document to NASA personnel; NASA officials did not understand that U.S. export control regulations allowed them to return this information to the Germans. As a result, NASA personnel unnecessarily undertook the lengthy process of obtaining a license to return the information. Multiple NASA project managers also complained about having to go through the NASA export control process when shipping a piece of technology back to the country from which it was originally obtained.

Finally, NASA project managers reported having to ask international partners to leave meetings due to U.S. export control restrictions. They indicated that excluding partners can be detrimental to relationships and make meetings less efficient. Several project managers told us they structured meetings to provide for both NASA-only and joint partner sessions to avoid having to ask partners to leave the room for ITAR-sensitive discussions. See Figure 17 for an outline of the process for sharing technical data with foreign partners.

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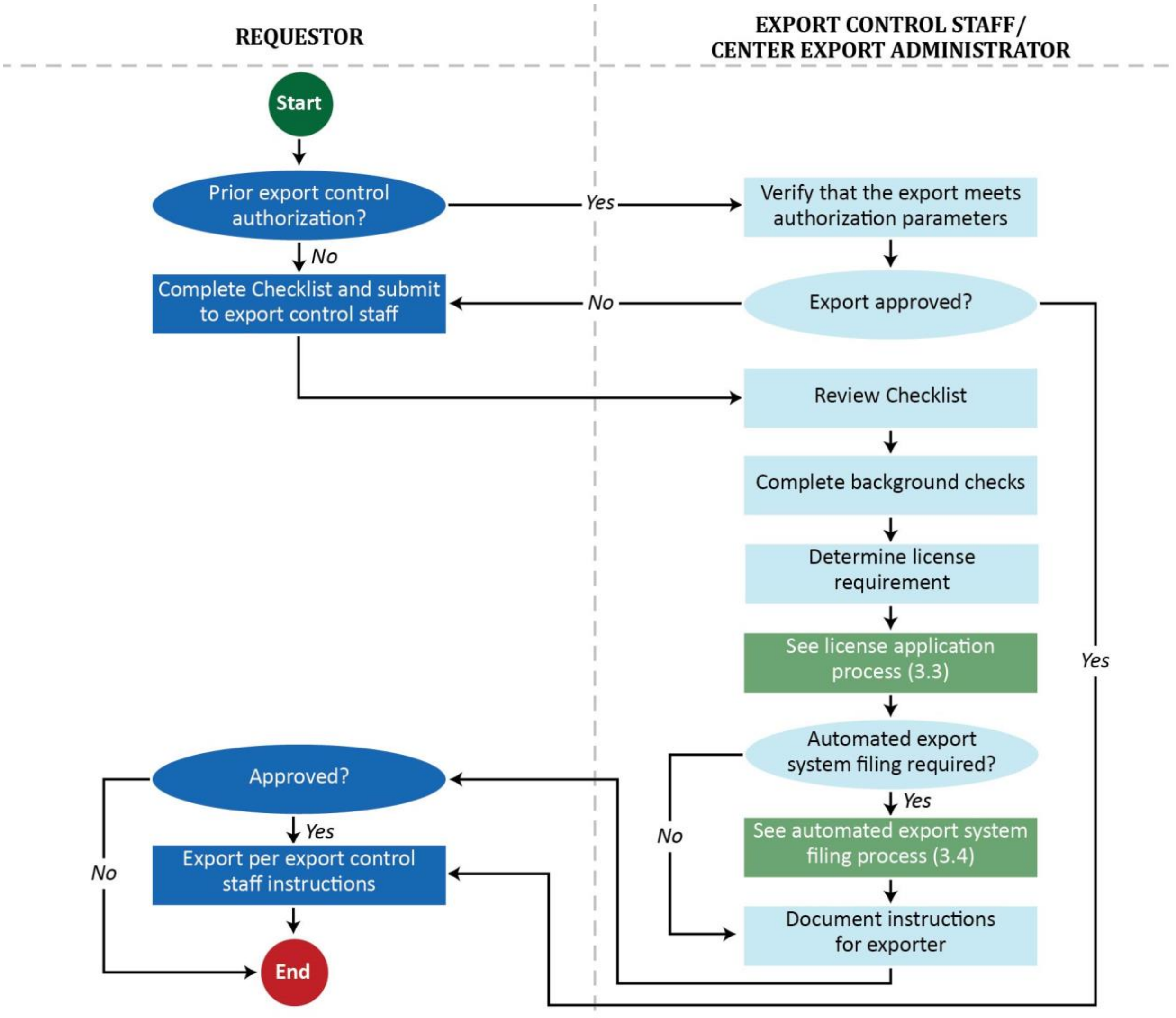
[65] One agency did not address export control issues.

Figure 17: Process for Sharing Technical Data or Technology with a Foreign Person



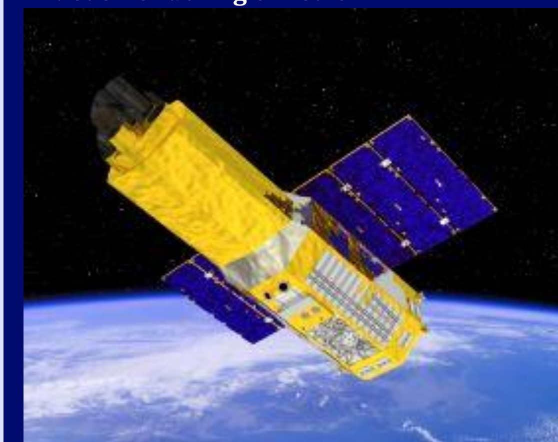
Source: NASA Advisory Implementing Instruction 2190.1, "Export Control Operations Manual," April 2015.

Complying with U.S. export control regulations also adds to project costs and requires a significant commitment in resources and training. In 2014, the Export Control Program at NASA Headquarters had a budget of approximately $868,000. In addition, each Center has assigned export control staff. NASA's contractors and international partners must have programs to ensure compliance with U.S. export control regulations. For example, Japan's space agency offers a basic ITAR training course to its employees every few months and an advanced ITAR training regularly. Furthermore, violations of U.S. export control regulations come with both civil and criminal liability. For example, in 2008, Northrup Grumman Corporation, the Boeing Company, and Lockheed Martin Corporation settled allegations of export control violations by agreeing to pay State a combined total of $22 million.[66] NASA personnel may also be subject to civil or criminal penalties for violating the regulations.

[66] The alleged violations did not involve NASA technology.

CASE STUDY: ASTRO-E2

Artist's Rendering of Astro-E2



Source: JAXA.

The Astro-E2 mission was a joint collaboration between NASA and the Japanese space agency. The mission involved an X-ray astronomy satellite designed to observe celestial X-ray sources and launched on a Japanese M-V launch vehicle from Uchinoura Space Center on July 10, 2005. Approximately 3 weeks after launch, an issue with the liquid helium cooling system caused the Astro-E2's main instrument, the X-ray Spectrometer, to fail.

In 2006, we performed an audit that examined several NASA-Japanese projects, including the Astro-E2, and found that project managers had identified information-sharing risks stemming from U.S. export control laws.[67] However, they failed to work with NASA export administrators during the planning phase of the project to develop an information sharing plan. As a result, there was insufficient time to obtain approval for sharing technical data along with confusion among project personnel regarding what information could be shared. Our report, which was issued prior to the report of investigation regarding the failure of the X-ray Spectrometer, found that due to a lack of insight and information sharing project personnel were challenged when integrating instrument components with the spacecraft. We concluded that "improper integration can lead to a malfunction of an instrument or spacecraft level-system and can ultimately result in the loss of scientific data or mission failure." This observation was confirmed in NASA's mishap report, which described a failure to implement a data transfer plan as a contributing factor to the mishap – primarily due to a misunderstanding of what data sharing was allowed under the ITAR.

International partners expressed that the difficulty of complying with U.S. export control regulations has led to the exclusion of NASA from some international partnerships. In addition, according to media reports, Brazil is actively trying to avoid using U.S. technology due to the perception that U.S. export control laws impose a significant administrative burden.[68] To this end, countries wishing to market aerospace technology to Brazil must ensure the technology is generally free of U.S. parts. While Brazil interacts on major projects with several of NASA's international partners, including Canada, China, France, Germany, Russia, and Ukraine, its partnership with the Agency mostly consists of smaller educational and climate studies.

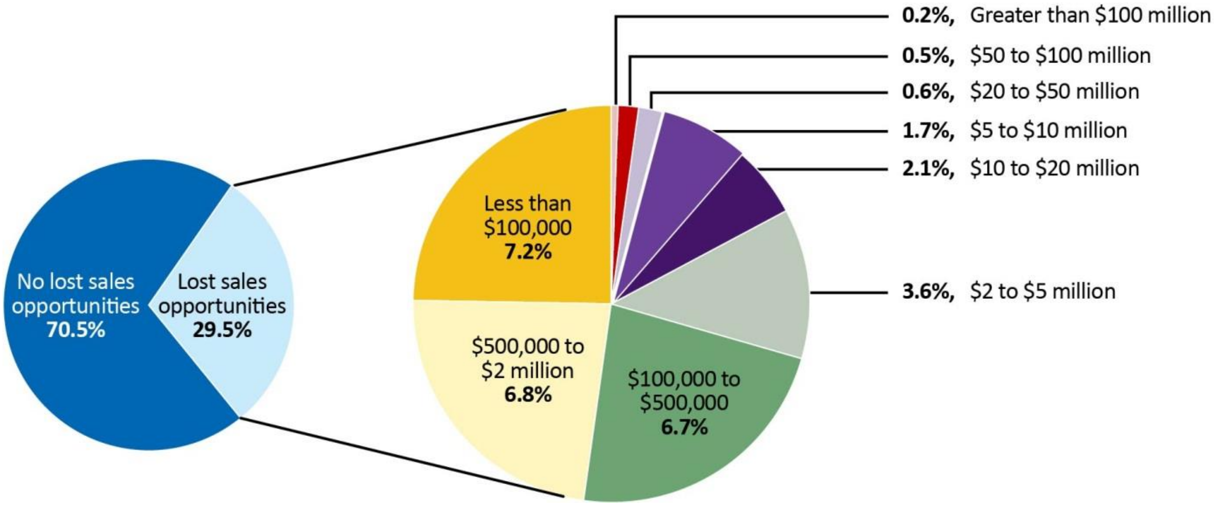
The U.S. space industry has also reported lost business opportunities due to complex U.S. export control regulations. The Department of Commerce's Bureau of Industry and Security published an in-depth

[67] NASA Office of Inspector General, "NASA Can Improve its Mitigation of Risks Associated with International Agreements with Japan for Science Projects" (IG-06-020, September 12, 2006).

[68] Peter B. de Selding, "Brazil Bypassing the U.S. as It Builds Out a Space Sector," *SpaceNews*, April 16, 2015, http://spacenews.com/brazil-bypassing-the-us-as-it-builds-out-a-space-sector/ (last accessed March 6, 2016).

report on the impact of space-related export controls on industry in 2014.[69] The report surveyed the U.S. space industry and found that 35 percent of providers of space-related products and services reported lost sales opportunities estimated at between $988 million and $2 billion (see Figure 18). A quarter of respondents stated that they avoided export of space-related products or services subject to ITAR-related controls and more than 20 percent stated they incentivized non-U.S. organizations to "design-out" or avoid buying U.S. origin space-related products or services. Several foreign partners noted the negative impact export control regulations have on the competitiveness of the U.S. space industry, and U.S. space industry representatives described lost business opportunities as a result of U.S. export control regulations.

Figure 18: Lost Export Sales Opportunities due to U.S. Space-Related Export Control Regulations, 2009–2012



Source: NASA Office of Inspector General presentation of the Department of Commerce's Bureau of Industry and Security data.
Note: Nominal differences in percentages due to rounding.

Reforms in Export Control Regulations

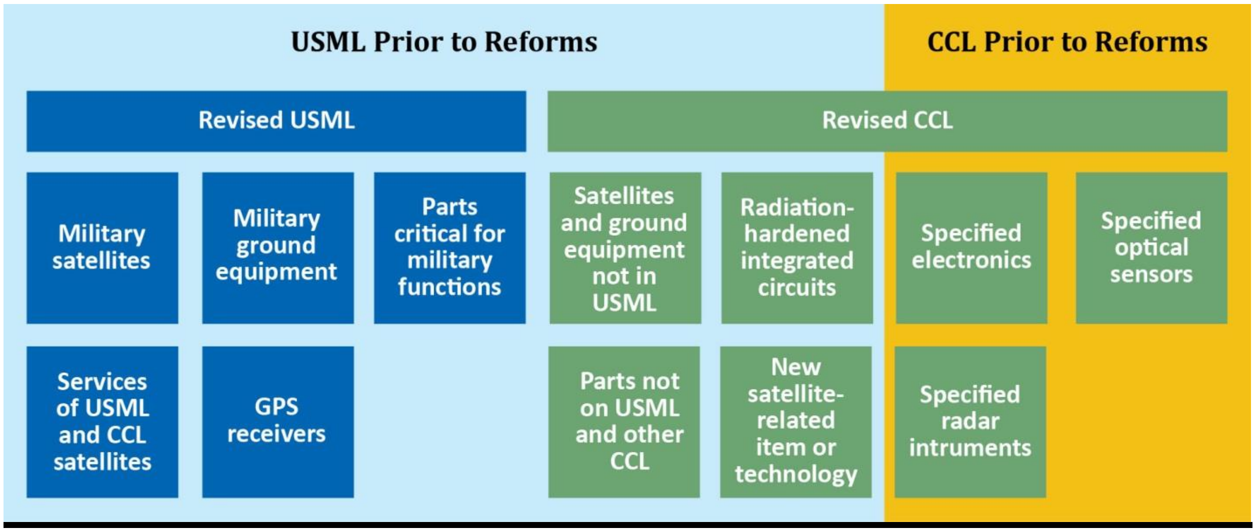
Some of the negative effects of export control compliance on international collaboration may be addressed by recent revisions to U.S. export control regulations. A 2009 interagency review of U.S. export control regulations concluded that the United States' export control process is "overly complicated, contains too many redundancies and in trying to protect too much, diminishes [the country's] ability to focus [its] efforts on the most critical national security priorities."[70] This led to implementation of the Export Control Reform Initiative in October 2013, which encompassed several regulatory changes, including the reclassification of many items (see Figure 19).[71]

[69] U.S. Department of Commerce, "U.S. Space Industry 'Deep Dive' Assessment: Impact of U.S. Export Controls on the Space Industrial Base," February 2014.

[70] Export.gov, "President's Export Control Initiative"; http://export.gov/ecr/ (last accessed March 21, 2016).

[71] The final State and Department of Commerce rules relating to military and other advanced electronics took effect on December 30, 2014.

Figure 19: Summary of Changes to Spacecraft Systems and Related Equipment as a Result of the Export Control Reform Initiative



Source: NASA Office of Inspector General presentation of the Department of Commerce's Bureau of Industry and Security data.

Note: This figure illustrates the change in categorization of various items under the original U.S. Munitions List (USML) and Commerce Control List (CCL) (light blue and yellow, respectively), to the revised U.S. Munitions List and Commerce Control List (dark blue and green, respectively).

The Export Control Reform Initiative focused export control enforcement efforts on items critical to national security and moved many categories of less-sensitive items formerly listed on the State's U.S. Munitions List, including many commercial, scientific, and civil satellites and their components, to the Department of Commerce's Commerce Control List. This move is significant because the EAR has broader exceptions from license requirements, which means NASA and its contractors will be required to obtain fewer licenses and Technical Assistance Agreements. For example, the export administrator at NASA's Goddard Space Flight Center estimated that the majority of JWST's more than 200 Technical Assistance Agreements would not be necessary under the new regulatory regime. As a result of these changes, State registered a 64 percent reduction in license volume between October 2013 and October 2014 for the 13 U.S. Munitions List categories that had been implemented during that time.

While NASA export control officials expect the reforms to reduce significantly the time NASA and its contractors devote to ITAR compliance, early implementation of the reforms has achieved mixed results. For example, the JWST project team hoped the reforms would allow the entire telescope to be moved from the ITAR to the EAR. However, because of potential military applications for some of the technologies used on the telescope's primary mirror, it remains on the ITAR list, increasing the number of licenses the Agency will need to obtain for the instrument.

Given how recently the reforms were implemented, it is too early to determine their impact on NASA projects. Moreover, although the space industry sees the reforms as a positive step, some believe further reforms are needed. For example, GAO noted the United States takes a "transactional" approach to export control pursuant to which separate licenses are generally needed for each proposed arms export.[72] In contrast, some of NASA's international partners utilize a "risk-based" approach in which export classification is based on factors such as an exporter's compliance record and the risk

[72] GAO, "Export Controls: Observations on Selected Countries' Systems and Proposed Treaties" (GAO-10-557, May 2010).

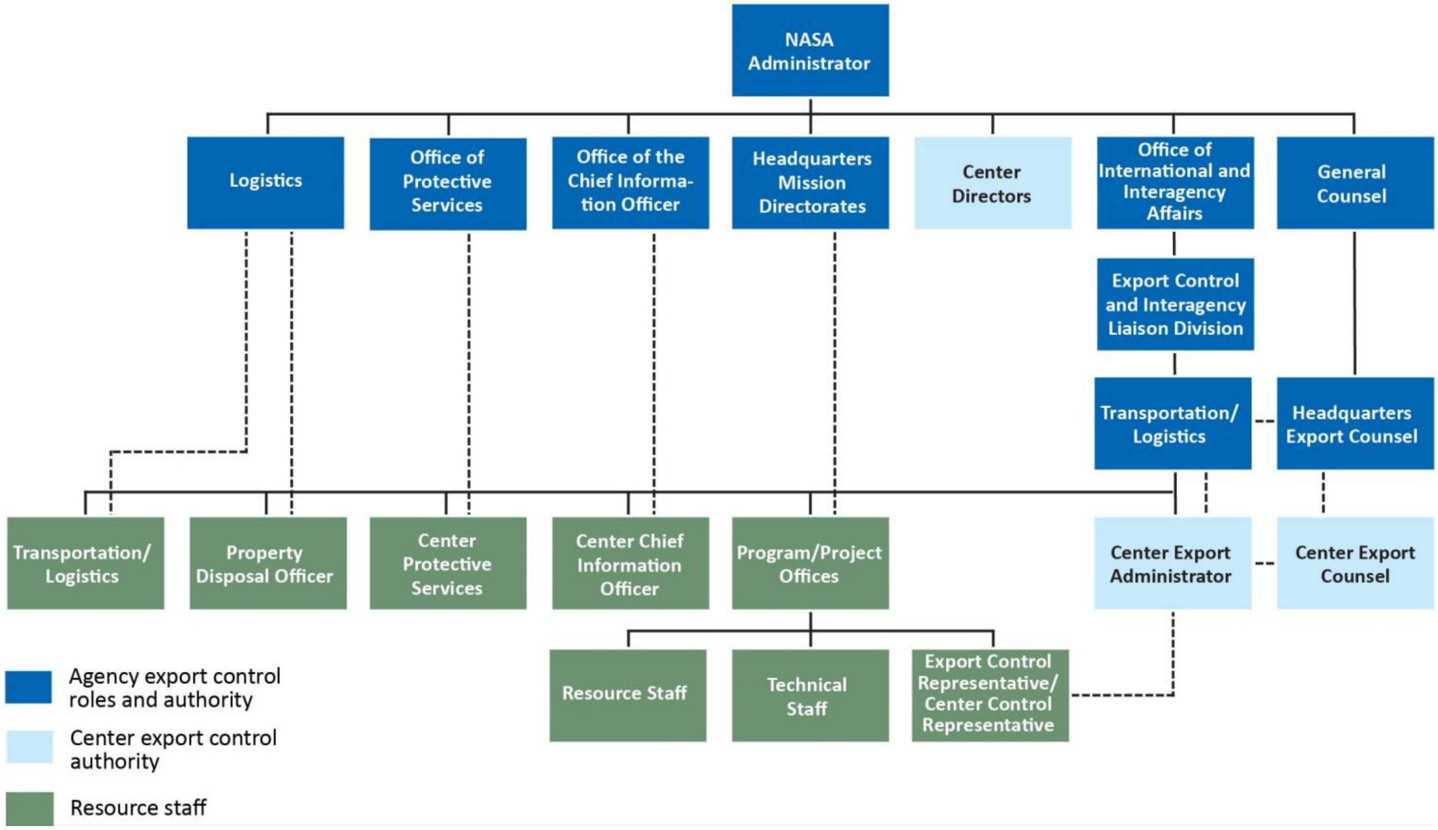
posed by the destination country. For example, France and the United Kingdom allow companies with a record of compliance to export multiple items to multiple recipients under a single license. Similarly, Germany issues "global export licenses" valid for 2 years that allow for multiple shipments of items to North Atlantic Treaty Organization (NATO) or NATO-equivalent countries. The European Union has also taken steps in the past 5 years to reduce licensing requirements for member states, implementing "open" licenses under which countries require that actors receiving exports have a satisfactory compliance program in place to safeguard the items.

Another set of issues not addressed by the Export Control Reform Initiative is the administrative idiosyncrasies associated with management of U.S. export control regulations. Although most of NASA's international partners, including Australia, Germany, Japan, and the United Kingdom, have only one agency that regulates export control, the United States continues to split these regulatory duties between State and the Department of Commerce, which can lead to inconsistent application of the regulations. Similarly, enforcement of U.S. export control laws remains a complicated division of authority involving offices within the Departments of Commerce, Homeland Security, Justice, and State. Many of NASA's international partners use only their customs department to enforce export control compliance, with a minority of other partners, including Canada and Japan, using two agencies to monitor compliance. Lastly, the recent reforms failed to merge the U.S. Munitions List and the Commerce Control List into a single, consolidated classification list, which may have created a simpler process for classifying items.

NASA Is Standardizing Its Export Control Process

NASA's export control compliance responsibilities are spread across a number of Agency offices, as shown in Figure 20. According to the Export Administrator for NASA Headquarters, decentralization of responsibilities can be beneficial and compliance programs work best when participants are active and invested in the process. Moreover, he cautioned against imposing requirements that create needless administrative burdens. To this end, the Export Administrator said NASA is taking steps to increase standardization of its Export Control Program without imposing unnecessary requirements.

Figure 20: Export Control Delegation of Authority



Source: NASA Office of Inspector General presentation of NASA Advisory Implementing Instruction 2190.

To increase standardization of NASA compliance practices, the Export Administrator developed the NASA Export Control Operations Manual (Operations Manual) in 2015. The Operations Manual provides background information on export control regulations and relevant policies and outlines the general process for identifying controlled information and obtaining licenses. The Operations Manual also includes best practices for export control compliance for the Center Export Administrators, project managers, and export representatives, and training specially focused on each of the major export control compliance positions. Guidance is also given for each type of export, including shipment of items, sharing of technical data with a foreign person, and publishing data online.

In addition to the Operations Manual, several tools are available to Export Administrators to streamline compliance. For example, the Technology Transfer Control Plan (TTCP) is created at the beginning of a project to guide the project team in the exchange of information with foreign partners. NASA's export control policy requires a TTCP when working with a country that is not a member of NATO or a major non-NATO ally and recommends a TTCP for all programs or projects that involve foreign partners. The use of a TTCP can provide clarity for a project team in navigating the requirements of export control regulations. Furthermore, Export Administrators can place Export Control Representatives in a program, project, or a Center Export Control Office to further facilitate export control compliance and information sharing among NASA and its international partners. For example, at the Jet Propulsion Laboratory several engineers serve as Export Control Representatives to provide technical expertise to projects on export control issues.

LIMITS OF INTERNATIONAL COORDINATION GROUPS

Several forums exist that attempt to foster international collaboration in space; however, these groups have limited ability to coordinate a common set of exploration missions among the world's space agencies. While NASA has made an effort to engage international partners in its projects, the Agency has traditionally approached international cooperation on a project-by-project basis. Rather than working to establish collective exploration missions, NASA and its international partners have generally set their own domestic space agendas and entered into partnerships when those individual agendas have aligned. Although major goals may align (as discussed in Chapter 1), a lack of consensus exists across the world's space agencies on which large scale exploratory missions ought to be undertaken. Specifically, NASA and its traditional partners have differing ideas regarding the future of space flight over the next few decades, with NASA working towards a human mission to Mars and ESA advocating for a colony on the Moon. Furthermore, although the ISS is a positive example of collaboration on a large scale exploratory mission, ESA has not yet committed to continue ISS operations until 2024 and is currently engaging in a cost feasibility study.

International committees were created to increase cooperation and enhance communication among developing space agencies. The United Nations Committee on the Peaceful Uses of Outer Space was created in 1961 during the Cold War in response to the Soviet Union's launch of Sputnik and continues to address international principles pertaining to the use of outer space. Although the Committee has been instrumental in establishing the legal framework in which the world's space agencies operate, it is not tasked with developing common space policy objectives or directing agencies toward a specific vision.

First Meeting of Permanent United Nations Committee on the Peaceful Uses of Outer Space on November 27, 1961

Source: United Nations Committee on the Peaceful Uses of Outer Space.

The International Space Exploration Coordination Group seeks to address international space exploration goals, providing member states with a common vision for space exploration and attempting to outline a general methodology to achieve that vision. However, the International Space Exploration Coordination Group is by necessity voluntary and its actions nonbinding, giving space agencies the ability to abandon its collective mission scenario at any time to pursue their individual goals. To this point, the NRC recently remarked that "[i]t is evident that near-term U.S. goals for human space exploration are not aligned with those of our traditional international partners" and noted that although NASA is interested in missions to an asteroid and Mars, its international partners are primarily interested in missions to explore the lunar surface.[73] Such divergent goals may limit the effectiveness of the International Space Exploration Coordination Group in forming a consensus mission scenario. Although the International Space Exploration Coordination Group coordinates human exploration initiatives, coordination of space science generally takes place through topical working groups. Until NASA and ESA withdrew their support in the early 2000s due to a reduced interest in participating, the

[73] NRC, "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" (2014), p. 3.

Inter-Agency Consultative Group for Space Science served as an international coordinating mechanism for space science. According to our interviews, NASA's international partners are interested in a more centralized international institution to facilitate cooperation and reduce the need for redundant capabilities in the space science field.

Restrictions on NASA Participation at International Conferences Limits Exchange of Information

Officials at NASA Centers and several space advisory groups have raised concerns about the Agency's limited participation at international conferences. NASA operates under statutory restrictions and budgetary constraints that limit its ability to send employees and scientists to international conferences. The NASA Office of Communications Exhibit Manager estimates that the cost of displaying exhibits at international conferences can range from $45,000 to $1.6 million per conference. In 1993, NASA issued a policy limiting exhibits at international conferences and the Agency's Headquarters Office of Communication has sponsored exhibits at only four foreign conferences in the past 10 years. In addition, beginning in 2006, NASA's appropriations legislation has restricted attendance at any foreign conference to 50 agency employees, which the Agency has interpreted to include both civil servants and contractors.[74] NASA's Office of Communications stated that this limitation makes it difficult to staff exhibits, as most of the 50 slots go to senior Agency officials leaving few spots for non-executive employees to work exhibits or attend presentations.

In our judgment, attendance and presentations at international conferences, although costly, can provide important benefits. Conferences are important venues for space agencies and scientists to interact and discuss collaborative ventures, with attendance and exhibitions providing broad exposure for participants. Both NASA and international partner officials told us conferences are one of the best ways to identify opportunities for cooperation, particularly on science projects.

The 2015 International Astronautical Congress was held in Jerusalem, Israel, and had more than 2,000 attendees from 60 countries and featured more than 100 exhibitions and presentations, including private companies, such as Lockheed Martin and Airbus Defense and Space, and space agencies, such as the Korea Aerospace Research Institute and the South African National Space Agency. NASA brought 47 employees to the conference, but did not present an exhibit. Citing the benefits that come with participating in international conferences, some nonprofit organizations such as the American Institute of Aeronautics and Astronautics have pushed for easing the restrictions that limit NASA attendance at such conferences.

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[74] In late March 2016, just prior to the publication of this report, the Agency updated its international conference attendance policy to allow 50 NASA civil service employees and an additional 50 contractor employees to attend international conferences.

In addition, attendance at conferences could further relationship-building opportunities between NASA and foreign space agencies. For example, NASA Administrator Bolden attended the 2014 International Astronautical Congress in Canada where he signed two documents with the Chairman of the Indian Space Research Organization: (1) an agreement to cooperate on a satellite mission to observe Earth and (2) a document establishing a working group to explore possible cooperation between the two agencies in the exploration of Mars.

NASA Administrator Charles Bolden (Left) and ISRO Chairman K. Radhakrishnan (Right) Signing Agreements at 2014 International Astronautical Congress in Toronto, Canada

Source: NASA.

In another example, the China National Space Administration made a large presentation at the Latin American Aero and Defense exhibition in Rio de Janeiro, Brazil, in April 2015, displaying both its satellites and its Long March 3B and Long March 5 carrier rockets. The Chinese used the opportunity to engage Brazil on specific satellite systems and to gain more information about the potential market for Earth science observation satellites in South America. NASA did not make a presentation or send employees to this conference.

OIIR has effectively utilized its desk officers and managers to coordinate with foreign space agencies to achieve the Agency's international objectives. However, OIIR's budget for international travel decreased from $613,859 in 2011 to $497,600 in 2014. The reduction has made it more difficult for desk officers to meet with their foreign counterparts and gain a comprehensive understanding of the countries and agencies with which they work. Moreover, the reductions have occurred at the same time NASA's international activities have increased.

U.S. Political Process and Geopolitical Environment Impact NASA's International Collaboration

Both the U.S. political process and the geopolitical environment influence NASA's ability to work with foreign partners. First, shifting priorities and uncertain annual budgets impact NASA's programs. For example, NASA's participation in ExoMars – an ESA led Mars exploration mission – and SOFIA have been canceled or threatened with cancellation due to lack of funding. NASA's partners indicated that political and budgetary uncertainties make it challenging to plan complex, long-term missions with the Agency. Moreover, geopolitical realities, which often relate to national security issues, have prevented NASA from expanding its work with major space powers such as Russia and China.

Shifting U.S. Space Policy Leads to Uncertainty in U.S.-Partnered Projects

As the U.S. space program transitioned from a national priority during the Apollo Program to a competing domestic priority under President Richard Nixon and subsequent administrations, Executive Branch and congressional direction to NASA has also shifted, sometimes creating confusion regarding the U.S. vision for space exploration. For example, in a 1989 speech President George H.W. Bush outlined his “Space Exploration Initiative,” which, in contrast to President Nixon’s vision, challenged the U.S. space program to once again venture beyond low Earth orbit, establish a permanent presence on the Moon, and launch a human mission to Mars. President Bill Clinton subsequently scaled back the program by removing human exploration outside of low Earth orbit from the national agenda. When President George W. Bush took office in 2001, he established the Constellation Program that called for a mission to the Moon “no later than 2020.” However, President Barack Obama terminated the Constellation Program in April 2010 and directed NASA to undertake a crewed mission to a near-Earth asteroid as a precursor to a human mission to Mars.

The shifting priorities of the U.S. space program can also affect NASA’s relations with its foreign partners. A 2009 report examining U.S. space flight plans, initiated by the Office of Science and Technology Policy, noted that “[m]uch of the international community, probably justifiably, faults the United States [for] unilaterally changing its aerospace plans to the detriment of its partner.”[75] NASA’s involvement with the Laser Interferometer Space Antenna (LISA), ExoMars, and SOFIA illustrate these challenges. In 2011, NASA cut funds to LISA – a project between NASA and ESA – to redirect funds to JWST, which has experienced significant cost overruns. ESA subsequently revised the mission to incorporate smaller roles for foreign partners.

More recently, NASA bowed out of the ExoMars project, a mission designed to search for life on Mars using an orbiter that detects trace gases and a demonstration lander. At the time of NASA’s withdrawal, the project was planned as a joint mission between NASA and ESA with NASA contributing more than $500 million and providing launch services and ESA providing the orbiter. However, budget constraints led to ending funding for the program. According to the ESA ExoMars Project Manager, NASA’s withdrawal from the program was devastating for ESA, which had to find a new launch services provider, eventually agreeing to partner with Russia.

The SOFIA Program and its associated international partners have also been impacted by budget instability. Developed by NASA and the German space agency, SOFIA is the world’s largest airborne telescope. SOFIA reached full operational capability in February 2014 after a problematic 23-year development history and a cost of $1.1 billion – more than 300 percent over original estimates. President Obama’s fiscal year 2015 budget proposed to place SOFIA in storage for an undefined period unless NASA identified partners to help subsidize operating costs.

SOFIA Aircraft

Source: NASA.

[75] Review of U.S. Human Space flight Plans Committee, “Seeking a Human Space flight Program Worthy of a Great Nation” (October 2009).

Although the project was one of the German space agency's largest science projects, the Germans were given only 2 days notice of the Administration's plans. While the SOFIA Program was ultimately fully funded by Congress and is scheduled to continue flying for the next 20 years, the SOFIA Project Manager told us the episode adversely impacted the relationship between the NASA SOFIA team and their German counterparts.

As other foreign space agencies advance their technical capabilities, opportunities for partnerships will become more and more competitive. The international partners we spoke with that had experience with cancelled NASA projects expressed their willingness to continue partnering with NASA despite the Agency's past withdrawal from several commitments. However, countries like China and India are quickly establishing themselves as viable partners, with India targeting an increase to 10 launches per year of science missions and communications satellites by 2016. If NASA cannot provide partners with reliable commitments, foreign space agencies may look elsewhere for opportunities. Indeed, some foreign space agency representatives expressed a preference for partners other than NASA that have more stable and dependable program and project budgets.

Stable Budgets Help ESA Managers Effectively Plan for the Future

In contrast to NASA, ESA enjoys a more stable, albeit lesser, funding environment. ESA has two types of programs: mandatory and optional. Mandatory programs include space science programs and ESA's General Budget. In 2015, ESA's mandatory program budget was approximately 20 percent of its total budget, with the remainder used for optional programs in which member states may choose to participate. Ministers of member states decide on the General Budget and then fund that budget in 5-year increments.[76] Member states contribute to mandatory programs in a percentage based upon their respective GDPs. In contrast, for optional programs such as Earth observation, communications, and space flight transportation and navigation members decide their individual levels of involvement. This relative funding stability allows ESA managers to plan more effectively – especially in their procurement activities – and has played a role in ESA's ability to maintain its international commitments.

While this practice may not extend to NASA, some Federal programs, such as the Department of the Navy's aircraft carriers, have been "fully funded" in a single year at the start of the project in a manner similar to ESA. Fully funded projects provide both transparency to Congress regarding the expected cost of the project and a defined amount of funds available to the Navy in future years, which can be increased in case of cost overruns. Aircraft carriers can also be funded using a hybrid model of full and incremental funding – also known as "advance appropriations" – where the full cost of the project is appropriated upfront but the budget authority for the funds is enacted annually. Although Congress has not given the Navy advance appropriation authority for aircraft carriers, it has granted this authority to some Federal agencies, including the Departments of Agriculture and Education. NASA unsuccessfully attempted on numerous occasions in the late 1990s and early 2000s to gain this authority for the ISS.

[76] Once the budget is established, the Science Program Committee decides its content. All member states sit on the Science Program Committee and all have an equal vote in its determinations. Changes to the content of ESA's science program require a two-thirds vote among members, which provides further stability.

Geopolitical Environment Limits Cooperation with International Partners

NASA's international partnership efforts can be disrupted by policy considerations unrelated to its programs. For example, following fighting between Russia and Ukraine in April 2014, NASA circulated an internal memorandum suspending the Agency's contact with Russian government representatives with limited exceptions related to the ISS and several other ongoing programs. Similarly, since November 2011, annual appropriations bills have limited NASA's participation in bilateral agreements with China. According to its authors, this ban is in response to China's human rights record and perceived threat to the security of U.S. technology. Many other Western European countries have also enacted restrictions on working with Russia and China.

Russia

Despite concerns about partnering with a country that had been viewed as an enemy of the United States during the Cold War decades, NASA has been working closely with Russia since 1992 when NASA and the Russian space agency – Roscosmos – signed an implementing agreement on human space flight cooperation. As discussed in Chapter 2, the NASA-Roscosmos collaboration includes construction and operation of the ISS. The two agencies have also collaborated on a variety of science projects, including Russian instruments on NASA's Mars Odyssey, Lunar Reconnaissance Orbiter, and Mars Science Laboratory missions. Moreover, Russia has committed to extending operation of the ISS through 2024.

Roscosmos has been one of the most reliable crew and cargo providers for the ISS, with 45 successful Soyuz missions (crew) and 62 successful Progress launches (cargo), and NASA has been dependent on the space agency for transporting astronauts to the ISS since retirement of the Space Shuttle Program in 2011. Although NASA is currently working with two commercial companies to provide a domestic carrier for crewed missions to the ISS, the contractors have experienced significant delays, causing the Agency to purchase astronaut transportation from Russia into 2019. In addition, the U.S. commercial space industry also has been heavily dependent on Russian rocket engines. United Launch Alliance's Atlas V rocket, utilized by NASA and the Department of Defense, uses a Russian RD-180 engine for its first stage. Orbital ATK – under a $1.9 billion contract with NASA for eight cargo resupply flights to the ISS – used Russian AJ-26 engines for four launches of its Antares rocket and plans to use Russian RD-181 engines for its reconfigured Antares 230 rocket.

Although both NASA and the U.S. commercial space industry remain heavily dependent on Russia's aerospace capabilities, NASA is currently prohibited from engaging in cooperative activities with Russia with the exception of the ongoing operation of the ISS and a small number of other science-related projects. For its part, Russia has begun to search for other partners for space-related projects, including China. The two countries signed a space exploration agreement in May 2014 that established a control group for eight strategic projects.

China

China has a well-funded space agency, with an estimated annual space development budget of approximately $5 billion, and the country has made significant technical advances in recent years, including crewed missions to low Earth orbit and a robotic lunar rover. However, since November 2011, NASA's appropriation legislation has restricted the Agency from entering into bilateral partnerships with China. As of 2015, the two countries have exchanged data relating to space geodesy, lunar science, Earth observation for glacier characterization in the Himalayan region, and air traffic management. The information NASA provided in these exchanges was primarily publicly available data.

OIIR officials and NASA's representative on the International Space Exploration Coordination Group cautioned that striking the right balance between risk and reward is a key issue when considering whether to expand NASA-Chinese partnerships. NASA counterintelligence personnel have identified China as one of the United States' top cyber-security threats, and China is suspected of stealing U.S. military technology. The counterintelligence personnel cautioned that expanded partnership with China would require increased controls to protect U.S. technology.

Similar threats to the security of NASA technology existed when the United States decided to partner with Russia in construction and operation of the ISS. To manage this threat, NASA established a strategy of minimizing technical exchange between partners. For example, in building the ISS, different countries were responsible for constructing different Station modules. ESA's largest physical contribution is the Columbus Laboratory, a scientific laboratory attached to the ISS in 2008. Similarly, Roscosmos built and operates the Russian Orbital Segment of the ISS, which includes the Pirs, Poisk, Rassvet, and Zvezda modules, and is one of the two main segments of the ISS. This division of responsibilities is apparent in NASA's smaller projects as well. For the joint NASA-Indian satellite named the NASA-ISRO Synthetic Aperture Radar (NISAR), NASA is to provide the Engineering Payload System and L-Band radar instrument, while the Indian Space Research Organization is to provide the Spacecraft Bus System and S-Band radar instrument. By dividing the responsibility to develop different instruments, technical exchange is limited to integration.

In November 2011, NASA Administrator Bolden stated that "some level of engagement with China in space-related areas in the future can form the basis for dialogue and cooperation in a manner that is consistent with the national interests of both our countries, when based on the principles of transparency, reciprocity and mutual benefit."[77] Similarly, the NRC has noted that "current federal law that prevents NASA from participating in bilateral activities with the Chinese serves only to hinder United States ability to bring China into its sphere of international partnerships and substantially reduces the potential international capability that might be pooled to reach Mars."[78]

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[77] U.S. House of Representatives Subcommittee on Oversight and Investigations, Committee on Foreign Affairs, Efforts to Transfer America's Leading Edge Science to China, 112th Cong., 1st sess., September 2, 2011, p. 45.

[78] NRC, "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" (2014), p. 4.

CHAPTER 4
Improving Management of International Partnerships

The international partners we surveyed suggested three ways for NASA to improve international cooperation: (1) streamline information sharing regarding opportunities for cooperation, (2) increase opportunities to share Agency test facilities, and (3) adopt successful past practices. One possible medium they identified for information sharing was NASA's Technology Portfolio System (TechPort). Although currently of limited use to potential international partners, TechPort or similar databases could be used to advertise NASA opportunities beyond the current method of posting infrequent "announcements of opportunity." Partners also discussed increased sharing of wind tunnels and other NASA test facilities. For example, the service module ESA built for the Orion Multi-Purpose Crew Vehicle was tested at Plum Brook Station, part of NASA's Glenn Research Center. Lastly, NASA program and project managers we interviewed discussed a number of successful practices they have employed to improve information sharing and cultural awareness.

TechPort Could Help Partners Gain Awareness of NASA's Projects

In addition to international coordination groups, NASA may be able to use existing mediums to increase communication and coordination among potential international partners. TechPort is an integrated, Agency-wide software system designed to capture, track, and manage NASA's portfolio of technology investments. The system provides a number of search options, allowing interested parties to sort NASA's technology portfolio by date, technology area, directorate, program, Center, or location. Available to NASA employees and contractors since 2012, NASA made some of the information in TechPort available to the public in March 2015. In December 2015, we found that the information in TechPort remains incomplete and inaccurate, impairing the value of the database as a tool to manage and share information about NASA's space technology portfolio.[79] As NASA continues its efforts to address our concerns and improve the system, the Agency could also examine the feasibility of modifying TechPort to add input and search capabilities that would allow international partners to identify technologies of mutual interest. For example, an international partner interested in starting a project relating to global positioning systems (GPS) could search TechPort for "GPS" and receive a list of related ongoing or pursued NASA projects. Representatives of Japan's space agency told us that they conducted a test of TechPort at NASA's request and determined it would be helpful to add a search option to the system enabling users to identify projects that are seeking international collaboration.

[79] NASA Office of Inspector General, "NASA's Efforts to Manage Its Space Technology Portfolio" (IG-16-008, December 15, 2015).

We believe that a search tag identifying projects open to international collaboration could be a useful, low-cost tool to raise awareness of potential opportunities and facilitate international collaboration.

Shared Use of Assets

Several international partners noted that space agencies with similar interests sometimes expend funds and effort building test facilities and infrastructure to support similar projects. For example, in recent years, space agencies around the globe have increased efforts to develop climate-monitoring technology to meet demands for a more accurate picture of the Earth's atmosphere, waters, and land. However, no coordinated approach exists for determining which Earth science projects will be done in a given year, and several countries are building and testing similar projects and supporting test facilities.

Representatives of Japan's space agency suggested a mechanism that facilitates a more flexible and affordable shared use of NASA's unique testing facilities and capabilities would be beneficial. They cited facilities like the Ames Research Center's wind tunnel and Plum Brook Station's Space Power Facility and Spacecraft Propulsion Research Facility (B-2) as examples (see Figure 21).[80]

Figure 21: Photos of NASA Testing Facilities at Ames and Glenn Research Centers

Source: NASA.

ESA also cited benefits in improving shared use of NASA assets. For instance, in the past ESA considered using the B-2 to test second stage rocket engines. Although the B-2 is the only facility in the world capable of verifying rocket engine and upper-stage starts and restarts after long-term exposure to the cold and vacuum of space, the facility has not been used for such testing since 1998 and requires an estimated $15 million in refurbishment. In lieu of paying these funds, ESA decided to build its own facility to test its engines. An improved coordinated effort among international partners could help NASA keep facilities like B-2 utilized while lowering maintenance and operation costs for the Agency.

[80] The Space Power Facility is an environmental simulation chamber used to test hardware in a simulated space or planetary environment. The B-2 is the world's largest thermal vacuum chamber capable of testing rocket engines.

In addition, NASA could use its assets as part of barter agreements with international partners. Officials from France's space agency indicated a barter component is a necessary element of future agreements for large missions. France is interested in increased cooperation with NASA but budgetary limitations require innovative approaches to funding projects. Providing agencies the option to use NASA test facilities in exchange for participation on large international projects is one possible alternative.

Successful Mission Engagement Practices

Representatives from several space agencies we surveyed identified a number of practices they used to improve management of international projects:

- **Early Participation by All Partners.** Within a year of President Reagan's 1984 announcement of plans to build a space station in low Earth orbit, Canada, ESA, and Japan expressed their commitments. Building on lessons learned from SpaceLab, NASA established a task force to facilitate collaborative relationships with agencies interested in participating. This early engagement of partners enabled participating agencies to secure funds and provide meaningful contributions to the project.
- **Plug-and-Play Approach that Maximizes Participants' Capabilities**. Early on in the development of the ISS Program, many international partners expressed interest in providing components and modules for the Station. The Program adopted a "distributed architecture" to build the ISS not as a single facility, but rather as a compilation of modules, trusses, and platforms that fit together to carry out the ISS's various missions. This "plug-and-play" approach enabled international partners to use their technical skills and manufacturing base and gain a sense of national pride beyond providing astronauts to work on the Station. Ultimately, Canada contributed the Mobile Servicing System, ESA the Columbus module, Japan the Japanese Experiment Module, and Russia the Zvezda service module. Partners also shared responsibility for furnishing transportation services, including Russia's Soyuz rocket transporting astronauts, the U.S. Space Shuttle carrying the Station modules, and ESA's Automated Transfer Vehicle and Japan's H-II Transfer Vehicle delivering supplies. The plug-and-play approach also simplified ISS Program implementation by eliminating the need for international partners to share technical details about their components. Instead, the partners only needed to know how the components would interface – that is, how they would connect physically and initiate power, communication, and environmental control. This allowed the partners to avoid export control restrictions on sensitive technologies.
- **Centralized Communication for Key Information.** Multiple international partners noted that a centralized communication structure using a designated representative from each participating agency improves the decision-making process, streamlines the exchange of information, and minimizes project disruptions. For example, NASA's JPL has adopted the practice of designating an ITAR representative as the central point of contact for each international mission team to timely address questions that may arise throughout the life of the project. JPL officials report this practice has improved project management.
- **Consolidated Program and Project Reviews.** We found that consolidated joint program reviews between NASA and the partner of project milestones help alleviate challenges associated with program planning and coordination of efforts. While "national" program reviews help an international partner on a specific aspect of the project, joint reviews at all key milestones could improve project planning and enable international partners to address project and technical

challenges at the conclusion of each milestone phase. As illustrated by NASA's InSight mission – discussed in Chapter 3 – delays in the development of one instrument can significantly affect completion of an entire project. Cases like InSight, where missing a launch window to Mars may result in a 2-year delay, highlight the importance of joint project reviews.

- **Alignment of Project Schedules.** NASA, ESA, and French space agency officials noted that conducting joint program planning ensures each partner's schedule accommodates the other agency's programmatic needs. Alignment of subsystem design reviews, testing schedules, and manufacturing schedules could minimize unnecessary delays when international partners must wait for one another to complete deliverables. For example, the French SWOT Project Manager noted considerable project phase misalignment between his agency's schedule and NASA's schedule, and said this required significant attention to resolve the inconsistencies. He suggested a flexible project planning schedule with joint planning sessions would address issues as they arise and minimize unnecessary delays.
- **Consideration for Sensitive Areas.** NASA and its international partners indicated increased efforts to better educate and train staff in sensitive and agency-specific areas such as agreement processes and export control regulations helps minimize project disruptions. For example, ESA and Japanese officials provide training to their staff on NASA's ITAR requirements, and officials from these space agencies have reported this helps their staff better understand the process. NASA JPL also finds providing export control and ITAR training to staff who work on international projects has improved employees' understanding of the process of information and technical exchange.
- **Cultural Training.** Training NASA project managers and teams on cultural and programmatic differences between the Agency and its international partners has improved working relationships and minimized unnecessary project disruptions. For example, ESA officials indicated that NASA and ESA work well together because they have similar technological and managerial culture. Additionally, JPL officials told us that they use a NASA organized week-long mandatory training for project managers and staff working on international projects. The training uses interactive course work with a portfolio of past projects as case studies covering successes and failures with specific examples and lessons learned to educate employees on partners' policies, programmatic organization, and business culture. ESA and the Japanese space agency employees also participate in this training.

Identifying and adopting management and program practices like these can improve international cooperation and increase the probability of meeting cost and performance schedules. The NASA-Japanese partnership is an example of how working together to address differences in governmental and agency structures, programmatic priorities and technical challenges, political and legal limitations, and cultural differences has improved cooperation. Japan is one of NASA's leading international partners in civil space cooperation and has more than 50 active agreements with the Agency for human space flight, Earth and space science, and aeronautics. Both agencies attribute this success to improved program management practices and increased staff training on each other's cultural and organizational characteristics.

For example, the NASA GMP Project Manager hired a contractor to provide a 5-week Japanese cultural and language training course his team. He also purchased uniforms for NASA staff to mirror Japanese customs and reached out to local Japanese communities, schools, and governments to educate them on the project. To address challenges related to day-to-day decision making and export control, both NASA and the Japanese space agency designated ITAR and GPM management representatives to facilitate smooth information exchange by serving as the approving authority prior to each exchange and ensuring that all information is sent through secure servers.

Good Luck Japanese "Daruma Doll" during a Launch Team Rehearsal for the GPM Mission

Source: NASA.

CONCLUSION

NASA's International Partnerships are Critical to Achieving NASA's Goals and Objectives

NASA's efforts to partner with foreign space agencies are extensive and cover all facets of the Agency's mission. In 2014, NASA had 820 active agreements with countries located in every region of the world that addressed Agency missions from science to human exploration to aeronautics. While foreign space agencies may share common space exploration goals with NASA, the timing and prioritization of their goals may not align with NASA's plans. In addition, although partners have demonstrated emergent technical capabilities that generally support identified goals for space exploration and Earth observation, financial capability remains the key driver in meeting those goals. As one of 15 members of the International Space Exploration Coordination Group, NASA has significantly greater ability to fund space activities compared to the other members given that it controls almost 50 percent of the group's collective financial resources. Nonetheless, given the competing priorities that affect NASA's budget allocations, the Agency is better able to maintain its diverse portfolio of science, aeronautics research, space technology, and human exploration and operations missions by participating in international partnerships rather than undertaking most projects by itself.

With that said, NASA faces several significant challenges to expanding its use of international partnerships. First, the process of developing agreements with a foreign space agency requires approval from State and often takes many months, if not years, to complete. Second, U.S. export control regulations can hinder dialogue between NASA and its partners, causing frustration with project planning and implementation and reducing the competitiveness of the U.S space industry. Third, the lack of strong, centralized international space coordination groups and restrictions on the number of NASA employees who may attend international conferences makes dialog between NASA and its partners more difficult. Finally, both the U.S. political process and geopolitical realities complicate NASA's efforts to expand international partnerships, particularly with the Russian and Chinese space agencies.

In the face of these challenges, NASA's foreign partners have suggested three ways for the Agency to improve international cooperation: (1) streamline information sharing regarding opportunities for cooperation, (2) increase opportunities to share Agency test facilities, and (3) adopt successful past practices. One possible medium for information sharing is TechPort – a web-based system that describes ongoing NASA projects. Although currently of limited use to potential partners, TechPort or similar databases could be used to describe future projects and advertise opportunities to partner with NASA beyond the current method of posting infrequent "announcements of opportunity." Furthermore, partners proposed increased sharing of wind tunnels and other NASA test facilities, which in turn could lower the Agency's maintenance and operations costs for those facilities. NASA program and project managers have also highlighted a number of successful practices such as joint planning sessions and centralized communications they have employed to improve information sharing and cultural awareness between NASA and its foreign partners.

Our work shows that NASA retains a key leadership role in the eyes of its foreign partners. However, although NASA and potential partners have identified Mars as the horizon goal for human exploration, the actual timeline and how each agency will contribute remains undetermined. This uncertainty limits the ability of NASA and its partners to address shifting political commitments, the challenges of shrinking or static budgets, and commitments to other projects. Therefore, NASA leadership in proposing a way forward in science and human exploration beyond low Earth orbit is essential to achieving the long-term space exploration goals of the United States and its foreign partners.

The Agency reviewed our draft report and provided comments, which we have included in Appendix VII.

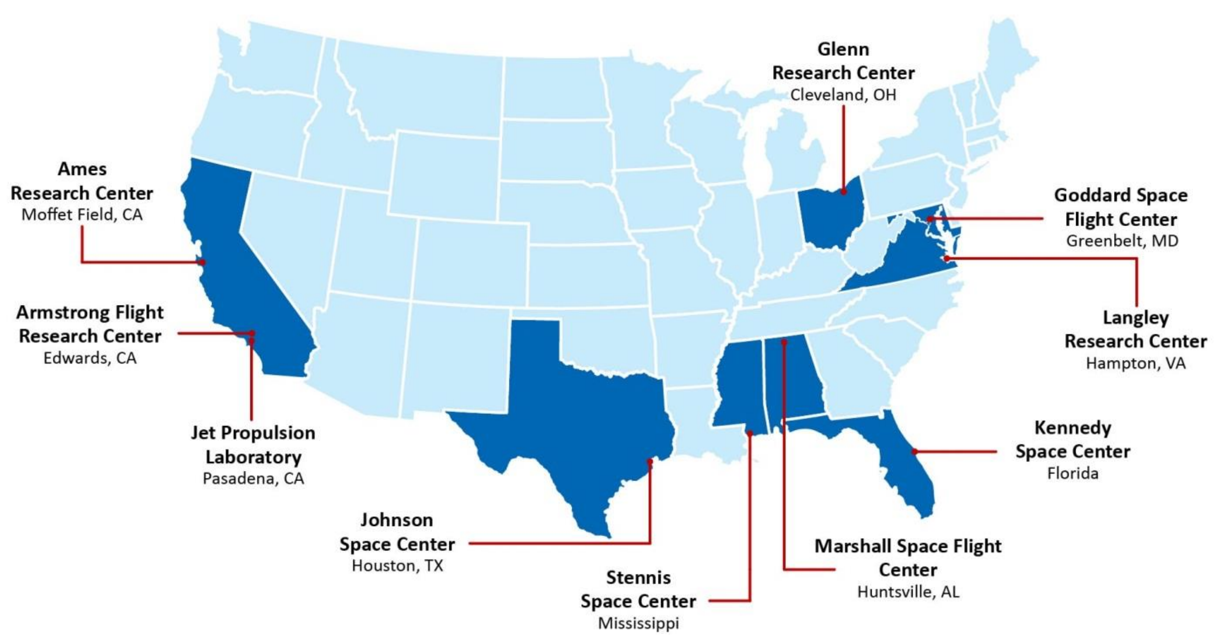
APPENDIX I: NASA ORGANIZATION

NASA was created on October 1, 1958, "to provide for research into the problems of flight within and outside the Earth's atmosphere and for other purposes." At the time, NASA had 8,000 employees, an annual budget of $100 million, three major research laboratories, and two smaller test facilities, and over the past 57 years, the Agency has only continued to grow. In fiscal year 2015, NASA employed more than 17,000 people, had an annual budget of $18 billion, and included 10 major Centers. In addition to NASA's Centers and the Agency's Headquarters in Washington, D.C., NASA also has eight smaller facilities located across the United States: Dryden Aircraft Operations Facility, Goddard Institute for Space Studies, Independent Verification and Validation Facility, Michoud Assembly Facility, NASA Shared Services Center, Plum Brook Station, Wallops Flight Facility, and White Sands Test Facility.

NASA CENTERS

Each of NASA's 10 Centers (see Figure 22) provide areas of technical capability supporting different elements of NASA's missions.

Figure 22: NASA Center Locations



Source: NASA Office of Inspector General.

Ames Research Center

The Ames Research Center (Ames) contributes to virtually every major NASA mission and has expertise in a variety of core areas, including entry systems, supercomputing, NextGen air transportation, Airborne Science, low cost missions, biology and astrobiology, exoplanets, autonomy and robotics, lunar science, human systems integration, and wind tunnels.

Armstrong Flight Research Center

The Armstrong Flight Research Center (Armstrong) is NASA's primary center for atmospheric flight research and operations. Armstrong is chartered to research and test advanced aeronautics, space and related technologies that are critical to carrying out the Agency's missions of space exploration, space operations, scientific discovery, and aeronautical research and development.

Glenn Research Center

In partnership with U.S. industry, universities, and other Government institutions, the Glenn Research Center (Glenn) develops critical systems technologies and capabilities to address national priorities. Glenn's world-class research, technology, and capability development efforts are key to advancing space exploration of our solar system and beyond while also maintaining global leadership in aeronautics. The Center is distinguished by its unique blend of aeronautics and space flight expertise and experience. As Glenn moves towards a greater focus on space flight hardware development, the Center's work is focused on technological advancements in space flight systems development, aeropropulsion, space propulsion, power systems, nuclear systems, communications, and human-related systems.

Goddard Space Flight Center

The Goddard Space Flight Center (Goddard) is home to the United States' largest organization of scientists, engineers, and technologists who build spacecraft, instruments, and new technology to study Earth, the Sun, our solar system, and the universe. Center engineers construct sensitive instruments, build telescopes that peer into the cosmos, and operate the test chambers that ensure those satellites' survival. In addition, Goddard manages communications between mission control and orbiting astronauts aboard the ISS.

Jet Propulsion Laboratory

The JPL is a federally funded research and development facility managed by the California Institute of Technology for NASA. A world leader in science and technology, JPL has developed tools for space exploration that have proved invaluable in providing new insights and discoveries in studies of Earth and its atmosphere, climate, oceans, geology, and biosphere. JPL is also active in the development of more-sensitive space sensors that have resulted in a myriad of technology applications for medical, industrial, and commercial uses on Earth.

Johnson Space Center

The Johnson Space Center (Johnson) currently is home to Mission Control, the Orion Multi-Purpose Crew Vehicle, and numerous advanced human exploration projects. The Center also serves as NASA's lead for ISS operations and missions and plays an important role in NASA's Commercial Crew Program. Johnson has expertise in systems engineering of human space flight, including design, development, and testing of spacecraft and components, technology development and demonstration, human health, environmental monitoring, astromaterials analysis and curation, and domestic and international partnership development.

Kennedy Space Center

The Kennedy Space Center (Kennedy) offers a full range of technical support for developing, processing, and launching flight hardware and payloads, including expertise in design, assembly, processing, testing, transporting and handling, integration, launch and recovery for human, expendable, and reusable spacecraft. The services required for these complex operations are diverse and broad, and include everything from modeling and simulations for command and control systems to chemical analysis to mishap investigations.

Langley Research Center

Work undertaken at the Langley Research Center's (Langley) ranges from fundamental research through technologies, demonstrations, and prototypes to mission design and development. Specifically, the Center focuses on advanced materials and structural systems; aerosciences; atmospheric characterization; entry, descent, and landing; intelligent flight systems; measurement systems; and systems analysis and concepts. Langley partners with U.S. industry, universities, and other Government institutions to solve national challenges and develop cutting-edge solutions that provide new capabilities, improve performance, and reduce cost. This combination of expertise, capabilities, and leadership in systems innovation enables on-demand air mobility; improves the understanding, adapting and mitigating of Earth's climate system; and extends human reach throughout the solar system.

Marshall Space Flight Center

The Marshall Space Flight Center (Marshall) has been used to design and build the engines, vehicles, space systems, instruments, and science payloads that make possible unprecedented missions of science and discovery throughout our solar system. Specifically, the Center developed new rocket engines and tanks for Space Shuttle Program, built sections of the ISS, and currently manage all the science work of the astronauts aboard the ISS. In addition, Marshall develops and tests the hardware and instruments for the JWST – NASA's premier observatory of the next decade, able to study every phase in the history of the universe.

Stennis Space Center

Stennis Space Center has total responsibility for conducting and managing all propulsion test programs for NASA and the Department of Defense, as well as the private sector.

NASA LEADERSHIP

NASA Headquarters provides overall guidance and direction to the Agency, under the leadership of the Administrator. The Office of the Administrator is supported by advisory groups, the Office of Inspector General, and Administrator staff offices. To implement NASA's mission, NASA Headquarters is organized into five principal organizations called Mission Directorates:

- **Aeronautics Mission Directorate.** Manages research focused on meeting global demand for air mobility in ways that are more environmentally friendly and sustainable, while also embracing revolutionary technology from outside aviation.
- **Human Exploration and Operations Mission Directorate.** Focuses on ISS operations, development of commercial space flight capabilities, and human exploration beyond low Earth orbit.
- **Science Mission Directorate.** Explores the Earth, our solar system, and the universe; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society.
- **Space Technology Mission Directorate.** Rapidly develops, innovates, demonstrates, and infuses revolutionary, high-payoff technologies that enable NASA's future missions while providing economic benefit to the nation.
- **Mission Support.** Oversees the management of institutional offices and operations that support NASA's mission, including Human Capital Management, Strategic Infrastructure, Headquarters Operations, the Shared Services Center, Protective Services, and Procurement.

Further, NASA Headquarters provides overall guidance and direction to the Agency. In order to effectively carry out U.S. civil aeronautics and space policies, NASA Headquarters maintains a close relationship with the White House and other Executive Branch offices.

OFFICE OF INTERNATIONAL AND INTERAGENCY RELATIONS

NASA's OIIR provides executive leadership and coordination of all NASA international activities and partnerships and for policy interactions between NASA and other U.S. Executive Branch offices and agencies. OIIR serves as the principal NASA liaison with the National Security Council, the Office of Science and Technology Policy, the Departments of Defense and State.

OIIR is comprised of the Office of the Associate Administrator and six divisions: Human Exploration and Operations, Aeronautics and Cross Agency Support, Science, Advisory Committee Management, Export Control and Interagency Liaison, and Resources Management. A matrix approach within OIIR allows for provision of support to each NASA Mission Directorate and for specific country or regional issues of interest to the Agency. In addition to its personnel at NASA Headquarters in Washington, D.C., OIIR also has representatives in Europe, Japan, and Russia.

Human Exploration and Operations Division

The Human Exploration and Operations Division manages international relations for the Human Exploration and Operations Mission Directorate, providing policy guidance and program support for human exploration capabilities, systems development and operations of the ISS Program, space communications and navigation, launch services, human space flight, space life and physical sciences research, and commercial space flight and crew issues. Division support includes providing policy guidance and recommendations on international issues and relationships with current and prospective foreign partners, drafting and negotiating international agreements for new space cooperation, and supporting ongoing interaction with international partners for existing cooperative missions. Currently, the Human Exploration and Operations Division serves as the lead role for NASA relations with Russia, Ukraine, and other states of the former Soviet Union.

Aeronautics and Cross Agency Support Division

The Aeronautics and Cross Agency Support Division fosters NASA's international engagement in aeronautics research, as well as a wide range of activities in support of the Agency's mission, including the development of new space technologies, educational activities, and communication with the public about NASA's past and present accomplishments. The Division oversees a diverse assortment of cooperative activities, from research aimed at improving the safety and efficiency of global aviation to complementing U.S. space technology investments with research activities in other countries to help meet NASA goals. In addition, the Aeronautics and Cross Agency Support Division also serves as the lead division for NASA's relations with Canada and Europe. Finally, the Division oversees all international efforts for and provides policy and programmatic support on international matters to NASA's Aeronautics Research Mission Directorate, the Office of the Chief Technologist, the Office of the Chief Scientist, and NASA's Office of Education.

Science Division

The Science Division coordinates international activities in support of NASA's Science Mission Directorate and develops and implements policies for carrying out those activities. In addition to serving as the lead division for various regions, including Asia, the Middle East, Africa, and Latin America, the Science Division works primarily on cooperation related to Earth science, solar system exploration, heliophysics, and astrophysics. The Science Division's work includes developing and negotiating international agreements with many different countries and intergovernmental organizations, including NASA's traditional partners in Asia, Canada, and Europe, as well as with nontraditional partners. The latter includes countries with rapidly developing space capabilities, such as Argentina, Brazil, India, and the Republic of Korea, as well as nations with less spacefaring experience that are beginning to engage in space activities both for scientific purposes and societal benefits. NASA's international scientific cooperation encompasses a broad range of activities, including strategic partnerships on major space and Earth science missions, flights of foreign instruments on NASA spacecraft and NASA instruments on foreign spacecraft, exchanges of data from research conducted in space and on the ground, and coordination and interoperability of ground system assets. The Science Division also supports the Science Mission Directorate through the development and coordination of policies with other Government agencies.

Advisory Committee Management Division

The Advisory Committee Management Division is responsible for providing management oversight of NASA's six external Federal advisory committees and ensuring that they operate in full compliance with the Federal Advisory Committee Act, the Government in the Sunshine Act, and related Federal statutes, regulations, and policies. These six Federal advisory committees are

- Aerospace Safety Advisory Panel,
- Applied Sciences Advisory Committee,
- ISS Advisory Committee,
- ISS National Laboratory Advisory Committee,
- NASA Advisory Council, and
- National Space-Based Positioning, Navigation, and Timing Advisory Board

The Division also provides direct staff and administrative support for the two long-standing senior advisory committees to the NASA Administrator: the Aerospace Safety Advisory Panel and NASA Advisory Council.

Export Control and Interagency Liaison Division

The Export Control and Interagency Liaison Division supports all four NASA Mission Directorates through the administration of the NASA Export Control Program, administration of the NASA J-1 Exchange Researcher Program, and oversight of certain NASA foreign travel. In addition, the Division coordinates Agency-level policy interactions with Executive Branch departments and agencies, and is the principal Agency liaison with the National Security Council, Office of Science and Technology Policy, and the Departments of Commerce, Defense, Energy, and State. The Export Control and Interagency Liaison Division manages the NASA Export Control Program, ensuring Agency compliance with U.S export control laws and regulations, providing policy guidance, and representing the Agency on interagency working groups dealing with international technology transfer, nonproliferation, and export control. In addition, the Division serves as the NASA liaison to other Government agencies on a wide spectrum of areas, including national security policy, national space policy, interagency agreements, and personnel exchange agreements. Activities also include the NASA International Exchange Visitor Program and coordination of international travel of NASA personnel.

Resources Management Division

The Resources Management Division is responsible for OIIR's internal operations, including budget, personnel, information technology, space planning, and administrative support for NASA's overseas representatives and Department of Defense liaisons. The Division also manages the Agency-wide interpretation and translation services and visa processing contract, and is the State liaison for issues pertaining to overseas staffing, security, and facilities; the International Cooperative Administrative Support Services interagency group; and the Capital Security Cost Sharing group. The Resources Management Division is responsible for the initiation, management, and implementation of institutional resources and operations. Specifically, the Division plans, develops, and manages the budget and human resources for OIIR and NASA's international and interagency liaison offices. The Resources Management Division also has oversight responsibilities for operations and policy initiatives in the overseas offices.

APPENDIX II: NASA AND INTERNATIONAL SPACE PARTNERSHIPS

We examined the overall capabilities of NASA and the Agency's international partners. As part of our review, we visited French, German, and Japanese space agencies and ESA; conducted teleconferences with others, including the Indian Space Research Organization; and surveyed nine other partners regarding their capabilities and skills. Table 9 lists the international partners from whom we collected information.[81]

Table 9: Select International Partners and Associated Space Agencies

International Partner	Space Agency
Argentina	National Commission on Space Activities (CONAE)
Australia	Commonwealth Scientific and Industrial Research Organization (CSIRO)
Brazil	Brazilian Space Agency (AEB)
Canada	Canadian Space Agency (CSA)
China	China National Space Administration (CNSA)
ESA [a]	22 member states
France	Centre National d'Etudes Spatiales [National Center for Space Studies (CNES)]
Germany	German Aerospace Center (DLR)
India	Indian Space Research Organization (ISRO)
Italy	Agenzia Spaziale Italiana [Italian Space Agency (ASI)]
Japan	Japan Aerospace Exploration Agency (JAXA)
Russia	Roscosmos State Corporation (Roscosmos)
South Korea	Korea Aerospace Research Institute (KARI)
Spain	National Institute for Aerospace Technology (INTA)
Ukraine	State Space Agency of Ukraine (SSAU)
United Kingdom	United Kingdom Space Agency (UK Space Agency)
United States	National Aeronautics and Space Administration (NASA)

Source: NASA Office of Inspector General.

[a] The 22 member states of ESA are Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom. Canada takes part in some projects under a cooperation agreement.

The following pages provide information about the joint missions, technical expertise, and funding of NASA and its international partners. In addition, we discuss how each partner's capabilities are or can be utilized in current and future international collaboration opportunities.

[81] We did not interview or otherwise obtain information from officials at the Chinese or Russian space agencies. Information on these agencies was obtained from publically available sources.

NATIONAL COMMISSION ON SPACE ACTIVITIES

The National Commission on Space Activities (CONAE) is responsible for implementing Argentina's National Space Program. Established in 1991, CONAE's mission is to encourage the development of socio-economic sectors of the country, improve quality of life, and improve and conserve the global environment. CONAE's main activities include conducting Earth observation, strengthening the relationship between scientific and educational communities, developing and implementing advanced technology, and optimizing the use of human resources. In 2014, NASA had six active agreements with Argentina, four of which were with CONAE.

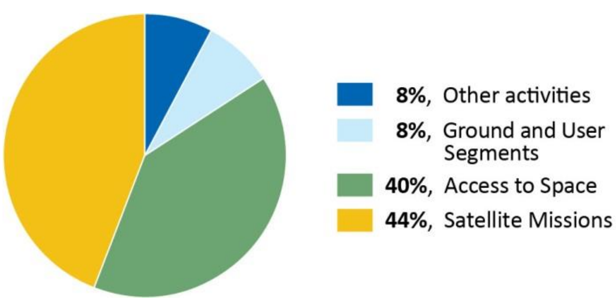
Governance

CONAE operates both publicly and privately in the scientific, technical, industrial, commercial, administrative, and financial fields. CONAE is under the scope of the Ministry of Science, Technology, and Scientific Innovation, and has five locations in Argentina, including its headquarters in Buenos Aires.

Budget

In fiscal year 2015, CONAE's budget was $197.8 million (1.9 billion pesos), which was split between satellite missions, access to space, ground and user segments, and other activities.[82]

Distribution of CONAE's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Key Projects with NASA

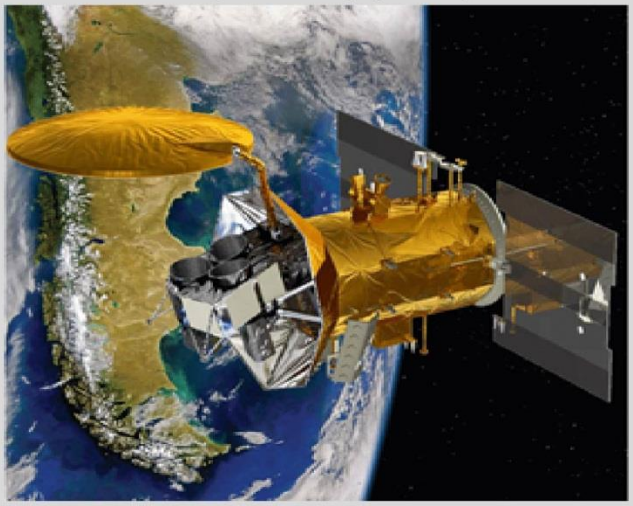
Scientific Application Satellites (SAC). CONAE and NASA have developed four satellite projects:

- *SAC-B.* Launched in 1996, SAC-B was designed to study solar physics and astrophysics through the examination of solar flares, gamma-ray burst sources, and the diffuse soft X-ray cosmic background. NASA provided two scientific instruments and launch services on a Pegasus XL vehicle, while CONAE was responsible for the design and construction of the SAC-B satellite.
- *SAC-A.* Launched in 1998, SAC-A was a technological demonstration mission developed by CONAE.
- *SAC-C.* Launched in 2000, SAC-C provided multispectral imaging of terrestrial and coastal environments. The satellite studied the structure and dynamics of the Earth's atmosphere, ionosphere, and geomagnetic field. CONAE was responsible for developing the spacecraft and several scientific instruments, while NASA supplied the launch vehicle and several additional scientific instruments.
- *SAC-D (Aquarius).* Aquarius launched in 2011 to provide a better understanding of the regional and global processes that link variations in ocean salinity to climatic changes in the global water cycle and how these variations influence ocean

[82] U.S. dollar values as of September 30, 2015.

circulation and climate. The satellite was jointly built by NASA, with CONAE providing the SAC-D observatory, an optical camera, a thermal camera in collaboration with Canada, and a microwave radiometer.

Artist's Rendering of SAC-D (Aquarius)



Source: NASA.

Scientific Application Satellites (SAOCOM). CONAE's SAOCOM IA and IB missions are scheduled to launch in 2017 and 2018, respectively, on Space Exploration Technologies Corporation (SpaceX) Falcon 9 launch vehicles. NASA will provide CONAE advice on mission integration topics, including effects of secondary payloads on SAOCOM IB.

CONAE Capabilities

CONAE has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Development of space-based tools for Earth observation
- Small rockets
- Satellites
- Test and integration facilities
- Ground tracking stations

Emerging Capabilities

- Space technologies
- Satellite launch systems

Opportunities for Cooperation

CONAE has interest in planetary exploration and cooperation with NASA on the SABIA-Mar mission (Argentinean-Brazilian Satellite of Environmental Information of the Sea). The agency is also working with NASA to identify common goals and define future cooperative missions. In addition, CONAE is focused on optimizing the development of areas within Argentina's socio-economic field. To achieve this, CONAE is studying six space information cycles:[83]

- *Cycle I*. Relevant space information concerning agricultural, fishing, and forestry production, including monitoring and protection of ichthyic resources.
- *Cycle II*. Relevant space information related to weather, hydrology, and oceanography, including monitoring of climate changes and freshwater courses throughout the territory, including South Atlantic Ocean and Antarctic Sea studies. In addition, Cycle II also includes, in a wider geographical range, seasonal forecast on global phenomena like El Niño.
- *Cycle III*. The management of natural as well as human-induced disasters, including fires, floods, volcanic eruptions, earthquakes, tornados, cyclones and hurricanes, landslides, and hydrocarbon leakage.
- *Cycle IV*. Environment and natural resources monitoring, focused on different applications for the study of climate and global atmospheric changes. Cycle IV also refers to soil, air, and water pollution.
- *Cycle V*. Remote sensing and processing of relevant information to be used in cartography, geology, mining production (including oil and gas prospecting), and territorial planning.
- *Cycle V*. Remote sensing and processing of field data information in order to set up human disease hazard predictable patterns.

[83] The six space information cycles are included in the CONAE's Space Program Revision (2004–2015).

Commonwealth Scientific and Industrial Research Organisation

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) celebrates its 100th Birthday this year having been first created by its Government in 1916 as an advisory council. CSIRO's mission includes the development and delivery of world-class national facilities for radio astronomy and spacecraft tracking. The organization's purpose is to carry out scientific research assisting Australian industry and furthering the interests of Australia. CSIRO conducts research and development in a variety of fields, and although not a "space agency," many of Australia's space-related activities are carried out within CSIRO's division of Astronomy and Space Science (CASS). In 2014, NASA had 20 active agreements with Australia, 2 of which were with CSIRO.

Governance

CSIRO is responsible for carrying out Australian obligations under treaty-level agreements with NASA relating to space activities. The organization has an independent Board of Directors that sets strategic direction and a Chief Executive that leads the management and operations with his Executive Team of five people. Australia has a Space Coordination Office within the Department of Industry responsible for Australia's limited national civil space-related activities and any space-related discussions with foreign commercial or government entities. CSIRO has more than 5,000 staff working out of 57 centers located throughout Australia and overseas.

Budget

In fiscal year 2014–2015, CSIRO's budget was approximately $899.5 million (1.28 billion Australian dollars).[84] Space related activity is a small percentage of this budget. CASS's budget for radio astronomy activities during this period was approximately $28.8 million (41 million Australian dollars). CSIRO also receives an additional $14.8 million (21 million Australian dollars) from NASA for the operation of the Canberra Deep Space Communications Complex. With regard to space-related activities conducted elsewhere within CSIRO, approximately $14.1 million to $21.1 million (20 million to 30 million Australian dollars) is currently invested annually on activities relating to Earth observations from space.

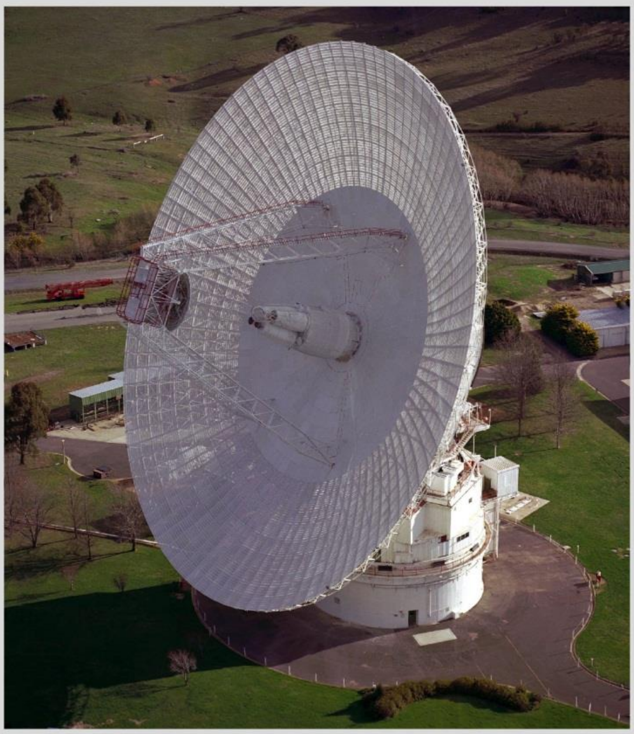
Key Projects with NASA

Generally, Australia's space program is focused on advancing Australian industrial development and growth rather than advancing science, human space flight, and future space exploration. NASA and the Australian government have several agreements and contracts for the operation of NASA's Canberra Deep Space Communication Complex; NASA balloon launches near Alice Springs, Australia; a NASA loan of geodetic equipment for the MOBLAS-5 Satellite Laser Ranging Station, Global Navigation Satellite Systems; a cooperative cloud study; and Australian participation in the international Global Learning and Observation to Benefit the Environment science and education program. In addition, NASA is investing $84.3 million (120 million Australian dollars) in new antennas at the Canberra Deep Space Communication Complex to provide increased capacity for the Agency's Deep Space Network.

[84] U.S. dollar values as of September 30, 2015.

CSIRO provides expertise in design, modelling, fabrication, coatings, and metrology of precision optical components and systems for three international observational programs: (1) the Gravity Recovery and Climate Experiment mission, which maps Earth's gravity field by making measurements between two satellites using GPS and a microwave ranging system; (2) Solar Orbiter, a spacecraft that will be placed into an elliptical orbit around the Sun in 2018 to examine the central questions of heliophysics; and (3) Laser Interferometer Gravitational Wave Observatory (LIGO), a facility dedicated to the detection and measurement of cosmic gravitational waves for scientific research.

View of the Canberra Complex-Deep Space Network



Source: NASA.

CSIRO Capabilities

CSIRO has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Radio astronomy
- Spacecraft tracking
- Transfer of space related technologies to mining automation applications
- Earth observation analytics
- Determining the effects of space radiation on human DNA
- Wireless technology and sensor networking
- Ground station support

Emerging Capabilities

- Optical components and systems
- Geologically intelligent telerobotics
- InSitu resource utilization
- Earth observation technology

Opportunities for Cooperation

CSIRO has interest in the following areas:

- Space tracking technologies
- "Big data" infrastructure for the collection, management, processing, and operational use of large multi sensor Earth observation data archives
- Development of methods that transform Earth observation data into publicly accessible information products
- Developing and applying new Earth observation technologies such as imaging spectroscopy, LIDAR, SAR, MWIR, and LWIR
- Global ocean observation using satellite altimetry
- Climate monitoring and modelling
- Developing new detectors, high frequency communications, and new materials
- Remote mining and automation

Brazilian Space Agency

The Brazilian Space Agency (AEB) was established in 1994 and is charged with overseeing Brazilian space activities and fostering cooperation, both nationally and internationally, to further the country's goals in space. The agency coordinates the major elements of Brazil's space activities carried out by other institutions that constitute the National System for the Development of Space Activities. AEB's main activities include space applications, satellites and payloads, satellite launching vehicles and sounding rockets, space infrastructure, space sciences, and research and development on space technologies. In 2014, NASA had 10 active agreements with Brazil, 4 of which were with AEB.

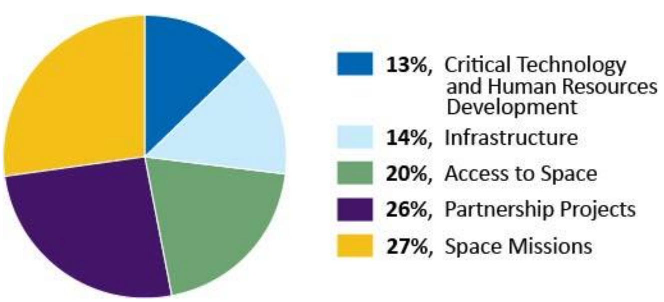
Governance

AEB is a civilian authority in the Executive Office of the President of Brazil. AEB has a mandate to formulate and carry out the Brazilian National Policy on the Development of Space Activities and the Brazilian National Space Activities Program. Covering a 10-year period, the Brazilian National Space Activities Program organizes Brazil's space activities into major programs intended to achieve the country's national space policies.

Budget

The budget for space activities in Brazil has grown steadily in recent years, and in 2015, AEB had budgeted approximately $253.9 million (1.03 billion reals) for five main activities, including space missions, partnership projects, and access to space.[85]

Distribution of AEB's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.
Note: Nominal differences in percentages due to rounding.

Key Projects with NASA

Global Precipitation Measurement (GPM) Mission. GPM is an international satellite mission launched in February 2014 that seeks to provide observations of rain and snow information worldwide every 3 hours. While NASA and the Japan Aerospace Exploration Agency provided the GPM Core Observatory satellite, NASA and AEB are conducting a feasibility study of potential cooperation in GPM related scientific research, ground validation of GPM satellite data, and other related activities.

Artist's Rendering of GPM Core Observatory

Source: NASA.

Heliophysics and Space Weather Research Agreement. NASA and AEB signed an agreement in June 2015 with the Brazilian National Institute for Space Research (INPE), which is carrying out AEB's responsibilities in this

[85] U.S. dollar values as of September 30, 2015.

joint research project. NASA scientists are working with their counterparts in INPE's space weather program, focusing on the Brazilian low-latitude chain of magnetometers and ionospheric monitors, as well as the science models developed at INPE. INPE scientists will participate in NASA's magnetospheric missions, the Magnetospheric Multi-Scale mission, and the Van Allen Probes mission through joint data analysis, theory, and modeling.

Space Geodetic Research Agreement. As part of the agreement, NASA and AEB established permanent GPS ground stations in Brazil, with the first agreed upon station located at the INPE, Cachoeira Paulista, Sao Paulo, Brazil. The GPS stations provide critical geodetic reference points in South America and significantly improve accuracy of global and regional geodetic measurements. Another objective of the agreement was to encourage scientists from both Brazil and the United States to develop research programs based on Brazilian network data along with geodetic and related data available from the global networks. The original agreement was signed in April 2000 with an expiration date of April 2010; however, the agreement was extended in 2010 and will now expire in 2020.

Satellite Launch Vehicle (VLS-1)

Source: AEB.

AEB Capabilities

AEB has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Small satellites: partner in developing components for communication, observation, and climate/ weather satellites
- Sounding rockets
- Satellite testing facilities
- Ground facilities for launch operation

Emerging Capabilities

- Reentry platforms
- Commerical launch operations
- Earth observation radar satellite
- Atmospheric reentry
- Complete satellite development and manufacturing
- Launch vehicles for satellites
- Experiments in microgravity

Opportunities for Cooperation

AEB would like to expand international partnerships by prioritizing joint development of technological and industrial projects of mutual interest especially in Earth observation, meteorology, and telecommunications. Specific main areas of emphasis to support these endeavors are advanced satellite and launch system development. Projects that include capacity building for Brazilian industry and technological skills will be highly sought after. Brazil intends to increase public-private partnerships including academia, industry, and other government agencies.

CANADIAN SPACE AGENCY

Established in March 1989, the Canadian Space Agency's (CSA) objectives are to promote the peaceful use and development of space, advance the knowledge of space through science, and ensure that space science and technology provide social and economic benefits for Canadians. CSA directs its activities through these programs: Space Data, Information and Services; Space Exploration; future Canadian Space Capacity; and Internal Services – that focus on Earth and the environment, space science, human presence in space, satellite communications, and space technologies. In 2014, NASA had 53 active agreements with Canada, 23 of which were with CSA.

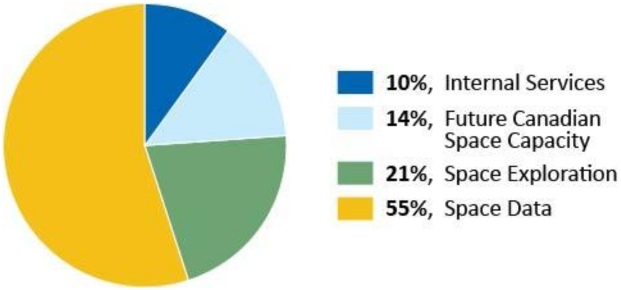
Governance

The CSA President serves as CSA's Chief Executive Officer and, under the direction of the Minister of Innovation, Science, and Economic Development, has control and supervision over the work, officers, and employees of the agency. The agency has approximately 600 employees, the majority of whom are employed at CSA's headquarters in Quebec.

Budget

CSA's fiscal year 2014–2015 budget of approximately $344.9 million (462.5 million Canadian dollars) funded internal services, future Canadian space capacity, space exploration, and space data activities.[86]

Distribution of CSA's 2015 Budget Based on Work Type

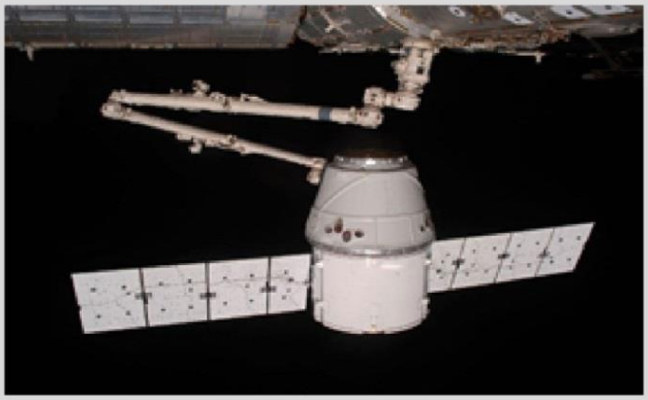


Source: NASA OIG analysis of space partner information.
Note: Nominal differences in percentages due to rounding.

Key Projects with NASA

International Space Station. Canada contributed the Mobile Servicing System (MSS), an external robotic system that has been critical to the successful assembly and maintenance of the ISS since 2001. The MSS is made up of three main elements: the Space Station Remote Manipulator System, or Canadarm2; a Mobile Base System that extends the reach of Canadian robots along the ISS truss; and the Special Purpose Dexterous Manipulator, or Dextre, a two-armed dexterous robot.

Canadarm2 Grapples Dragon



Source: NASA.

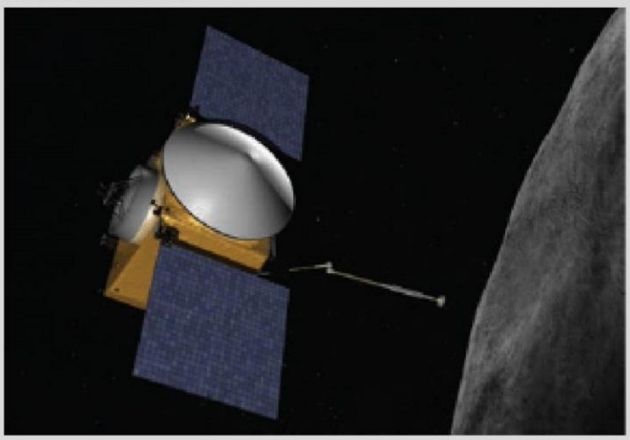
Canadarm2, a large 17 meter manipulator arm, was instrumental in assembling the ISS by manipulating large modules, elements, and truss segments delivered by the Space Shuttle and supporting Extravehicular Activity - also known as space walks. Today, Canadarm2 is utilized

[86] U.S. dollar values as of September 30, 2015.

in the commercial cargo resupply of ISS with capture and release operations of the Dragon and Cygnus spacecrafts. The addition of Dextre to the MSS enhanced the external robotic capability for removal and replacement of critical components, thereby reducing associated risks to crew.

Origins Spectral Interpretation Resource Identification Security-Regolith Explorer (OSIRIS-REx). OSIRIS-REx is the first U.S. mission developed to return asteroid samples to Earth, and will launch in late 2016 and reach the asteroid in 2018. NASA is collaborating with CSA and CNES on this mission, with CSA providing the OSIRIS-REx Laser Altimeter. OSIRIS-REx marks the first time Canada will participate in an international mission to return an extraterrestrial sample to Earth.

Artist's Concept of OSIRIS-REx Approaching the Bennu Asteroid



Source: NASA.

The Phoenix Mars Lander. The first mission to explore the Arctic region of Mars at ground level, the Phoenix Mars Lander launched on August 4, 2007. Landing near Mars's northern polar cap on May 25, 2008, the Phoenix continued to operate successfully for more 5 months, measuring Mars' temperature and pressure, and probed clouds, fog, and dust in Mars' lower atmosphere. Most significantly, the Phoenix mission confirmed that it snows on Mars. This marked the first time that Canada, as a nation, landed on the surface of Mars, with the Phoenix operating far beyond its planned 90-day mission.

Mars Science Laboratory (MSL). NASA's MSL mission utilized an innovative sky crane to land the Curiosity rover safely on the surface of Mars in August 2012. CSA provided MSL's on-board Alpha Particle X-ray Spectrometer (APXS), which measures chemical elements in Mars' rocks and soils. The ultimate objective of the APXS is to determine the geological context of Curiosity's surroundings and investigate the processes that formed the surface of Mars.

James Webb Space Telescope (JWST). The successor to the Hubble Space Telescope, JWST is a large, complex infrared-optimized space telescope. An international project using innovative technologies, CSA has been involved with the mission since the 1990s, contributing the Fine Guidance Sensor (FGS) and the Near-InfraRed Imager and Slitless Spectrograph (NIRISS). The FGS provides accurate direction finding while the NIRISS has unique capabilities for finding the most distant objects, and discovering and characterizing planets in other solar systems.

CSA Capabilities

CSA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Astronaut training[a]
- Radar (LIDAR and SAR)
- Space robotics (manipulators, on-orbit servicing systems)
- Radiation dosimetry
- Space instruments
- Space communications
- Vision systems (inspection and rendezvous sensors)

Emerging Capabilities

- Ground navigation and control for planetary roving
- Planetary surface mobility systems
- Multispectral observations
- Space medicine and life science systems
- Surveying, prospecting, mining, and InSitu Resource Utilization

[a] Eight Canadian astronauts have flown on 16 missions.

Opportunities for Cooperation

CSA is interested in and collaborates on space missions that cover a variety of disciplines and destinations, including Earth observation and the science of climate change, health and life sciences on the ISS, space-based astronomy, planetary exploration, and the commercialization of space. In 2015, the Canadian government announced that Canada will continue its participation in the ISS program to 2024.

China National Space Administration

The China National Space Administration (CNSA) of the People's Republic of China was established in 1993 to coordinate the country's space exploration efforts. CNSA's mission is to explore outer space, learn more about the Earth, promote mankind's social progress, and meet the growing demands of economic construction, national security, and science and technology development. CNSA's main activities include human space flight, Earth science, development of launch vehicles, and ground tracking. In 2014, NASA had one active agreement with China.

Governance

CNSA is the governmental organization responsible for managing China's space activities and international space cooperation with other countries. CNSA is an internal part of the State Administration of Science, Technology and Industry for National Defense, which is a subordinate agency of the Ministry of Industry and Information Technology. An Administrator oversees the four main CNSA departments: planning; system engineering; science, technology and quality control; and foreign affairs.

Budget

Although little reliable public information is available on the Chinese space budget, estimates of the country's annual space development budget from 2014 run as high as $5 billion (31.8 billion yuan). According to the European space consulting firm, Euroconsult, the 2008 CNSA budget was $1.3 billion (8.3 billion yuan).[87] The firm noted that launch vehicle development accounted for 25 percent of the estimated overall budget followed by human space flight and Earth observation, with 20 percent each.

Key Projects with NASA

Bilateral cooperation with China has been restricted since 2011 by congressional legislation that forbids NASA from using any of its funds to "develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company." Limited exceptions to this ban on bilateral cooperation include four low-level activities:

- Exchange of respective lunar science mission information.
- Reactivation of cooperative activities in space geodesy.
- Coordination of Earth observation data products for glacier characterization in the Himalaya region.
- Collaboration in basic air traffic management research.

While bilateral cooperation is limited, NASA is not prohibited from interacting with CNSA through joint participation in multilateral groups such as the International Space Exploration Coordination Group, Committee on Earth Observing Satellite, and the United Nations Committee of the Peaceful Uses of Outer Space.

[87] Yuan values as of September 30, 2015.

Shenzhou 5

Source: NASA.

CNSA Capabilities

CNSA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Human space flight
- Lunar orbiter
- Earth observation and aeronautics
- Lunar missions, including robotic lander
- Launch vehicles

Emerging Capabilities

- Planetary mission

Opportunities for Cooperation

The NASA Administrator met with top leaders of CNSA's human and robotic space programs in October 2010. According to the Administrator, the objectives of the visit were to become acquainted with Chinese space officials, gain a better understanding of Chinese human space flight programs, and reach a common understanding with respect to any future interaction between the two nations in the area of human space flight. The visit did not include consideration of any specific proposals for future cooperation, but intended to form the basis for further dialogue between the two countries. The NASA Administrator also visited China in November 2014 and met with the Director of CNSA.

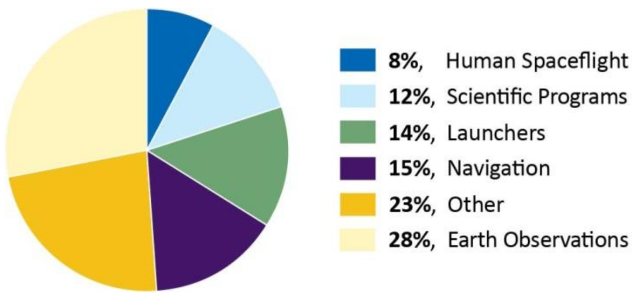
European Space Agency

An interagency and intergovernmental organization established in 1975, the European Space Agency's (ESA) mission is to shape development of Europe's space capability and ensure investments in space continue to deliver benefits. Comprised of 22 European member states that jointly fund multiple programs, ESA promotes cooperation among European States in space research and technology. ESA's main activities include launch vehicle development, human space flight, space science, Earth observations, telecommunications, and navigation. Canada has a long standing cooperation agreement with ESA and takes part in some ESA programs, and Bulgaria, Cyprus, Malta, Latvia, Lithuania, Slovak Republic, and Slovenia have specific cooperation agreements with ESA designed to prepare their potential future adhesion to ESA. The United States and ESA cooperate on many projects, each with a dedicated agreement. In 2014, ESA had 52 active agreements with NASA.

Governance

ESA's decision making resides with the ESA Council, which is composed of representatives from each member state. The Director General, supported by 10 directors, is responsible for the execution of the programs and for ESA's management. ESA has approximately 2,000 employees, with most staff located in Belgium, France, Germany, Italy, the Netherlands, Spain, and the United Kingdom.

Distribution of ESA's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Budget

ESA's 2015 budget of approximately $4.97 billion (4.4 billion euros) funds human space flight, science programs, launchers, navigation, Earth observation, and other activities.[88] Member states contribute to ESA's mandatory programs comprised of space science and technology (approximately 20 percent of its annual budget) on a scale based on their GDP and may choose their level of involvement for ESA's optional programs.

Key Projects with NASA

International Space Station. ESA's most significant contribution to the ISS – the Columbus Module – is a research laboratory that provides 75-cubic meters of the Station's research facilities. ESA also provided the European Robotic Arm and the Station's Cupola, an observation and work area that provides the crew with visibility to control the Station's robotic arms and to observe Earth, celestial objects, and visiting vehicles. In addition, ESA's Automated Transfer Vehicle delivered supplies to the ISS for 6 years, and at regular intervals, also boosted the ISS into a higher orbit, flying its last mission in July 2014.

[88] U.S. dollar values as of September 30, 2015.

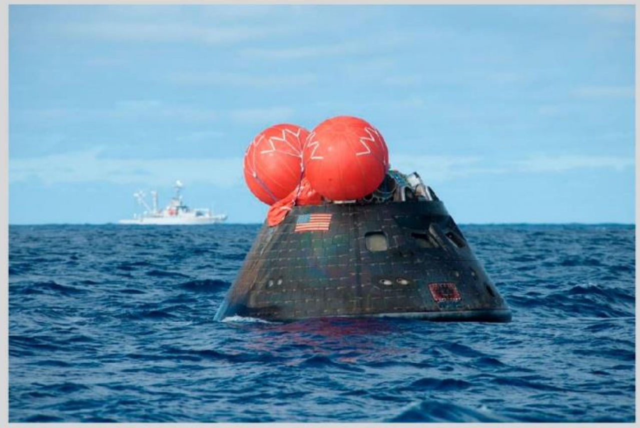
Ariane 5 Launch Vehicle

Source: NASA.

Solar Orbiter. The Solar Orbiter is a spacecraft equipped with instruments for both in-situ measurements and remote-sensing observations of the Sun. It will be placed into an elliptical orbit around the Sun and address the central question of heliophysics – how does the Sun create and control the heliosphere. NASA is contributing two instruments to the Solar Orbiter: SoloHI, a wide-field heliospheric imager, and the Heavy Ion Sensor, which will measure the composition and kinetic properties of heavy ions in the solar wind. ESA is providing the spacecraft, while several member states are providing the remainder of the 10 instrument payload. NASA is also providing the launch and associated services. The expected launch date for the Solar Orbiter is October 2018.

Orion Multi-Purpose Crew Vehicle (Orion) Service Module. Orion is the spacecraft NASA is developing to send humans and cargo into space beyond low Earth orbit. The vehicle's configuration includes the habitable crew module, service module, crew module adaptor, spacecraft adaptor, spacecraft adaptor jettisoned fairings, and launch abort system for crew safety. ESA is providing the Orion Service Module, which provides electricity, water, oxygen and nitrogen for the crew. Orion will launch on NASA's Space Launch System in 2018.

NASA's Orion Spacecraft Awaits the U.S. Navy's USS Anchorage for a Ride Home



Source: NASA.

ESA Capabilities

ESA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Systems integration
- Launchers and associated launch site (Ariane 5 and Vega)
- Automated rendezvous and docking
- Pressurized modules
- Robotic satellite systems
- Scientific instrumentation
- Space communication and tracking
- Thermal structure
- Propulsion technology (Smart-1)
- Astronaut training
- Planetary exploration (Mars Express, Rosetta, and Gaia)

Emerging Capabilities

- Lunar transportation (Ariane 5)
- Existing Ariane 5 improvements and evolution
- Advanced rocket development (Ariane 6 and Vega-C)
- Advanced lunar, planetary and solar system exploration (Aurora Program; Mars - ExoMars; Jupiter's Moons - JUICE; Mercury - BepiColumbo)

Opportunities for Cooperation

ESA's interests include human space flight, space and Earth science missions, as well as Moon and Mars exploration. In September 2014, ESA officials indicated that a decision to extend their participation in the ISS will not occur until late 2016.

National Centre for Space Studies

Founded in 1961, Centre National d'Etudes Spatiales (CNES) is the French government agency responsible for developing and executing France's space policy. CNES's mission is to provide an overall vision of space solutions drawing on the agency's core system skills and constant innovation while remaining attentive to the needs of users; working at the intersection between scientific and technology laboratories, manufacturers, and service companies; and meeting institutional and commercial needs by stimulating scientific, technological and industrial research and innovation. CNES' main activities include science, observation, defense, telecommunications, and the Ariane rocket program. In 2014, NASA had 93 active agreements with France, 49 of which were with CNES.

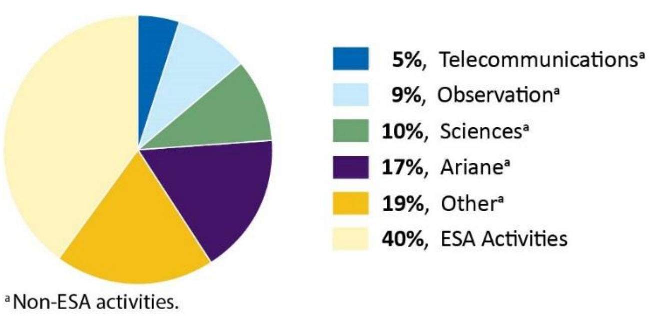
Governance

A President and several Directors manage CNES's approximately 2,400 staff and four centers, including a headquarters and launch program facility in Paris, a spaceport in French Guiana, and a center in Toulouse, France, that develops space systems with partners in industry and the scientific community.

Budget

With a budget of $37 (33 euros) per year, per citizen, France's civil space budget is second only to the United States for per capita funding. In 2015, CNES' budget of $2.3 billion (2.1 billion euros) was used to fund various ESA activities and non-ESA activities, including Ariane, science, observation, telecommunications, and other activities.[89]

Distribution of CNES's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.
Note: Nominal differences in percentages due to rounding.

Key Projects with NASA

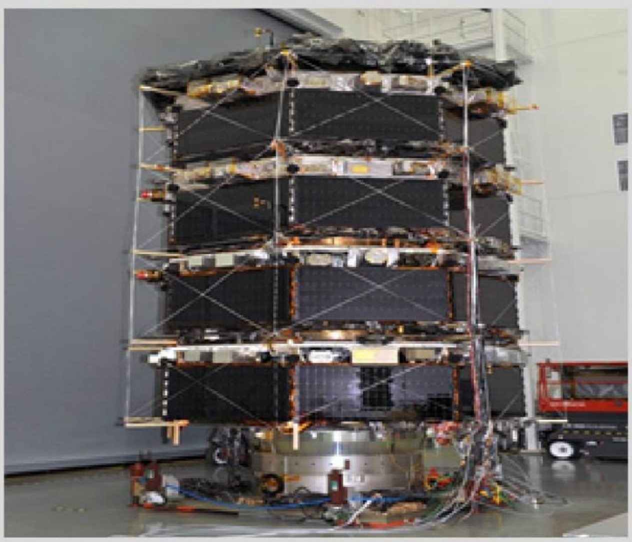
International Space Station. CNES participates in the ISS Program through ESA. In addition, CNES and NASA collaborated on the development, launch, and operation of the Device for the Study of Critical Liquids and Crystallization (DECLIC) instrument, a mini-laboratory with a range of optical equipment to study high-temperature and high-pressure critical fluids and directional solidification of transparent materials. DECLIC was installed on the ISS in August 2009.

Surface Water Ocean Topography (SWOT). The joint NASA-CNES SWOT mission, planned for launch in 2020, is designed to improve our understanding of the world's oceans and terrestrial surface waters by using wide-swath altimetry to measure spatial fields of surface elevations for inland waters and oceans. This data should lead to new information about the dynamics of water and improve estimates of deep-ocean and near-coastal marine circulation patterns. CNES plans to provide the spacecraft bus, the dual-frequency Nadir Altimeter, the Doppler Orbitography and Radiopositioning Integrated by Satellite receiver package, and the Radio Frequency Unit for the KaRIn instrument. NASA plans to provide the payload module, the Ka-band Radar Interferometer (KaRIn) Microwave Radiometer, a laser retroreflector array, a Global Positioning System receiver package, and all launch services.

[89] U.S. dollar values as of September 30, 2015.

Magnetospheric MultiScale Mission. The Magnetospheric MultiScale mission is a solar-terrestrial mission comprised of four identically instrumented spacecraft that will use Earth's magnetosphere to study the microphysics of three fundamental plasma processes: magnetic reconnection, energetic particle acceleration, and turbulence. Launched in March 2015, the mission is investigating how the magnetic fields of the Sun and Earth connect and disconnect, explosively transferring energy from one to the other in a process known as magnetic reconnection. This process impacts geospace weather, which in turn affects technological systems such as telecommunications networks, GPS navigation, and electrical power grids. CNES designed and developed the Search Coil Magnetometers, supported electronics for the four mission spacecraft, and supported the integration and testing of the Search Coil Magnetometers.

MMS Fully Stacked Without Protective Covers



Source: NASA.

Mars Science Laboratory (MSL). The MSL mission used a crane to set down the Curiosity Rover on the surface of Mars in August 2012. The primary scientific objective of the MSL mission is to assess the biological potential of at least one target area by characterizing the local geology and geochemistry, investigating planetary processes relevant to habitability, and characterizing the broad spectrum of surface radiation. CNES provided significant hardware for two of MSL's instrument suites: the Laser-Induced Remote Sensing for Chemistry and Micro-Imaging (ChemCam) and the Sample Analysis at Mars (SAM). For the ChemCam instrument suite, CNES provided the ChemCam mast unit, including the laser, telescope, camera, and front-end electronics. The ChemCam instrument suite is used to characterize the geology of the Mars landing region, investigate planetary processes relevant to past habitability, assess the biological potential of a target environment, and look for toxic materials. CNES provided the gas chromatograph portion of the SAM instrument suite. SAM is used to study geochemical conditions that are directly relevant to the larger goal of assessing the habitability of Mars. SAM also searches for compounds of the element carbon, including methane that are associated with life and explores ways in which they are generated and destroyed in the Martian ecosphere.

CNES Capabilities

CNES has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Space launch systems and facilities
- Satellite structures, components, and systems
- Scientific instrumentation
- Formation flying
- Propulsion technology
- Launch system support

Emerging Capabilities

- Sample return (Mars, near Earth objects)
- Landed lunar and Mars robotic science network mission
- Potential nuclear propulsion/power development
- Rocket nozzle extension with possible application for NASA's Orion second stage engine
- On-orbit storage, transfer, and measurement of cryogenic propellants

Opportunities for Cooperation

CNES' current interests include Earth observation, microgravity, and robotic exploration. Even though CNES participates in various exploration activities through its membership in ESA, human exploration is not a high priority for the agency because it has decided that the scientific benefits do not outweigh the large investments required. However, CNES indicated that if ESA is inclined to commit to extending the ISS to 2024 then France would support such an extension.

German Aerospace Center

The German Aerospace Center (DLR) is the national aeronautics and space research center and space agency of the Federal Republic of Germany. Established in 1969 with a mission focused on exploring Earth and the solar system and conducting research aimed at protecting the Earth's environment, DLR's main activities include space, aeronautics, transportation, defense and security, and energy research. In addition to being responsible for planning and implementing Germany's space program, DLR is an ESA partner and the umbrella organization for Germany's largest project management agency. In 2014, NASA had 91 active agreements with Germany, 51 of which were with DLR.

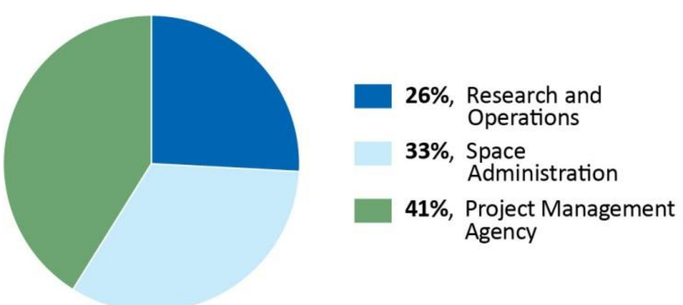
Governance

DLR is a chartered, nonprofit organization comprised of a General Assembly, Senate, Space Committee, Executive Board, and Scientific-Technical Advisory Council, and is headquartered in Cologne, Germany. With approximately 8,000 employees, DLR operates out of 16 locations in Germany.

Budget

DLR's 2015 budget of $3.7 billion (3.34 billion euros) funded research and operations, ESA contributions and the national space program (space administration), and DLR and Aeronautics Project Management Agency activities.[90]

Distribution of DLR's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.
Note: Nominal differences in percentages due to rounding.

Key Projects with NASA

Mars Exploration Rover (MER). Part of NASA's Mars Exploration Program, MER involved two robotic geologists – Spirit and Opportunity – that were launched separately in June and July 2003 and landed in different areas of Mars in January 2004. MER's goals for these two rovers included searching for and characterizing a range of rocks and soils for clues to past water activity and determining if conditions may have been favorable to life by analyzing the climate and water histories at sites on Mars. DLR provided two science instruments: the Alpha Particle X-ray Spectrometer, which determined the elemental composition of rocks and soils while providing scientists with information about crustal formation and weathering processes, and the Mössbauer Spectrometer, which determined the composition and abundance of iron-bearing minerals and examined the magnetic properties of surface materials.

Interior Exploration Using Seismic Investigations, Geodesy, and Heat Transport (InSight). InSight is a NASA Discovery Program mission that plans to place a lander on Mars to study the planet's deep interior. This mission will seek to understand the evolutionary formation of rocky planets, including Earth, by investigating the interior structure and processes of Mars. The lander will be equipped with two science instruments, the Seismic Experiment for Interior Structure provided by the French space agency and the

[90] U.S. dollar values as of September 30, 2015.

Heat Flow and Physical Properties Package provided by DLR. InSight's anticipated launch is in 2018.

Gravity Recovery and Climate Experiment (GRACE). GRACE is a joint partnership between DLR and NASA's Jet Propulsion Laboratory (JPL), with DLR responsible for providing mission management and satellite flight operations and JPL responsible for project management and systems engineering. GRACE consists of two identical spacecraft launched in March 2002 that fly about 137 miles apart in a polar orbit 310 miles above Earth. GRACE maps Earth's gravity field by making measurements of the distance between the two satellites using GPS and a microwave ranging system. The results from this mission are yielding crucial information about the distribution and flow of mass within Earth.

Stratospheric Observatory for Infrared Astronomy (SOFIA). SOFIA is the world's largest airborne observatory, capable of making observations that would otherwise be impossible for even the largest and highest ground-based telescopes. SOFIA is a partnership between NASA's Ames Research Center (Ames) and DLR that uses a modified Boeing 747 aircraft carrying a reflecting telescope. Ames manages SOFIA's science and mission operations in cooperation with the Universities Space Research Association and the German SOFIA Institute. While DLR covers 20 percent of SOFIA's annual operational costs and receives about 30 scientific flights per year, NASA is responsible for the remaining 80 percent of the program's operating costs and expects to accumulate approximately 14,000 research flight hours over SOFIA's 20 year life cycle.

SOFIA Arrives in Germany for Major Maintenance

Source: NASA.

DLR Capabilities

DLR has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Spacecraft thermal protection components and sensors
- Pressurized modules
- Automated rendezvous and docking
- Optical communications
- Vehicle health monitoring systems
- Aerothermodynamics diagnostic sensors components
- Robotics
- Scientific instrumentation
- Radar
- Propulsion technology

Emerging Capabilities

- Closed loop life support technology
- Precise landing technology
- Planetary surface robotics
- Laser communications
- Hyperspectral instrumentation (Lunar Orbiter)
- Lunar exploration orbiter/lunar lander
- Reversible fuel cell technology
- ISRU technologies
- Metallic flexible wheels
- Electro-Mechanical mole drills
- Radiation detectors
- Landing dynamics testbed

Opportunities for Cooperation

DLR provides critical support for scientific and commercial utilization of the ISS and NASA's planned robotic and human expeditions to Mars. For example, DLR is contributing to the European Service Module for the Orion spacecraft and provides scientific instrumentation for several space exploration missions, including the InSight Mars lander. In addition, DLR is leading development of the Mars Organic Molecule Analyzer for the ESA 2018 ExoMars rover. DLR's aeronautical research contributes to NextGen activities with a focus on Air Traffic Management for efficient use of airspace, safety and environmentally friendly air transportation. DLR and NASA are the main players in the International Forum for Aviation Research. Working with NASA and leading research institutions in the U.S., DLR enables the development of high-tech solutions for sustainable energy, advanced ground transportation, and security applications (e.g. optical communication) using an interdisciplinary approach and synergies from aerospace technologies.

Indian Space Research Organisation

The Indian Space Research Organisation (ISRO), founded in 1969, seeks to harness space technology for national development while pursuing space science research and planetary exploration. ISRO's mission is to design and develop launch vehicles and related technologies for providing access to space; satellites and related technologies for Earth observation, communication, navigation, meteorology, and space science; space-based applications for societal development and disaster management support; and research and development in space science and planetary exploration. ISRO's main activities include Earth observation, navigation, satellite communications, climate and environment, and disaster management. In 2014, NASA had 16 active agreements with India, 7 of which were with ISRO.

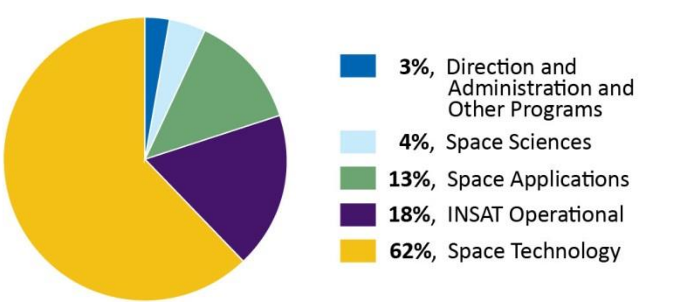
Governance

ISRO operates under the Department of Space, which is overseen by the Prime Minister. Led by its Chairman, ISRO Headquarters is located at Antariksh Bhavan in Bengaluru. ISRO has 17 centers throughout India and a staff of approximately 16,000.

Budget

For 2015–2016, ISRO's budget of $1.1 billion (73.9 billion rupees) supported four main operational activities: space technology, Indian National Satellite (INSAT) operations, space applications, and space sciences.[91]

Distribution of IRSO's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Key Projects with NASA

Mars Orbiter Mission. India's first interplanetary mission, Mars orbiter was launched in November 2013 and entered the Martian atmosphere on September 24, 2014. The goal of the mission was to explore and observe Mars surface features, mineralogy, and the Martian atmosphere. Under a reimbursable agreement, NASA is providing ISRO with tracking, navigation, and telecommunication support services for this mission.

ISRO Launches the Mars Orbiter Mission Spacecraft from Satish Dhawan Space Center

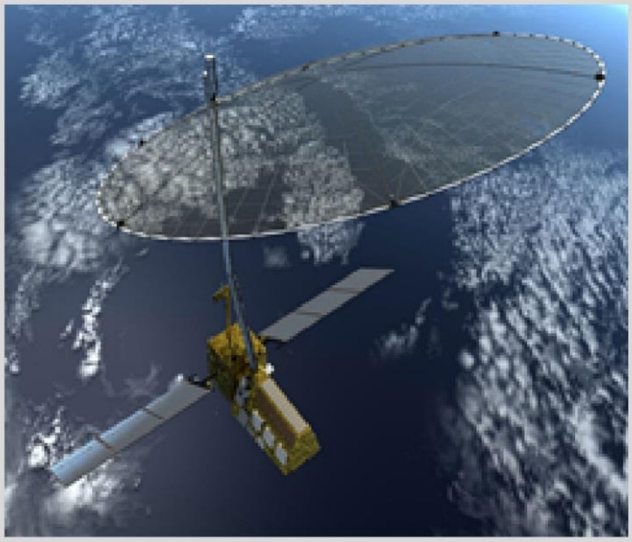
Source: ISRO.

[91] U.S. dollar values as of September 30, 2015.

Global Precipitation Measurement (GPM) Mission. GPM is an international network of satellites providing global observations of rain and snow to advance the understanding of Earth's water and energy cycles, improve climate prediction, and advance weather prediction. Led by NASA and the Japan Aerospace Exploration Agency, GPM involves a consortium of foreign space agencies, including ISRO. ISRO launched the first satellite, Megha-Tropiques – a joint ISRO-CNES venture.

NASA-ISRO Synthetic Aperture Radar (NISAR). NISAR is a satellite designed to observe and measure some of the Earth's most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes, and landslides. Data collected from NISAR will reveal information about the evolution and state of the Earth's crust, help scientists better understand Earth's changing climate, and aid future resource and hazard management. ISRO will provide the spacecraft bus system, S-band synthetic aperture radar, and the launch vehicle, and NASA will provide L-band synthetic aperture radar. The satellite is expected to launch in late 2020.

Artist's Concept of the NASA-ISRO Synthetic Aperture Radar



Source: NASA.

ISRO Capabilities

ISRO has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Lunar orbiter
- Mars Orbiter Mission
- Satellites
- Natural disaster monitoring
- Launch vehicles
- Earth Science and Observation
- Regional navigation
- Sounding rockets

Emerging Capabilities

- Lunar robotic lander mission
- Specialized composite materials
- Human space flight
- Heavy launch capability
- Advanced launch capability

Opportunities for Cooperation

ISRO is committed to carrying out research in satellite and launch vehicle technology, providing satellite services for weather forecasting, satellite imagery to survey natural resources, and satellite imagery for application of space science and technology for developmental purposes.

ITALIAN SPACE AGENCY

Founded in 1988, the Italian Space Agency (ASI) is responsible for coordinating and conducting Italian national space activities. The two major objectives of ASI's Strategic Vision are awareness of the space sector within Italian society and responsiveness to the goals and needs expressed by Italian citizens. In meeting these objectives, ASI hopes to strengthen cooperation with European and other world leaders in space. The agency's main activities include Earth observation, science and robotic exploration, and education and communication. In 2014, NASA had 28 active agreements with Italy, 18 of which were with ASI.

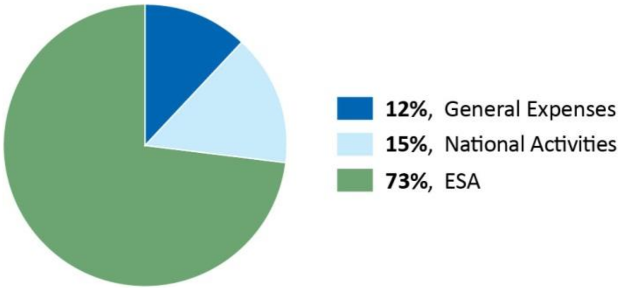
Governance

ASI is funded directly by the Italian government and reports to the Ministry of Public Instruction, Universities, and Research. A President and Board of Directors manage ASI's activities. The agency has a staff of 237 and the Headquarters is located in Rome. The Center of Geodesy and Earth Observation is located in Matera, Italy and a Space Center is located in Malindi, Kenya.

Budget

ASI's 2015 budget of $614.9 million (548.53 million euros) funded agency contributions to ESA, general expenses, and national activities.[92] Contributions to ESA and the budget for national activities may fund Earth and deep space observation, telecommunication, technology, access to space, and microgravity and human exploration.

Distribution of ASI's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Key Projects with NASA

International Space Station. ASI provided three Multi-Purpose Logistics Modules, one of which is permanently attached to the ISS. Italian contributions for the ISS have been exchanged for Station scientific utilization and astronaut flight opportunities. As of November 2015, seven Italian astronauts have flown to the ISS.

Fermi-Gamma-ray Large Area Space Telescope (GLAST). In 2008, NASA's Fermi-GLAST mission was launched to observe the Universe in the gamma-ray wavelength. ASI was involved in the manufacturing of the Large Area Telescope tracker, mission control, and data analysis.

Dawn Asteroid Rendezvous Mission. In 2007, NASA's Dawn mission sent an orbiting space probe to examine the dwarf planet Ceres and the asteroid Vesta, two of the largest bodies in the asteroid belt. Dawn's goal is to characterize the conditions and processes of the solar system by investigating Ceres and Vesta. ASI developed, supported, and integrated the Visual and Infrared Mapping Spectrometer for the mission, a high-spatial-resolution spectrometer used to study the surface and atmosphere of Ceres and Vesta.

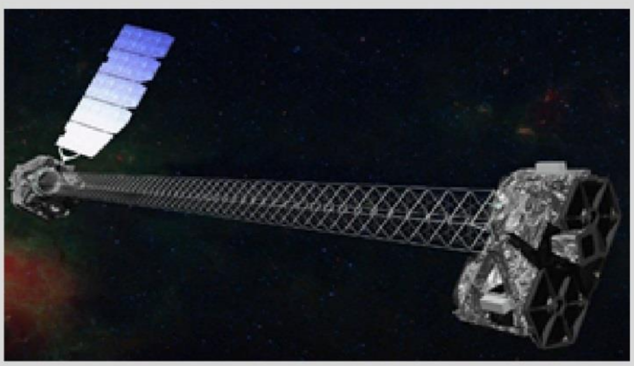
Mars Reconnaissance Orbiter. The Orbiter is a multipurpose spacecraft designed to advance understanding of Mars through detailed observation, examine potential landing sites for future surface missions, and provide a high data-rate communications relay for those missions. Scientists will use the spacecraft to study the surface, monitor the

[92] U.S. dollar values as of September 30, 2015.

atmosphere, and probe underground to gain better knowledge about the planet. ASI provided the mission with the Shallow Radar instrument which will penetrate and study the first one hundred meters of Mars subsurface.

Nuclear Spectroscopic Telescope Array (NuSTAR). Deployed in June 2012, the NuSTAR mission has the first orbiting telescopes to focus light in the high energy X-ray region of the electromagnetic spectrum. The goal of the mission is to map supernovae, search for black holes, and study active galaxies. The Malindi Ground Station, operated by ASI and located in Malindi, Kenya, is the primary data downlink and command uplink facility for NuSTAR. In addition, a team of ASI scientists from the National Institute for Astrophysics collaborates with NASA on the project's scientific goals.

Artist's Rendering of NuSTAR



Source: NASA.

Cassini-Huygens Mission. An ongoing NASA, ESA, and ASI mission to Saturn and its moons, ASI contributed the telecommunications system, radar instruments, and the Visible and Infrared Mapping Spectrometer to the orbiter.

Juno Mission. An ongoing mission launched in 2011, Juno is designed to study the inner structure, atmosphere, and the polar magnetosphere of Jupiter. ASI contributes to the mission with two instruments: the Jovian Infrared Auroral Mapper spectrometer and the Ka-band transponder.

ASI Capabilities

ASI has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Pressurized modules
- Satellite structures, components, systems
- Scientific instrumentation
- Space communications
- Space geodesy
- Global precipitation measurements

Emerging Capabilities

- In situ analysis
- Lunar orbiters
- Lunar robotics
- Descent and landing systems (reentry technologies)
- Surface mobility, including microrover
- Remote sensing
- Lunar based radio-astronomy and Earth observation
- High energy astronomy
- Inflatable structures
- Pressurized lunar logistics modules
- Lunar communications
- Ka-band deep space communications
- Liquid oxygen and methane engine development
- Advanced technology and exploration

Opportunities for Cooperation

ASI's interests include international cooperation on the use of space to enhance life on Earth, especially in mitigation of natural disasters; expanding human presence on other bodies in the solar system and exploratory missions to the Moon, asteroids, and Mars; deep space exploration and robotic missions such as Europa (one of Jupiter's moon); and Earth observation. Given ASI's in-depth involvement in the ISS – modules, cargo vehicles, and operations and research – the agency is interested in tailoring the remaining years of ISS research toward preparing for deep space missions.

Japan Aerospace Exploration Agency

The Japan Aerospace Exploration Agency (JAXA) was created in 2003 through the merger of three institutions: the Institute of Space and Astronautical Science, National Aerospace Laboratory of Japan, and National Space Development Agency of Japan. Designated as a core performance agency supporting the Japanese government's overall aerospace development and utilization, JAXA's purpose is to "Explore to Realize," reflecting its management philosophy of utilizing space and the sky to achieve a safe and affluent society. JAXA's main activities include human space flight, Earth and space science, space transportation, satellites, lunar and planetary exploration, and aeronautics. In 2014, NASA had 93 active agreements with Japan, 52 of which were with JAXA.

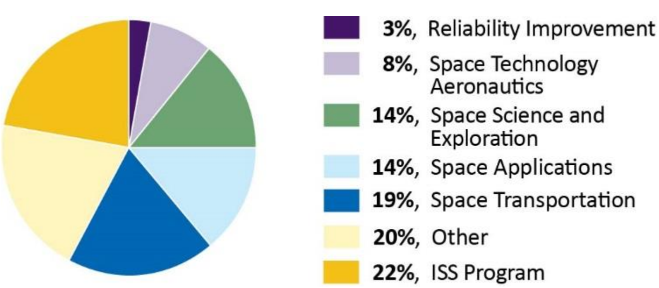
Governance

JAXA is the core organization providing technical support for all Japanese government development and utilization of space projects. In April 2015, JAXA's status changed from an independent administrative agency to the National Research and Development Agency. Led by a President and several vice presidents, JAXA is headquartered in Tokyo, Japan, with an additional 22 facilities around the world and a staff of approximately 1,500.

Budget

In fiscal year 2015, JAXA's budget of $1.28 billion (154.1 billion yen) supported seven main activities, including the ISS Program, space transportation, and space applications.[93]

Distribution of JAXA's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.
Note: Nominal differences dues to rounding.

Key Projects with NASA

International Space Station. JAXA is one of NASA's primary partners on the ISS, providing the Japanese experiment module and H-II Transfer Vehicle, an unmanned cargo transporter capable of delivering up to six tons of food, clothes, equipment, and experiments to the ISS per trip. JAXA will provide a total of nine flights to the ISS between 2009 and 2019. In addition, four JAXA astronauts have completed five stays on the ISS.

HTV2 Approaching the International Space Station

Source: JAXA/NASA.

Global Precipitation Measurement (GPM) Mission. GPM is an international network of satellites that provides global observations of rain and snow. The GPM Core Observatory was launched by JAXA in February

[93] U.S. dollar values as of September 30, 2015.

2014 and carries the JAXA-provided space-borne Ku/Ka-band Dual-frequency Precipitation Radar, as well as a NASA-provided multichannel GPM Microwave Imager. Through improved measurements of global precipitation, the GPM mission seeks to advance understanding of Earth's water and energy cycles and improve weather forecasting including extreme events and flood forecasting. The consortium of foreign space agencies and international organizations involved in the GPM mission includes CNES, the Indian Space Research Organization, the National Oceanic and Atmospheric Administration, and the European Organisation for the Exploitation of Meteorological Satellites.

Hayabusa/Hayabusa 2. Launched in May 2003, Hayabusa was an unmanned mission led by JAXA that collected and returned to Earth a surface sample of material from the Itokawa asteroid. Hayabusa mapped the asteroid in the visible, infrared, and X-ray spectra while also performing gravity modeling with a laser altimeter. NASA provided scientific support and backup spacecraft tracking, telemetry, command, and navigation support through its Deep Space Network. In 2014, JAXA launched Hayabusa 2 to the asteroid 1999 JU3 in an attempt to build upon the success of the original Hayabusa mission. NASA intends to participate in this follow-up mission by providing a similar level of support.

Artist's Rendering of Hayabusa 2

Source: JAXA.

JAXA Capabilities

JAXA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Robotics and manipulator systems
- Space communications and tracking
- Launchers and associated launch sites (H-2A and H-2B)
- Space logisitics vehicle (HTV)
- Astronaut training
- Nanotech
- Pressurized space structures
- Satellite structure, components, and systems
- Scientific instrumentation
- High-definition optics
- Simulation and modeling
- Cyogenic propulsion stage and related technologies

Emerging Capabilities

- Long term observation of Earth's environment (GCOM-C and EarthCARE)
- X-ray astronomy (ASTRO-H)
- Mercury exploration (BepiColombo)
- Exploration of Energization and Radiation in Geospace (ERG)

Opportunities for Cooperation

JAXA's interests include crewed space transportation systems, lunar lander, cargo transfer systems, crewed rover system, power systems, solar electric propulsion, and in-situ resource utilization. In December 2015, JAXA announced its commitment to support the extension of ISS operations to 2024.

STATE SPACE CORPORATION ROSCOSMOS

The State Space Corporation (Roscosmos) is responsible for implementing Russian government space policies and regulations and providing government services and managing state property in the areas of space exploration, international space cooperation, space research, military missile and space technology, and strategic missile systems. Roscosmos also provides management of activities carried out at Russia's Baikonur space center. The Russian government renamed and reorganized its space agency previously known as Roscosmos as the State Space Corporation Roscosmos in January 2016. In 2014, NASA had 19 active agreements with Russia, including 12 with Roscosmos. The other eight agreements were with various entities including: Moscow State University, the Russian Academy of Sciences, the National Research Nuclear Institute, and the Central Aerohydrodynamics Institute.

Governance

Roscosmos is a state corporation headquartered in Moscow, with its Mission Control Center located in Korolev, the Cosmonauts Training Center located in Star City near Moscow, and its chief launch center – the Baikonur Cosmodrome – located in Kazakhstan.

Budget

Roscosmos is funded by the draft Federal Space Plan at $21.4 billion (1.4 trillion rubles) for the 10-year period 2016 through 2025. Major activities funded under the plan include $3.1 billion for lunar exploration, $430.5 million for Mars research, and $569.9 million for a series of Earth-orbiting telescopes known as Spektr.[94]

Key Projects with NASA

International Space Station. Roscosmos' primary contributions to the ISS Program are the Soyuz and Progress vehicles, the Zvezda service module, the Pirs Airlock and Docking Compartment, and the U.S.-owned, Russian-built Zarya Functional Cargo Block.[95] The Soyuz vehicle transports crewmembers to the ISS, while Progress is a cargo resupply vehicle. Zvezda forms the structural and functional center of the Russian segment of the ISS, and the Pirs Airlock provides the capability for spacewalks from Zvezda and a port for docking Soyuz and Progress vehicles. In 2017, Roscosmos expects to launch the Multipurpose Laboratory Module (Nauka) to the ISS, which will be used for experiments and serve as a crew work and rest area.

Soyuz Spacecraft

Source: NASA.

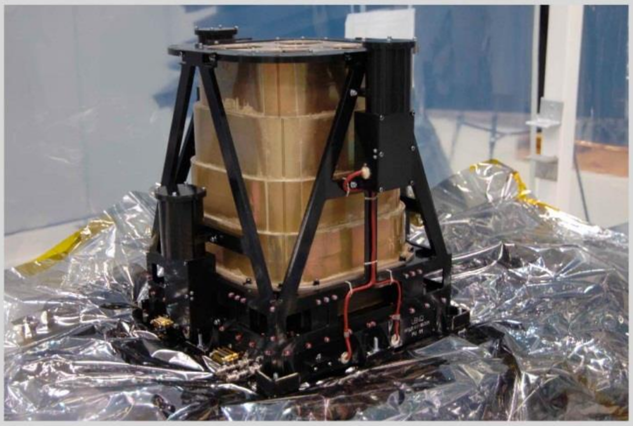
Lunar Reconnaissance Orbiter. Roscosmos provided the Lunar Exploration Neutron Detector (LEND) instrument for NASA's Lunar Reconnaissance Orbiter, which launched in June 2009. The primary objective of the Orbiter was to obtain data to facilitate returning humans safely to the Moon and enable extended stays. LEND

[94] U.S. dollar values as of September 30, 2015.

[95] NASA has contracted with Roscosmos for transportation of its astronauts to the ISS through 2018 when SpaceX and The Boeing Company are expected to begin their commercial crew flights.

provides high spatial resolution maps of neutron emission at the lunar surface to search for evidence of water and ice and provide measurements of the lunar radiation environment.

Lunar Exploration Neutron Detector Instrument



Source: NASA.

Mars Odyssey. Roscosmos provided the High-Energy Neutron Detector (HEND) instrument for NASA's 2001 Mars Odyssey mission. This mission mapped the amount and distribution of chemical elements and minerals on the surface of Mars. HEND is part of the Gamma-Ray Spectrometer instrument suite that has provided data on the elemental distribution at the surface of Mars and search for water on the planet. In 2008, the Mars Odyssey mission found salt deposits consistent with the presence of once-flowing water.

Wind Satellite. The Wind satellite launched on November 1, 1994, to measure the mass, momentum, and energy of the solar winds that are transferred into the space environment around Earth. Wind, together with other satellites, aims at gaining an improved understanding of the physics of solar terrestrial relations. The satellite included the Russian Konus instrument, which monitors cosmic gamma-ray bursts, soft gamma repeaters, solar flares, and other transients. In conjunction with other instruments, Konus has helped to determine gamma-ray burst locations, which enables the prompt and ongoing study of this elusive phenomenon. The Wind satellite remains in operation.

Roscosmos Capabilities

Roscosmos has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Launchers and associated launch sites
- Human-rated launch vehicle/spacecraft (Soyuz)
- Space Robotic Cargo Vehicles (Progress)
- Automated rendezvous and docking systems
- Pressurized modules, launch, assembly, operations, and maintenance
- EVA suits
- Emergency crew rescue system during a launch abort
- Robotic lunar lander, orbiter, and rover
- Robotic Space Systems
- In-situ and remote exploration capabilities
- Ground facilities including deep space tracking
- Communications and navigation
- Remote sensing, including meteorology
- Long duration human spaceflight experience
- Cosmonaut training facilities
- Search and rescue organization capability and training
- Heliophysics

Emerging Capabilities

- Prospective piloted spacecraft for missions beyond LEO
- New family of launch vehicles (Angara)
- Modification of Soyuz rocket (Soyuz 2)
- Nuclear propulsion unit of megawatt class
- Free flyers launched directly from the ground and potentially deployed from or rendezvousing with the ISS
- New cosmodrome
- Deep space radio astronomy
- Plasma physics

Opportunities for Cooperation

Roscosmos is studying programs and projects that include lunar sample return, development of rockets for deep space exploration, a Jupiter exploratory mission, a mission to the asteroid Apophis to plant a radio beacon, a Martian moon sample return flight, and a Venus robotic mission. Russia has committed to participating in the ISS until 2024.

KOREA AEROSPACE RESEARCH INSTITUTE

The Korea Aerospace Research Institute (KARI), established in 1989, seeks to contribute to the solid development of the national economy and enhancement of national life through new exploration and technological advancements, development, and dissemination in the field of aerospace science and technology. KARI's main activities include launch vehicles, Earth observation satellites, and technology research and development. In 2014, NASA had 11 active agreements with the Republic of Korea, 3 of which were with KARI. NASA also has agreements with Korea Astronomy and Space Science Institute, which includes research in solar and space physics (heliophysics) and space weather.

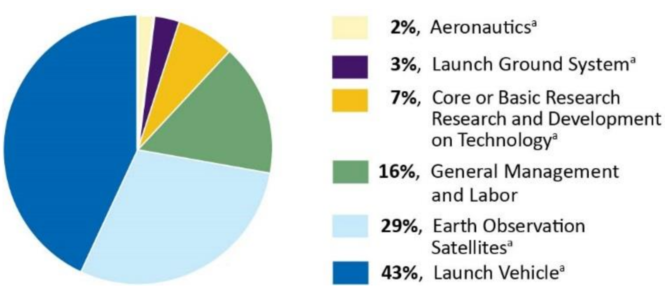
Governance

KARI manages the Korean space program under the Ministry of Science, Information and Communications Technology, and Future Planning. KARI's headquarters are located in Daejeon, Korea, and the Naro Space Center (launch site) is located in Oenaro-do, a southern province of Korea.

Budget

In 2015, KARI's budget of $416.6 million (493 billion South Korean won) supported the institute's six main activities, with the majority spent on launch vehicles and Earth observation satellites.[96]

Distribution of KARI's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Note: Nominal differences in percentages due to rounding.

Key Projects with NASA

General Mission Analysis Tool (GMAT). GMAT is an open-source space software project mission design tool developed by a team of NASA employees, private industry, and public and private contributors. KARI contributed to all aspects of development. The software models, optimizes, and estimates spacecraft trajectories ranging from low Earth orbit to lunar applications, interplanetary trajectories, and other deep space missions. GMAT is used for engineering studies, education, and flying operational spacecraft. KARI has significant satellite capabilities for – Earth observation, navigation, and communication – and plans to launch 104 satellites by 2040.

KARI Satellite Integration and Test Center

Source: KARI.

[96] U.S. dollar values as of September 30, 2015.

Feasibility Study about Potential Lunar Robotic Cooperation. In July 2014, NASA and KARI formed two working groups to conduct conceptual studies in space communications and spacecraft systems technologies related to robotic lunar exploration activities. The Space Communications Working Group assessed joint communications and navigation activities, services, and experiments, including Deep Space Network and Near Earth Network and other mission operations support, Disruption Tolerant Networking, and the feasibility of KARI hosting a commercial communications relay on the Korea Pathfinder Lunar Orbiter. The Spacecraft Systems Working Group studied technologies and subsystems needed for lunar orbiters, landers, and rovers.

Naro KSLV-1

Source: KARI.

KARI Capabilities

KARI has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Nanotechnology
- Satellite structures, components, and systems
- Scientific instruments
- Earth observation instruments that produce 1 meter resolution multi-spectral imagery and SAR
- Unmanned aerial vehicles
- Small satellites
- High resolution calibration/validation technology
- Space launch vehicles (NARO and ongoing Korean Space Launch Vehicle II) and associated launch sites

Emerging Capabilities

- Cryogenic propellant in microgravity, liquid acquisition device, and cryogenic propellant storage and transfers
- Payload structure, design, and analysis
- Planetary atmosphere modeling
- Lunar mission
- Airborne measurement techniques for atmospheric trace gases and aerosol
- Research and development on core aeronautics technology for eco-friendly and highly efficient future aircraft

Opportunities for Cooperation

KARI is interested in lunar exploration, including sending a lunar orbiter and lander, and expanding its capability to join the international Mars program and other planetary exploration programs, including asteroids. Korea also hopes to cooperate with NASA in aviation technology development.

National Institute for Aerospace Technology

Spain's National Institute for Aerospace Technology (INTA) was established in 1942 and specializes in aerospace research and technological development. INTA's purpose is to acquire, maintain, and continuously improve technologies applied to the aerospace field, and check, approve, and certify materials, component equipment items, subsystems, and systems that have an aerospace application. INTA's main activities include astrophysics, planetary exploration, and life evolution. In 2014, NASA had 10 active agreements with Spain, 4 of which were with INTA.

Governance

INTA reports to the Ministry of Defense through the Secretary of State for Defense. The institute consists of a President, General Director, and several sub-directorates with a headquarters based in Torrejón de Ardoz, near Madrid, Spain. INTA has eight facilities located throughout Spain and a staff of more than 1,200, approximately 1,000 of which are dedicated to research and development. Besides three major ground tracking stations for spacecraft and satellites, INTA also operates aerospace test facilities and the Astrobiology Center, which is studying the habitability of different solar system bodies.

Budget

INTA received appropriations from Spain's national budget of $63.56 million (47.79 million euros) in 2014; an increase of 2.3 percent over 2013 levels of $62.11 million (46.70 million euros). While INTA receives most of its funding from the central government, it also obtains funds through its own commercial operations, bringing its total funding to more than 100 million euros in 2014.[97] In the past, 65 percent of INTA's financial resources were dedicated to carrying out technological development activities, 27 percent was spent on applied research, and 8 percent on basic research activities. The primary technological areas examined by INTA include aviation and space technology, energy, environment, and automotive and transportation security.

Key Projects with NASA

Deep Space Network (DSN). INTA, on behalf of NASA, manages the Madrid Deep Space Communications Complex in coordination with NASA's Jet Propulsion Laboratory. The Madrid Complex – which celebrated 50 years of operation in 2014 – is one of three main facilities that comprise NASA's DSN. DSN is an international network of antennas that communicates with interplanetary spacecraft, is used by radio and radar astronomers to observe the solar system and the universe, and provides communication support to Earth-orbiting satellites.

Overview of Madrid Deep Space Communications Complex

Source: NASA.

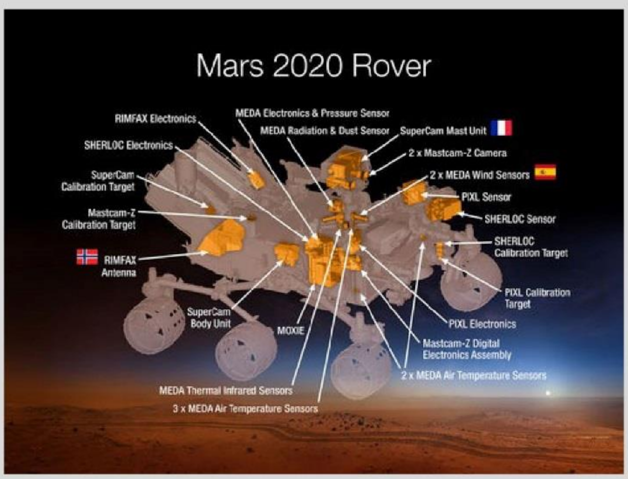
Mars Science Laboratory (MSL). INTA provided an environmental monitoring station carried by the Curiosity rover launched in 2011. Part of NASA's Mars Exploration Program, MSL's Curiosity rover was designed

[97] Budget numbers provided by INTA to the NASA OIG on February 5, 2016, after their review of the draft INTA summary.

to assess whether Mars ever had a habitable environment. The Rover Environmental Monitoring Station was developed by INTA to measure and provide daily and seasonal reports on atmospheric pressure, humidity, and ultraviolet radiation at the Martian surface; wind speed and direction; air temperature; and ground temperature around the rover.

Mars Environmental Dynamics Analyzer for Mars 2020. Building on the success of Curiosity's landing, NASA announced plans for a new robotic science rover set to launch in 2020. Designed to advance high-priority science goals for Mars exploration, the mission would address key questions about the potential for life on Mars and provide opportunities to demonstrate technologies related to the challenges of future human expeditions to Mars. INTA will provide the Mars Environmental Dynamics Analyzer for the mission, which is a set of sensors that will capture measurements of temperature, wind speed and direction, pressure, relative humidity, and dust size and shape on the Martian surface.

Diagram of NASA Mars 2020 Rover Science Instruments



Source: NASA.

INTA Capabilities

INTA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Ground station design and operations
- Development of payloads
- Turbine engine and aerospace structure testing
- Astrobiology research
- Radio-astronomy
- Small satellites design, manufacturing, and operations
- Scientific instrumentation
- Spacecraft and satellite tracking
- Airborne atmospheric monitoring

Emerging Capabilities

- Miniaturization of electronic instruments for planetary exploration missions
- Exploration of planetary sub-surfaces/drilling
- Optical material technologies: development, characterization, and space qualification
- Advanced astrobiology research

Opportunities for Cooperation

INTA has interests in solar system and planetary exploration, including joint planning for future missions, radio-astronomy, space missions with shared instrumentation for Mars exploratory missions, astrobiology, and development of instruments and technologies for both robotic and future human exploration.

STATE SPACE AGENCY OF UKRAINE

Established in 1992, the State Space Agency of Ukraine (SSAU) implements state policy for space activities, serves as the national customer for work relating to the exploration and utilization of outer space, and conducts research for developing and testing space rocketry, including the interests of national defense and security. The main policy objectives of SSAU are developing and manufacturing competitive launch vehicles, conducting science research, and utilizing and disseminating Earth remote sensing data. SSAU's main activities include launch services, Earth observation, telecommunications, space exploration, and education. In 2014, NASA had three active agreements with Ukraine, one of which was with SSAU.

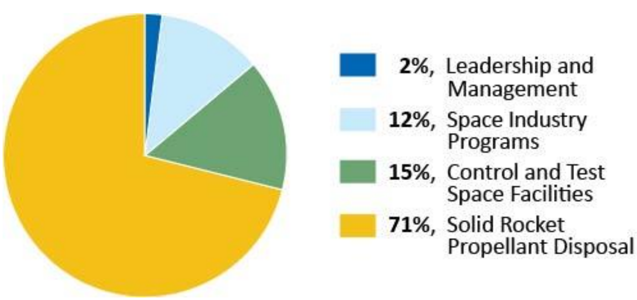
Governance

SSAU is overseen by a head of agency, a first deputy head, and deputy head. The agency is responsible for administering 30 economic entities, including 19 state enterprises, 6 institutions, and 5 companies. More than 20 space-related institutes and companies are directly subordinate to SSAU. The total number of employees at the entities overseen by SSAU is approximately 26,000.

Budget

In 2015, SSAU's budget of $19.5 million (410.8 million hryvnia) was used to fund solid rocket propellant disposal, control and test space facilities, space industry, and leadership and management activities.[98]

Distribution of SSAU's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.
Note: Nominal differences in percentages due to rounding.

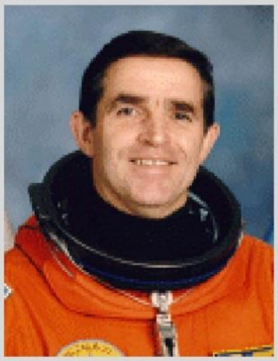
Key Projects with NASA

Framework Agreement for Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes. On March 31, 2008, NASA and SSAU established a legal framework for cooperation on future programs or projects in the areas of Earth observation, science, and monitoring; space science; exploration systems; space operations; aeronautics; and other relevant areas of mutual interest. Future implementing arrangements under the framework will establish the roles and commitments of each agency, the nature and scope of joint activities, and any other provisions necessary to conduct joint activities.

Space Shuttle. In 1997, the first cosmonaut of independent Ukraine – Leonid Kadenyuk – flew in space onboard the U.S. Space Shuttle Columbia. During the 16-day flight, the Ukrainian cosmonaut conducted scientific experiments on space biology. Kadenyuk's flight opened a new stage of cooperation between the United States and Ukraine in terms of preparing and carrying out research onboard space stations.

[98] U.S. dollar values as of September 30, 2015.

Ukraine Cosmonaut Leonid Kadenyuk



Source: NASA.

International Space Station. Ukrainian companies provided the first stage of the rocket used by Orbital Sciences Corporation to deliver cargo to the ISS and carry out launches into low Earth orbit for the U.S. Government and commercial satellites. In 2008, two Ukrainian companies signed a long-term contract with Orbital Sciences Corporation to produce the Taurus-II (now called Antares) rocket until 2019. The Ukrainian companies designed and produced the first stage of the launch vehicle.

Antares Rocket Launches from NASA's Wallops Flight Facility

Source: NASA.

SSAU Capabilities

SSAU has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Multiple launch vehicles
- Nonproliferation of weapons of mass destruction (WMD)
- Reorientation of WMD experts into civil services
- Earth observation satellites

Emerging Capabilities

- Advanced space launch systems
- Development of space technologies and their integration into the sectors of national economy, national security, and defense
- Development of the outer space monitoring of the low-orbit space
- Advanced satellites
- Systematic data reception from national ERS satellites and Geophysical Monitoring Space System
- Development of the national GIS and emergency monitoring support system as part of the European and worldwide systems

Opportunities for Cooperation

SSAU has current interests in establishing a joint United States-Ukraine launch operator company to operate a launch pad for the Cyclone-4 launch vehicle. The Cyclone-4 launch program was an agreement between Ukraine and Brazil designed to provide space launches for their countries, as well as other countries and private clients. SSAU was responsible for the development and manufacturing of the launch vehicle, while Brazil was responsible for the development of launch infrastructure. In 2015, Brazil decided to unilaterally cancel the agreement. SSAU officials also believe it would be beneficial to coordinate common export rules and increase cooperation for education and training programs.

UNITED KINGDOM SPACE AGENCY

Established in 2011, the United Kingdom Space Agency (UK Space Agency) replaced the British National Space Centre and is at the heart of the United Kingdom's efforts to explore and benefit from space. The agency is responsible for setting civil space policy for the United Kingdom and developing regulation and licensing regimes for the country's space activities. Its mission is to capture 10 percent of the global space market by 2030. To achieve this, the agency fosters the United Kingdom's space sector, delivering benefits to public services, science and innovation, national security, and the economy. The agency's main activities include leading the United Kingdom civil space policy, participating in European space programs, building a strong national space capability, working on national and international space projects in cooperation with industry and academia and coordinating strategic investment. The agency is also responsible for regulating the United Kingdom civil space activities and ensuring they meet international treaty obligation. In December 2015, the agency published its first National Space Policy, which sets out the enduring principles underpinning United Kingdom activities in space. In 2014, NASA had 69 active agreements with the United Kingdom, including 25 with the UK Space Agency.

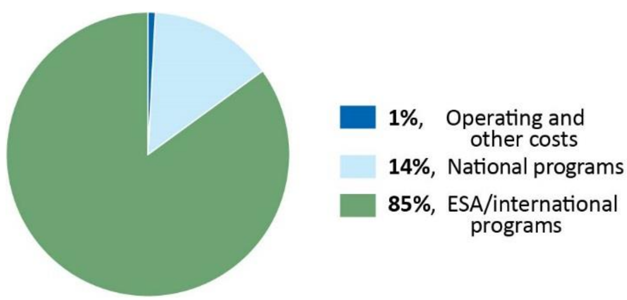
Governance

The UK Space Agency is an executive agency of the Department for Business, Innovation, and Skills. The agency is overseen by a Chief Executive Officer, who is advised by a four-member steering board, and has approximately 70 staff based at headquarters in Swindon and at two smaller offices in Harwell and London.

Budget

For the fiscal year April 1, 2014, through March 31, 2015, the UK Space Agency's budget was $480 million (316.3 million pounds), which funded its ESA and international contributions, national programs, and operating costs.[99]

Distribution of UK Space Agency's 2015 Budget Based on Work Type



Source: NASA OIG analysis of space partner information.

Key Projects with NASA

International Space Station. The United Kingdom joined the International Space Station in 2012, reversing a long history of noninvolvement in human space flight. It participates via membership of ESA's ISS program. In total it has contributed around $100 million (70 million pounds) to the ISS program and the complementary European Programme for Life and Physical Sciences program, which is conducting microgravity research. This has enabled a new telecommunication terminal for the Columbus module and a range of scientific experiments, including providing some hardware for

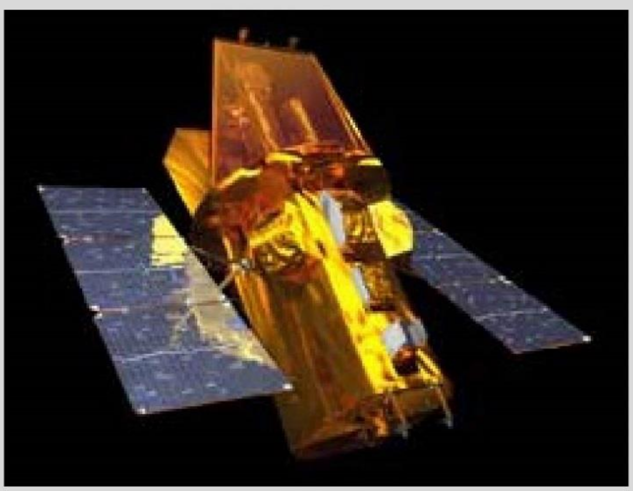
[99] U.S. dollar values as of September 30, 2015.

NASA's Fluid Shifts experiment. ISS Expedition number 46-47 (December 2015 to June 2016) includes the mission of Tim Peake, the first British ESA astronaut and the first British astronaut to visit the Station.

Cassini Orbiter's Magnetometer. Launched in 1997, the Cassini orbiter is a joint project between NASA, ESA, and the Italian Space Agency. Cassini orbits Saturn and its moons, and the mission has been extended until 2017. A team of scientists from the United Kingdom's Imperial College is using the orbiter to measure the strength and direction of Saturn's magnetic field.

Swift Gamma-Ray Burst Explorer. Launched in 2004, NASA's Swift Gamma-Ray Burst Explorer mission is a multi-wavelength astrophysics observatory operating in low Earth orbit and studying gamma-ray bursts in an effort to determine the origin and physical processes of such events. Several universities and scientific institutes in the United Kingdom cooperated with NASA on the development and assembly of the observatory's telescopes, supplying data analysis software, system engineering support, the focal plane camera, telescope alignment monitor, and other major components.

Swift Gamma Ray Burst Explorer



Source: NASA.

Space Environment Testbed-1 (SET-1). SET-1's goal is to improve through research and investigation the engineering approach to mitigating the effects of solar radiation on spacecraft design and operations. NASA and the UK Space Agency are conducting an investigation known as the Cosmic Radiation Environment Dosimetry and Charging Experiment as part of the SET-1 project. The investigation uses an environment monitor to measure the energetic space-radiation during the mission. The monitor's measurements will support data analysis for other experiments on the SET-1 project and can be used to improve and validate environment specification models for electrons, protons, and heavy ions and to predict solar particle events. The UK Space Agency will make available an experiment carrier that can be used by the monitor and will provide the interface between the monitor and the host spacecraft. The anticipated launch date for SET-1 is March 2017.

UK Space Agency Capabilities

UK Space Agency has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Lunar seismology and geophysics
- Lunar petrology and mineralogy
- Infrared mapping of the lunar surface
- Isotopic studies of the lunar surface
- Lunar volcanism
- Space optics
- Science instruments for probes
- Multispectral imagers
- Instrumentation for lunar landers
- X-ray fluorescence spectroscopy from orbit
- Geochemistry and dating of lunar materials
- Communications satellites

Emerging Capabilities

- Science: many astrophysics and heliophysics payload contributions and scientific collaboration
- Advanced Earth observation satellites
- Advanced engine development
- Rover vehicles

Opportunities for Cooperation

The UK Space Agency's interests include space communication satellites, lunar landers, autonomous surface mobility systems, advanced imaging systems, and orbit launch vehicle technology. The agency has also noted that establishing a joint exploration program under a framework like the International Space Exploration Coordination Group would be beneficial. Additionally, the UK Space Agency would like to develop capabilities to mitigate the effects of severe space weather events through an improved surveillance capability.

NASA

Formed in 1958, NASA's mission is to drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth. NASA's main activities include human space flight, aeronautics, science, and space applications. In 2014, NASA had 820 active agreements with international partners.

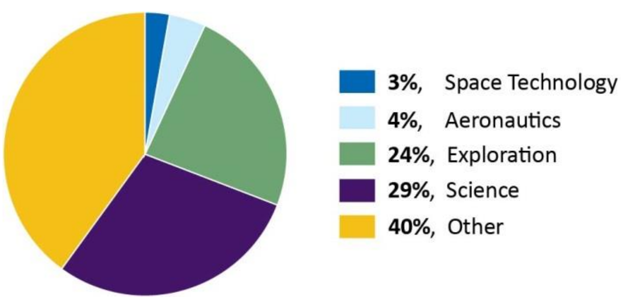
Governance

Based in Washington, D.C., NASA Headquarters, under the leadership of the Administrator, provides overall guidance and direction to the Agency's approximately 17,000 employees located at Headquarters, 10 Centers, and other research and testing facilities. NASA conducts its work through four mission directorates – (1) Aeronautics, (2) Human Exploration and Operations, (3) Science, and (4) Space Technology.

Budget

NASA's fiscal year 2015 budget of $18 billion was divided among aeronautics, space technology, exploration, science, and other areas such as space operations and education.

Distribution of NASA's 2015 Budget Based on Work Type



Source: NASA OIG analysis of Agency budget data.

Key Projects with International Partners

James Webb Space Telescope (JWST). JWST is an international collaboration among NASA,the Canadian Space Agency, and ESA. A large infrared telescope with a 6.5 meter primary mirror, JWST will study every phase in the history of our universe. Four science instruments – Near-Infrared Camera (NIRCam), Near-Infrared Spectograph (NIRSpec), Mid-Infrared Instrument (MIRI), and the Fine Guidance Sensor/Near Infrared Imager and Slitless Spectograph (FGS/NIRISS) – form the heart of JWST and will be housed in the Integrated Science Instrument Module. ESA will provide NIRSpec, components of the NIRSpec will be provided by NASA, and MIRI is a joint product of NASA and ESA. The University of Arizona will provide the NIRCam, and the FGS/NIRISS will be provided by the Canadian Space Agency.

Testing of JWST MIRI Thermal Shield

Source: NASA.

Rosetta. ESA's Rosetta arrived at "67P/Churyumov-Gerasimenko (C-G)" in August 2014 and the Philae lander landed on the comet in November 2014, and will be the first spacecraft to accompany a comet as it enters our inner solar system, observing at close range how the comet changes as the Sun's heat transforms it. Partnering with ESA, NASA contributed three instruments to the mission – ALICE (an ultraviolet spectrometer), the Microwave Instrument for the Rosetta Orbiter (MIRO), and the Ion and Electron Sensor (IES) – as well as a significant portion of the electronics package for the mission's mass spectrometer. ALICE, MIRO, and IES will provide information about the dynamics of the comet, including how it develops its coma and tails, and interacts with radiation and solar wind.

Artist's Concept of the Rosetta Spacecraft

Source: NASA.

Global Precipitation Measurement (GPM) Mission. GPM is an international satellite mission that provides observations of rain and snow worldwide every 3 hours. NASA and the Japan Aerospace Exploration Agency provided the GPM Core Observatory satellite that launched in February 2014. The data GPM provides is being used to unify the measurements made by an international network of satellites to quantify when, where, and the amount of rain or snowfall around the world.

NASA-ISRO Synthetic Aperture Radar (NISAR). A partnership between NASA and the Indian Space Research Organization, the NISAR satellite uses advanced radar imaging to provide an extremely detailed view of Earth. The satellite is designed to take measurements of some of Earth's most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes, and landslides. NASA will provide the L-band Synthetic Aperture Radar and the Engineering Payload System, while ISRO is responsible for the Spacecraft Bus System, the S-band Synthetic Aperture Radar, and the launch vehicle. Anticipated launch is in late 2020.

NASA Capabilities

NASA has demonstrated and emerging capabilities in the following areas:

Demonstrated Capabilities

- Robotic exploration
- Systems engineering
- Aeronautics
- Space technology
- Entry systems
- Space propulsion
- Human related systems
- Low Earth orbit
- Lunar science
- Human exploration
- Human systems integration
- Aeropropulsion
- Space flight systems development

Emerging Capabilities

- Interplanetary space weather
- Hypersonic propulsion

Opportunities for Cooperation

NASA's interests include facilitating and utilizing U.S. commercial capabilities to deliver cargo to the ISS, using the ISS for research, and developing space technology and building capabilities for deep space human space exploration. In addition, NASA's Asteroid Redirect Mission is developing a robotic mission to visit a large near-Earth asteroid, collect a multi-ton boulder from its surface, and redirect it into a stable orbit around the Moon. Once orbiting the Moon, astronauts will explore the asteroid and return with samples. To be conducted during the 2020s, the mission is part of NASA's plan to advance the new technologies and space flight experience necessary for a human mission to Mars in the 2030s.

APPENDIX III: AEROSPACE CORPORATION SCOPE AND METHODOLOGY

The Aerospace Corporation maintains a significant data set for the examination of relationships between space system cost and schedule and the implications of various collaboration approaches. To examine the collaboration among multiple U.S. agencies and international partners, the Corporation assembled cost and schedule data for more than 90 missions launched over the past 25 years (1989 to 2015) using a Corporation-developed database of mission technical specifications, costs, development time, and cost and schedule growth during development. These data include NASA planetary, near-Earth, and Earth-orbiting spacecraft, as well as other Government satellite systems, but did not include manned spacecraft such as the ISS.

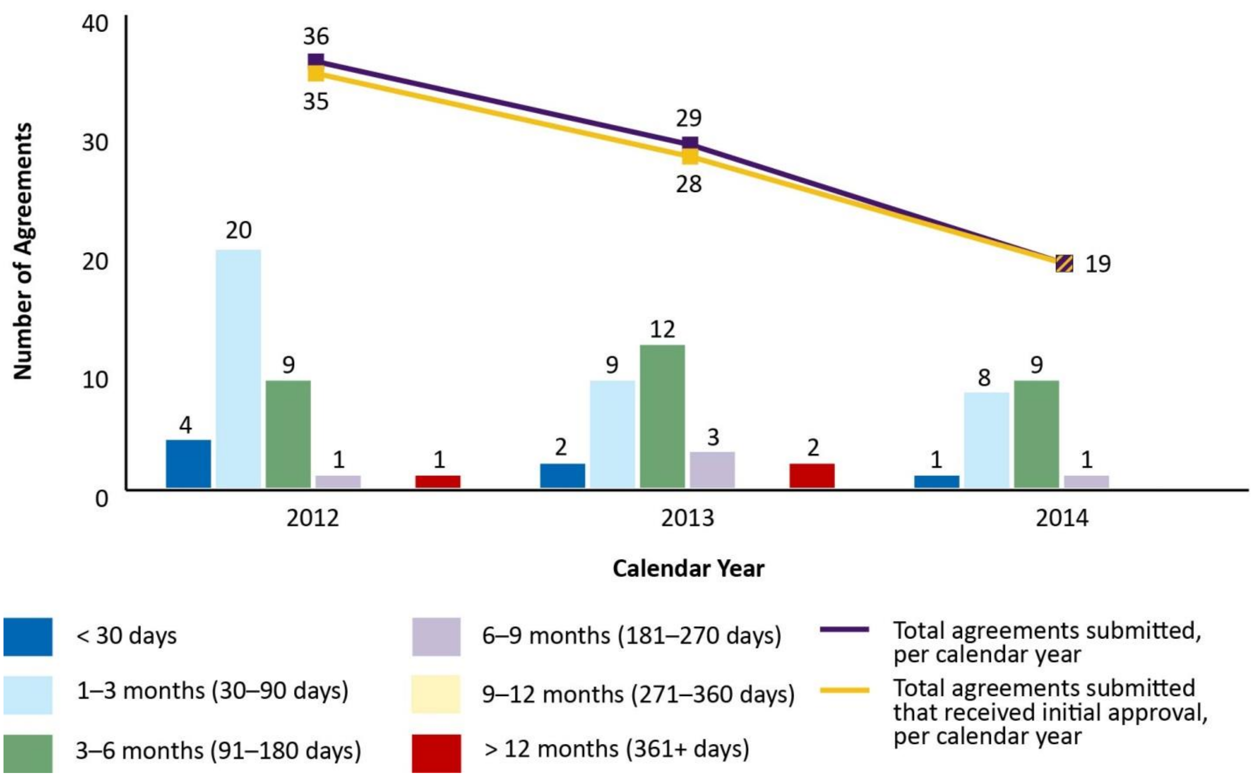
In addition to single U.S. agency missions, two classes of collaborations were considered: (1) collaboration among multiple U.S. agencies and (2) collaboration with international partners. U.S. multiagency partnerships include cases where multiple agencies sponsored development of a system or systems with multiple agency operators. Only cases with significant payloads that drove system design or operational requirements were included. Cases where multiple agencies were users of a system but did not interact significantly during development or jointly levy design or operational requirements were not categorized as U.S. multiagency. Collaborations with international partners included missions whose participants contributed specific systems such as one or more payload instruments, a spacecraft bus, or one or more significant subsystems (e.g., solar panels, propulsion, avionics, etc.). Cases where an international partner contributed only a ground station for downlink of data, spacecraft components (e.g., star tracker, momentum wheel, etc.), or a vehicle or service were not included as international collaborations. In 2011, it was reported that international collaboration led to more cost growth than projects with no collaboration or U.S. multiagency projects. However, when we asked the Corporation to update information for this review, the combination of a more stringent classification method for what was considered an "international" project and the addition of projects begun or completed since issuance of the 2011 report resulted in the opposite conclusion – that projects with international collaboration actually experienced less cost growth.

To understand how technical complexity relates to budget and schedule, a complexity index was derived based on performance, mass, power, and technology choices to arrive at a broad representation of the system for the purposes of comparison. The Aerospace Corporation uses a complexity index – a matrix of 30 to 40 technical factors to place, in rank order, the complexity of a particular spacecraft relative to all the other spacecraft in the data set. Complexity is tied to demonstrable objective technical parameters (e.g., number of instruments, mass, power, performance, subsystem characteristics, pointing accuracy, downlink data rate, technology choices, etc.). These descriptive parameters are normalized based on the applicable range as designated by the programs in the database, that is, they are given as percentile values for the data set. The total flight system development cost (payload instruments and spacecraft bus, excluding launch and operations) is the independent variable against which the complexity is compared. Missions were grouped according to level of international participation and U.S. multiagency involvement. Only robotic spacecraft missions that meet certain criteria and constraints were considered (i.e., shuttle science experiments and university-developed spacecraft were not considered). Large (e.g., Flagship/Great Observatory-class), medium (e.g., New Frontiers-class) and small (e.g., Discovery-class or smaller) missions were included. Landed systems (e.g., Mars landers) are included with the caveat that when a larger data set becomes available, the technical drivers used to assess these missions may differ from those used for orbiting systems. Missions yet to complete a portion of their development are included; however, it is noted that final cost is yet to be determined.

APPENDIX IV: AGREEMENTS AND DAYS FOR APPROVAL

From January 2012 through December 2014, OIIR submitted 84 packages to State for review and approval through the C-175 process.[100] While 82 of the 84 packages received initial State approval, only 4 received initial approval in the 20-day regulatory timeframe. Figure 24 shows the number of agreements submitted to State in each year, the number that received initial approval, and the range of elapsed days for initial approval.

Figure 24: NASA Agreements Submitted to State and the Timeframe for Initial State Approval

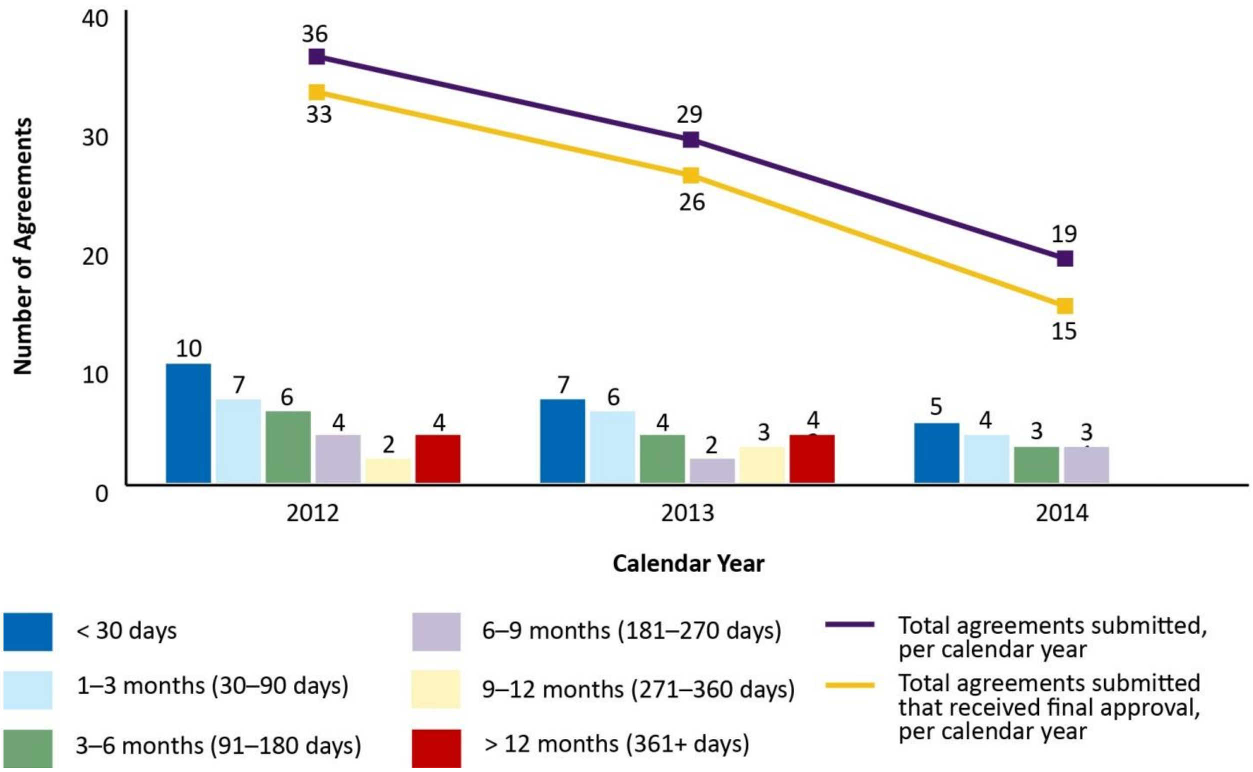


Source: NASA Office of Inspector General analysis of OIIR information.

[100] There were an additional 14 agreements submitted to State for review in 2015 (through June 8, 2015). Of these 14, 10 agreements received initial State approval and 6 received final approval. The auditor did not include them in the total number of agreements submitted because at the time the report was written, calendar year 2015 was not complete.

Of the 84 agreements submitted to State in the same 3-year period, 74 have received final approval. Figure 25 shows the number of agreements submitted to State in each year, the number that received final State approval, and the range of elapsed days for final approval.

Figure 25: NASA Agreements Submitted to State and the Timeframe for Final State Approval



Source: NASA Office of Inspector General analysis of OIIR Information

APPENDIX V: ABBREVIATIONS

AEB	Brazilian Space Agency
ASI	Italian Space Agency
CNES	Centre National d'Etudes Spatiales
CNSA	China National Space Administration
CONAE	National Commission on Space Activities
C.F.R.	Code of Federal Regulations
CSA	Canadian Space Agency
CSIRO	Commonwealth Scientific and Industrial Research Organization
DLR	German Aerospace Center
EAR	Export Administration Regulations
ESA	European Space Agency
GDP	Gross Domestic Product
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
InSight	Interior Exploration using Seismic Investigation, Geodesy, and Heat Transport
INTA	National Institute for Aerospace Technology
ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulations
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KARI	Korea Aerospace Research Institute
MMS	Magnetospheric Multiscale
NATO	North Atlantic Treaty Organization
NRC	National Research Council
OIG	Office of Inspector General
OIIR	Office of International and Interagency Relations
Roscosmos	Roscosmos State Corporation
SOFIA	Stratospheric Observatory for Infrared Astronomy
SSAU	State Space Agency of Ukraine
SWOT	Surface Water Ocean Topography
TTCP	Technology Transfer Control Plan
U.S.C.	U.S. Code

APPENDIX VI: SCOPE AND METHODOLOGY

We performed this review from October 2014 through April 2016 in accordance with the Council of Inspectors General on Integrity and Efficiency's Quality Standards for Inspection and Evaluation, and in compliance with the Inspector General Reform Act of 2008. Those standards require that we maintain appropriate levels of competency, independence, professional judgment, and quality control. We believe that the evidence obtained provides a reasonable basis for our observations and conclusions based on our review's objectives.

Our scope of work primarily focused on NASA and the foreign space agencies that NASA has agreements with, including both international agreements and agreements governed by U.S. law. Additionally, we engaged the U.S. Department of State offices responsible for processing and approving NASA's international agreements, selected U.S. corporations, and space advisory groups and institutions. The Aerospace Corporation was most helpful in providing the data analysis for the cost, schedule, and complexity implications of projects involving NASA and foreign space agencies. Due to his previous work on this subject, Dr. Scott Pace of George Washington University provided invaluable assistance to the team.

Our methodology consisted of document reviews of requested material, including history archives from the NASA History Program Office, answers to our questionnaires, interviews in person and by phone, and the observation of numerous programs and projects at locations in the United States and abroad. Most importantly, we asked for and received a significant amount of feedback from the 15 space agencies that we surveyed (see Table 2, Chapter 1 for the list of partners or Appendix II for agency summaries). These space agencies provided responses for our questions through written questionnaires (nine agencies), on-site interviews (five agencies), and telephonic interviews (one agency).

We also conducted interviews across multiple levels of current and former NASA management and several parties external to NASA in order to collect opinions and attitudes about NASA's relationships with international partners. In addition, we received briefings from program and project managers from five different space agencies and conducted structured interviews of NASA officials at the following NASA locations: NASA Headquarters, Ames Research Center; Goddard Space Flight Center; and the Jet Propulsion Laboratory. Finally, several members of the review team had also participated in our prior audit of NASA's plans to extend the operational life of the ISS and were able to draw from the research gathered during that audit.[101]

The primary contributors to this review include: Ridge Bowman, Program Director; Kevin Fagedes, Project Manager; Letisha Antone, Project Manager; Sarah Beckwith, Team Leader; David Balajthy; Sasha Mannion; Sarah McGrath; and Cedric Campbell, Associate Counsel.

[101] NASA Office of Inspector General, "Extending the Operational Life of the International Space Station Until 2024" (IG-14-031, September 18, 2014).

APPENDIX VII: NASA MANAGEMENT'S COMMENTS TO DRAFT REPORT

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

May 2, 2016

Reply to Attn of: Office of International and Interagency Relations

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for International and Interagency Relations

SUBJECT: Agency Response to OIG Draft Report "NASA's International Partnerships: Capabilities, Benefits, and Challenges" (A-14-024-00)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled "NASA's International Partnerships: Capabilities, Benefits, and Challenges" (A-14-024-00), dated March 23, 2016.

The Office of International and Interagency Relations (OIIR) values the level of effort that went into preparing such a detailed report that highlights many of the positive attributes of NASA's cooperative international engagements. While we are pleased that the draft report contains no specific recommendations to NASA as a result of the review, the report does highlight four challenges that NASA faces in terms of expanding its use of international partnerships. Most of the identified challenges are well known to our office, and OIIR is working, to the best of its ability within the limits of the law, to address these challenges. Our response to each of the identified challenges follows:

Developing Agreements with Foreign Space Agencies
The State Department is a strong partner with NASA in its international activities. OIIR works closely with the State Department and NASA's programs to try to mitigate the impact of the long processing time, as well as continuously working with the State Department to try to improve the processing time. In recent years, OIIR has established an internal team to better track agreement status and coordinate regularly with the State Department to monitor the status of agreements. OIIR has also taken on greater responsibility for drafting the internal State Department documentation to expedite the processing by the State Department staff. Additionally, to further expedite the review, OIIR and OGC have negotiated two "blanket" authorities with the State Department – one for Implementing Arrangements under Framework Agreements and one for extensions and simple amendments of existing agreements – such that, as long as OIIR follows templates approved by the interagency community, the approval time and quantity of required approvals are reduced. For those agreements falling under the two blanket approvals, OIIR has already seen improvement in the review times. OIIR is now considering options for additional blankets to further expedite the process.

<u>Export Control Regulations</u>

NASA's export control policies, like those of U.S. industry, are governed by U.S. Federal law. Within this limit, OIIR works to provide full support to NASA's programs in navigating and complying with export control laws. For more than 20 years, NASA, through OIIR, has had in place a robust export compliance program. NASA established an Agency Export Control Administrator within OIIR and each NASA Center has export control staff to directly assist the projects. In 2014, NASA released its Export Control Operations Manual that provides specific guidance and best practices to be followed by our Centers and affected contractors. OIIR has also established an export control training course that is being distributed Agency-wide that increases individuals' awareness of these regulations and NASA's processes for compliance. At the U.S. Government level, the transfer of many items from the International Traffic in Arms Regulation (ITAR) to the Export Administration Regulations (EAR) as part of the President's Export Control Reform Initiative has improved the process and time for obtaining the proper documentation and approvals for many exports by NASA and U.S. industry. Within its available budget, OIIR will continue to implement these regulatory changes and provide increased opportunities for training and outreach on export controls to the NASA community. A better understanding of how these regulatory changes can facilitate international cooperation is a part of that outreach.

<u>Centralized International Space Coordination</u>

Building strong international coordination groups is not up to NASA alone, but also NASA's international partners, and very few agencies have the authority or desire to cede control to a multilateral body. NASA works as closely as possible with its partners in non-binding international working groups, such as the International Space Exploration Coordination Group (ISECG), to coordinate and formulate a consolidated international space exploration approach. Such coordination forums can and do lead to strategic consensus building as well as programmatic cooperation. In fact, the ISECG membership continues to grow, having recently added the United Arab Emirates (UAE) as a member. NASA and OIIR believe there are sufficient formal opportunities to engage with our partners on a bilateral and multilateral basis to further our exploration goals. NASA will also continue to pursue opportunities to further the Agency's international objectives through existing and, as warranted, new fora. For example, on the margins of the last International Astronautical Congress (IAC) and recent National Space Symposium, Administrator Bolden held multilateral discussions at the Head-of-Agency level to present NASA's Journey to Mars concept and receive feedback on partner interests.

Regarding attendance at international conferences, NASA's procedures are fully consistent with applicable Federal law and Administration policy. Recently, NASA updated its internal policies and procedures by changing the application to the 50-person limit at international conferences from an all-inclusive policy to one that allows a limit of 50 NASA civil servants and an additional 50 NASA-funded contractors to attend. This change should allow for additional exchanges between NASA and NASA-funded researchers and the international community.

U.S. and Geopolitics
NASA's international cooperation with over 120 nations is fully consistent with U.S. Government foreign policy objectives as well as applicable laws and regulations. NASA has bilateral and multilateral engagement with Russia, most notably, the remarkably stable and successful International Space Station cooperation. In the case of China, NASA currently has numerous multilateral engagements, as well as bilateral activities in Earth and space science and aeronautics.

Regarding the uncertainties of the U.S. political process, specifically the annual appropriations process addressed in the report, NASA's international partners accept the limitations of an annual appropriations process as part of doing business with the U.S. As is the case with most of our international partners, NASA faces certain financial planning constraints as a public institution, and, as a result, all of NASA's international agreements are very clear that any cooperation is subject to the availability of appropriated funds.

NASA will also take under consideration the three actions raised by our international partners to help improve international cooperation (streamline information sharing about opportunities for cooperation, increase opportunities to share Agency test facilities, and adopt successful past practices) to see where it can incorporate them in our regular international engagements, to the extent permitted by law and policy.

We have reviewed the draft report and have not identified any information that should not be publicly released.

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please feel free to contact me at (202) 358-0400 or Mr. Timothy Tawney, OIIR's point of contact for this review, at (202) 358-1867.

Al Condes

APPENDIX VIII: REPORT DISTRIBUTION

National Aeronautics and Space Administration

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Office of Management and Budget
    Chief, Science and Space Branch

Department of State
    Director, Office of Space and Advanced Technology

Government Accountability Office
    Director, Office of Acquisition and Sourcing Management

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
    Subcommittee on Space, Science, and Competitiveness

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies

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(Assignment No. A-14-024-00)

Office of Inspector General

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