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Spotlight on the U.S. Space Program: Problems and Solutions

by George W.S. Abbey

Overview

In today's budget environment and what is likely to be the budget environment for some time to come, NASA needs to establish some clear and meaningful priorities. Staying on the present course does not provide the nation with a meaningful and visionary program. A reassessment of the present course of action is very much in order. In light of this, we offer the following recommendations:

- **Recommendation 1:** Maximize support for the International Space Station (ISS) and robotic space exploration.
- **Recommendation 2:** Prioritize biomedical research to understand and develop countermeasures to protect long-duration spacefarers. Carry out this research in collaboration with our space station international partners.
- **Recommendation 3:** Include China as a partner on the ISS, regaining the dual access to the ISS that was lost when the U.S. space shuttle program ended, an approach already supported by our international partners.
- **Recommendation 4:** Reinvigorate an effective space and aeronautical research and development program within NASA that will stimulate and develop a new generation of scientists and engineers.
- **Recommendation 5:** Elevate the priority of Earth observation missions. More research is needed to understand rapidly changing surface and atmospheric conditions.
- **Recommendation 6:** Re-evaluate the need for, and the cost effectiveness of, the National Launch System and the Multi-Purpose Crew Vehicle (MPCV) and the ability of the MPCV to support realistic space exploration architectures.
- **Recommendation 7:** Give major consideration to in-orbit assembly options and architectures for manned space exploration that would negate the need to design a space exploration vehicle for reentry into the Earth's atmosphere. A variation of the X-37 could carry crews to and from orbit.
- **Recommendation 8:** The true catalyst for increasing the commercialization of space is reducing the cost of flying to space. Develop fly-back booster rockets that could operate with a variation of a reusable spacecraft such as the X-37, thus providing a total reusable system, in order to dramatically reduce the costs of flying in space.

Background

> *"Well, space is there, and we're going to climb it, and the moon and the planets are there, and new hopes for knowledge and peace are there. And therefore, as we set sail, we ask God's blessing on the most hazardous and dangerous and greatest adventure on which man has ever embarked."*
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> *—John F. Kennedy, U.S. President, September 12, 1962*

> *"For any country, for any people, a space program is indispensable; the program mirrors the rising global status of China."*
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> *—Wang Zhaoyao, Director, China Manned Space Agency, June 29, 2012*

At 8:40 am on July 15, 2012, *Soyuz* TMA-05M was launched from Baikonur, Kazakhstan, carrying Russian cosmonaut Yuri Malenchenko and astronauts Sunita Williams and Akihiko Hoshide into space to rendezvous with the International Space Station (ISS). It was just six days short of a year since the last American space shuttle, *Atlantis*, touched down at the Kennedy Space Center on July 21, 2011. *Soyuz* TMA-05M was the fourth flight of a Russian spacecraft carrying crews to the ISS since the U.S. space shuttle's final flight.

The *Soyuz* spacecraft launched that Sunday morning in Baikonur now represents the only means to carry Americans to the ISS. Unfortunately, this will not change for a very long time. Since that morning in July, another *Soyuz* crew, which included American astronaut Kevin Ford and Russian cosmonauts Oleg Novitskiy and Evgeny Tarelkin, was launched to the ISS on October 23. And on December 19, 2012, a crew that included the first Canadian commander of the ISS, astronaut Chris Hadfield; American astronaut Tom Marshburn; and Russian cosmonaut Roman Romanenko was launched from Baikonur. For America and our international partners on the space station, the road to Baikonur and its Soyuz launchpad will be the road to space for many years to come.

The space shuttle carried American astronauts to space from 1981 until its last flight in 2011. The shuttle amassed an impressive record of achievements during its lifetime, including the very successful assembly of the ISS—which was not only designed to be assembled by the shuttle, but also to be serviced by the space shuttle. The ISS is a truly international station that brought Russia in as a partner, along with Canada, Europe, and Japan. Russia was made a partner because it makes a significant contribution to the ISS and, with its capabilities, provided dual access to the station. Thus, access was assured to the station if either the United States or Russia had a problem with their respective launch vehicles or spacecraft. The wisdom of that decision was proven in 2001 when Russia had a problem with its launch vehicles and again in 2003, after the *Columbia* accident. Yet barely a year later, the need for logistic support and the importance of dual access to the ISS were both ignored when President George W. Bush announced in 2004 the decision to end the shuttle program with the completion of the assembly of the ISS in 2010. That decision could have been reversed by the new administration, but it was reaffirmed.

Without the shuttle, the United States and the international partners—Canada, Europe, and Japan—are all dependent on Russia and its spacecraft, the *Soyuz*, and its unmanned cargo vehicle *Progress* to take the crews and supplies to and from the space station and to provide the majority of logistical support.

There are decisions that are made throughout a nation's history that have significant impact on its future growth and development and its ability to be a world leader. America's development, construction, and operation of the space shuttle was in a sense no less a technological achievement than the nation's successful landing on the moon. The shuttle was a reusable orbiter spacecraft that had the demonstrated ability to deliver large structures to space, and to retrieve, repair, and service both satellites and space telescopes. It provided the only way to assemble large structures in space, such as an ISS or a spacecraft that could fly out of Earth orbit to the moon and to the planets. In addition, with the exception of its fuel tank, the shuttle was reusable. It continued to demonstrate America's technological leadership every time it flew. Today, the nation and our international partners are left with an assembled space station that cannot be adequately supported or serviced. The plan to rely on the yet unproven "commercial space industry" to provide limited support to the station over and above Russia's *Progress* spacecraft, as well as European and Japanese infrequent logistical support spacecraft, places at risk the research yet to be accomplished on the space station.

The uncertainties and risks created by relying on only one means of flying humans to the ISS did not take long to become apparent. On August 24, 2011, about a month after the end of the U.S. space shuttle program, Russia experienced a failure of the *Soyuz* launch vehicle carrying an unmanned *Progress* spacecraft to the ISS. At about 325 seconds into the flight, and shortly after the third stage was ignited, the vehicle itself commanded a shutdown due to an engine anomaly. Unable to achieve its planned orbit, and given the trajectory and energy of the spacecraft at the time of engine shutdown, the vehicle and its three tons of supplies crashed in the Altai region of the Russian Federation.

The "dry" cargo tucked aboard the *Progress* amounted to 2,777 pounds of food, spare parts, life support gear, and experiment hardware. The *Progress*' refueling module carried 2,050 pounds of propellant for transfer into the Russian segment of the complex that supplies the station's maneuvering thrusters. The vessel also carried 926 pounds of water and 110 pounds of oxygen and air.

The cause for the failure had to be understood and corrected before the *Soyuz* could be launched with a crew of astronauts and cosmonauts. Fortunately, the Russians resolved the problem—narrowly averting the possibility of an unmanned space station—and successfully launched three crewmen to the station on November 13, 2011. A *Soyuz* spacecraft has a limited lifetime on orbit. It carries a three-person crew to the space station and remains docked to the station throughout the crew's six-month stay. The *Soyuz* has to return before its lifetime runs out. The lifetime limitation on the docked *Soyuz* spacecraft dictated that the crew manning the station would have had to return to Earth by no later than November 21—a close call to say the least.

A little over a month later, on December 23, a Russian communications satellite crashed just after liftoff when its rocket apparently failed. It was the fifth failed space mission experienced by Russia in 2011. The communication satellite was being launched from Plesetsk Cosmodrome in Russia on a *Soyuz-2* rocket, an upgraded version of the typically dependable *Soyuz* booster.

On January 27, 2012, Russia announced that worrisome cracks in the *Soyuz* spacecraft being prepared for a March launch had forced the postponement of the next two manned flights to the ISS. This situation brought back memories of the problems experienced in 2011 that left Russia's space transport vehicles grounded and again led to speculation that the space station might have to be abandoned.

Six crewmembers were aboard the ISS as members of Expedition 30, the 30th astronaut crew to man the space station. They included two Americans: commander Dan Burbank, who had been in space since November 16, and flight engineer Don Pettit. They were scheduled to return from the station on a March 30 flight. That return flight was postponed until mid-April.

Future *Soyuz* liftoffs were postponed because the *Soyuz* TMA-04M spaceship cracked while it was being tested in a pressure chamber and precluded the reentry capsule being used for any manned spaceflight. Due to the delay of the March 30 launch, the *Soyuz* TMA-05M mission was also delayed until the middle of July. Such problems unfortunately happen. Systems and spacecraft are not perfect. When these situations occur, dual access to the station becomes critical.

In addition to relying on the Russians being successful in their efforts to support the space station, NASA is also providing funding to three commercial space endeavors for American logistical support and crew transport. The *Dragon* capsule built by a California company, Space Exploration Technologies (SpaceX), has successfully performed two logistical flights in support of the station. However, these programs are several years away from having an initial operational capability for human spaceflights. Also, it is still an open question as to whether these companies will be able to operate with a sustainable and profitable business model. Their primary customer is the U.S. government. Thus, their long-term viability is in question, and we can expect that the gap in U.S. human spaceflight capability that started with the grounding of the space shuttle will likely last another five years or longer. NASA is also moving forward with the development of its Space Launch System (SLS)—a new heavy-lift vehicle—without any agreed upon destination or requirements. A major concern with the new system is related to the rocket itself.

The SLS and its associated requirements have been dictated by Congress. The NASA Authorization Act of 2010 mandated that NASA begin immediate work on the SLS, with a 2016 deadline for initial readiness. The performance requirements for the rocket are for an initial launch capacity of 70 to 100 tons, expandable to at least 130 tons. Congress also stated that, wherever possible, the SLS should include technology from the 1970s-designed space shuttle and from the cancelled Constellation program. The stated mission of the SLS is to explore deep space and to provide a NASA-owned option for reaching the ISS. The 70-ton capacity of the vehicle is of questionable value. The SLS is considerably oversized for supporting the space station, and the specific transportation requirements for exploring deep space are not clear since there is no definite destination or exploration architecture.

The 35,678-lb. truss segments delivered to the space station in June 2007 on the STS-117 mission was one of the heaviest payloads ever taken to the ISS. A 70-ton requirement greatly exceeds the 35,000-lb. payload carried by that space shuttle *Atlantis* flight.

The schedule for the new launch vehicle will depend on future NASA budgets. A first launch planned for 2017 will launch only a single stage of the SLS. NASA documents suggest that with a flat agency budget providing about $41 billion from 2012 through 2025, NASA will not be able to do much work on the second stage of the SLS until after 2017, with a first manned flight projected to occur in 2021.

This flight would presumably use what NASA has called a multi-purpose crew vehicle (MPCV). It is not clear what its multiple purposes will be, when and if it ever flies, though NASA has stated that the spacecraft would take astronauts to a still-to-be-determined destination. The MPCV has none of the capabilities executed so well by the space shuttle, such as supporting extravehicular activities (EVAs) and being able to assemble large structures in Earth orbit. The MPCV cannot support such activities. NASA has not established a design freeze or launch date for MPCV, and stated that its target mass is 28 tons. But it has said that number is subject to fluctuation as the design matures. The MPCV is in reality a continuation of the *Orion* spacecraft from the Constellation program. It will land by parachutes in the ocean. At its projected weight, it will indeed require very large parachutes.

In today's budget environment and what is likely to be the budget environment for some time to come, NASA needs to establish some clear and meaningful priorities. Staying on the present course does not provide the nation with a meaningful and visionary program. A reassessment of the present course of action is very much in order.

NASA's number one priority should be building on its two very successful programs: the ISS and its equally successful robotic exploration and science programs. Both programs should be vigorously supported. Of equal importance and priority is reestablishing and reinvigorating an effective research and development program within the agency—a research program that would involve both space and cutting-edge aeronautical research. NASA no longer has a strong and innovative research and development program such as existed in past years. If it is going to develop the talented engineers and leaders of the future, the young engineers and scientists need to be challenged with an active and ongoing space and aeronautical research program. The National Academies report

Rising Above the Gathering Storm highlighted the critical need for, and the importance of, investing in research and development.[1] NASA's shift away from research and development has worsened the problem. The agency's past successes are in no small way a result of the development of a cadre of bright young engineers and scientists steeped in a solid background of hands-on research and development. NASA icons such as George Low, Max Faget, and Chris Kraft developed their skills through such progressive programs.

The true catalyst for increasing the commercialization of space is reducing the cost of flying to space. The space shuttle was a step in that direction, but it fell short in achieving that goal. That is not to say that it will not help to pave the way for future efforts to achieve that objective. The space shuttle originally started out with a fly-back booster. NASA studied flyback boosters again more than a decade ago as part of a potential suite of upgrades to the space shuttles, but never pursued its development. The fly-back booster was considered too big a step in the 1970s to develop in parallel with the shuttle. Today it is well within the state of the art.

The U.S. Air Force has a vision of the future that includes rockets that are not only reusable, but also spacecraft that are able to fly back to Earth and land autonomously on a runway. And just as SpaceX founder and chief executive Elon Musk said in a speech at the National Press Club in Washington, D.C., a fully reusable rocket would dramatically decrease the cost of lifting cargo and humans to space, making the exploration and colonization of Mars at least feasible.[2] SpaceX has successfully tested its concept for a fully reusable rocket called Grasshopper at its proving ground in McGregor, Texas.

The Air Force has already flown two very successful missions of a small-scale version of the space shuttle, Boeing's robotic space plane X-37B. Like the space shuttle, the X-37B launches on a rocket and flies back down to a runway after reentering the Earth's atmosphere.

The chief engineer of the Space and Intelligence Systems' Experimental Systems Group at Boeing presented a paper at the American Institute of Aeronautics and Astronautics' (AIAA) Space 2011 conference that discussed the possibility of a manned version of the X-37B, a larger X-37C that could be used as a cargo ship for the International Space Station. He said that it could also be easily modified to carry up to six passengers. Unlike other cargo carriers slated to become manned spacecraft, the X-37B doesn't necessarily require major design changes. As in aviation, this vessel would keep our spacecraft on a similar track of evolution as that which occurs in the world of atmospheric flight. Our commercial aviation world has seen evolution and improved designs from Boeing's early 707 to today's 787. In contrast, capsules and parachutes return us to the early days of aerospace technology. With a research and development program, utilizing a modified X-37B and a fly-back booster, NASA could pave the way for low-cost reusable spacecraft and launch vehicles and reestablish our leadership in the competitive world of launch vehicles. Russian space officials have already said the first flight of a reusable Russian rocket booster that returns to a runway under its own power could occur by 2020. Many studies are being undertaken and architectures designed without giving priority to the life-science problems associated with long-duration flights beyond Earth orbit. Radiation protection for humans must be a major consideration for such flights. An aggressive research program to understand and develop the means for protecting the crews in this hostile environment has to be a prime consideration. An integrated research program should be undertaken as a priority with all the international partners to not only address radiation but to address all the life-science issues of long-duration spaceflights. The space station provides an excellent laboratory for performing this research, which should be undertaken by working together with all the partners and an integrated crew of astronauts and cosmonauts.

Space also provides an outstanding platform for studying our planet and its environment. NASA's Earth Observation Missions have contributed to not only increased scientific knowledge of Earth's surface and atmosphere but have also been critically important to weather prediction, hurricane tracking, and responding to natural disasters, among other societal applications. This program is equally deserving of continuing and elevated attention.

An additional priority is initiating a realistic human exploration program that returns man to the moon as its first step. The moon provides an excellent laboratory to test and learn how to operate in a remote location. It will provide the learning and experience for human exploration in space beyond the moon and it is only a three-day flight away in the event of a problem. The recommended human exploration program should build on the international partnerships of the ISS to develop the architectures and plans for an international human exploration program.

Consideration should also be given to in-orbit assembly options for manned space exploration systems. An orbiter-type vehicle could be utilized as a key element of such a system. The orbiter-type vehicle would be used as advocated by George Jeffs, the chief engineer for North American Aviation's Apollo Program: for assembly activities in orbit, and most importantly for the crew Earth-to-orbit and orbit-to-Earth transfer. Reliance on such a vehicle for reentry would eliminate having to design exploration spacecraft to carry all the weight of items such as heat shields, parachutes, and landing impact structure to outer space, as well as cut the energy needed to transport this otherwise useless added weight throughout the entire deep space mission. The design of the spacecraft to be flown to outer space could then be optimized for its exploration mission. This approach essentially would trade off these advantages against the development of an additional propulsion module for return from deep space to high/low Earth orbit. An orbiter-type vehicle, such as a modified X-37, could play a key role in the early development of such an in-orbit assembly system.

The exploration program should also take advantage of all the in-line capabilities of the ISS from its inception, and consideration should also be given to expanding the partnership. This year China demonstrated crewed rendezvous and docking, flying a crew of three (which included China's first female astronaut) to their crew-tended *Tiangong-1* orbital vehicle. China plans to launch *Tiangong-2* in 2013 and *Tiangong-3*, a Zvezda-class core module, in 2020.

The dual access we lost to the ISS, a capability we had with the space shuttle, can be regained by bringing China into the station program. The United States could lead the way in adapting the Shenzhou spacecraft to be compatible with ISS. The U.S. would continue funding the three commercial space endeavors as they would supplement and support the logistical needs of the station that were lost with the retirement of the shuttle. Jean-Jacques Dordain, director-general of the European Space Agency (ESA), and Vladimir Popovkin, head of the Russian space agency Roscosmos, have already expressed a desire to bring China into the International Space Station. It is clear that our international partners see the benefits of working with the Chinese on the ISS. It is time for the United States to provide the leadership to make it a reality.

On its present course, the United States is losing its perceived leadership role in human space exploration. By taking advantage of its flagship programs, the ISS and robotic space exploration, moving forward with the outlined research and development program, proposing initiatives to significantly reduce the cost of flying in space, implementing an exploration program to optimize collaboration with our international partners, and showing leadership in working with China, the U.S. could once again be leading the way in exploring the final frontier.

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