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Choosing the pathway to space

It may have been obvious to many in the civil space community, but it took a presidentially commissioned panel to make it unambiguous: The path to space that NASA has been following since January 2004—once termed the Vision for Space Exploration and subsequently emerging as Project Constellation—is unsustainable. The commission, chaired by Norm Augustine and populated by a host of experienced space engineers and former astronauts, laid out a series of scenarios in a September 8 summary report that called into question the viability of that policy if not its technical merits.

The missing element is money. The program, said the report, "appears to be on an unsustainable trajectory. It is perpetuating the perilous practice of pursuing goals that do not match allocated resources. Space operations are among the most complex and unforgiving pursuits ever undertaken by humans. It really *is* rocket science. Space operations become all the more difficult when means do not match aspirations. Such is the case today."

Originally tasked with keeping its review within the budget established last May by the Obama administration—a budget billions of dollars smaller than what the Bush administration initially proposed—the Review of U.S. Human Spaceflight Plans Committee was forced to ask the White House to let them roam a bit more freely in budget alternatives.

What followed became a stark picture of a space program that was locked in LEO with little chance of achieving the grandiose exploration goals set by the previous president to return to the Moon and then continue on to Mars. The committee concluded that the ultimate goal of space exploration is to chart a path for human expansion into the solar system. Mars, it said, was the ultimate destination of U.S. astronauts in space, but should not be the first such destination beyond LEO. And while the Moon could be within reach by the late 2020s, given sufficient funds, the committee laid out other scenarios that, for the same funds, could include other deep space manned missions, too.

The group developed five alternatives for NASA's human spaceflight program. It found that human exploration beyond LEO is not viable under the FY10 budget guideline, but is possible under a less constrained budget that ramps up to approximately $3 billion a year above the FY10 numbers and continues that extra funding until 2014, after which it would grow only 2.4% annually for inflation. Funding at that higher level would allow either an exploration program to explore the Moon first, or a program that follows a "flexible path" of exploration. Either could produce results in a reasonable timeframe, starting in the middle of the 2020s. The committee weighed in on the merits of developing a heavy-lift booster, commercial alternatives for crew de-

by Frank Sietzen Jr.
Contributing writer

A presidentially appointed panel finds NASA's human spaceflight program has too little money and too few options.

livery to the ISS, and the inclusion of international partners in future exploration missions. It also assessed the status of the shuttle and station programs. While the industry is awash with reactions to the summary, as of this writing the White House has not commented.

Reality check on current programs

The panel first looked at options regarding the space shuttle and international space station. Currently, NASA plans to retire the shuttle fleet after six more flights, the last scheduled for September 2010, with no funds in the FY11 budget for continuing operations much beyond that date. The group noted that the projected flight rate is nearly twice that of the actual flight rate since shuttle operations resumed in July 2005.

The panel suggested that a more realistic schedule be adopted and urged the administration to find the funds to fly out the remaining missions into 2011. They soberly predicted that, after the shuttle's retirement, the gap in U.S. access to space by astronauts will be at least seven years long. One option presented was to continue to fly the shuttle at a minimum annual flight rate until it is replaced by a new vehicle or vehicles. Should that option be pursued, the panel noted, NASA should conduct a thorough review of shuttle recertification and reliability to ensure that the risk associated with that extension would be acceptable. With many shuttle suppliers now exiting their manufacturing and production capabilities, this option would be increasingly expensive if selected.

The group was concerned that the ISS could be vulnerable once the shuttle is retired. After shuttle retirement, the ISS would rely on a combination of international and new and unproven commercial vehicles for cargo transport. Because this planned commercial resupply capability will be crucial to both ISS operations and use, it may be "prudent to strengthen the incentives to the commercial providers to meet the schedule milestones."

The report strongly suggested that the station's return on investment to both the U.S. and its international partners would be "significantly enhanced" by a life extension to 2020, saying that it seemed foolish to deorbit the station after 25 years of assembly and only five years of operational life. Not to do so, the panel said, would significantly impair U.S. ability to develop and lead future international space missions.

The only problem with this recommendation: The current budget funds station operations until only 2015.

Constellation status

The committee then compiled all of the status reports obtained during its site visits to NASA facilities and assessed the status of the emerging Constellation program and vehicles. The panel found that the original budget

"I want to go to Mars, but let's go the right way!"
Jeff Greason

Background

On May 7 John Holdren, director of the White House Office of Science and Technology Policy, sent a letter to NASA Acting Administrator Chris Scolese requesting that he assemble "an independent review of ongoing U.S. human spaceflight plans and programs" and alternatives, to ensure that the nation "is pursuing the best trajectory for the future of human spaceflight."

Holdren tasked NASA with identifying and characterizing a range of options that would span the reasonable possibilities for continuation of U.S. human spaceflight activities beyond retirement of the shuttle fleet. Those options should explore a new U.S. capability for supporting use of the ISS; supporting missions to the Moon and other destinations beyond LEO; and stimulating commercial spaceflight capabilities, all fitting within the current budget.

On June 1, Scolese responded by establishing the charter of the Review of U.S. Human Spaceflight Plans Committee. Ten members, appointed by NASA, would comprise the panel, chaired by retired Lockheed Martin executive Norm Augustine. They would include engineers, academic experts, former astronauts, and commercial space entrepreneurs.

The charter tracked the charge given NASA in Holdren's May 7 letter: Conduct an independent review of U.S. manned spaceflight programs from the shuttle and station to beyond Earth orbit, and examine the appropriate amount of research and complementary robotic activities needed to make human spaceflight more productive and affordable over the long term. It asked that the panel specifically evaluate "options for extending ISS operations beyond 2016."

Augustine divided the panel into four subgroups, with each member assigned to two. Sally Ride chaired the ISS-Shuttle subgroup, Edward Crawley headed the Exploration Beyond LEO subgroup, Gen. Lester Lyles chaired the Integration subgroup, and Bohdan Bejmuk headed up the LEO Access group. The subgroup reports would be folded into the full panel's final document.

Chair: *Norman Augustine*

Dr. Wanda Austin	*Dr. Christopher Chyba*	*Dr. Charles F. Kennel*
Mr. Bohdan Bejmuk	*Dr. Edward Crawley*	*Gen. (ret.) Lester Lyles*
Dr. Leroy Chiao	*Mr. Jeff Greason*	*Dr. Sally Ride*

estimates made in January 2004, along with the vehicle designs established in the 2005 Exploration Systems Architecture Study, were a reasonable plan for human exploration. But many of those estimates were based on funding being made available by shuttle retirement in 2010 and the decommissioning of ISS in early 2016.

Since those early projections, the development schedules of the Ares I crew launch vehicle and the Orion crew exploration vehicle have slipped, and work on the Ares V heavy lifter and Altair lunar lander has been postponed. The group said the emerging technical problems facing Ares I could be solved but would add to the vehicle's development cost.

The 2005 schedule showed Ares I and Orion available to support the ISS in 2012, only two years after shuttle retirement. But the current schedule now shows that date as 2015, and an independent assessment of the technical, budgetary, and schedule risk to the Constellation program performed for the committee by the Aerospace Corporation indicated a further delay of at least two years. This means those vehicles, designed specifically to support the ISS post-shuttle, will not be available before the station's currently planned demise. And the manned spaceflight gap will be seven years, not two.

The committee endorsed the designs of the CLV and CEV. But it had concerns about Orion's recurring costs, noting the design was considerably larger than previous Apollo craft. It hinted that a smaller and lighter four-person Orion could reduce operational costs, but that such a late-stage redesign would likely result in over a year of additional development delay and a significant increase in cost.

The future of the ISS is dependent on which option goes forward.

Where to go beyond LEO

The panel considered a series of possible targets for U.S. manned spaceflight beyond Earth orbit. Three paths were identified:

•Mars First, with a Mars landing, perhaps after a brief test of equipment and procedures on the Moon.

•Moon First, with lunar surface exploration focused on developing the capability to explore Mars.

•A Flexible Path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects, and the moons of Mars, followed by surface exploration of the Moon and/or Mars.

Humans to Mars followed by colonization was highlighted as the ultimate goal of U.S. manned spaceflight. "Mars is unquestionably the most scientifically interesting destination in the inner solar system," the report said. But the planet is not an easy place to visit with existing technology and without a substantial investment of resources, and the panel stated flatly that it is not the best first destination beyond Earth orbit.

By exploring the Moon first, the panel found, NASA could develop the operational

experience and technology for landing on, living on, and launching from another planetary surface. Astronauts could acquire an understanding of human adaptation to another world and apply this to Mars missions.

The report listed two main strategies for exploring the Moon. Both begin with a few short sorties to various lunar locations to scout the region and test landing and ascent systems. The next step would be to build a Moon base. Over many missions, a small colony of habitats would be assembled, and explorers would stay for extended periods, conducting scientific studies and prospecting for resources. In the second strategy, these sorties would continue on to different sites, with astronauts spending weeks and eventually months at each. Additional equipment would have to be brought on each trip, but explorations would cover more diverse sites and do so in greater detail.

In the third, or "flexible" path, the crews would visit sites for the first time and deepen the operational knowledge of space missions, all while traveling to destinations farther and farther from Earth. Potential missions would include lunar orbit, the Lagrange points, near-Earth objects, and entering orbit around Mars. Manned spacecraft such as Orion could rendezvous with a Martian moon, then coordinate with or control robotic landers on the planet's surface, without the complication of the time delay between the Earth and the vicinity of Mars.

The Flexible Path represents a new exploration strategy for NASA. It would provide a series of scientifically valid missions to keep the public engaged and political leaders supportive. Its flexibility would allow different options as exploration progresses, including a return to the Moon's surface, or a continuation to the surface of Mars.

The committee found that both the Moon First and the Flexible Path are viable exploration strategies and not necessarily mutually exclusive. And all paths share one other element: Each would require a further $3 billion a year every year until 2014.

Option families

Within these paths, five option families were identified for consideration. They include one based on the program of record, Constellation, but with sufficient funds to meet the original Bush goals, and four possible alternatives.

Augustine said he was asked to provide two options that fit within the existing FY10 budget profile: a NASA budget that is flat or decreases through 2014, then increases only at 1.4% a year thereafter, less than the 2.4% a year used to estimate inflation. The first two options are constrained to that budget.

"If Santa Claus brought us this system tomorrow, fully developed, and the budget doesn't change, our first action would be to cancel it."
Jeff Greason

•Option 1: Program of record as assessed by the committee, constrained to the FY10 budget. This is Project Constellation, with only two changes the committee deemed necessary: Providing funding for the shuttle into FY11, and including sufficient money to deorbit the ISS in 2016.

Although this is the current plan, the group found no money in the budget for actually doing it. When constrained to this budget profile, Ares I and Orion are not available until after the ISS has been destructively deorbited. Worse, the heavy-lift Ares V is not available until the late 2020s, and there is no money to develop the Altair lunar lander and lunar surface systems until well into the 2030s, if ever.

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AUGUSTINE MEETS THE HILL

Norm Augustine took his summary report on the future of the U.S. human spaceflight program to Capitol Hill September 15-16 in back-to-back hearings in the House and Senate. At the September 15 House Committee on Science and Technology hearing, a lukewarm reception turned hostile when several members defended the existing Constellation program and questioned why Augustine's panel proposed so many alternatives. "I have to say that I am extremely frustrated—in fact, I am angry," said Rep. Gabrielle Giffords (D-Ariz.), who chairs the subcommittee on space and aeronautics. "With all due respect to Mr. Augustine and his panel, I have to say that I think we are no further ahead in our understanding of what it will take to ensure a robust and meaningful human spaceflight program than we were before they started their review," she stated.

"At this point, my focus is on the future and finding the best path forward," said Rep. Bart Gordon (D-Tenn.), chairman of the full committee. Gordon expressed skepticism regarding any need for change. "NASA has been working for more than four years on the Constellation program, a development program in support of which Congress has invested billions of dollars over that same period. I think that good public policy argues for setting the bar pretty high against making significant changes in direction at this point."

Giffords ridiculed Augustine's assertion that the need for more NASA funding was uncovered by his panel. "But we didn't need an independent commission to tell us that. That's been painfully obvious for some time now," she told Augustine.

The panel received a warmer reception the next day at a hearing before the Senate subcommittee on science and space. "Now the president needs to provide the visionary leadership required to continue American leadership in space exploration. That means not just the necessary funding to take us beyond low Earth orbit, but a plan to keep our workforce and industrial base engaged and productive," said the subcommittee's chairman, Sen. Bill Nelson (D-Fla.).

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•Option 2: ISS and lunar exploration, constrained to the FY10 budget. This option extends the ISS to 2020, and conducts a program of lunar exploration using a smaller version of Ares V. It assumes a shuttle flyout in FY11, and includes a technology development program, a program to develop commercial crew services to LEO, and money for enhanced utilization of ISS. This option does not deliver heavy-lift capability until the late 2020s and does not have funds to develop the systems for lunar landing or exploration.

The remaining three alternatives are sized to a larger budget profile—one the panel judged more appropriate for a program designed to carry humans beyond LEO. It adds $3 billion above the FY10 guidance each year to FY14, then slows to a 2.4% inflation adjustment a year.

•Option 3: Baseline case—implementable program of record. This is an executable version of Constellation. It consists of the content and sequence of the existing program—deorbiting the ISS in 2016, developing Orion, Ares I, and Ares V, and beginning lunar exploration. The committee made only two additions—budgeting for the flyout of the shuttle in 2011, and ISS deorbit. The assessment is, under this funding profile, that the option delivers Ares I/Orion in FY17, with human lunar return in the mid-2020s.

•Option 4: Moon first. This keeps the Moon as the first destination. It extends ISS life to 2020 using commercial crew-carrying vehicles and funds technology advancement. There are two variants to this option: Variant 4A retires the shuttle in FY11 and develops the Ares V Lite heavy-lift booster for lunar missions. Variant 4B includes the only foreseeable way to eliminate the gap in U.S. human-launch capability: It extends the shuttle to 2015 at a minimum safe-flight rate. It also develops a heavy-lift booster that is more directly shuttle-derived. Both variants of Option 4 permit human lunar return by the mid-2020s.

•Option 5: Flexible Path. This option follows the Flexible Path as exploration policy. It flies the shuttle into FY11, extends the ISS until 2020, funds technology development, and develops commercial crew services to LEO. There are three variants within this option (they differ only in the heavy-lift booster design selected). Variant 5A develops Ares Lite, the most capable of the heavy-lift vehicles in this option. Variant 5B employs an EELV-heritage commercial heavy-lift rocket and assumes a significantly smaller role for NASA. It has lower operational costs but requires major restructuring of NASA. Variant 5C uses a shuttle-derived heavy-lift vehicle, taking maximum advantage of existing infrastructure, facilities, and production capabilities.

All variants of Option 5 begin exploration along the Flexible Path in the early 2020s, with lunar flybys, visits to Lagrange points and near-Earth objects, and Mars flybys occurring at a rate of about one mission a year, and a possible rendezvous with Martian moons or human lunar return by the mid-to-late 2020s.

All paths lead to funding

The committee found that no strategy compatible with the FY10 budget profile allows manned spaceflight to continue in any meaningful way. But with a budget increasing by $3 billion annually above the FY10 budget levels, both the Moon First and Flexible Path strategies begin human exploration on a reasonable, though not aggressive, timetable. The panel believed an exploration program that will be a "source of pride for the nation" requires more money annually for NASA.

Regardless of the pathways selected, the group strongly urged the design and development of some form of heavy-lift booster to support manned spaceflight.

"I think it would be fair to say that our view is that it would be difficult with the current budget to do anything that's terribly inspiring in the human spaceflight area."
Norm Augustine

It also suggested that the U.S. make greater use of international cooperation and partnerships beyond any missions from LEO. And it found attractive the prospect that selection of a commercial crew spacecraft development effort to lower costs for access to the station would help to develop a new commercial space industry for the nation.

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As was the case following the 2003 Columbia disaster, NASA and the U.S. civil space program again face the prospect of a new direction. Whatever option the Obama administration chooses, neither a blue-ribbon panel, nor NASA, nor the White House will have the final say as to what the nation does in space. "Whatever space program is ultimately selected, it must be matched with the resources needed for its execution," said the report.

And that choice remains, as it should, with the public at large.

"So you have a heavy-lift vehicle in 2028, but absolutely nothing to put in it to send to the Moon."
Sally Ride