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What's next for U.S. human spaceflight?

Indigenous fighters make a comeback

ISS: Dawn of a new era

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What's next for U.S. human spaceflight?

Falcon 9, with Dragon, stands on the launch pad. Credit: SpaceX/Roger Gilbertson.

by **J.R. Wilson**
Contributing writer

With the demise of the shuttle, concerns over lack of U.S. access to space have grown even more intense. As controversy swirls in Congress, NASA, and the space community over the future of U.S. manned spaceflight, industry has mounted a surprisingly robust response to the need for filling the gap, with several candidate vehicles and related systems now in various stages of development.

Despite starting from behind, the U.S. manned space program surged past that of the old Soviet Union nearly a half-century ago, carrying the first human being to the Moon less than a decade after the Soviets put the first man into orbit.

Twelve U.S. astronauts walked on the Moon between 1969 and 1972. But in the ensuing four decades, no one from Earth has gone beyond LEO.

When the space shuttle first flew in 1981, NASA restored the nation's dominance in the arena of manned space activities, which had ceased in the U.S. after Apollo ended in the late 1970s. Although the shuttle never achieved the high launch rate originally envisioned, the fleet carried astronauts on a wide range of LEO missions for 30 years and played an essential role in the construction and manning of the ISS.

With the shuttle decommissioned and the Ares/Constellation follow-on canceled, NASA must rely on expensive seats in Russia's three-person Soyuz to take U.S. astronauts to the ISS. What NASA has planned for the future of manned space activities has been a matter of controversy and confusion for the past three years, especially since the shuttle's final flight.

Divergent views

On September 22 and again on October 12, the House Committee on Science, Space and Technology and its subcommittee on space and aeronautics held hearings on the future of human spaceflight. What lawmakers heard from former astronauts, spaceflight engineers, and NASA officials differed markedly, with the former sharply critical of the agency and President Barack Obama, and the latter painting a far rosier picture of continued NASA efforts and international cooperation.

"NASA, hobbled by cumbrous limitations, has been unable to articulate a master plan that excites the imagination and provides a semblance of predictability to the aerospace industry," former astronaut Neil Armstrong told lawmakers. "We will have no American access to, and return from, low Earth orbit and the international space station for an unpredictable length of time in the future. For a country that has invested so much for so long to achieve a leadership position in space exploration and exploitation, this condition is viewed by many as lamentably embarrassing and unacceptable.

INDUSTRY RESPONDS TO THE CALL

Several companies have responed to the administration's call for commercial participation in deverloping the next generation of human space transportation vehicles.

ATK Space Launch Systems *(Magna, Utah)*
- *Orion multipurpose crew vehicle (MPCV) launch abort system*
- *Liberty launch vehicle*
- *Space launch system (SLS) reusable solid rocket motors (RSRMs)*

Bigelow Aerospace *(Las Vegas, Nevada)*
- *Expandable orbital space platform*

Blue Origin *(Tacoma, Washington)*
- *Crew transportation system for LEO (CCDev2 proposal)*
- *Reusable booster system man-rated launcher for CTS*

Boeing Space Exploration Division *(Houston, Texas)*
- *Crew space transporation-100 (CST-100) manned LEO spacecraft (CCDev2)*
- *Man-rated launch vehicle (NASA SLS competitor)*

Lockheed Martin Space Systems
- *Orion MPCV*

Orbital Sciences *(Dulles, Virginia)*
- *Orion crew exploration vehicle launch abort system*

Scaled Composites *(Mojave, California)*
- *SpaceShipTwo (SS2) suborbital manned spaceship*
- *WhiteKnightTwo (WK2) carrier aircraft*

Sierra Nevada Space Systems *(Louisville, Colorado)*
- *Dream Chaser manned LEO spacecraft (CCDev2)*

SpaceX *(Hawthorne, California)*
- *Falcon 9 man-rated launch vehicle*
- *Dragon manned spacecraft (CCDev2)*

The Spaceship Company *(Mojave, California)*
- *SS2 suborbital manned spaceship*
- *WK2 carrier aircraft*

United Launch Alliance (ULA) *(Centennial, Colorado)*
- *Atlas V man-rated launch vehicle for CTS-100*

Virgin Galactic *(Spaceport America, New Mexico)*
- *SS2 suborbital manned spaceship*
- *WK2 carrier aircraft*

"The uncertainties associated with the radical changes in space plans and policies of the last two years contributed to a substantial erosion of the United States' historically highly regarded space industrial base. Thousands of jobs have been lost, and the space component of the industry is perceived as unstable, discouraging students from considering preparing themselves for entry into this exciting but demanding career path," he continued.

Three weeks later, however, William Gerstenmaier, NASA associate administrator for the newly created Human Exploration and Operations Mission Directorate, assured the committee that NASA's commercial crew development (CCDev) and commercial crew program, among other efforts, do address the issues raised by critics.

"NASA investments have been aimed at stimulating efforts within the private sector to develop and demonstrate human spaceflight capabilities through the CCDev initiative. Since 2009, NASA has conducted two CCDev rounds, soliciting proposals from U.S. industry participants to further advance commercial crew space transportation system concepts and mature the design and development of elements of the system, such as launch vehicles and spacecraft," Gerstenmaier testified.

"On September 19, 2011," he continued, "NASA released a draft RFP that outlines a [commercial crew program] contract to provide a complete end-to-end design, including spacecraft, launch vehicles, launch services, ground and mission operations, and recovery....NASA's strategy has evolved into an overall hybrid structure over the life cycle of the program, building on the progress made by the SAAs [Space Act Agreements] and transitioning into a series of competitively awarded contracts."

Industry responds

Following cancellation of Constellation, the shuttle follow-on program proposed by the Bush administration, and the president's announcement that future U.S. manned space efforts would rely on commercial spacecraft and launch vehicles, private industry responded far more vigorously than some had expected. By the start of FY12, more than a dozen companies had signed agreements with NASA or had announced plans to build manned spacecraft, human-rated launchers, or manned orbital platforms.

One of the key projects is the NASA-led MPCV (multipurpose crew vehicle), a con-

tinuation of the Ares/Constellation's Orion, with Lockheed Martin still the prime. It is meant to carry up to four astronauts on 21-day missions to LEO and the space station in a capsule resembling the old Apollo, but larger. As with Apollo, it will land in the ocean, but NASA claims it will be 10 times safer than the airplane-style shuttle during both ascent and reentry.

"In terms of human-rated spacecraft, NASA has chosen to go to the next generation of LEO access through commercial procurement," says Keith Reiley, Boeing's deputy program manager for commercial crew programs. "Building human-rated space systems is part of the business Boeing is in, from the shuttle to the ISS. There clearly are advantages to doing procurement in the way NASA has chosen, with reduced costs and overhead. And I think it's healthy there is now new, young startup competition that makes everybody better.

"Apollo happened very quickly, as did shuttle, which was a lot more complex than what we're doing here. The big difference now is how we are working with NASA, which is more of an investor. Our core business plan is based on the NASA missions and supporting the Bigelow missions, but if others need services, we will look at those. We also can take the Boeing commercial aircraft approach, which is the basic Boeing business model. If the market gets large enough, there are problems with being both a builder and an operator. But it would be good news if, in the future, we just become a platform provider."

Boeing (largely through its acquisitions of McDonnell Douglas and Rockwell) and Sierra Nevada (one of the world's largest manufacturers of small satellites) have solid backgrounds in building successful launch vehicles and spacecraft, as do Scaled Composites (the only private company to have launched humans into space), Lockheed Martin, ULA, and SpaceX. But some critics question whether private industry is truly prepared to take on all of the requirements of safe, efficient, and cost-effective manned spaceflight.

"Although I do believe and hope that someday they will succeed, I still assess that those entrepreneurs in the world of commercial space who continue their claims of being able to put humans in space in little more than three years for something less than $5 billion, today still 'don't yet know what they don't know,'" retired astronaut Eugene A. Cernan told Congress. "My statement [in 2010 testimony] that 'sole reliance on the commercial sector without a concurrent or backup approach could very well lead to the abandonment of our $100-billion, 25-year investment in the ISS' is now more prophetic than ever.

Engineers at NASA Langley conducted the third drop test of the Orion test article as part of Phase 1 water impact testing on November 8. The capsule was hoisted about 20 ft above the ground with a pitch of 17 deg. It reached a horizontal velocity of about 22 mph before splashing into the Hydro Impact Basin. Credit: NASA/Sean Smith.

"It will be near the end of the decade before these new entrants will be able to place a human safely and cost effectively in Earth orbit. Should the development of the SLS [heavy-lift space launch system] go forward as mandated by Congress—along with the Orion spacecraft, as just announced by the administration—I believe we will have the best and perhaps only opportunity within reach to narrow the gap that now exists between the final shuttle flight and America's capability to regain access to Earth orbit and the ISS. Access to low Earth orbit should be our primary objective in

SLS is a next-generation version of the Saturn V, which took astronauts to the Moon more than 40 years ago.

any plans in the evolutionary development of a new versatile lift vehicle, with future deep space missions as a follow-on," added Cernan, commander of Apollo XVII and the last man on the Moon,

NASA turns to heavy lift

In what is by now almost a tradition for NASA programs, the heavy lift SLS was born in controversy, with critics accusing the agency and the Obama administration of dragging their heels in meeting congressional mandates for a new government manned space system.

"The short-term solution is more complex in light of NASA and the present administration's now obvious agenda to dismantle a space program that has been five decades in the making," Cernan told the House committee. He called the grounding of the shuttle fleet, cancellation of the Constellation vehicle, and commercial turnover of future manned flight to LEO a "mission to nowhere." He said, "Although it is the intent that the 'full-up' SLS give us the capability of designing a variable set of missions, I firmly believe that the time for a well-thought-out, long-term initiative for our nation's role in space, with or without the SLS, is long overdue.

"My assessment of NASA's progress in the development of a heavy-lift launch system to enable exploration beyond Earth orbit, as well as provide a capability to service the ISS should a commercial market entrant or our international partners become unavailable, is that it has been deceptive, inadequate, and to date nonproductive. Now is the time to overrule this administration's pledge to mediocrity. Now is the time to be bold, innovative, and wise in how we invest in the future of America. Now is the time to reestablish our nation's commitment to excellence. Mr. Chairman, ladies and gentlemen, it is not about space—it's about the country."

The SLS essentially is a next-generation version of Saturn V, the most powerful rocket ever built, which carried astronauts to the Moon more than 40 years ago. According to NASA, its purpose will be to carry the Orion, cargo, equipment, and science experiments beyond LEO, "providing a safe, affordable, and sustainable means of reaching the Moon, asteroids, and other destinations in the solar system."

Beginning with a 70-metric-ton version, comprising only core stage and strap-ons, the SLS ultimately is to evolve into a 130-metric-ton rocket. It will use the shuttle's proven RS-25 engine for the core stage, a Rocketdyne J-2X upper stage, and two five-segment side-mounted solid rocket boosters. It builds on Saturn, shuttle, and Ares development efforts, but uses cutting-edge tooling and manufacturing technologies to reduce development and operations costs.

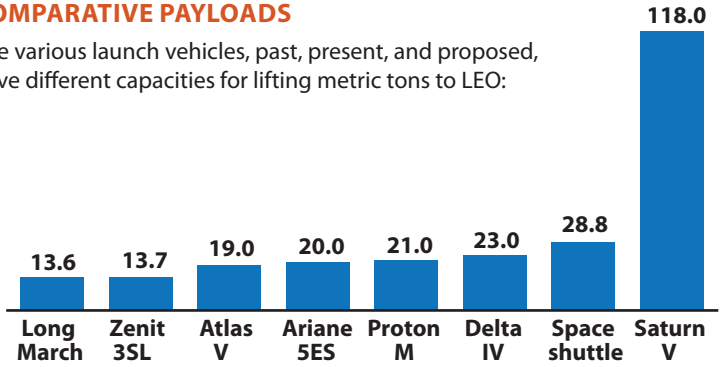
"Our vision is to have an interface that's generic, and we'll be able to carry potentially different boosters and change them out as needed," Gerstenmaier told the International Astronautical Congress, which met in South Africa in October 2011. "So we could go compete in the future, maybe downsize if something's easier for a mission that requires less thrust. We have some variability there, so if we do our job right, we'll have the ability to change the boosters that sit on the side. That's our ultimate goal. If we don't need an upper stage for certain missions, we don't have to fly an upper stage. We don't have to add a new plant, new facilities, and new tooling.

"We're not really ready to step up to the booster activity right away with a full-up competition. We think there's some technology that needs to get explored and understood as we go forward. We think we also need to define a little bit better the core interface with the solid rocket boosters or the liquid rocket boosters, so we have that as a design condition," he added. "We're going to have a kind of a study phase, with potentially multiple contractors participating in that study phase for a period of about 30 months or so; then we'll roll right into the actual competition. But the idea is to have the new booster system available, probably in about the 2019 time frame." (That is two years later than the date he was using three weeks earlier.)

Some experts, however, are question-

COMPARATIVE PAYLOADS

The various launch vehicles, past, present, and proposed, have different capacities for lifting metric tons to LEO:



ing why it is expected to take six to eight years and $18 billion for what is essentially an expansion of existing technology to reach first launch.

Former astronaut and Boeing aerospace executive Robert Springer, for example, echoes Reiley's comment about Apollo, but with a twist related to SLS: "NASA did the Apollo evolution faster—and it was pretty much new technology; even the proposed look at liquid boosters is hardly new." Springer also says NASA's procurement plan for the SLS "seems like a giant leap backward."

Boeing, Liberty, and ULA

Since about September 2011, NASA has announced several new manned space initiatives. Some of them, such as an unfunded SAA with ATK and EADS Astrium to develop the Liberty rocket for the CCDev program and a possible future ISS resupply contract, had previously been rejected or shelved indefinitely.

While most SAAs include NASA funding, the agency offered ATK only personnel—24 full-time and 50 part-time—and the use of NASA facilities, including a Kennedy Space Center launch pad. Following an earlier NASA decision not to fund Liberty in the second CCDev round, it also was the first SAA to include a foreign company.

Liberty incorporates five shuttle SRBs for its first stage and Ariane 5's Vulcain 2 as a second stage. Both are human-rated, but the Vulcain has never been used for a crewed spacecraft launch.

Boeing's CST-100, although currently scheduled to launch atop a human-rated Atlas V, could be a future Liberty user, as both spacecraft and launch vehicle companies work toward full interoperability. Boeing also is keeping options open for future evolutions, including a winged version, that could carry more than the CST-100's seven crewmembers. Even the CST-100, though, is being designed to service not only the ISS, but also other orbital platforms such as Bigelow's inflatable habitat.

An initial unmanned orbital test flight is scheduled for early 2015, with the second flight toward the end of that year, carrying two astronauts to the ISS, where it will dock for a week or so. The CST-100 is designed to make 10 flights before being retired.

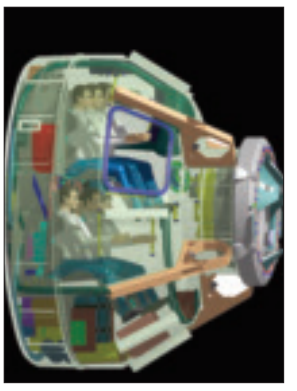
"If we were just servicing NASA with two flights a year, we would have three capsules—two flying and one spare. But if we also are servicing Bigelow or others, we would need to build more of those capsules," says Reiley.

The ATK Liberty rocket is planned for 20 metric tons (first launch 2014).

Sierra Nevada dreams big

While Boeing anticipates a commercial aircraft-style approach—building spacecraft for others to operate—Sierra Nevada is planning to both build and operate its seven-man Dream Chaser. This is a follow-on to the 10-man HL-20 ISS lifeboat that NASA mothballed after seven years of Sierra Nevada development. That design has been significantly updated, according to Mark Sirangelo, head of Sierra Nevada Space Systems, including the ability to carry all crew or a mixture of crew and cargo, or to operate as an unmanned cargo vessel. In addition to a $20-million CCDev1 award from NASA, Sierra Nevada put $30 million of its own money into that year-long effort.

"In April 2011, we were awarded a CCDev2 contract for $80 million, containing nine milestones. We have now completed the first four of those, on time and on budget, and will have completed the fifth by the time this is published. We expect to complete the remaining four on time by next May," he tells *Aerospace America*. "Things are moving quickly, and NASA de-



The pressure vessel of Boeing's CST-100 awaits testing. After an initial umanned orbital test flight scheduled for early 2015; a second flight would carry two astronauts to the ISS later the same year.

Sierra Nevada's plans call for both building and operating its seven-man Dream Chaser.

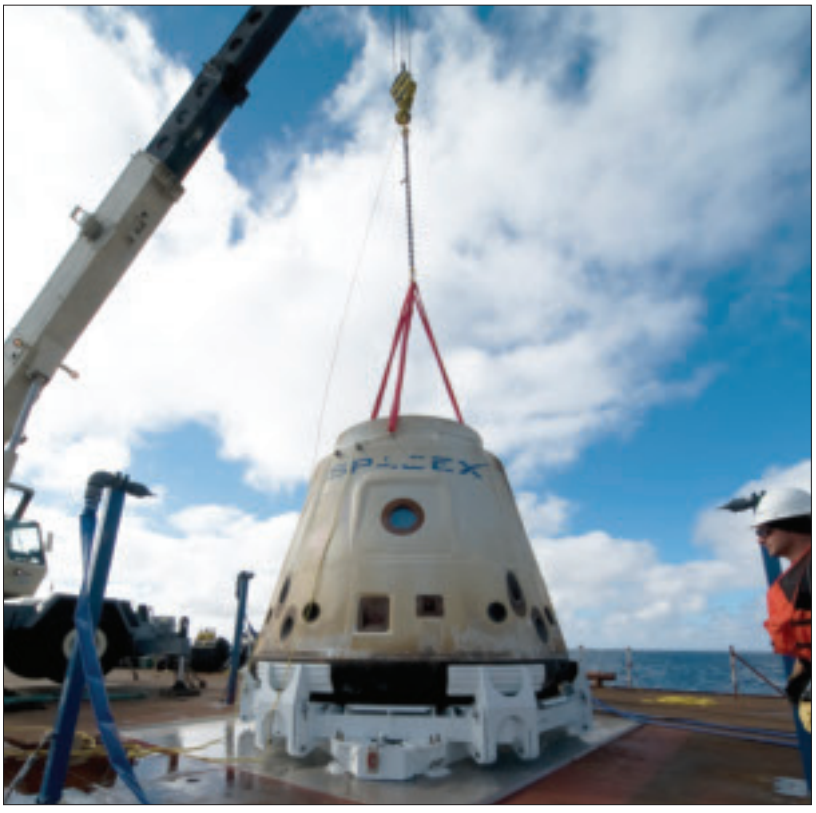
cided to exercise four additional milestones, which was an option in our original plan, for an additional $25 million. Those would extend the program to August 2012."

An initial unmanned approach and landing test is scheduled for the summer of this year, with that same vehicle to be used for the first unmanned orbital test in 2014, but not operational missions.

"The first manned flight would be in early 2015; we believe it will conduct a station operation, but that is NASA's call," says Sirangelo. "We anticipate a multiple vehicle fleet for crew transfer and servicing missions, possibly including some autonomous. We believe LEO access enables a lot more than just space station operations, so we gave the potential markets a lot of thought, with NASA being only one of those.

"Our market is to provide competition to Soyuz and to be the primary supplier, or equal to the Russian program. We think by maintaining and driving those jobs and dollars into the U.S. instead of sending them to Russia, we can better evolve the future of the U.S. space program. We're not in competition with NASA, but with Russia, because we don't think it is good to have only one way into space. And if it is Americans flying, we believe those vehicles should be built in and flown from the U.S., with Soyuz as a backup, not primary."

The SpaceX Dragon capsule is recovered after two full orbits and a sea landing.



SpaceX steps forward

SpaceX's confidence in the future of the commercial launch market was demonstrated in mid-November 2011, when CEO Elon Musk announced the company was looking for a third launch site. SpaceX already launches from Cape Canaveral Air Force Station in Florida and has a second site under development at Vandenberg AFB.

"Our growing launch manifest has led us to look for additional sites. We're considering several states and territories," Musk says. "I envision this site functioning like a commercial Cape Canaveral."

At the time of the announcement, the company already had over 40 contracts for Falcon 9 missions through 2017, with 14 ordered in 2011. More than half are for commercial customers, a number SpaceX expects will grow rapidly in this decade.

While Falcon 9's initial missions involve cargo delivery to the ISS, it also is intended to carry astronauts—up to seven per flight—aboard SpaceX's human-rated, reusable Dragon spacecraft. The company received $1.6 billion from NASA in 2008 for a minimum of 12 Falcon 9/Dragon flights, with an option to nearly double the value of that order. The first cargo missions are scheduled for this year.

A follow-on Falcon Heavy, announced last April and scheduled for first flight this year, would be the most powerful launcher since the Saturn V that carried Apollo astronauts to the Moon. Its addition to U.S. lift capability would significantly increase both cargo and passenger capacity to LEO.

"Each milestone we complete brings the U.S. one step closer to once again hav-

ing domestic human spaceflight capability," according to former astronaut Garrett Reisman, one of the program leads of DragonRider, the manned version of the spacecraft.

Growing urgency

The drive for new U.S. capability increased on August 24, 2011, when a Soyuz rocket carrying cargo to the ISS failed to achieve orbit. All Soyuz flights—cargo and manned—were suspended until an investigation by the Russian space agency, Roscosmos, determined the failure likely was caused by contamination in the rocket's fuel lines or stabilizer valve.

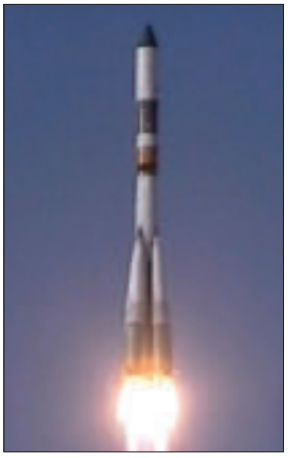
But U.S. efforts also suffered a setback at almost exactly the same time, when a Blue Origin spacecraft was destroyed during a test flight from the company's West Texas spaceport. The lost craft was a suborbital test vehicle, not the CCDev2 vehicle being developed for NASA.

While the *Wall Street Journal* said the failure "shines a spotlight on the risks of commercial space ventures," NASA said it would not affect any of its programs. Agency spokesman David Weaver added that NASA "will rely on multiple providers to ensure success...[and] has confidence in American industry to help our nation maintain its leadership in space and transport U.S. astronauts and their cargo."

Despite the failures of the two systems both Sirangelo and Reiley believe the commercial world is ready to take over Earth-orbital manned spaceflight. And in so doing, it will free NASA (with greater industry involvement than ever) to concentrate on returning to the Moon and beyond.

Those who made the first such voyages hope they are right.

"Public policy must be guided by the recognition that we live in a technology-driven world where progress is rapid and unstoppable. Our choices are to lead, to try to keep up, or to get out of the way. A lead, however earnestly and expensively won, once lost, is nearly impossible to regain," Armstrong concluded in his rare public appearance before Congress. "America cannot maintain a leadership position without human access to space." ⍋



A Russian Progress cargo ship was lost during a failed launch of a Soyuz rocket last August. Both the spacecraft and rocket crashed about five minutes after liftoff.