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AEROSPACE AMERICA

REAL ESTATE IN FREQUENCY SPACE

The ephemeral 'advanced propulsion'

Strategic bombers—relevant again

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President Obama announced in 2010 that NASA's next major destination would be an asteroid, an interim step in long-range plans for travel to Mars. Missing from the administration's roadmap is the Moon, which is getting a second look from planners who now see it as an ideal site for proving hardware and training crews for the coming asteroid missions.

SLS Development begins

The towering Space Launch System (SLS) rocket, under design by NASA to propel U.S. astronauts beyond Earth orbit again, may find the road to President Obama's 2025 asteroid goal paved with Moon dust.

There are two versions of the SLS: the initial Block 1, which will lift 70 metric tons of payload to Earth orbit, and the much larger Block 2, with 130-metric-ton capability. Major contracts for initial development will be awarded to several major contractors this year.

LEAN APPROACH

For the Block 1 version, NASA plans to use lean manufacturing techniques that can equally benefit development of the larger Block 2 rocket. The purpose is to achieve a matrix of cost-effective launch capabilities needed to accomplish the deep-space human exploration goals of this century.

Scientists believe NASA must also plan visits to more than one asteroid to make such a national undertaking worthwhile, although the president called for only one.

Engineers led by John Shannon, former space shuttle program manager, are now working on an SLS Exploration Roadmap. Details emerging from that work indicate that a first mission, to take place as early as 2017, will be an unmanned lunar orbit flight, although the vehicle will be carrying the Orion multipurpose crew vehicle. Reentry from a high apolune will test the Orion heat shield's performance with at least 20,000-mph reentry heating.

Then, in 2018 or 2019, the second SLS mission could be launched carrying astronauts into lunar orbit. The proposed mission would be a unique exploration focusing on the far side of the Moon and the Aitken Basin, an 8-mi.-deep crater exposing eons of lunar geology.

The SLS program has worked out in ways that are having some profound effects. The Obama administration opted for an asteroid mission as a stepping-stone to Mars, shunning the Moon because "we've already been there," as the president said.

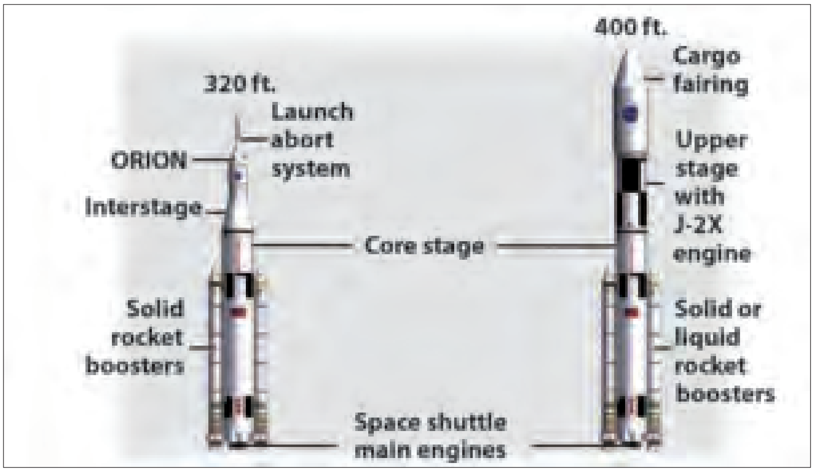
That drew unusually sharp public criticism, led by former astronauts Neil Armstrong and Gene Cernan, former NASA Administrator Mike Griffin, and the agency's first manned flight director, Chris Kraft, who was an architect of the Apollo program and also director of NASA Johnson.

With all that will be required for reaching and studying an asteroid, it has become clear to NASA and its contractors that much remains to be learned—about all the hardware and human interactions with it, including life-support systems. The Moon, they believe, is a good place for learning all this. Training on or near the Moon would mean crews could return to Earth in only three or four days. That would be instead of taking on, at first shot, the six-to-eight-month round trips required for minimum asteroid missions.

It will be several more months before the Exploration Roadmap is complete, and NASA is not commenting on it yet, all of which has left a vacuum for more criticism by Kraft: "The present concept, to initiate [the SLS] large-scale rocket with the plan to land on an asteroid in 2025 and travel to Mars in 2035, is not a realistic goal," Kraft wrote in a December 2011 opinion piece in *Space News*. "The national budget will not

The initial 320-ft-tall Block 1 version of the SLS could fly as early as 2017. It would be 43 ft shorter than the 363-ft Saturn V, and its 70-metric-ton payload capability would be somewhat less than the two-stage version of Saturn V that launched Skylab. Depending on mission needs, the Block 1 could have an interim cryogenic propulsion system as a small upper stage. NASA image.

by Craig Covault
Contributing writer



A comparison between the Block 1 (left) and Block 2 versions shows the scale of the two rockets. The smaller vehicle would fly by 2017; the larger would wait until about 2024. NASA Image.

support the cost and the technology required to accomplish these objectives. The money is simply not available, nor will it be anytime soon."

LUNAR ALTERNATIVES

Given the emerging emphasis on lunar precursor missions, Kraft may get his wish in a serendipitous way. Instead of the SLS, he is calling for "an aggressive multinational effort to pool launcher and spacecraft capabilities" for a push to return to the Moon, this time for exploitation of its resources. This would include use of the lunar far side for optical and radio telescopes that will "search the universe to uncover secrets not viewable by other means," he sayst.

If SLS-2 is launched in 2018 it will mark the 50th anniversary of Apollo 8, when astronauts Frank Borman, Jim Lovell, and Bill Anders were the first humans to fly 240,000 mi. to visit the Moon from lunar orbit and see the entire Earth from afar. In other words, it will have taken the U.S. 50 years to return to what it had already achieved as a human exploration starting point half a century ago.

This time, however, the proposed SLS-2/L2 mission would fly a far different trajectory, splitting the time between the L2 Lagrange point and a course above the lunar far side, where the crew would have more dwell time.

The strawman manifest is important under the Obama administration plan, because of costs and because the missions on the coming roadmap are the only reasons for the SLS to exist. A return to limited lunar landings, theoretically, would also demonstrate on the Moon a range of asteroid-related shelters and space exploration vehicle candidates—a must, some planners believe.

One option proposes that five manned lunar missions log a total of 28 days on the Moon to prove out such hardware before sending a crew to an asteroid. But that plan would have a near impossible ride in the budget process.

PERFORMANCE TRADEOFFS

NASA public affairs personnel often tout how the SLS will be the most powerful rocket ever built. And that will be true for Block 2, but not for the 70-metric-ton payload version to be developed and flown between now and 2021. The Block 1 SLS will have 4 tons less payload capability than the two-stage Saturn V that launched the Skylab space station.

The 70-metric-ton version is based on no second stage or upper stage. But for manned missions it might well use an interim cryogenic propulsion system—essentially a Delta IV Heavy upper stage.

The Saturn V of Apollo and Skylab fame could place 260,000 lb, or 117 metric tons, in orbit in its Apollo three-stage configuration. It could launch about 74 metric tons in its two-stage form. Ironically, during its only launch carrying Skylab, that 'small' Saturn V's first stage developed nearly 9 million lb of thrust during its climbout, more than any other Saturn V flown, NASA documents show. All Saturn Vs had five first-stage Rocketdyne F-1 engines powered by LOX/RP-1 propellants; the 12 flown as three-stage lunar versions, nine of them to the Moon, had LOX/ hydrogen second and third stages.

The 70-metric-ton SLS version will be powered by three space shuttle main engines (SSMEs) in the first-stage core and two five-segment ATK solid rocket boosters. Dominating development until about 2021, it will trailblaze new manufacturing processes and lead testing of most structures, propulsion, and avionics.

The more powerful SLS Block 2 will have five first-stage SSMEs to launch 130-metric-ton payloads. Again, the issue is cost savings.

Comparisons with the 363-ft, 7.5-million-lb-thrust Saturn V are unavoidable: Both versions of the SLS will improve on the Saturn's liftoff thrust, the smaller one by 10% and the larger one by 20%.

For the larger, five-SSME-engine version, NASA plans to use the same tooling and lean manufacturing technology to realize cost savings. The development would be staggered so that they would not be built until closer to the time they will be flown, starting about 2025.

Twin strap-on solid rocket boosters like the new five-segment ATK motors will be used initially. But as 2021 looms, NASA will compete large solid motors against large liquid-propellant strap-ons, likely using LOX/RP-1 propellants. Potential contender strap-on Block 2 engines are the SpaceX Falcon 9, the Energomash/Pratt Atlas V RD-180, and the Orbital Sciences Aerojet Taurus II AJ26 program modification of Russian NK-33s, used in the first stage of the Soviet N-1 Moon rocket.

Powering the vehicle's upper stage will be the Rocketdyne J-2X, an uprated version of the engine that powered the second and third stages of the Saturn V. Conceivably, it could also see service atop the Block 1 SLS with the program's matrix philosophy.

Between 2017 and 2024, Block 1 could launch payloads to the ISS and astronauts to Lagrange points and geosynchronous orbit. One concept yet to be raised significantly is a capability for SLS/ Orion astronauts to service the Webb Space Telescope, set for launch in 2018 to a Lagrange point a million miles from Earth. Many planners believe that after the troubled and expensive Webb development it makes sense to have a servicing capability via the SLS/Orion. A simple grapple fixture is on the Webb for this purpose, and Lockheed Martin has already designed an Orion version equipped with a manipulator arm for such servicing.

BUDGET CONCERNS

Kraft and other experienced space managers remain concerned about whether the coming administrations, and especially Congress, will fund the SLS program adequately. The Obama administration, on being presented with the booster program, had sticker shock for months.

After extensive review with the administration, NASA has settled on an $18-billion budget spread over six years to develop the Block 1 through its first unmanned test flight in 2017. That figure also includes continuing development of the Lockheed Martin/Ball Aerospace Orion, proposed by the company for a 2014 initial Earth orbit test to be launched on a Delta IV Heavy. This will provide the project with $3 billion a year in level funding until the first ascent.

But there is a catch. Only about $1.2 billion out of the $3 billion will be solely for the SLS. The rest will go to Orion, to the continuing search for asteroids that would be suitable mission destinations, and to development of everything else needed to support such missions.

"We think this is a very good funding number for the initial capability and shows we have the core system and ground operations for a 70-metric-ton capability that can be human rated with the Orion multipurpose crew vehicle on the first SLS unmanned flight," explains Bill Gerstenmaier, NASA's associate administrator for space operations.

"The way we have been looking at this is that roughly $3 billion per year [is] for six years of core system design, development, and initial flight with an Orion multipurpose crew vehicle and the ground operations involved.

"We think that is a very good number for the initial capability. It shows that we have a 70-metric-ton capability that flies initially in an uncrewed configuration but is designed to be human rated; and part of the human rating is this first uncrewed flight," Gerstenmaier says.

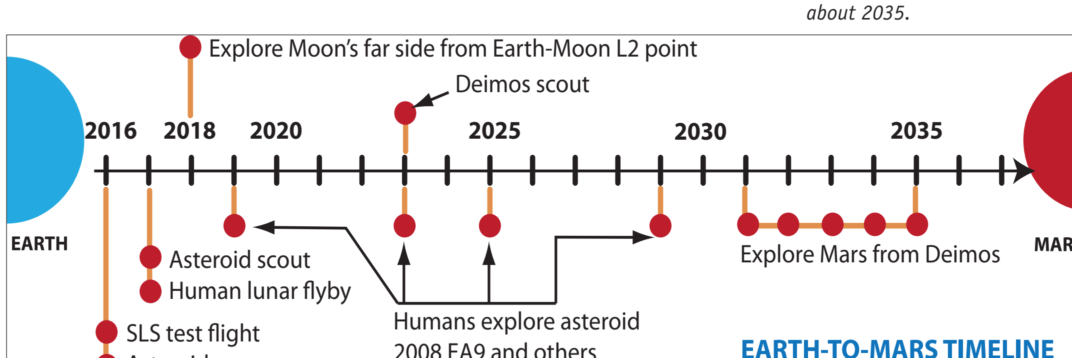
The cost through the mid-2030s for gaining experience beyond the Moon is estimated at about $35 billion.

"So we have that basic capability in place, and then we have to buy production units and other elements to fly, to add additional capability to the rocket," he says.

Dan Dumbacher, NASA deputy associate administrator for exploration systems development, told potential SLS contractors in Huntsville in December that "SLS development is on track, and we are meeting the dates" NASA set for the program.

Mission planning is also a key element in building excitement and support for continued human exploration and for develop-

The straw man manifest proposed by Lockheed Martin, the company that is building the Orion multipurpose crew vehicle, shows a range of SLS missions, including four asteroid landings, before the big push to manned Mars flights about 2035.



The six space shuttle main engines (SSMEs) that powered Endeavour and Atlantis on the final two shuttle missions are readied at KSC for shipment to Pratt & Whitney Rocketdyne. There they will be prepared for use as expendable engines on early SLS flights. NASA image.

ment of the SLS booster, especially if budgetary or political turbulence in Congress becomes a serious threat to the program.

That mission planning includes at the front end a wholesale restructuring of management leadership lines, directorates, and their roles and internal offices at NASA Marshall, Johnson, and Kennedy.

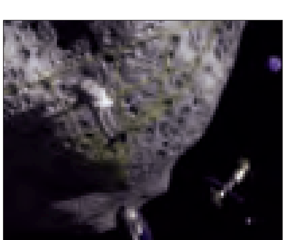
"For example, in Houston, the famed Mission Operations Directorate has outlined a draft memorandum of understanding with the SLS program, ranging from their involvement from a flight operations standpoint, through to ascent operations and participation with the systems requirements review process," says Chris Bergin, writing for the authoritative NASAspaceflight.com website.

In documentation prepared for introducing specifications to an initial group of 60 major contractors, NASA opted for a much broader view, saying "SLS is a national asset for 'multiple stakeholders' and partners." The lunar science, asteroid, and Mars science communities are all examples of 'multiple stakeholders,' as are the Defense Dept., National Reconnaissance Office, and CIA.

EXPLORING THE FAR SIDE

One idea drawing considerable interest is a possible 2018 mission to explore the lunar far side by using an SLS to launch an Orion crew to the L2 Lagrange point. The minimal planetary gravity there would enable a highly instrumented Orion to cycle easily between the lunar far side and L2. This would give crews unprecedented time over the target area, enabling them to conduct studies and control rovers that explore the Moon's south pole Aitkin Basin. Difficult to reach with a cost-effective manned mission, the basin is "among the highest priority activities for solar system science." The mission could retire risk by:

- Demonstrating Orion in deep space with a high-speed Earth reentry.
- Enabling a 30-35-day mission into translunar space as early as 2018.
- Providing a crew with deep space flight distances 15% greater and three times longer in duration than those of Apollo.
- Enabling crews on Orion to practice controlling robotic rovers on the lunar far side before asteroid or Mars missions.
- Demonstrating the use of small orbital habitats like those to be used during longer stays at asteroids or Mars.



This graphic illustrates how a future astronaut could lay a grid structure on an asteroid as both a handhold and workspace guide. Orion, with circular solar arrays attached to a habitat, is far below, while an astronaut vehicle is tethered to the asteroid. NASA image.

A Human Space Exploration Science Community Workshop held in San Diego in November 2011 ended by proposing the L2 lunar far side mission for 2018, to be followed by asteroid missions in 2019, 2024, 2025, and 2029.

The Martian moon Deimos could be explored on a 2031-2035 flight, leading to the initial manned Mars landing in that timeframe.

HARDWARE NEW AND ALSO OLD

To make these future visions a reality, a great deal of SLS hardware development will be needed over the next four years. Both the 70- and 130-metric-ton SLS vehicles will have 27.56-ft-diameter first-stage cores with both liquid hydrogen and liquid oxygen tanks. Saturn had a 33-ft-diameter first stage, but the SLS will still have a larger propellant load because it uses hydrogen rather than RP-1 and has a much taller first stage—176.7 ft for SLS compared to 'only' 138 ft for the Saturn V.

The SLS first-stage diameter was selected to save development money up front at the Kennedy Space Center, says Gerstenmaier. Because the diameter is the same as that of the shuttle's external tank, the same huge processing equipment used for the shuttle during stacking in the Vehicle Assembly Building and transport on a mobile launch platform can also be used with the SLS during stacking and transport to Launch Complex 39B.

"We will initially use three Pratt & Whitney Rocketdyne RS-25D 500,000-lb-thrust space shuttle main engines underneath the core and at some point grow to five first-stage SSME engines," he says. "That will give us a variable thrust capability, which will help for different versions of SLS."

The Michoud Assembly Facility in New Orleans will manufacture the core, as it did the shuttle external tank and the Saturn V first stages before that. Contract selections are pending, however, for SLS tank work.

Pratt & Whitney's continued management and hardware support for the RS-25Ds, or SSMEs, is being retained for the SLS program. Fifteen of these reusable engines are now being readied for SLS flights beyond Earth orbit. There will be a transition to the less expensive expendable version of the SSME, known as the RS-25E, either after the four sets of RS-25Ds have been used or after two additional RS-25D sets have been manufactured. Eventually, the engine driving the core stage will be the expendable, and cheaper, RS-25E.

The MPS (main propulsion system) engine plumbing that snaked through the shuttle's aft compartment has been pulled from each orbiter for use in the SLS program. Discovery's MPS will likely be used on test stands. Atlantis and Endeavour's MPS plumbing will probably be reflown to provide the liquid oxygen and liquid hydrogen propellant to the engines powering SLS-1 and SLS-2 on their initial ascents.

The propellant tanks that will make up the SLS upper stage are being designed simultaneously and with the same 27.6-ft diameter as the first stage so it too can be built with the same tooling to save costs.

Manufacturing of upper stages will be paced more with flights that need them in the 2020 time frame. The upper and core stages will be designed simultaneously to use the same core as well as common electronics and tooling, again to save costs.

"We think the RS-25D and newer E engines will give us a nice flexibility...a rocket that can fly in a variety of thrust ranges, a variable rocket that meets our heavy-lift needs for exploration activity beyond LEO, and that also can satisfy some other potential needs," Gerstenmaier says.

The Pratt & Whitney Rocketdyne J-2X upper-stage engine that was in development for the Constellation program is being retained as the upper-stage engine for the 130-metric-ton SLS.

The initial LOX/hydrogen J-2 was used on the Saturn V. There were six on each Saturn—five on the second stage and one in the third. But the J-2X for SLS is a substantially uprated engine. The J-2 had 232,000 lb of thrust and a specific impulse of 421 sec. The J-2X for the SLS rocket will have 294,000 lb of thrust and a 448-sec I_{sp}.

Some J-2X testing continues at a low level at NASA Stennis. A November 9, 2011, J-2X test lasted 499.97 sec and will likely be the last big test until later in the program, to help smooth out the cost picture.

But a major effort is under way to develop as many common components and suppliers as possible for parts and electronics used on both the J-2X and SSMEs, again to lower costs.

NASA intends to use ATK five-segment solid rocket motors in the first few flights of the SLS, then shift to more advanced solids or liquid propellant strap-on boosters for added safety and performance for the 130-metric-ton SLS.

The planned shift away from the ATK five-segment motor is going to spark one of the most significant rocket propulsion competitions in decades, and both solid and liquid entrants will be accepted. The competition will also advance the work already under way at various contractors and federal labs on new LOX/kerosene engines that could provide tremendous power as strap-on boosters to the SLS hydrogen-fueled core.

The 355-ft-tall mobile launcher built at Kennedy for the Constellation program will fit both SLS versions very well. In late 2011 the launcher was rolled to Launch Complex 39B, where its dominating presence on the coast in front of the VAB was a sign that the U.S. manned space program, despite cancellation of the shuttle, is alive.

However, Chris Kraft remains undeterred. "Come on NASA, wake up!," he writes in *Space News*. "Take the lid off and turn loose the human resources you already have in place. Most of these bright people came to NASA excited about the future, about going back to the Moon to stay and becoming a part of what could be another renaissance in space.

"Building a great big rocket is not a necessary expenditure at this time. In fact, the budget that will be consumed by this big rocket will prevent NASA from any meaningful human exploration for at least the next decade and probably beyond. We don't have to march in place while we wait for the powers that be to cancel it. Let's be innovative; let's wake up the sleeping giant and have at returning to the Moon right now," urges Kraft.

But such a concept has its own major challenges, and given the space program's state following the termination of the shuttle and layoffs in the thousands, the program is ready to move on with development of an SLS. And the rocket may possibly be Moon-bound after all, at least as a stepping stone toward new human discovery and enterprise in deep space.

A highly uprated and modernized version of the Pratt & Whitney Rocketdyne J-2X used originally in the Apollo second and third stages will be the upper-stage engine Block 1 SLS. It will have 294,000 lb thrust, 69,000 lb more than the Apollo J-2. NASA Image.

The ATK five-segment SRB produced 3.6 million lb thrust during more than 2 min of burn time during this test near Promontory, Utah. Two five-segment motors can provide an SLS with 30% more boost than the four-segment versions used on the shuttle. ATK image.