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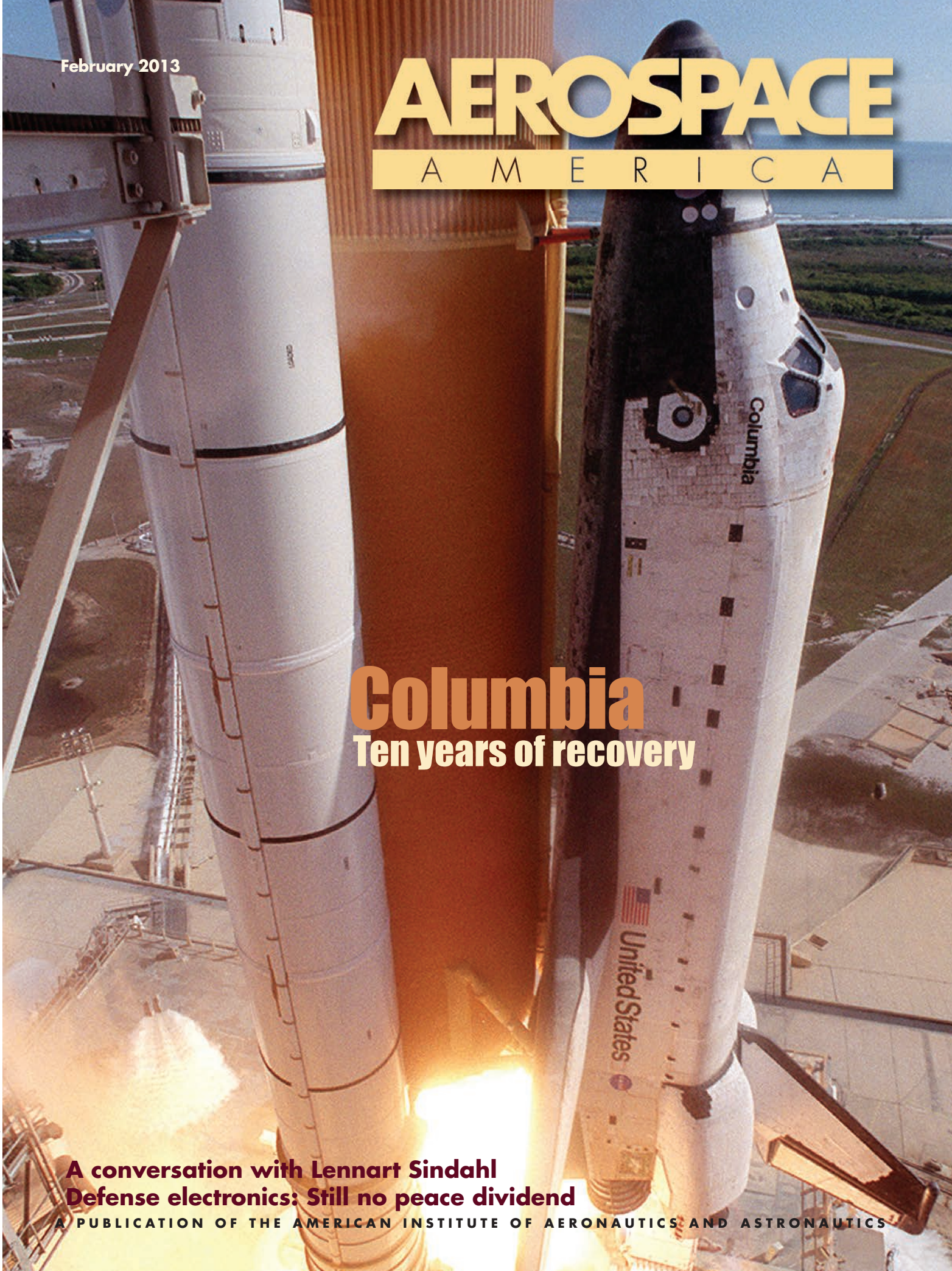
# AEROSPACE AMERICA




## Columbia
### Ten years of recovery

**A conversation with Lennart Sindahl**

**Defense electronics: Still no peace dividend**

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# BEYOND Curiosity

## A MARS SAMPLE RETURN

NASA is weighing a matrix of new options and strategies for enabling the retrieval and return of Martian samples to Earth to determine if there is or ever was life on Mars. A Martian sample return is the top priority of the recent National Research Council (NRC) Planetary Decadal Survey.

Planned under an FY13 new start is a 2020 repeat of the plutonium-powered Curiosity Mars Science Laboratory (MSL) rover chassis and Sky Crane landing system, but with different instruments. Strongly endorsed by the Obama White House and the Office of Management and Budget, it would land on Mars in 2021. It remains to be seen, however, whether the new $1.5-billion mission will pass Congress, especially the fiscally conservative, Republican-controlled House of Representatives.

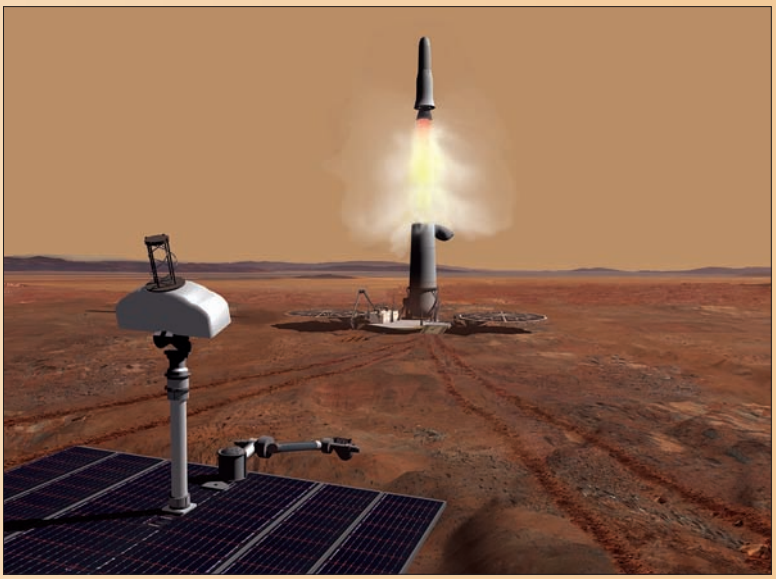
NASA believes the mission could provide a huge science payoff with minimal risk, since Curiosity is proving the MSL design and has retired the risk on virtually all of its components. These include key challenge areas that forced Curiosity into a two-year launch delay and a nearly $1-billion overrun. That cost growth pushed Curiosity's total cost, with launch vehicle, to nearly $2.5 billion.

*A solar-powered version of Curiosity will be defined for a 2020 mission in case a plutonium-powered RTG proves unavailable. Credit: NASA.*

The Mars exploration options for 2020 and beyond were conceived in part by NASA's Mars Program Planning Group (MPPG), composed of leading NASA and university planetary scientists, engineers, and technologists from the human and robotic programs.

The group has recommended that NASA consider post-2020 versions of the Curiosity rover, possibly solar powered, that could carry a rocket to fire samples

**by Craig Covault**
Contributing writer



*Different configurations of Mars ascent vehicles are under consideration for future Mars sample return options. Credit: Wickman Spacecraft & Propulsion.*

***Now that the Curiosity rover has begun its work on the Martian surface, NASA is seeking to focus the U.S. space program on determining if life has ever existed on Mars. Among the agency's highest priorities is returning Martian samples to Earth, an effort likely to involve both manned and robotic missions. NASA's Mars Program Planning Group laid out strategy options for sample return missions that would involve a new 2020 Curiosity-type rover. It could cache samples for pickup later, and carry an instrument to detect existing life.***

into Mars orbit. These would be retrieved by an orbiting robotic Earth return vehicle or an Orion spacecraft, on perhaps the first manned mission to orbit Mars, by the mid 2030s. The MPPG also recommended that upgraded versions of the lower cost rovers Spirit and Opportunity be considered for similar or supporting roles.

Under the MPPG strategy, the first in a series of robotic missions would begin after 2020, with more to follow every two years, so actual samples could be returned robotically as early as the late 2020s along with Mars orbiting return spacecraft.

The programs will be coupled from the start with human manned Mars orbital mission designs, so the human and robotic technologies can cross-pollinate to enable the return of more samples on board manned Orion Mars orbiter missions by the mid-2030s.

### MPPG architecture and goals

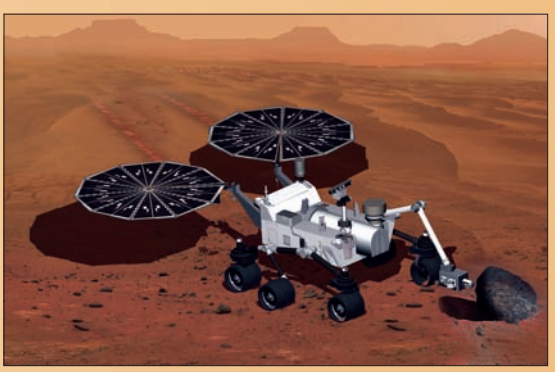
MPPG's new architecture is a milestone in efforts to turn the U.S. space program's primary focus toward a joint science/human exploration plan with an initial goal of determining if life evolved beyond Earth in the solar system.

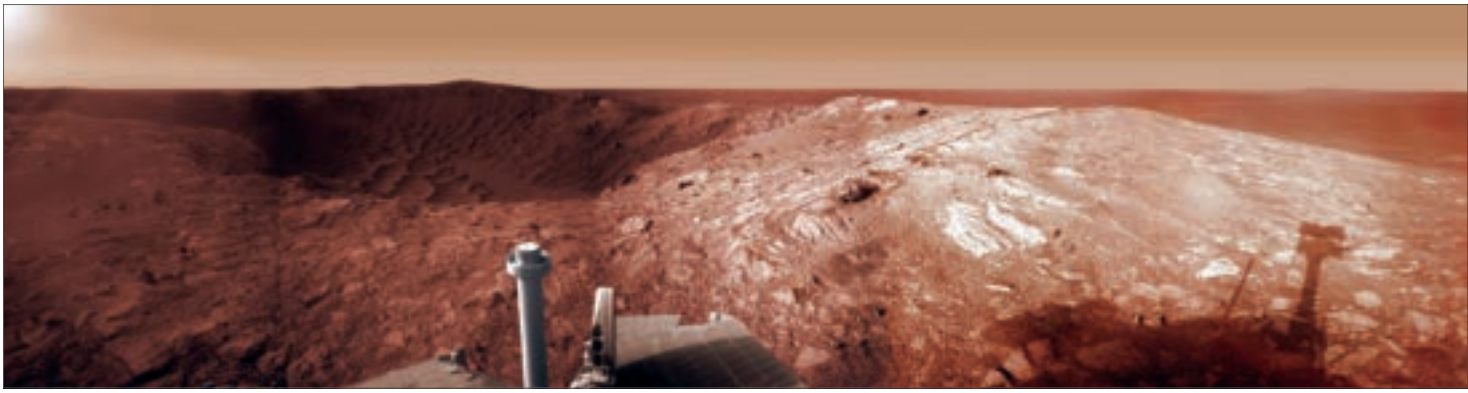
During 2012 the MPPG conducted an intensive assessment of what Mars missions the U.S. should pursue now that Curiosity is operational, and in view of the agency's limited budgets.

A key difference between this and previous mission studies is that this time "there was an imperative for strategic collaboration" between the human exploration, robotic, science, and technology divisions at NASA from the start, explains Orlando Figueroa, chairman of the MPPG. He previously served NASA as director of its overall Mars Exploration Program, as Solar System Division director, and as deputy director of NASA Goddard.

"The MPPG has given us a series of specific options and strategies about how NASA can develop a forward-looking and exciting

*The Mars Program Planning Group raised the option of placing a Mars Ascent Vehicle launcher on a Curiosity-type chassis to fire samples into Martian orbit for pickup by a robotic orbiter or manned Orion. Credit: NASA.*





*Opportunity in its ninth year of roving Mars takes a self portrait as it circles rugged Santa Maria crater enroute to clay deposits that must have formed in water similar to fresh water on Earth. Such sites, more hospitable to early life, may be good sample return targets. Credit: NASA/JPL/Marco Di Lorenzo/www.KenKremer.com.*

Mars exploration plan," says former astronaut John Grunsfeld, NASA associate administrator for space science. Grunsfeld has flown on five shuttle missions, three of them to service the Hubble Space Telescope. "We think that Orlando Figueroa and his team have queued up a great series of options and rationales to look at linking the science and human programs," he says.

The MPPG's purpose was to develop the foundations for a post-Curiosity program architecture for robotic exploration of Mars, consistent with President Obama's challenge to send humans to Mars in the 2030s. At the same time, its options had to remain true to the highest priority scientific goal of the 2011 NRC Decadal Survey for Planetary Science: A Mars sample return.

"That all makes sense," says Grunsfeld, "Because sending a robotic mission to Mars and returning a sample to Earth looks a lot like sending a crew to Mars and returning them safely to Earth."

The MPPG reached out to Mars-related science, technology, and engineering communities, both within and outside NASA, to develop the new mission options and architecture alternatives for consideration by senior agency officials.

Under the MPPG options, such a mission would be accomplished by either robotic or human means, or a combination of the two, depending on which of the proposed strategies are pursued.

One key issue was whether the current Mars orbiter relay communications infrastructure would need to be upgraded starting with the 2018 launch opportunity, or whether the high payload mass possible with the unusually favorable 2020 launch window argued more for a rover.

During the last quarter of 2012, NASA studied the issue and determined that with minimal spending, the agency could develop more efficient operations with the Mars Reconnaissance Orbiter (MRO), increasing its lifetime by at least two years to 2020 or beyond.

That option—along with the planned 2013 U.S. MAVEN (Mars atmosphere and volatile evolution) orbiter for relay and atmospheric science, and the 2016 European/Russian Trace Gas Orbiter (which will also be a relay)—could support surface relay operations well into the 2020s.

That caused NASA to bypass the 2018 orbiter window for a 2020 Curiosity-type rover. "Besides, the surface is where the action is," Grunsfeld says.

Figueroa told a gathering at the Lunar and Planetary Institute in Houston that one of the goals of the MPPG is for NASA not to skip more than one Mars launch opportunity in a row (meaning no more than four years between missions).

NASA formed the MPPG because of the need to replan the Mars exploration strategy in light of three baseline factors:

- Funding cuts, including a 38.5% cut to NASA's original $361-million FY13 budget estimate for Mars exploration, and an accompanying White House directive for future NASA spending reductions for Mars. The MPPG was tasked to "define technolo-

***Curiosity: Paving the way for human exploration***

*There is already active cooperation between the human and robotic exploration science teams operating Curiosity, which carries a radiation assessment detector, sent to Mars specifically to prepare for future human exploration.*

*Curiosity also carries a Russian space agency pulsing neutron generator sensitive enough to detect water content as low as one-tenth of 1% and to resolve layers of water and ice several feet below the surface. This type of instrument will also be a vital tool for future human explorers.*

*On its heat shield, Curiosity carried the NASA Langley MEDLI (MSL entry, descent, and landing instrument), an array of 14 temperature and pressure sensors for mapping critical reentry data that can later be applied to much larger heat shields used for manned landers.*

gies and options that could provide notional Mars exploration pathways into the 2030s," Figueroa said.

• President Obama challenged NASA to develop the Space Launch System heavy-lift booster and Orion spacecraft capabilities for astronauts to orbit Mars and return safely to Earth by the mid-2030s. This goal drove the MPPG to come up with options that involved collaboration between the human and robotic space communities "because the country is on a course to have human capabilities at Mars by the 2030s," said Figueroa.

• The NRC's 2011 Planetary Science Decadal Survey recommendation for Mars exploration singled out a sample return as the highest planetary priority of the 2020s.

The MPPG was tasked with defining options and strategies that are responsive to the primary scientific goals of the NRC Decadal Survey. That study chose a Mars sample return as its top science objective because, "crucially, the Martian surface preserves a record of earliest solar system history on a planet with conditions that may have been similar to those on Earth when life emerged," says the survey.

"It is now possible to select a site on Mars from which to collect samples that will address the question of whether the planet was ever an abode of life," the council reports.

The Curiosity rover is assessing the habitability of a specific area—the central layered hills of Gale Grater—for evidence of the area's suitability, nearly 3 billion years ago, as a past habitat for life.

The first big casualty of the tight Mars budgeting was NASA's role in what would have been a joint U.S./European ExoMars program involving a specialized astrobiology rover to assess samples on the surface for evidence of past life or prebiotic chemistry. In place of the U.S., ESA is now teaming with the Russian space agency.

## Building on past efforts

In planning a sample return strategy, Figueroa's team drew lessons from the initial Mars replanning effort led in 2000 by G. Scott Hubbard, then deputy director for research at NASA Ames.

That replanning followed the 1992 loss of the Mars Observer orbiter and the 1999 loss of four NASA Mars spacecraft: the South Polar Lander, its two attached Deep Space 2 hard landers, and the Mars Climate Orbiter—losses all due to human error.

In the Hubbard replanning effort, the science theme 'follow the water' and its related overarching program strategy were reflected in a sequence of interconnected strategic missions. The results were the 2001 Mars Odyssey orbiter and the 2005 MRO, whose water-related goals involved use of advanced sensors and imaging of the landing site; the strategy also included critical relay capability for the landers.

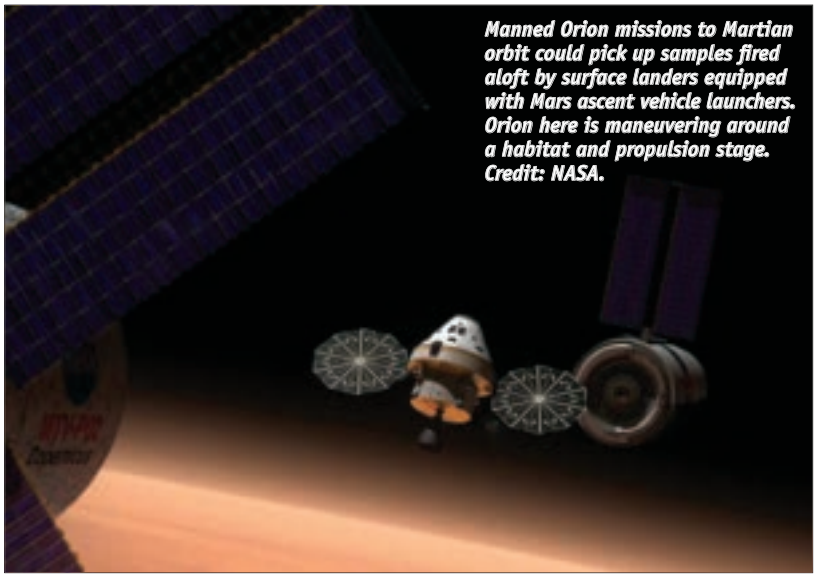
The landers and rovers that came out of Hubbard's 2000 plan were the water-related geology rovers Spirit and Opportunity; the separately planned 2008 Phoenix north polar lander, which found perchlorates and icy brine; and Curiosity.

Interspersed among the strategic flights are the $500-million-class MAVEN Mars orbiter, set for launch later this year to gather atmospheric data, and the 2016 InSight, a Phoenix-type lander. InSight carries a French seismometer and German heat flow instruments that will be lifted onto the surface by the lander's manipulator arm.

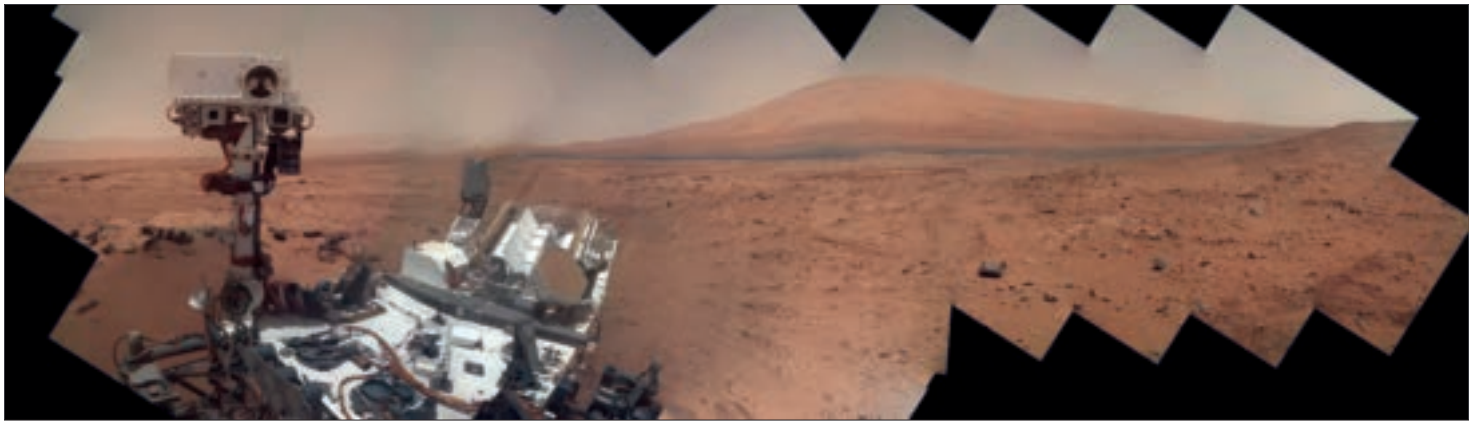
## Choosing a path

Based on weeks of input, the team recommends that NASA look at two different 'pathways,' either of which would fulfill sample return objectives, one sooner than the other. The options are:

**Pathway-A**: This would be based on a near-term search for signs of *past life* using samples collected from a single Martian area determined with existing data to have astrobiological significance. Those samples would be returned to Earth as soon as possible. The group says its studies show that two types of mission strategies are viable:



*Manned Orion missions to Martian orbit could pick up samples fired aloft by surface landers equipped with Mars ascent vehicle launchers. Orion here is maneuvering around a habitat and propulsion stage. Credit: NASA.*



*Curiosity and its Mt. Sharp destination were captured 200 million mi. from Earth by a camera on the 7.5 ft. robotic arm. NASA will build a duplicate rover for launch in 2020, possibly with sample collection and life detection instrumentation. Credit: NASA/JPL/Marco Di Lorenzo/ www.KenKremer.com.*

•Pathway-A1, where the sample return objective would be spread across three or four Mars missions employing "multiple focused spacecraft."

•Pathway-A2, which would combine functions into one or two larger multifunction spacecraft, potentially lowering costs.

The MPPG says the strategies match "the highest priority 'large mission' recommended by the NRC Decadal Survey" and that the "MPPG mission concepts have reduced costs" compared with NRC Decadal Survey concepts for this case.

**Pathway-B**: This strategy would search for signs of *past life* based on analysis by sensors on the surface at multiple sites. Using in-situ information (ideally from three sites), the science community would select optimal samples for return to Earth, according to the group.

Examining multiple sites would dramatically improve the probability of identifying biologically relevant samples.

The rocks and soil would be returned from sites where in-situ measurements show the rock units were formed under conditions most favorable for habitability and for the preservation of biosignature—the kinds of sites Curiosity is seeking.

The search for existing life in 'modern habitats' would also be done, especially since more evidence of liquid water on or near the surface has come to light since the completion of the Decadal Survey, which focused on past life.

But the MPPG's reticence to fly biological or other sensors for analysis of *existing life* was disappointing to initial reviewers, even to Grunsfeld, to some extent.

Grunsfeld says this does not mean the MPPG team is interested only in past Mars life, as opposed to both current and previous life. He stresses that, actually, "the team said something different. It said members in the science community would find it very interesting to [put] a life finder chip on a rover to find existing water or life.

"What we are doing is putting together a framework" for future missions, he says. "I pressed the team about it, but it did not fit into their plan for an architecture."

But at the announcement of the 2020 rover plan, Grunsfeld said that the Science Definition Team planning the rover's science objectives would be encouraged up front to look favorably on the potential for life detection, and on carrying a sample selection and cache capability.

## Expanding alternatives

A key juncture for the MPPG effort was a large meeting of the robotic science, technology, and human spaceflight communities at the Lunar and Planetary Institute last June near NASA Johnson. The sessions ex-

***ROVER OPTIONS***

*The four rover options differ in cost and in several other areas:*

*•Rover-A, costing up to $1.38 billion, would be a clone of Spirit and Opportunity, but with new avionics and an added sampling capability. It could be launched to Mars on a SpaceX Falcon 9, but fitting it in the original MER heat shield will be a challenge. Spirit was operational for more than six years before dying in March 2010, stuck in a sand trap. On January 24, Opportunity's ground controllers celebrated its ninth year of roving Mars.*

*•Rover-B is another MER-derived design that could be launched on a Falcon 9. It would be a bit more expensive, up to $1.4 billion, because its slightly larger volume would require "new airbag and touchdown system development," says the MPPG final report.*

*•Rover-C, for sampling would be based on the MSL design, with large aft-mounted circular solar arrays instead of an RTG. The rover itself could be built for about $1.7 billion, but launching it would require an Atlas V.*

*A 2020 or later RTG-powered rover would actually be cheaper, because of all of the design and testing for an RTG electrical power and thermal distribution system, to keep key areas of the vehicle warm using residual heat generated by the plutonium system. That design must be different for an MSL-type solar-powered rover.*

*•The car-sized Rover D would be the most ambitious of the new upgraded designs, because on its top deck it would carry a Mars ascent vehicle rocket measuring about 6x2 ft. Traveling wherever the rover traveled, the rocket would fire collected samples into Martian orbit, where they would be retrieved and then maneuvered back to Earth. Samples would be loaded robotically into the ascent vehicle's payload container.*

*Its costs are still to be determined, but this concept, combined with an Orion crew retrieval in Martian orbit in the mid 2030s, is gaining popularity in NASA.*

panded the trade space for alternative concepts on accessing the surface sampling and analysis instrumentation and the capabilities of the surface systems.

According to the MPPG report, multiple dual-use human/robotic technologies were cited, including optical communications, deep space atomic clocks, solar electric propulsion, and large deployable supersonic decelerators that could be used for "early" sample return missions by the mid-2020s.

Selected ideas served as a catalyst for the MPPG to charter subteams to explore lower cost approaches to sample return, including hardware such as a solar electric propulsion-propelled orbiter that would rendezvous with samples launched from the surface, than return to the vicinity of Earth, where an Orion astronaut crew beyond Earth orbit would retrieve them for return to a ground-based laboratory or the ISS. This could be done in the late 2020s using capabilities such as:

- A "mini Mars ascent vehicle" rocket design that could be landed with airbags, then robotically loaded with several pounds of samples that would be fired off the surface to Martian orbit for pickup.
- An Orion human-crew-based sample return from Martian orbit in the mid-2030s.
- Mini-rovers that could be deployed two or three at a time using a Mars Exploration Rover (MER) airbag system.
- Small extreme-terrain vehicles that could reach difficult Martian areas for sample pickup.

## Launch options

The MPPG looked at accomplishing a Mars sample return with one, two, or three launches. The first, a single SLS mission concept for 2024, found no real support, but sample return operations involving two and three launches will remain under active study and involve:

- Three launches: The architecture proposed to the Decadal Survey by its separate analysis teams proposed a three-launch mission with the first flight carrying a single Curiosity/Sky Crane-type 'sampling rover.' The second would carry a moderately sized fixed lander with a Mars ascent vehicle launcher and a small 'fetch' rover that could retrieve rock samples from the sampling rover. The third launch would carry a sample return orbiter.
- Two launches: In this more limited scenario, a Curiosity-type sampling rover and its Sky Crane lander would be launched first. A second mission would carry a lander with the ascent vehicle, a small fetch rover, and a small Earth return orbiter propelled by solar electric power.

*Opportunity, here undergoing prelaunch tests, is now into its ninth year of successful Martian surface operations. The MPPG said upgraded versions of the MERs could be useful to find and cache samples, then transfer them to a more expensive lander with an ascent vehicle launcher. Credit: NASA/JPL.*

## Rover choices

Finally, four rover options were defined by the MPPG as capable of carrying out various Mars sample return missions. Two are upgraded MERs like Spirit and Opportunity, with airbag landing systems; the other two are derived from the MSL Curiosity design and require a Sky Crane landing system. All would have guided entry capability for pinpoint landings like the one performed by Curiosity. However, the two Curiosity-derived rovers could possibly be powered by circular solar arrays instead of a radioisotope thermoelectric generator (RTG).

The 2020 MSL-type rover is now aimed at using Curiosity's backup plutonium RTG system and possibly even some of its remaining plutonium. The DOE is working to develop additional nuclear power sources for the follow-up MSL-type rovers. But NASA is also studying more costly solar array systems in case a nuclear RTG for the 2020 spacecraft should be unavailable.

Going with upgraded MER and MSL designs would keep the highly experienced JPL/Lockheed Martin and other Mars contractor teams intact.

Grunsfeld says that before rovers start to cache samples, he wants to make sure they have the right tools for selecting which samples to cache. These could include life detection instruments or new drills to obtain rock and soil core sections, something that Curiosity's rock drill cannot do.