By Leonard David

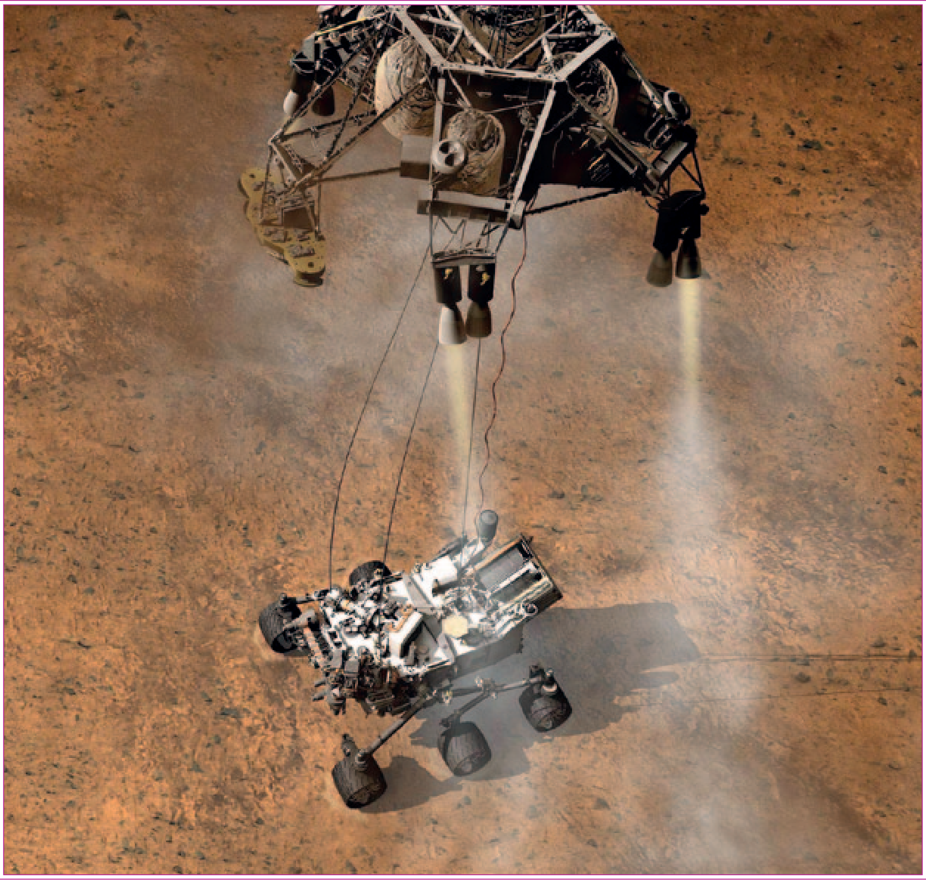
Landing a Nuclear Powered Rover

The next grand adventure in exploring Mars is set to begin in early August. NASA's now en route Mars Science Laboratory (MSL) mission is on track to dispatch onto the Martian landscape the 900 kg nuclear-powered Curiosity rover.

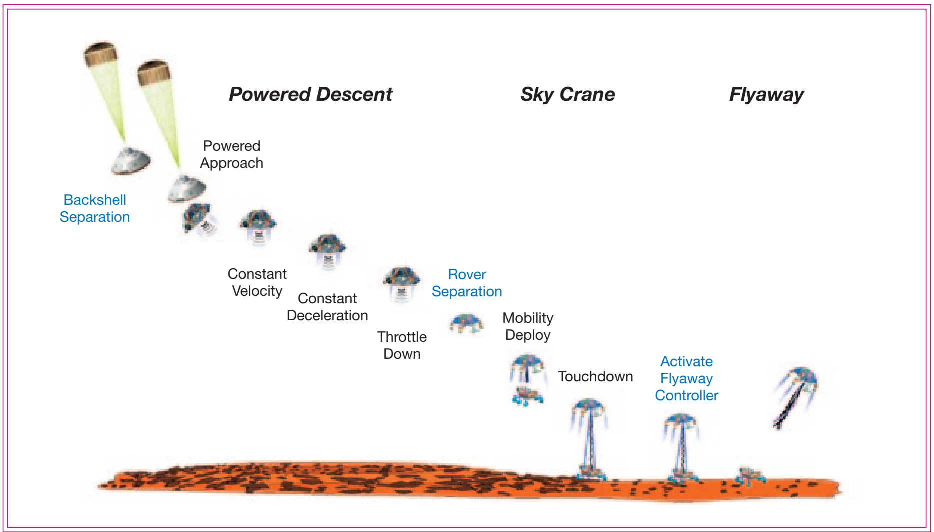
The MSL rover is loaded with a suite of instruments built to seek answers to questions of geochemistry and biological processes, and measure aspects of surface and sub-surface materials potentially linked with ancient life and climate. The MSL could also pave the way for a future sample return mission.

Curiosity's meeting with Mars is set for the evening of August 5, Pacific Daylight Time (Aug. 6, Universal Time and Eastern Daylight Time) to begin a two-year mission of reconnoitering the red planet. But getting MSL's Curiosity rover down safe and sound is no easy feat.

Plunging through the thin atmosphere of Mars, MSL will perform a guided entry. The spacecraft will be controlled by small rockets during descent through the atmosphere towards the surface. The craft will then be slowed by a large parachute. In powered descent mode, rockets will control the spacecraft's descent until the rover separates from its final delivery system - the novel, never flown before, Sky Crane. Like a large crane on Earth,



Pictorial description of the touchdown, after pyrotechnic cutters have severed the connections between the rover and the spacecraft's descent stage, which will fly away and crash at a safe distance. - Credits: NASA/JPL-Caltech



The MSL descent will be guided by small rockets, and then slowed by a large parachute. As the spacecraft loses speed, rockets will control the deployment of the Sky Crane, which will lower the rover to a soft landing. - Credits: NASA/JPL-Caltech

> "Getting MSL's Curiosity rover down safe and sound is no easy feat"

the Sky Crane system will lower the rover via a bridle system to a "soft landing" – wheels down – on the terrain of Mars. If all goes well, Curiosity will land at about 0.75 meters per second.

Sensing touchdown, the landed craft will cut the connecting cords and the Sky Crane will fly out of the area, destined to crash-land away from the rover's position.

Rover Power

Curiosity is powered by a multi-mission radioisotope thermoelectric generator (MMRTG) supplied by the U.S. Department of Energy. The MMRTG makes use of a heat source that contains 4.8 kilograms of plutonium-238 dioxide – a non-weapons-grade form of the radioisotope – and a set of solid-state thermocouples that convert the plutonium's heat energy to electricity.

Heat emitted by the MMRTG will also be circulated throughout the rover system to keep instruments, computers, mechanical devices, and communications systems within their operating temperature ranges.

The electrical output from the multi-mission radioisotope thermoelectric generator charges two lithium ion rechargeable batteries. This enables the power subsystem to meet peak power demands of rover activities when the demand temporarily exceeds the generator's steady output level. The batteries, each with a capacity of about 42 amp-hours, are expected to go through multiple charge-discharge cycles per Martian day.

Wary of Water-Ice

The MSL mission is complying with a requirement to avoid going to any site on Mars known to have water or water-ice within a meter of the surface. This is a precaution against any landing-day accident that could introduce hardware not fully sterilized by pre-launch dry heat treatment. The concern centered on heat from the mission's radioisotope thermoelectric generator meeting a Martian water source, a situation that could provide conditions favorable for microbes from Earth to grow on Mars.

Curiosity is targeted to land within a flat section of Gale Crater – a feature that includes a 5 kilometer high mountain of layered materials in its middle.

Scientists suggest that flowing water appears to have carved channels in both the mound and the crater wall. To get to the mound, the nuclear powered rover will work its way upward, layer by layer of the huge mound. Along the way, the wheeled robot can survey how the layers formed and the environments in which they were created.

According to Catharine Conley, NASA's Planetary Protection Officer, the Gale Crater landing site was preferred by those concerned with planetary protection.

Curiosity will land near the foot of a mountain – dubbed Mount Sharp – inside the 154 kilometer wide Gale Crater. - Credits: Art Kees Veenenbos, Data Mola Science Team (NASA)

> "In early MSL planning, scientists and engineers did evaluate unfavorable landing scenarios"

"All available research suggests that ice is not present within reach of the surface," Conley told Space Safety Magazine. "Even in the unfortunate event of an off-nominal landing, the very dry conditions at Gale Crater mean that the small number of Earth microbes carried on MSL wouldn't be able to grow."

NASA Credo

Planetary protection is the term given to the practice of shielding solar system bodies – planets, moons, comets, and asteroids – from contamination by Earth life. This action is also designed to protect Earth from possible life forms that may be returned from other solar system bodies.

According to NASA: "Planetary protection is essential for several important reasons: to preserve our ability to study other worlds as they exist in their natural states; to avoid contamination that would obscure our ability to find life elsewhere — if it exists; and to ensure that we take prudent precautions to protect Earth's biosphere in case it does."

The credo adopted by NASA's Office of Planetary Protection is "all of the planets, all of the time."

Clean Machine

The assignment of categories for specific missions is made by the NASA Planetary Protection Officer based on multidisciplinary scientific advice.

Given the selected landing site and as a result of changes in hardware configuration, Conley said that MSL was re-evaluated several months before launch and the mission was given a Category IVa classification.

Why the re-evaluation and classification change? They were driven by a set of drill bits carried by the Curiosity rover. Project developers made an internal decision not to send the equipment through a final ultra-cleanliness step. That marked a deviation from the MSL planetary protection plans.

That judgment, however, didn't reach Conley until very late in the game.

Conley said that the initial plan called for placing all three of the drill bits inside a sterile box. Then, after Curiosity reached Mars, the box would be opened for access to the sterilized bits via the rover's robot arm - extracted one by one and fit onto a drill head as the mission progressed. But in readying the rover for departure to Mars, the box was opened, with one drill bit affixed to the drill head, Conley said. Also, all of the bits were ▶▶

tested pre-launch to assess their level of organic contamination. While done within a very clean environment, that work strayed from earlier agreed-to protocols, she said.

Despite this procedural breakdown, Conley said the Curiosity assembly team and technicians did an excellent job of keeping Curiosity cleaner than any robot that NASA's sent to Mars since the Viking landers in the 1970s.

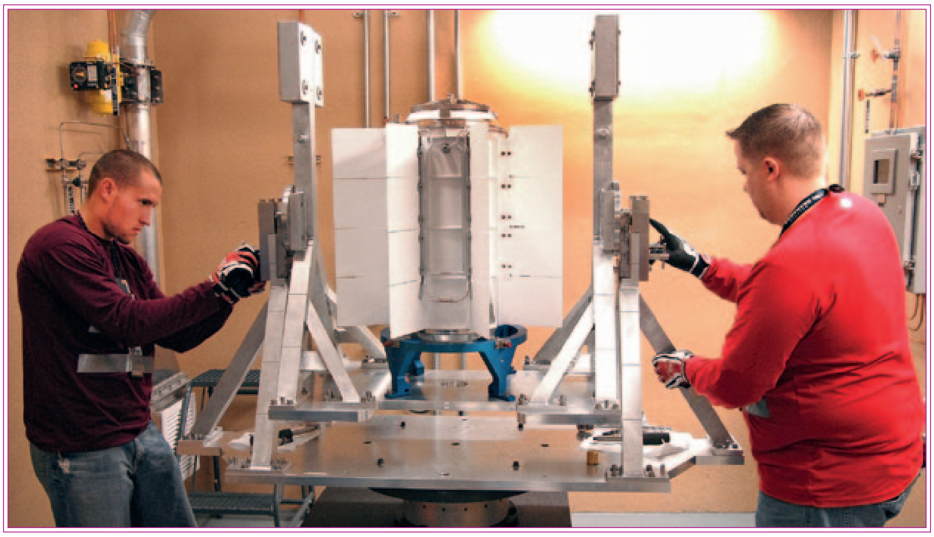
A Category IV includes certain types of missions – typically an entry probe, lander or rover – to a target body of chemical evolution or origin-of-life interest, or for which scientific opinion holds that the mission would present a significant chance of contamination which could jeopardize future biological exploration.

Requirements include rather detailed documentation, bioassays to enumerate the microbial burden, an analysis of contamination probability, an inventory of the bulk constituent organics, and an increased number of implementing procedures.

The latter may include trajectory biasing of the spacecraft, the use of clean rooms (Class 100,000 or better) during spacecraft assembly and testing, bioload reduction, possible partial sterilization of the hardware having direct contact with the target body, a bioshield for that hardware, and, in rare cases, a complete sterilization of the entire spacecraft.

Subdivisions of Category IV – designated IVa, IVb, or IVc – address lander and rover missions to Mars, with or without life detection experiments, and missions landing or accessing regions on Mars which are of particularly high biological interest.

“COSPAR: We don't anticipate any RTG-related issues, with or without a soft landing”



The Mars Science Laboratory's radioisotope power system was fueled and tested at the U.S. Department of Energy's Idaho National Laboratory. - Credits: Idaho National Laboratory

Clean Up Our Act

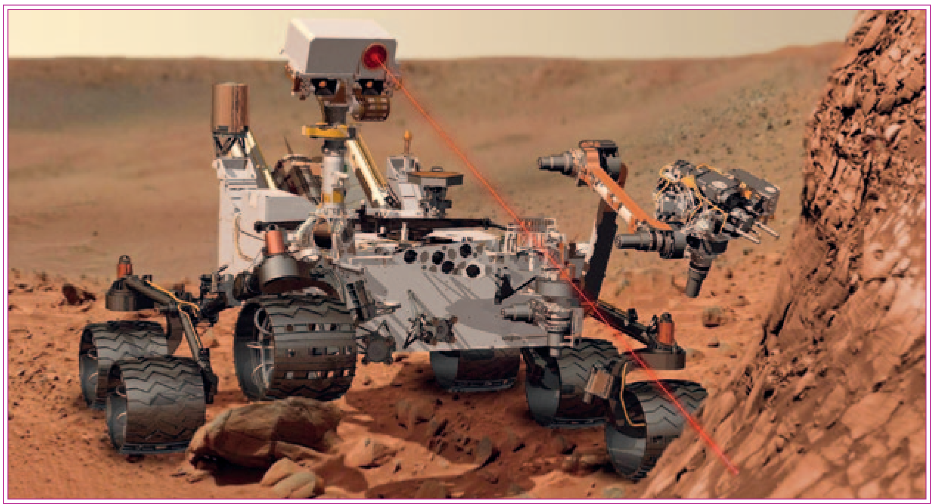
In early MSL planning, scientists and engineers did evaluate unfavorable landing scenarios, said John Rummel, a professor of biology at East Carolina University, Chair of the COSPAR Panel on Planetary Protection and former Planetary Protection Officer for NASA.

Such a situation could result from a failure of the Sky Crane, leaving the RTG and not-fully-sterile spacecraft to land together on top of ice - and under dirt within a meter or so of the surface. That scenario can yield a warm little pool where microbes can grow, Rummel said.

“So MSL was constrained not to go to a place where ice is detectable under the surface. The Gale Crater landing site met that requirement,” Rummel told Space Safety Magazine, “so we don't anticipate any RTG-related issues at Gale, with or without a soft landing.”

Rummel added that, for the future, if one wants to land at a place with ice, or poke into places with gullies/seeps and find out what that is all about…then the whole spacecraft will have to be sterilized.

Accordingly, it is likely that the RTG will have to be ‘sterilizable’ – as were the Viking RTGs sent to Mars in the 1970s – and that poses a problem for both the ASRG (mechanical systems) and the MMRTG (materials choices) currently available, Rummel added. “Late, aseptic assembly of the RTG into the sterile spacecraft should be the answer to that problem,” he said, “but clearly if we want to go to the best places we know about on Mars, then we need to be able to clean up our act and get there with a usable power supply.”



Artist's conception of NASA's Curiosity rover, as it uses its Chemistry and Camera (ChemCam) instrument to investigate the composition of a rock surface. - Credits: NASA/JPL-Caltech

Leonard David is an American space journalist and a senior research associate with Colorado-based Secure World Foundation. His articles can be read at SPACE.com, AIAA Aerospace America, and in the Space Safety Magazine.