

VICTO

Opportunity to unravel ancient mysteries as other Mars missions face new escapades

CRAIG COVAULT/KENNEDY SPACE CENTER

The Mars Rover Opportunity is beginning complex and dangerous science operations 242 million mi. from Earth at the massive Victoria crater, the most spectacular and potentially significant target of the entire \$800-million twin-rover Mars surface exploration mission.

"We are frankly feeling a little overwhelmed by what we see so far," says Steve Squyres, rover principal investigator on his Cornell University web site.

Opportunity has been driving at the speed of a tortoise for 5.7 mi. and almost three years to reach the 2,500-ft.-dia., 230-ft.-deep crater. Every inch has been a marvel of autonomous robotics and dedicated command and control by Pasadena, Calif.'s Jet Propulsion Laboratory (JPL), as well as 24/7 plan-

ning by a dispersed international science battle staff led by Squyres and Deputy Principal Investigator Ray Arvidson at Washington University in St. Louis. The teams have been preparing for almost two years for their arrival at Victoria.

From a position about 8 ft. from the rim, one can see 0.5 mi. to the far side of the crater, framed by rocky cliffs. The crater's rim comprises alternating promontories, recessed alcoves and rocky points towering 230 ft. above the bottom of the crater. Martian wind-carved sand dunes cover the crater floor.

For this Navcam panorama above, colorized by outside analysts, Opportunity was about 8 ft. from the lip at Duck Bay alcove (see image right).

The rover has made dozens of sampling stops over the last 21 months. At the mission's outset, no one dreamed that Opportunity could reach Victoria, imaged well south of the landing site by the Mars Global Surveyor orbiter.

"We're so proud of Opportunity, the rover that 'takes a lickin' but keeps on tickin,'" says Cindy Oda, a Mars rover mission manager at JPL. "It continues to overcome all challenges despite its aging parts and difficult terrain. We are

looking forward to exciting new discoveries as Opportunity begins its new adventures exploring Victoria crater."

The trip began in earnest after several months spent in Endurance crater in mid-2004. The team could hardly believe Opportunity survived that, let alone reach Victoria, five times bigger than Endurance. Victoria was carved out much deeper by a large meteorite perhaps more than a billion years ago. Researchers believe Victoria has the potential for revealing once deeply buried rock layers as evidence of possibly abundant, perhaps life-sustaining water. Layers 200-ft. deep may be exposed, compared to 25-ft. layers at Endurance.

Victoria is 40 times larger than Eagle crater, where Opportunity made initial stunning discoveries in only 1.5-ft. layers about the permanence of Martian water, which is a key to the formation of life, if it ever existed, on Mars.

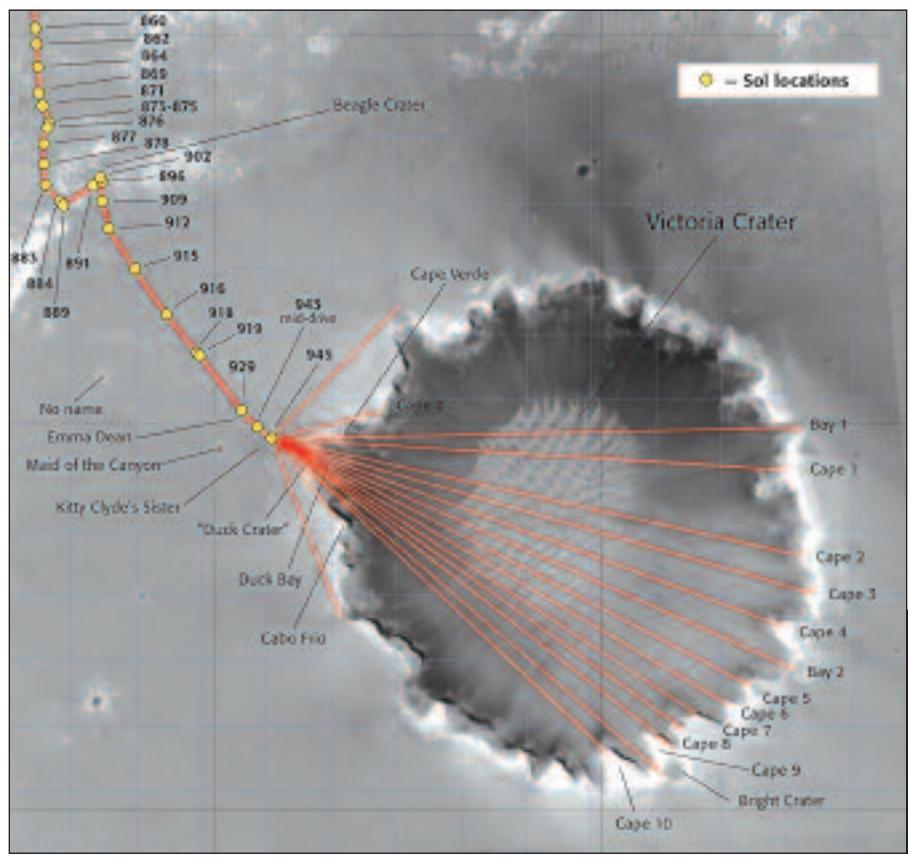
Victoria's secrets are buried in the rock layers; the more layers, the more detailed the story. "This is a geologist's dream come true," says Squyres. "Those layers of rock, if we can get to them, will tell us new stories about the environmental conditions long ago. We especially





Rover Opportunity Navcam panorama, colorized by an outside team, reveals 2,500-ft.-wide, 230-ft.-deep Victoria crater. Geologic layers will reveal the history of water here.

OPPORTUNITY'S SECRET



NSA/JPL-CALTECH/NAISS want to learn whether the wet era that we found recorded in the rocks closer to the landing site extended farther back in time. The way to find that out is to go deeper, and Victoria may let us do that.”

Opportunity’s arrival at Victoria kicks off a very busy period of Mars exploration this month involving three U.S. and one European orbiter, along with preparations for another U.S. lander. The main events involve:

- The Mars Reconnaissance Orbiter (MRO): The most powerful planetary imaging spacecraft ever flown is this week in the midst of its initial high-resolution Mars science-imaging after the completion of aerobraking to reach its low-altitude science orbit (*AW&ST* Sept. 25, p. 21).

“This is truly a significant moment for

Shown here is a Mars Global Surveyor image looking down from orbit on Victoria Crater and overlaid with rover Opportunity approach graphics and viewing angles. Victoria is Opportunity’s most important target for the purpose of studying deep rock strata.

ARIZONA STATE UNIVERSITY/IRON MILLER



New Odyssey spacecraft data indicate that sand-laden jets rocket into the Martian south polar sky, propelled by carbon-dioxide gas trapped under the CO₂ ice cap, which melts in spring. The jets leave spotted deposits on the ice that had earlier baffled researchers.

the MRO team,” says Jim Graf, MRO project manager at JPL, which is commanding the spacecraft with Lockheed Martin near Denver.

MRO’s first priority target will be the proposed northern polar region landing site for the NASA Phoenix lander. Phoenix is less than a year away from launch to Mars from Cape Canaveral on a mission to dig for subsurface ice that may hold clues to the potential for life in that specific environment.

The MRO University of Arizona High-Resolution Imaging Science (HiRISE) camera, coupled with a suite of other sensors, was to relay its first low-altitude images Sept. 29 and continue through this week. The objective is to image the Phoenix site for landing obstructions as early as possible.

“We want to image it while the area is still fully illuminated,” Graf says. “There is a period of solar conjunction coming when the Sun will block signals from Mars. If we wait, the imaging will start degrading—but the Phoenix team needs the data this October.”

The imaging through Oct. 6 will also be the first time that MRO will use its onboard targeting algorithms to point at desired targets on Mars.

- Phoenix: The NASA/University of Arizona Phoenix lander with its powerful digging arm, developed by Alliance Spacesystems Inc. in Pasadena, and miniature sample ovens is itself undergoing major hardware buildup at Lockheed Martin.

- Europe’s Mars Express: Mars Express is just emerging from a period where its

solar arrays could not generate power because Mars blocked the Sun for up to 75 min. at a time. This occurs periodically, but was especially serious in late September, when complications from an earlier failure prevented full battery charging even when the Sun was in view. “This was potentially critical, and we knew we had to devise a solution that wasn’t in the manual,” says Michel Denis, Spacecraft Operations Manager at ESA’s Space Operations Center, in Darmstadt, Germany.

Systems were turned off and, at times, the spacecraft pointed away from Earth and its critical communications link with Darmstadt. The spacecraft was forced into survival mode. The Mars Express prime contractor, Astrium, in Toulouse, France, worked closely with ESA, providing detailed information and conducting a parallel study to cross-check and verify the survival procedures. The effort worked, and Mars Express is this week getting back to normal imaging operations.

- Mars Global Surveyor and Mars Odyssey: Global Surveyor, which arrived at Mars in 1997, and Odyssey, which began specialized imaging in 2001, are being budgeted for two more years each, says Doug McCuistion, NASA’s Mars Exploration Program director.

Odyssey has also made a remarkable new discovery about Mars. New analysis of data from its Raytheon Thermal Emission Imaging System, operated by Arizona State University, has found that violent gas eruptions occur every spring around the south polar ice cap.

Jets of carbon dioxide erupt at 100 mph. from the ice cap as it warms, carrying dark sand and dust high aloft. “The dark material falls back to the surface, creating dark patches on the ice cap, which have long puzzled scientists,” says Phil Christensen of Arizona State University, principal investigator for Odyssey’s camera. “All around you, roaring jets of carbon dioxide are throwing sand and dust a couple hundred feet into the air [image top left].”

Both the rovers Spirit and Opportunity are also getting one-year budget extensions into early 2008.

The original Victoria sailed into exploration history in 1522 as the only ship under captain Ferdinand Magellan to circumnavigate the globe. Now, the ship’s namesake will be the focal point of at least a year of rover exploration on the surface of Mars—a mission so important that Opportunity may spend its final days there, perhaps sacrificing its life for science in a “crater-to-grave” sce-

nario to reach rock layers so deep in the crater that the rover may not escape.

But rover drivers at JPL are this week much more concerned about a "Thelma and Louise" scenario where the rover could fatally drive over the extremely steep edges of the cliff. It will be navigated as it uses commands from Earth and its own autonomous robotic navigation to move slowly near the rim.

Before the trip around the crater, JPL will command the rover to creep onto a promontory to spend several days taking a highly detailed Pancam image that will provide scientific data and vivid imagery to map future operations.

It will also bag major early findings, just in case anything goes awry on the jagged edge of the crater.

In late September, as Opportunity approached Victoria, the team performed a crucial software change. On Sept. 20, JPL rebooted the rover computer after loading the new flight software. Fortunately, the rover awoke that afternoon with the software functioning normally.

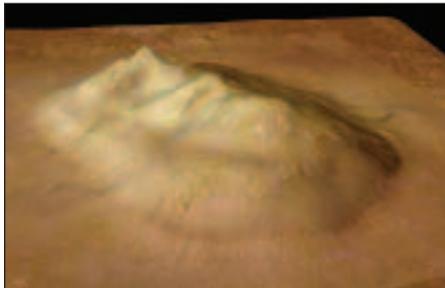
"This new software is going to be a pretty big deal for us," Squyres says on his web site. "It includes lots of new capabilities, things that we've figured out over all these sols [Martian days] that we have now taught the vehicle to do with this software. One capability is 'go and touch,' the ability to send the rover to a target and deploy the arm onto that target all in one sol. That's something we've never done on Mars before. Another is automated dust-devil finding, which should be pretty cool if Spirit is still hanging in there by summer. And there are a bunch of other things, too. The rovers are getting older, but they're suddenly a whole lot smarter," he says.

NASA chose to boot the new flight software when it did because "in a few weeks we will go into 'superior conjunction,' when Mars goes out of sight behind the Sun," Squyres says. "There will be a stretch of time when we can't send commands to the rovers at all, and during that time we want to have complete, unequivocal confidence in the software that's on board."

Spirit has also received a new software load. Halfway around Mars and farther south of the planet's equator, Spirit has been staying at one northward-tilted position through the southern Mars winter for a maximum energy supply to its solar panels.

In the meantime, Spirit is conducting studies that benefit from staying in one place, such as monitoring effects of wind on dust. It will begin driving again when

ESA
MARS EXPRESS



Mars Express is back in action after it was forced into emergency power measures. In September, it imaged the "face on Mars" bluff that some enthusiasts believe was sculptured by intelligent beings. The imagery shows no face, just an eroded mesa.

the Martian spring increases the amount of solar power available.

When it landed in January 2004, Opportunity, and its twin, Spirit, on the opposite side of the planet, had specification lifetimes of 90 days and 2,000 ft. of driving.

Opportunity's ability to survive and reach Victoria far from its original landing site, and Spirit's ability last year to climb to a Martian mountaintop, will live long in planetary science and rank among the great achievements of the U.S. robotic space program.

Lunar Rendezvous?

U.S., Chinese officials find common ground on lunar, Earth environmental science

CRAIG COVAULT/KENNEDY SPACE CENTER

The U.S. and China will discuss sharing data from respective lunar orbiter flights in 2007-08 and explore carrying each other's instruments on later unmanned Moon missions, following the first U.S./Chinese space-cooperation talks.

Possible placement of U.S. instruments on a Chinese lunar orbiter would be similar to what the U.S. is doing with two instruments on India's Chandrayaan 1 lunar mission, set to launch by 2008. That flight will carry a U.S. mineralogical mapper and miniature synthetic aperture radar.

Earth environmental and weather satellite cooperation and data-sharing is also likely, resulting from the visit of NASA Administrator Michael Griffin to China (*AW&ST* Sept. 25, p. 32).

The two sides agreed to hold annual high-level talks on space cooperation to raise new ideas and measure the pace of more detailed lower-level project and data coordination kicked off by the initial meeting. Any new NASA cooperation still requires White House and State Dept. approval, though.

Greater U.S./Chinese weather satellite cooperation will also be discussed in October in Beijing by National Oceanic and Atmospheric Administrator Adm. Conrad C. Lautenbacher.

As expected, manned flight coopera-

tion was not discussed during Griffin's trip because it is run by the Chinese People's Liberation Army (PLA). The NASA team did not see China's new astronaut training center, nor visit Shenzhou mission control, which will manage China's third manned flight in 2008—a three-man mission involving China's first extravehicular activity.

The Chinese are also to launch as many as six new environmental spacecraft through 2008, including the new Chinese FY-3A advanced polar orbit weather satellite.

They are also about to begin a major surge into 2008 in the launch of geosynchronous orbit communications satellites, with as many as eight satcom launches, including one for Nigeria.

Griffin and Chinese space managers will brief other international space officials on the result of the talks at the International Astronautical Congress wrapping up this week in Valencia, Spain (see *In Orbit*, p. 17).

Meanwhile, back in Washington, there are sharp concerns by some in the Bush administration and the Congress that cooperation with the Chinese may be proceeding too fast, given China's missile technology sales to Iran and other recent provocative acts.

But *The China Daily* in official communist party commentary on the Grif-

fin visit notes that China has already signed 16 pacts with 13 governments and organizations and established space industry cooperation with more than 40 countries and international groups.

In contrast, congressman Dana Rohrabacher (R-Calif.), a senior member of the House Science Committee and former chairman of the Subcommittee on Space and Aeronautics, criticizes Griffin's visit as "an ill-timed effort to increase Sino-American space cooperation."

Rohrabacher referred to recent reports of the Chinese firing high-powered lasers with the ability to blind U.S. reconnaissance satellites as "another example of why China should be considered an enemy instead of a partner."

Aviation Week & Space Technology reported more than 20 years ago that the Defense Dept. itself uses lasers to illuminate Chinese and Russian reconnaissance spacecraft to characterize their optics. Rohrabacher's concerns, however, are that recent Chinese actions involve offensive laser tests aimed at disabling U.S. reconnaissance spacecraft. Those Chinese actions were first reported by *Defense News*, which Rohrabacher held aloft in the Congress last week to make his point: "It is unfathomable this administration has decided to engage China on space policy, or any other technological endeavor. This latest revelation of the Chinese firing ground-based lasers to blind our reconnaissance satellites, while high level officials from NASA are participating in an alleged exploratory visit, is the highest level of contradiction," Rohrabacher said.

AW&ST reported eight years ago that China is actively pursuing the development of directed-energy laser- and high-power microwave weapons possibly to destroy U.S. satellites.

More broadly from the talks, the U.S. and China will explore the establishment of formal space cooperation working groups in Earth science, other diverse robotic exploration and the sharing of data on various scientific missions, Griffin says. "We believe that might be a productive thing to do. We did have very useful discussions," he said after meeting Chinese officials, including Sun Laiyuan, who heads the China National Space Administration (CNSA).

In addition to talks with CNSA officials and China's Minister of Science and Technology Xu Guanhua, the NASA team visited Chinese Academy of Space Technology (CAST) test facilities in Beijing; the Chinese Academy of Sciences in Beijing, where Griffin delivered a speech on U.S. space history to selected graduate students; the Beijing National Satellite Meteorological Center, and the Shanghai Academy of Science Technical and Physical Research Institute.

The NASA team included William Gerstenmaier, head of NASA space operations, and astronaut Shannon Lucid, born to U.S. missionary parents in Shanghai. They decided not to visit the Jiuquan launch site when told they

my time and did not need to go that far to see another one," Griffin quipped.

"I did make a point that with regard to operation on space programs generally, and human space-flight programs in particular, the greatest possible degree of transparency and openness is a requirement—if for no reason more important than [that] without it, we stand a chance to kill people," Griffin told *Aviation Week & Space Technology* from Shanghai at the end of his trip.

"If we are to conduct human space flight activity together, we have to have a great degree of trust, a great degree of sharing, a great degree of openness regarding what is going on with our engineering systems, or there is real danger in the mix. I made that point, and I

believe it was understood by all. Transparency and openness mean being able to see and touch and ask questions and get answers, and China and the U.S. are not at that point," he added.

The NASA team was shown CAST Shenzhou clean room manned spacecraft processing facilities in Beijing but was not shown Shenzhou spacecraft hardware and did not expect to be, given the program's affiliation with the PLA.

In Shanghai, the team was shown the engineering model of a Chinese laser altimeter to be carried on the Chang'e lunar orbiter set for

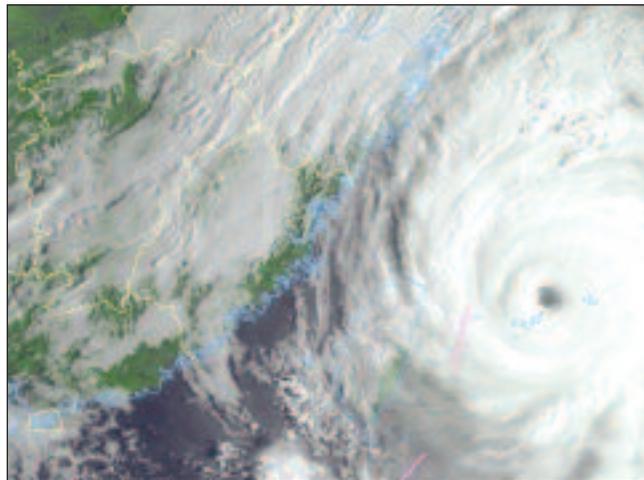
launch as early as April 2007. NASA's Lunar Reconnaissance orbiter mission is set for launch from Cape Canaveral in 2008.

A second Chang'e lunar orbiter is in the works, along with a Chinese lunar rover in 2010-12 and a possible Chinese robotic lunar sample return in 2015-17.

"The folks we met with did in fact discuss the lunar robotic mission goals that they have," Griffin said. "We had a very good and enjoyable discussion about their first lunar orbit spacecraft capabilities and its mission.

"I expected to meet capable, involved, committed, energetic people who are devoted to their country's space program, and that is exactly what I saw," Griffin said. "It has been very rewarding and very fulfilling."

"This trip accomplished what it was supposed to," Gerstenmaier said. "The next step will be more specific about where we are going." ❏



CHINA METEOROLOGICAL ADMINISTRATION

China's FY-1D polar orbit weather satellite images Super Typhoon Shanshan as it skirts the east coast of China in mid-September.

would not be shown spacecraft processing facilities, only the launch pads.

Griffin said, given the travel distance to Jiuquan in the Gobi desert, it was better to concentrate on facilities in Beijing and Shanghai.

That was also a reminder to the Chinese that NASA means business about the need for transparency and openness in future space cooperation.

"We were invited out there to see the launch pads and told we would not have access to the buildings and facilities where spacecraft were being built and tested and prepared for launch," Griffin said. "But I am not a tourist. This business is my profession, and the interesting part of a visit would be to see and understand the facilities and to discuss those [engineering] processes with our [Chinese] peers. If we had been invited to have eye-level discussions with our peers [at Jiuquan], I think it would have been worth the trip.

"I have seen a lot of launch pads in