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AEROSPACE AMERICA

Ready, set EXPORT

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Mars or bust

The case for optimism

NASA

Mars in an image from the Curiosity rover. Inset: scene from the movie "Mission to Mars," Buena Vista Pictures

As NASA's lead writer from 2002-2009, Edward Goldstein wrote speeches and opinion articles for two administrators, Sean O'Keefe and Michael Griffin. Goldstein earned his Ph.D. from George Washington University in 2007 with a dissertation on the history of NASA's Earth Science Program.

ANALYSIS
by Edward Goldstein

Sending human explorers to Mars is an idea that has seemed to many in the space community as elusive as a mirage on a red-hued desert planet, but it's something they've thought about for decades. Indeed, rocket pioneer Wernher von Braun advocated the idea in a Collier's magazine article in 1954, well before NASA came into being.

For dyed-in-the-wool space exploration advocates. there's a sense that for far too long we've been on a path that's led to roadblocks, detours and dead ends. After all, weren't we promised Mars in earnest by one vice president, Spiro Agnew — leader of the post Apollo-11 Space Task Group — and two president Bushes, only to have such plans disappear into the dustbin of history?

And let's not forget that four years ago in his Kennedy Space Center space policy address, President Obama asserted, "By the mid-2030s, I believe we can send humans to orbit Mars and return them safely to Earth. And a landing on Mars will follow." But of course that was in the heady pre-sequestration days, when his administration was proposing $6 billion in new funding for NASA over five years — with a big increase for technology development — on top of the $1 billion in extra stimulus funding the agency received in 2009. After the budget deal reached by Congress and the president in December, NASA has a fiscal year 2014 budget of $17.65 billion, roughly $1 billion lower than its FY 2010 budget — not exactly a good trajectory.

No plan, no funds, no ride

According to Scott Pace, director of George Washington University's Space Policy Institute, if NASA's budget today had the same purchasing power it had 20 years ago, it would be around $24 billion. I asked Pace, who is also former NASA associate administrator for program analysis and evaluation, to judge the likelihood of a viable human mission to the surface of Mars in the 2030s. His response: "Absolute zero. A mission doesn't exist. There is no plan, there is no funding, there's no near-term capability in place. The political conditions don't exist for it. The economic conditions don't exist for it. I might as well be talking about long-term plans for interstellar flight."

Similarly skeptical is former NASA chief historian Roger Launius, now associate director of collections and curatorial affairs at the Smithsonian Institution's National Air and Space Museum. "My question for anyone who thinks we should go off and send a human mission to Mars is simply this: What is the trigger mechanism, the set of economic, political, social or whatever factors … that would come together and create an environment in which the appropriate response to that challenge, whatever that challenge might be, is a trip to Mars?"

Edward Goldstein asked fellow Mars exploration advocates about the near-term prospects for sending humans to the Martian surface. Below are some of their responses, and a discussion of current approaches to achieving the goal.

said Launius. "I don't envision us finding that trigger. So I don't think it's real…There are enthusiasts, and that enthusiasm is real. But they don't have the size or the influence necessary to make a human mission to Mars something that's going on the national agenda."

That said, there is work under way now that I believe could lend itself to a more optimistic view, that a little over two decades from now, people around the world will gather to watch a crystal-clear live video feed and hear the historic words transmitted about 10 minutes earlier from a distance of at least 35 million miles: "Houston, Eberswalde Base here, the Millennium Eagle has landed." Eberswalde Crater preserves a Martian river delta system and could hold evidence of early life.

Causes for hope

- ***Technology gains*** — NASA and its contractors are making significant progress on critical elements for a human Mars mission — the Multipurpose Crew Vehicle and SLS, the Space Launch System. Moreover, research onboard the International Space Station is helping NASA understand the long-term biomedical challenges of such missions and is providing experience with operating a complex environmental life support system.
- ***Planning continues*** — NASA is taking a steady-as-she-goes attitude toward its Design Reference Architecture 5.0, whose authors modestly call it "a vision of a potential approach for human Mars exploration." NASA Headquarters is considering sensible refinements to the document, which provides a "common framework for future planning of systems concepts, technology development, and operational testing," say its authors. It is the fifth in a series the agency began publishing in 1993 in attempts to produce a plausible architecture for human Mars exploration.

This document lays out scenarios for three lengthy expeditions to the Martian surface. In conjunction with the scientific community, the paper pinpoints 58 possible landing targets. All are tied to learning more about whether Mars at one time sustained life, and about the planet's geology, subsurface and atmosphere.

- ***Wise spending*** — Another reason for optimism is the agency's investment in the 16 top technology priorities deemed critical by the National Research Council for future NASA missions, including several related to interplanetary exploration. An area of significant progress is cryogenic propellant storage and transfer, says Michael Gazarik, NASA's associate administrator for space technology. Another important area of investment, he says, is in high power solar electric propulsion. "Those are the number one and number two high-priority technology areas for future exploration," he says. Being able to store and transfer cryogenic fluids on orbit "is a real enabler, saving significant mass for human or robotic exploration," says Gazarik. High-power solar

In a 1954 Collier's magazine article, rocket pioneer Wernher von Braun advocated the idea of sending human explorers to Mars.

The Orion Multi-Purpose Crew Vehicle undergoes testing at Lockheed Martin.

NASA

NASA

The Space Launch System is still an artist's rendering, but it could someday send a crew toward Mars.

electric propulsion is also "a very efficient way to move cargo as we explore the solar system," he says.

On the question of forward momentum, Gazarik sees broader signs of progress: "What we had in the past were a lot of studies. We had probably 40 studies or so over the last 30 years that have asked, 'what are the technologies you need to get to Mars?' that all say about the same thing…The difference we're making now in space tech is [that] we're working on them. We're working on laser and optical communication. We're working on advanced entry descent and landing. We need to put more mass on the surface, as we can't go around exploring the universe in a Mini-Cooper," which is the size of the Curiosity rover.

● ***International support*** — The latest Global Exploration Roadmap, released in August by the International Space Exploration Coordination Group — an information exchange organization that includes NASA — has become more Mars focused and includes a single reference mission scenario leading to exploration of the red planet after 2030. In December, Mars exploration stakeholders from NASA and the contractor community discussed human missions to Mars at a meeting hosted by Explore Mars Inc. and the American Astronautical Society at George Washington University. Their conclusion: With space agency budgets that keep pace with inflation, international partnerships and alternative acquisition and development methods — including streamlined government oversight and Skunk Works/Phantom Works-like structures — the "initial human missions to Mars are affordable under reasonable assumptions and with sustained international political support."

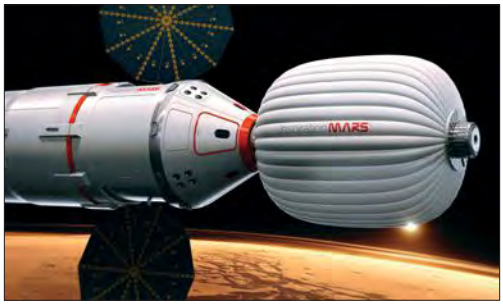
● ***Priceless opportunity*** — A final cause for hope is that Mars itself is in a cooperative mood. In 2033 and 2035, the planet's orbit relative to Earth is particularly favorable for minimum-energy trajectories, reducing the fuel required for sending a mission into Martian orbit, to the surface of Phobos or Deimos, or even to the planet's surface with spacecraft fueled by conventional propellants. This window may also occur during the "solar maximum" phase of the 11-year solar magnetic field. This is when the sun is at its most active state and provides protection against galactic cosmic rays, an insidious form of space radiation that can cause cancer and nerve damage in astronauts.

Also, because the 2033 and 2035 launch windows are unusually good ones, leading to a relatively shorter transition time to and from Mars — unlike in the Apollo era — the stay time for crews near or on the surface of Mars could be weeks to months.

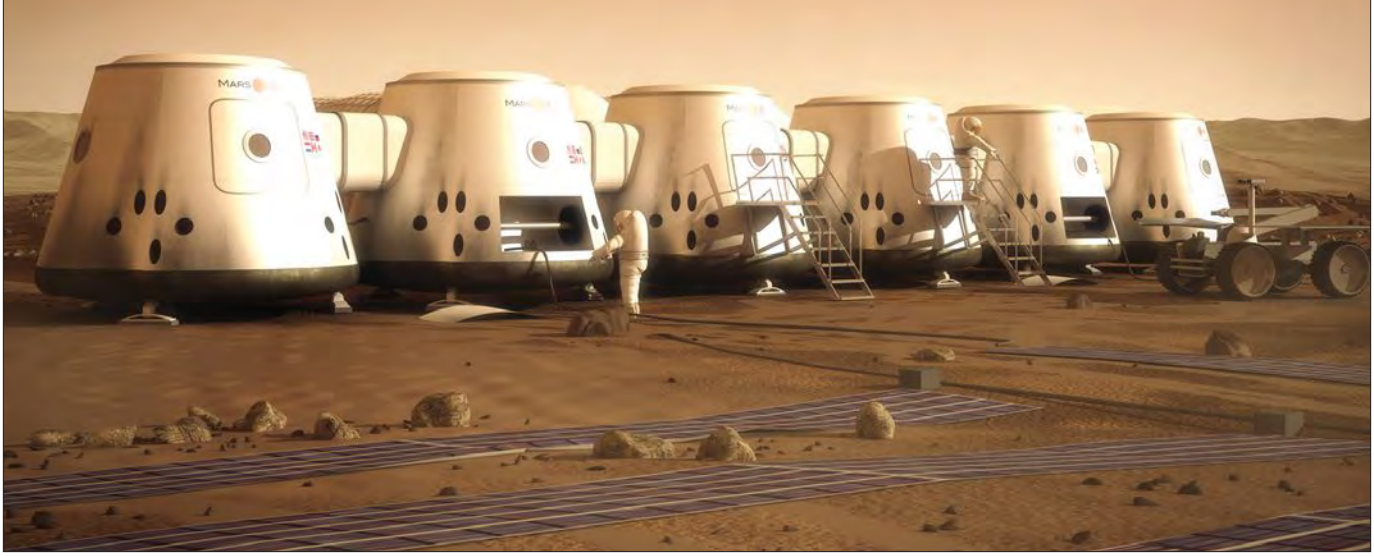
Indeed, there is growing optimism that NASA, with the support of international and commercial partners, can make a human Mars mission possible before the eightieth anniversary of the space age. Also, private sector ideas such as Mars One, Mars Direct and Inspiration Mars are viewed favorably

"I think that something in the early 2030s is achievable with the budget we have, if — and this is a big if — we can get international partners to come along and lay in other pieces of the infrastructure."

— James Crocker, Lockheed Martin Space Systems



Early artist's conception of Inspiration Mars capsule and habitat module.



NASA

Pressurized rovers would allow the crew to explore beyond the range permitted by their space suits and work in a shirtsleeve environment.

by many traditional space community professionals for stirring public interest about Mars, and for potentially pointing the way to new technological approaches or even meeting their bold objectives. It's worth noting, however, that NASA is not onboard with billionaire Dennis Tito's Inspiration Mars plan for launching a mission to the planet as early as 2017 using NASA's new Space Launch System.

In response to Tito's plan, David Weaver, NASA's associate administrator for public affairs, made this statement: "Inspiration Mars' proposed schedule is a significant challenge due to life support systems, space radiation response, habitats and the human psychology of being in a small spacecraft over 500 days. The agency is willing to share technical and programmatic expertise with Inspiration Mars, but is unable to commit to sharing expenses with them." The Inspiration Mars team is working on a revised plan for 2021 that seeks to address the issues NASA raised, and only time will tell if this new plan will gain acceptance.

But for the long haul, NASA appears committed to Mars, which "is today the ultimate destination in our solar system for humans and…a priority for NASA," said the agency's administrator, Charles Bolden, at George Washington University's Humans to Mars Summit in May. "Our entire exploration program is aligned to support this goal."

Confidence building

Mike Raftery, director of International Space Station utilization and exploration for Boeing, leads a team at his company examining Mars exploration architectures. "The community is starting to believe that we can make Mars happen, and that is a relatively recent thing," he says. Previously, the thinking was that Mars is "really big and hard and therefore too difficult and expensive to attempt," he says. But his experience with the ISS has given him a different view. Getting to Mars "isn't that much harder than what we've already done for ISS, with international cooperation and cost-sharing."

Raftery further argues the tonnage needed for a human Mars mission will be substantially lower than that required for ISS assembly and logistics flights, depending on the architecture and in-space propulsion technology used. The number of unique payloads needed will also be lower, he says.

The key to success, says Raftery, is to have an "architecture that takes advantage of the lessons learned from ISS and breaks down the overall requirements for a mission into as few pieces as possible, with as little revolutionary technology as possible."

Raftery describes a potential mission broken down into six basic elements: SLS for crew and cargo launch; Orion for crew return to Earth; a TransHab Module to carry crews to orbit around Mars; solar electric propulsion tugs to transfer cargo from high Earth orbit or cis-lunar space to a Mars orbit and/or the Martian surface; the Mars lander; and the Mars ascent vehicle. A launch campaign using an SLS or evolved SLS system for a landing mission would require five to seven launches for the crew — "if you don't push the technology too hard," says Bret Drake, principal editor of NASA's Design Reference Architecture 5.0 — with an additional four to seven launches needed to get cargo to the Martian surface.

In Raftery's view, nuclear electric propulsion, while desirable for reducing the transit time to Mars, should not be on the critical path. Some eight years after the Project Prometheus nuclear propulsion program was cancelled, NASA planners are still looking at this technology. However, it

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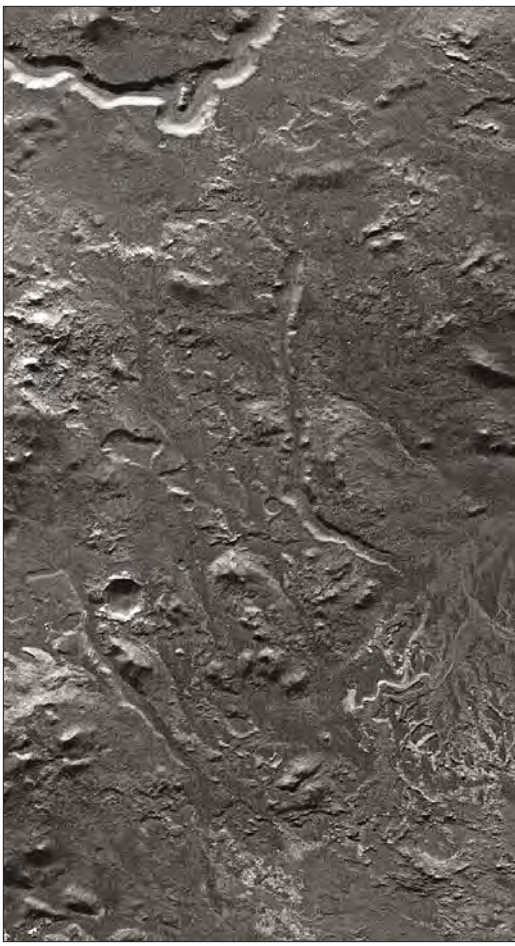
— Mike Raftery, Boeing

would require a major, sustained funding commitment to achieve engineering viability and reliability in deep space. "Nuclear thermal propulsion is one area, along with efficient surface and spacecraft power… where everyone can see tremendous benefit," says NASA's Gazarik. "Given today's tough fiscal environment, and specifically where [the] Space Technology [Mission Directorate] stands, it's a tough one to go push on in a very large way….We have some moderate investments to keep nuclear systems alive." At NASA Marshall, "we simulate the nuclear part. And we are working with the Department of Energy on the thermal management part and the management and control of the system," to "move that forward as best we can" until more resources become available.

Step-by-step planning

Perhaps crucial to turning Mars visions into reality is completing a viable near-term stepping-stone plan once the SLS and Orion are ready. James Crocker, vice president and general manager of civil space at Lockheed Martin Space Systems, says that after those systems are available, the next



Landing sites: *Jezero Crater (left), Eberswalde Crater (middle),and Mangala Valles (right) are among the contenders.*

step would be to develop a series of manned flights. These would start in 2020 and "would allow us to continue developing the technology within the budget that NASA has — this is pay as you go." The series of steps would keep progressing, he says, and would have "the ultimate goal of getting to Mars as soon as we could and within the budget we have. I think that something in the early 2030s is achievable with the budget we have, if — and this is a big if — we can get international partners to come along and lay in other pieces of the infrastructure." Whether it's the Russians or Europeans, he says, "Most spacefaring nations are very interested in being part of this journey."

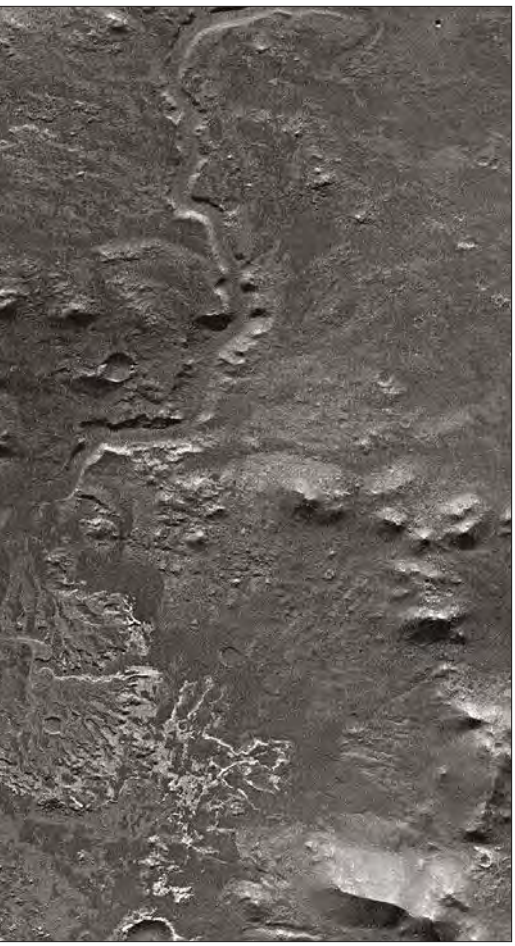
Adds Jason Crusan, director of NASA's advanced exploration systems division, "Every time we fly a mission, whether it's human or robotic, we evaluate it by the opportunity to increase the knowledge… and reduce the gaps that we have [on getting] from here to Mars." The 5.0 architecture is "pretty comprehensive in that regard," he says.

A major potential hurdle to overcome is the issue of crew radiation exposure, a concern that has already led to discussions about whether NASA's lifetime exposure limits — which are 20 percent lower for women than for men, because of greater risk for some cancers — would constrain flight opportunities for female astronauts. To deal with the overall risk, Gazarik reports the agency is in the early stages of studying advanced materials and other techniques for radiation shielding. And Crusan notes that NASA is looking at in-space systems such as the Mars Science Lab and Lunar Reconnaissance Orbiter for purposes of "revalidating some of our data related to plastics and their ability to absorb radiation and provide radiation shielding."

Big decision

If a concerted effort to conduct a human Mars mission does go forward, the potential landing sites are intriguing. NASA's 5.0 architecture document discusses at length sites such as Jezero Crater, where a standing body of water existed during the Noachian

All photos from NASA



NASA

Picking a landing site: *Data gathered by NASA's Mars Atmosphere and Volatile Evolution spacecraft, now on its way toward Mars, is intended to help.*

period, an early time in the planet's history. Another widely viewed target is Mangala Valles, an outflow channel that saw massive releases of water in the past and may contain icy near-surface deposits.

James Garvin, who co-chaired the NASA-chartered Human Exploration of Mars Science Analysis Group and is chief scientist at NASA Goddard Space Flight Center, cautions that it would be premature to select a landing site before additional information is gathered by the Mars Reconnaissance Orbiter and by upcoming missions such as NASA's Mars Atmosphere and Volatile Evolution, the ESA/Russian ExoMars and the NASA 2020 science rover missions. But he expresses a tentative preference for visiting a place such as the Eberswalde Crater, whose preserved river delta system could hold biosignatures in its rock record.

When asked if a human Mars mission would be worth the expense from a scientific standpoint, Garvin is emphatic: "Human flight systems would bring with them greater capabilities for accessing new places on Mars, and for returning 'high-graded' samples of rocks, ices and even atmospheric gases for study here on Earth," he says. Human explorers — ideally aided by robotic counterparts — would also accelerate the pace of discovery, "provided we can optimize where they should go and what specific questions they should pursue in earnest," he says. Indeed, human explorers "would enable progress that would otherwise have required decades….I do not think we have seen anything yet in terms of what Mars has to offer about our solar system, the prevalence of life and our role in the universe," says Garvin.

All the people I spoke with cite their career-long commitment and passion about the goal of getting humans to Mars. "I believe as a career NASA scientist with 28-plus years of service…that Mars is the optimal destination to give humanity the confidence to know that some day we can escape our precious Earth and go elsewhere, even in these 'pre-Warp' civilization days," said Garvin in an e-mail. "Mars is the place, and all we need is the dedication to make it our cathedral to the stars."

Lockheed Martin's James Crocker sums it up this way: "I know a young engineer, who happened to be me, who graduated just in time to get down to the Marshall Space Flight Center for the very last Apollo mission to the moon, Apollo. 17. And I was hurrying to get through Georgia Tech in four years, which was pretty challenging even in those days, because I was afraid they were going to get to Mars without me. Little did I know that it would take a long time for us to do that. I'm of the school that [says] we just ought to get on with it." ▲