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Where next in space?

By George Leopold

AS THINGS STAND NOW, U.S. manned spaceflight is dead in the water.

A combination of budget woes, disagreements over where in the heavens to go next and the absence of a clear set of goals has reduced the once-supreme U.S. manned space program to a space transport and maintenance operation in low-Earth orbit that's scheduled to end next year with the retirement of the Space Shuttle. That leaves only the International Space Station, and no way for the United States to get there without Russian help. Moreover, the station has drained tens of billions of dollars from NASA's coffers over the last two decades, hamstringing the space agency's other manned spaceflight operations.

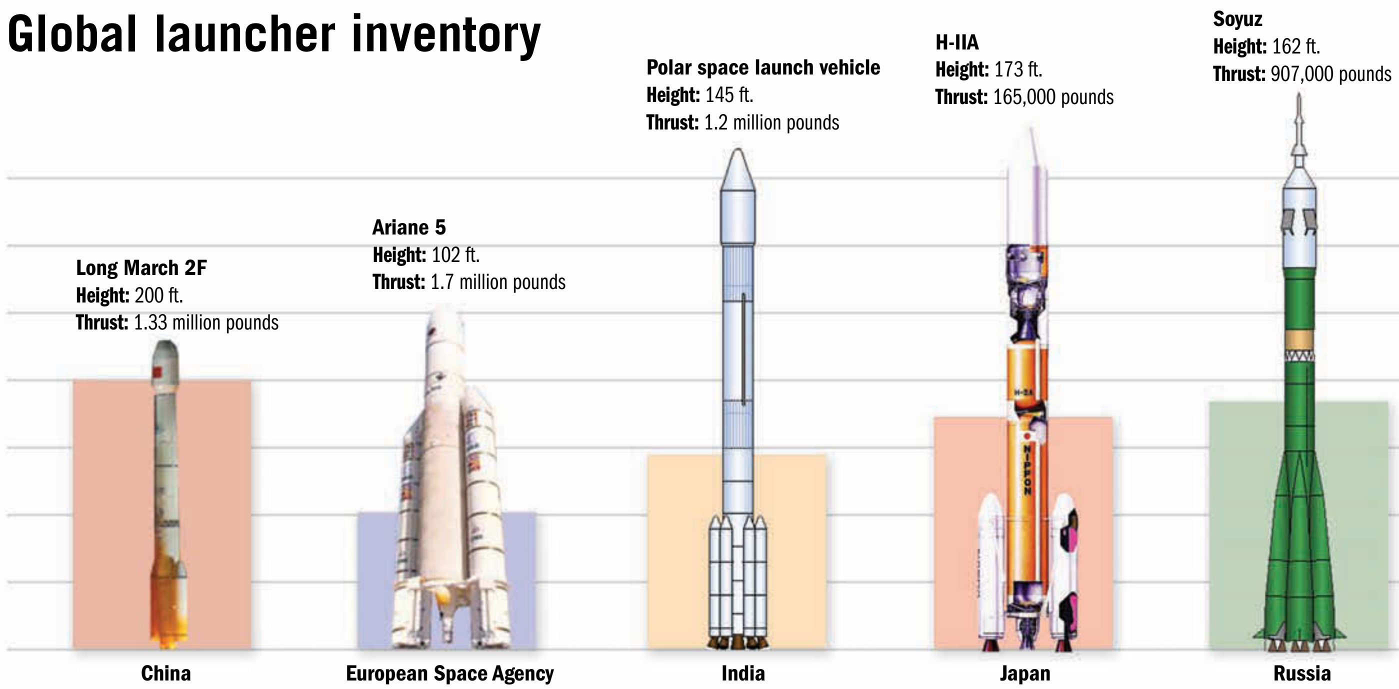
By contrast, NASA's unmanned missions to Mars, Mercury and the rest of the solar system have yielded astonishing advances in humankind's knowledge of the universe. With budget shortfalls expected to continue for the foreseeable future, many experts advocate exclusive reliance on machines to explore space, providing humanity with a "telepresence" in orbit or on the surface of planets, moons and even near-Earth asteroids.

Two things are clear. First, the United States can no longer afford to mount, say, a manned mission to Mars on its own. Nations must find new ways to pool technological and financial resources, while overcoming narrow political differences and rivalries, to explore the solar system.

Second, a clear set of goals, including a firm timetable, is needed to move beyond low-Earth orbit. Almost without exception, veterans of early U.S. manned spaceflight agree that President John F. Kennedy's challenge to land humans on the moon by the end of the 1960s was the unifying principle that took humans to the moon nine times between 1968 and 1972.

"The question kind of boils down to: What are you going

Global launcher inventory



back into space for?” said John Aaron, the legendary NASA flight controller who worked extensively on planetary exploration after the U.S. Apollo program. “Are you going back into space to stay, or are you going to focus on landing people on Mars and come home? If the philosophy is that we are going back into space to stay, then resources and operational experience are paramount.”

Aaron and many former astronauts agree that returning to the moon represents, in the words of former Apollo 11 crew member Michael Collins, a “technological briar patch” that would take our eye off the ball. Both Aaron and Collins believe returning to the moon only delays the day humans reach Mars.

“Going to Mars directly is probably the right answer,” Aaron said. “For reasons other than engineering, I think you would stay focused and get there sooner.”

Collins has said a Mars mission could be launched from Earth orbit just as easily as another moon mission could. Though he rarely grants interviews, Collins had this to say last July amid the hoopla over the 40th anniversary of the Apollo 11 moon landing: “[Mars] was my favorite planet as a kid and still is. As celestial bodies go, the moon is not a particularly interesting place, but Mars is. It is the closest thing to a sister planet that we have found so far.

“I worry that at NASA’s creeping pace, with the emphasis on returning to the moon, Mars may be receding into the distance. That’s about all I have to say.”

Ultimately, the biggest hurdles to resuming manned exploration of the solar system are posed not by technology, but by political and budget squabbles here on Earth.

A presidential commission on the future of U.S. manned spaceflight said NASA’s current program is seriously underfunded and has urged the Obama administration to add $3 billion a year to the agency’s budget to reinvigorate human space exploration.

‘When you’re throwing $700 billion around’ to bail out banks, ‘$3 billion for human spaceflight doesn’t sound like all that much’

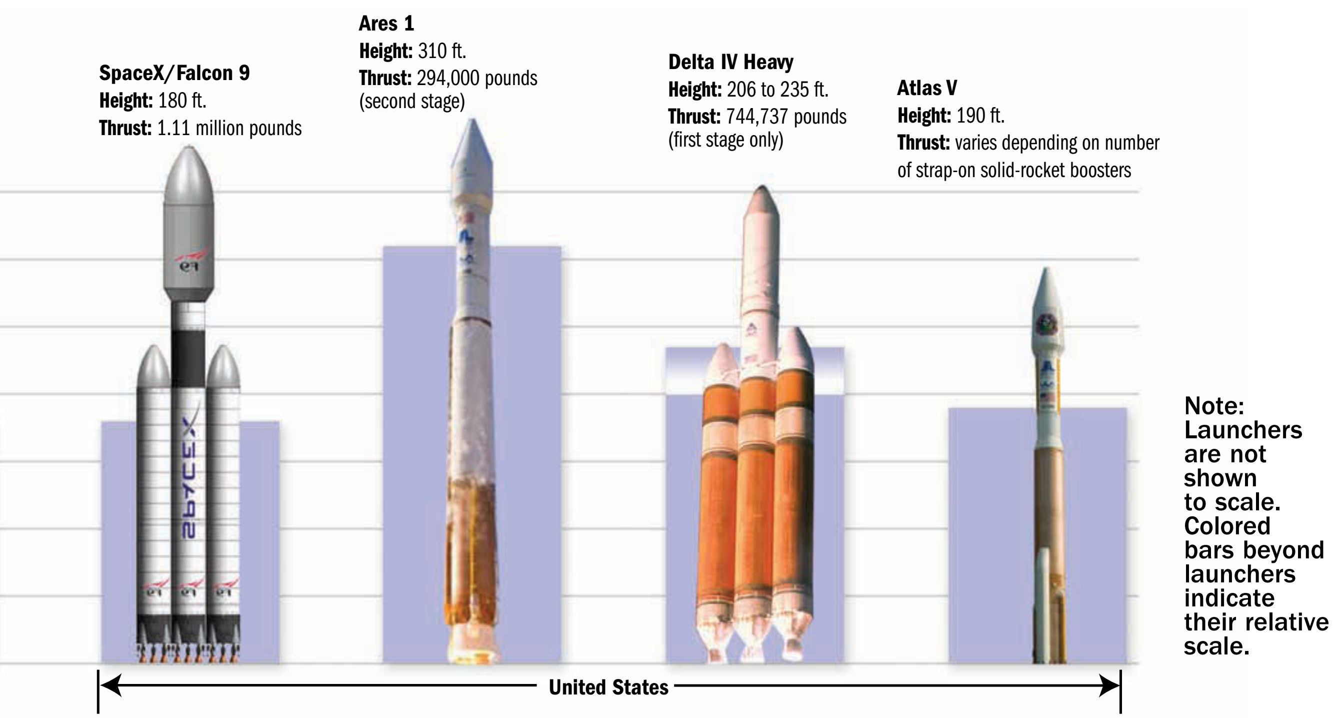
That funding, however, would likely come at the expense of other NASA programs.

“We’ve briefed the White House and have not been thrown out, [but] they certainly are not very happy with our findings,” commission chairman Norman Augustine said in September, shortly before his panel’s recommendations were released.

Augustine added that he remained “guardedly optimistic” that the administration would come around, noting that “when you’re throwing $700 billion around” to rescue failed banks and automakers, “$3 billion for a human spaceflight program doesn’t sound like that much.”

What is needed as soon as possible, Augustine said, is a new heavy-lift launch vehicle. Under the current budget, “it won’t be available until the late 2020s. When it does become available, there will be nothing to put on top of it and nowhere to go.

“So today’s program, today’s funding, is in our opinion dead-ended.”



Given the political and budget realities, the Augustine Commission argued for a "flexible approach" to future human space exploration that would likely avoid the need to send heavy payloads down and back up steep "gravity hills" like the surface of Mars. That could mean exploring its smaller, easier-to-reach moons, or even near-Earth asteroids.

Critics like Michael Griffin, NASA director during the Bush administration, counter that such a plan ends up short-changing manned space exploration while allowing the United States

NASA looks to SiGe for radiation-immune circuits

By R. Colin Johnson

THE SHIELDED CIRCUITRY in current-generation spacecraft meets requirements for radiation hardness. But a joint project among NASA, the U.S. Naval Research Laboratory and Georgia Tech aims to cast the next generation of space circuits in silicon germanium to boost their immunity to bombarding space hazards.

The circuits will need no shielding, the researchers say, because they will continue to operate properly even when cosmic rays cause random localized errors.

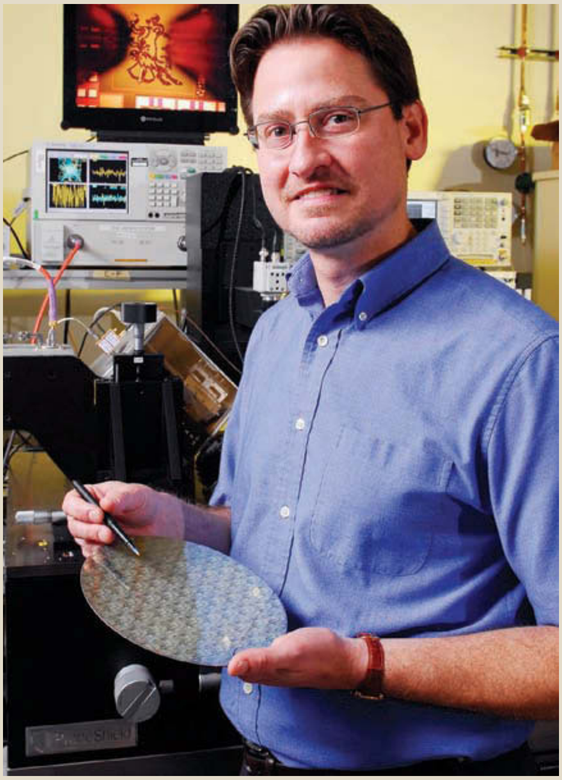
"The holy grail in this field is getting sufficient radiation hardness without resorting to any of the high-overhead schemes, such as shielding, process hardening or triple modular redundancy," said principal investigator John Cressler, an EE professor at the Georgia Institute of Technology. "We are closing in on that goal, using silicon germanium electronics."

Most of the advanced electronics now used in space were designed for the relatively benign atmosphere of Earth. When used in spacecraft, conventional electronics often require heavy shielding to prevent radiation damage, as well as triple redundancy to compensate for exposure to cosmic rays.

SiGe is naturally resistant to ionizing radiation, which comprises smaller particles, such as electrons and protons, that move at high speeds but do not deeply penetrate circuits. Cosmic rays, however, involve heavy ions moving at speeds so fast that no medium can stop them. When cosmic rays rip through a circuit, they affect charge distribution, causing a local error in the circuit. So Cressler's group is designing its SiGe circuitry to withstand such errors.

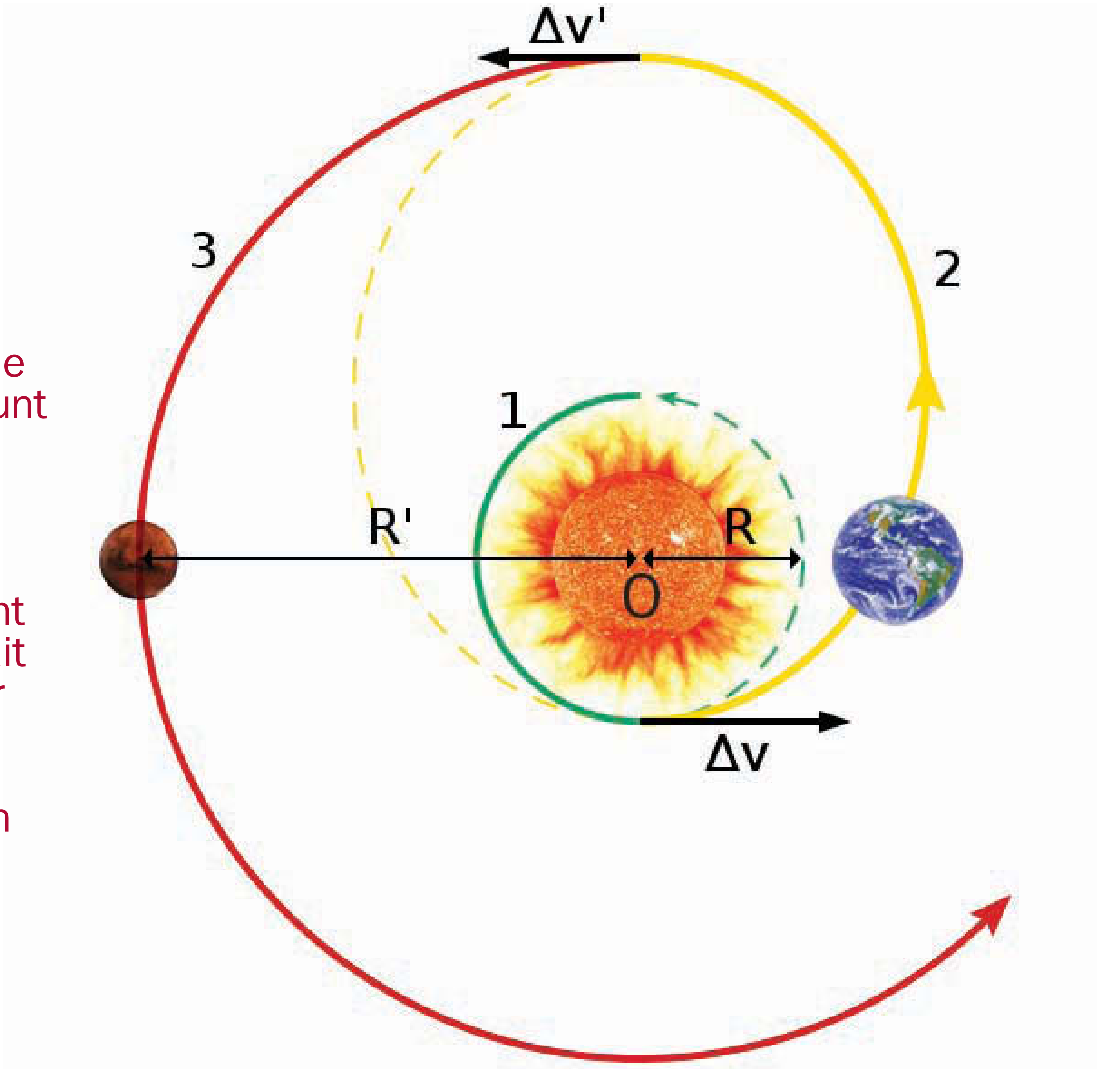
Space electronics currently employ triple modular redundancy, wherein three identical but physically separated systems are polled by a master computer. If a random cosmic ray causes an error in one of the three, the computer detects the difference in that system's results and reboots it while the two other systems continue to run. Cressler wants to design circuitry that implements a smarter version of that architecture, to cancel the effects of random errors without requiring triple modular redundancy.

The team has already begun to formulate a model of the effects of particle strikes on SiGe transistors and is using that model to simulate SiGe circuitry. To test the accuracy of their simulations, they fabricate the circuits, then use an ultrafast laser to inject current locally into the test designs, simulating the effect of cosmic rays. Using a high-speed data logger, the team captures the results for different impact points on their circuits, then redesigns them to avoid problems. By characterizing for direct hits on any part of a circuit, they hope to achieve designed-in immunity to all types of space radiation.



Georgia Tech EE professor John Cressler shows a silicon germanium wafer he is designing to take space circuitry from rad-hard to radiation-immune.

Once a circuit is achieved that passes the full laboratory testing regime, it will be shipped to Sandia National Laboratories, where a focused-ion microbeam will bombard it with real cosmic rays. As in the earlier tests, high-speed data loggers will be used to capture the results of each impact. The researchers hope to confirm their computer model's accuracy and fine-tune their predictions for new circuit designs achieved using the model. ■



The Hohmann trajectory requires the least amount of energy to reach Mars from Earth, but crews might have to wait months for the proper alignment for a return trip.

to claim it is maintaining leadership in space.

NASA and a small cadre of commercial space ventures claim they can fill the launch gap left by the retirement of the space shuttle to continue servicing the International Space Station. For example, Space Exploration Technologies, an ambitious commercial space venture launched by Internet entrepreneur Elon Musk, is preparing to test a rocket called the Falcon 9 as part of NASA's Commercial Orbital Transportation Services program. If the launcher works as advertised, it could eventually be used to service the International Space Station.

But previous commercial space ventures have a checkered past, with proponents often overpromising and then vainly struggling to raise the enormous sums needed to take a rocket from the drawing board to orbit. NASA thus is expected to rely on Russia's Soyuz launcher to continue servicing the space station after the shuttle is retired.

So what does all this mean for the electronics industry?

For one thing, reliability will be paramount on a Mars mission, a trip that could last up to three years. Several decades ago, manufacturers had to be certified to supply high-rel space components that could withstand prolonged exposure to radiation in low-Earth orbit. In the future, electronics manufacturers will have to supply extremely low-power components that also provide a level of reliability that astronaut Collins has called "Mars quality" radiation hardness.

One potential approach for achieving such reliability levels in space electronics is to use circuits made from silicon germanium. Investigators at the U.S. Naval Research Laboratory (Washington), working in collaboration with Georgia Tech engineers, think SiGe could be the linchpin for achieving electronics that don't require shielding or redundancy (see story page 22). With weight an even greater consideration on a trip to Mars (it still costs an estimated $20 million to place a ton into low-Earth orbit), such new materials could yield key components for manned solar system exploration.

But there's still a long way to go before NASA or its international partners can seriously think about sending humans beyond the moon.

Collins' Apollo 11 crewmate, moon walker Buzz Aldrin, proposed a timeline in July. "I believe we need to do more than put footprints on the moon," Aldrin said in laying out a plan to reach Mars by 2036. Noting that 66 years had separated the first powered flight at Kitty Hawk and the landing at Tranquility Base, Aldrin said the same time span should separate the first moon landing from humanity's first footfalls on Mars. ■