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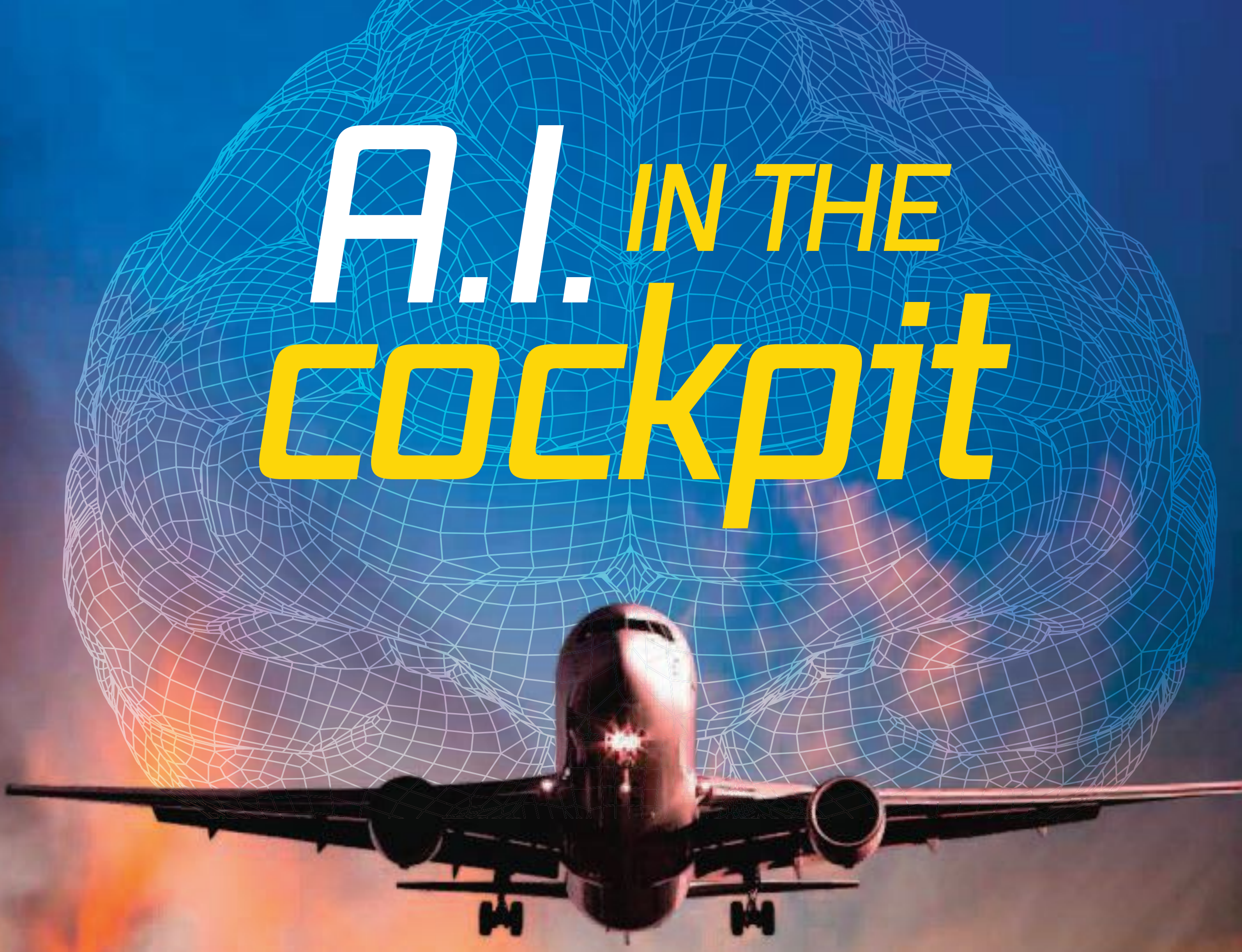

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OPINION

THE MOON AS STEPPING STONE TO MARS

Assuring safety to the maximum extent possible for a human mission to Mars depends in large part on proving technologies and procedures through human exploration of the moon. Once those techniques and procedures are proven, there should be no need for a human precursor orbital mission to Mars. Mike Helton, a retired risk management expert who once worked on the Apollo missions, explains.

When Columbus set sail in 1492 to find a new route to India, his command ship, the Santa Maria, was built as an ocean-going vessel with a deep draft of 3 meters to accommodate a crew of 41 and 98 metric tons of cargo. The other two ships, La Niña and La Pinta, were built for Mediterranean sailing with shallow drafts of about 2 meters. This assured Columbus that he would have vessels capable of exploring smaller water ways, inlets and shorelines. Multiple vessels also gave him lifeboats should something go wrong.

Columbus knew he needed to be ready for the unexpected and take advantage of all his opportunities, because he might not get a second chance at the resources for this kind of venture. Likewise, the first voyage to Mars must include the full complement of space exploration elements for a landing on the surface.

At the moment, NASA is considering a "human Mars orbital mission" and exploration of "interim destinations," such as the Martian moons Phobos

Astrobotic Technology

▲ **A commercial lunar lander in an artist's** rendering from one of the nine companies that NASA selected to participate in its Commercial Lunar Payload Services program.

and Deimos, before sending a separate mission to land on the surface, according to the September "National Space Exploration Campaign Report."

This approach should be truncated into a single mission that would reduce overall risk while saving time and resources. NASA could do this by combining lessons from future moon missions with the confluence of five major thrusts, or drives:

Drive 1: Mission elements

Over the years, NASA and human exploration advocates outside the agency have deliberated over whether to concentrate on going back to the moon, on to Mars, or do something with asteroids, or perhaps a little of each. Technology projects were started, so that no matter which way the political whims directed, NASA would be ready to explore. Because of this strategy, the necessary space exploration elements of a human mission to Mars are in various stages of build, design and study. Exactly how these elements would be connected in a physical or thematic sense remains to be fully defined under the current plan, which calls for returning astronauts to the moon as a proving ground for a later mission to Mars. Nevertheless, the elements are as follows:

- NASA's Space Launch System rocket, poised for its first flight in mid 2020.
- The SLS-launched Orion capsule with a European-supplied service module.
- A deep space habitat for the crew of a long-duration transfer vehicle.
- A propulsion and power tug for long-duration deep space transits
- An entry and ascent vehicle for landing and launching.
- A surface crew vehicle and systems for surface life support.

For long-duration flights away from low Earth orbit, there are still two major issues of concern centered on crew health: One is exposure to radiation outside of Earth's protective magnetosphere; the other is lack of gravity.

Drive 2: International partnerships

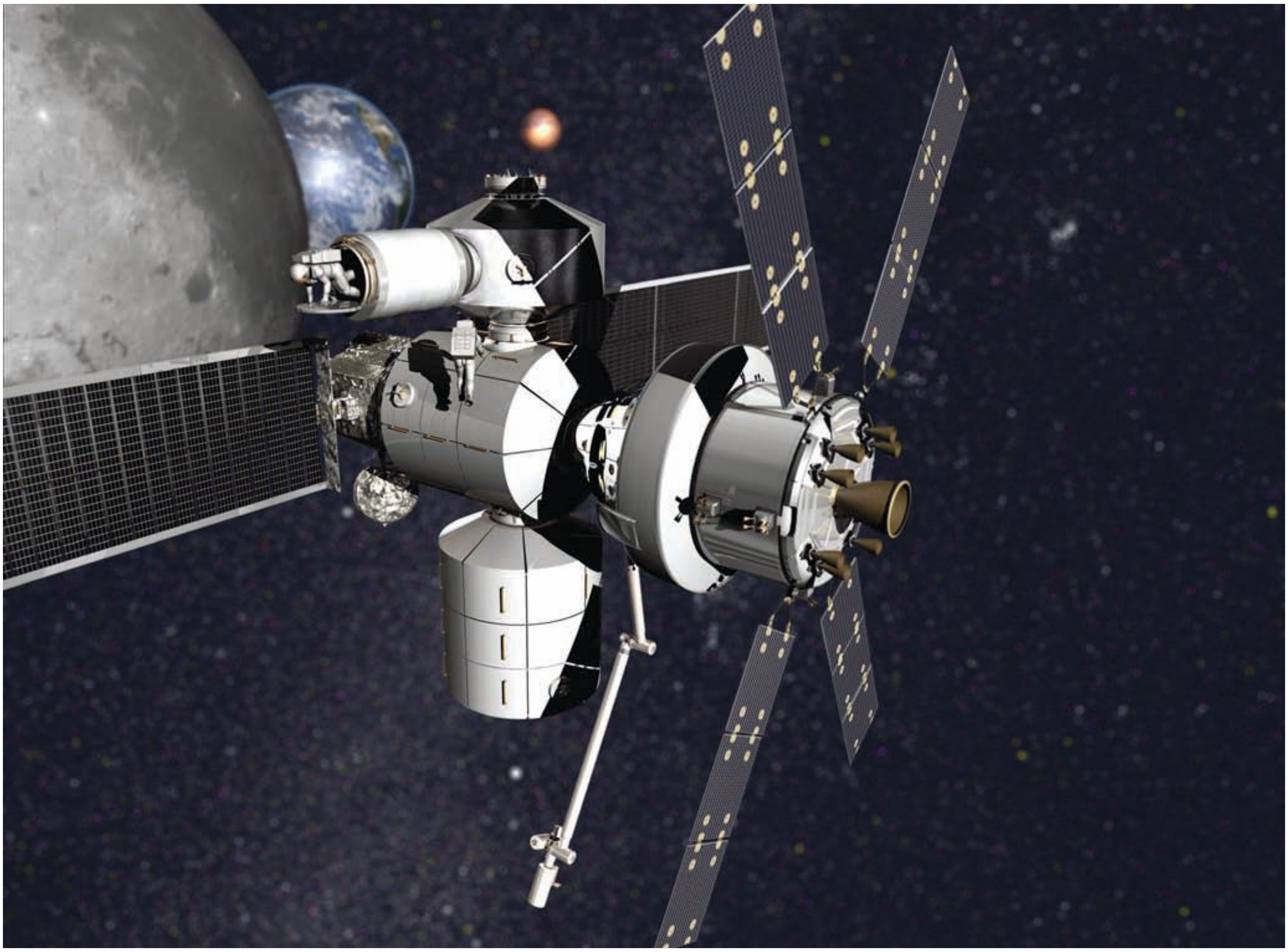
Most countries want to get more involved in space exploration, starting with the moon and someday extending to Mars. Government partnerships bring much needed expertise, capability and resources. NASA should integrate this vital asset into a tightly focused Mars program. Along the way we would learn more about the moon, its history and the resources it can yield.

Drive 3: Commercial partnerships

Also critical will be partnerships between NASA and commercial businesses, beginning with the moon. For NASA, private companies would bring new technologies and improved living conditions for explorers there and ultimately on Mars. Companies would realize several benefits: They could win future contracts from the U.S. government and perhaps other governments. They would have the opportunity to create new lines of business, including for materials mined from the moon and someday Mars, and products manufactured on the moon or in its orbit. A whole new industry of tourism on the moon, and possibly even Mars, could result. There could be hotels on the moon; exploration trips; a rail tram that one day goes all around the moon. Maybe most importantly, each company would earn the stature that comes from being a high-tech, space-exploration-oriented firm.

Drive 4: Lunar stepping stone

The moon, in NASA's latest plan, is no longer in competition with Mars; it is now an aid. The NASA Transition Authorization Act of 2017 specifies that NASA should consider "the applicable enabling aspects of the stepping stone approach to space



Lockheed Martin

▲ **Conceptual art of a** deep space habitat

exploration." The moon, in this analogy, would not be a stepping stone toward Mars in a geographic sense, but in the strategic sense as a place relatively close to home where we can demonstrate "the proficiency of specific capabilities and technologies," as the act says. In other words, we have the moon to use to get to Mars.

Drive 5: Public support

Currently in every sector of the American society (if not the world), I detect a slow buildup of excitement about robotic and human space exploration, particularly of Mars. Politically, space exploration is one of the few bipartisan subject areas in the U.S. Congress. This is very critical since a full Mars exploration program to be done correctly will need much more funding for continuing operations than is now envisioned, and our citizens must be behind a significant budget for Mars. Reaching Mars can be accomplished with a flat NASA budget, but exploring Mars will need greater considerations. At the same time, NASA needs to manage a full Mars program in a cost-effective way. What is this return on this public investment for the U.S. citizen? Most significantly, it is long-term national pride — an irreplaceable, generational value.

These five forces can produce a synergy to deliver an extensive Mars exploration program. The question is: How to get started with minimum risk to assure continued application of the required drives?

Reducing risk and budget

Risk could be substantially reduced by carrying out the first human mission to Mars with the same hardware, software, systems and procedures established for a lunar base, wherever possible. We are lucky to have the moon as a quasi-Mars test platform. Ideally, missions to the moon and Mars would be designed with identical versions of the space exploration elements listed above. The transfer vehicles could be flown in the same configuration, right down to the amount of fuel that's carried. If there were unused fuel, this could be put in storage in orbit around and moon — perhaps at the planned Lunar Orbiting Platform-Gateway, a proposed space station for lunar explorers. The transfer vehicle would fire retro rockets to enter into lunar orbit and make preparations for a landing. A precursor mission (or set of missions) would have already landed robotic ships on the moon with supplies and the start of some infrastructure needed for about an eight-month stay. One of these ships would be a launch vehicle

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to get the crew back to rendezvous with the orbiter. Another ship on the surface would be dedicated to carrying stored fuel. The infrastructure would include a surface habitat supplied by a partner and ways of making air, food, fuel, water, energy and parts. The moon has no atmosphere and Mars has very little atmosphere, so the entry and landing system should not rely on any atmosphere of the target body. This abides with the NASA space exploration theme of providing a set of vehicles for most of the small solar system bodies to be explored.

Eventually, an international partner would take over that lunar base and continue building and providing much science and exploration. There could be a Japanese base, another one for the European Space Agency and perhaps a third for another partner. Another base could be built by a commercial company or two. These bases would be funded by the corresponding partner from the start. Thus, with no spending of its own on the bases, NASA would nevertheless gain the opportunity to practice the same base establishment operation that will need to be done on Mars. The partners would get a "free" ride to the moon, and NASA would get a continued refinement and improvement of this base establishment process along with needed technology and processes to produce air, food, fuel, water, energy and parts.

This would allow the risk for the first human mission to Mars to be reduced by at least an order of magnitude — perhaps more. The closer the lunar base formation process is to what would be used for Mars, the lower would be the risk. Many of the crew members who help establish the lunar bases could also participate in the first Mars base establishment unless health reasons preclude them.

If this strategy were to begin in the early 2020s, a first landing/base formation mission to Mars could be done in the early 2030s.

This risk-reducing strategy means it is not necessary to follow the Apollo precedent of first sending orbiters with human explorers, as was done in the Apollo 8 and Apollo 10 missions that preceded Apollo 11. The Apollo 8 mission was, in part, a political move, but a proper one, since that was the first time a human was influenced by the gravity of a body other than Earth. We had to build confidence in the celestial mechanics capability and flight hardware. This was further enhanced with the Apollo 10 mission, which included lunar orbit insertion, undocking, orbital maneuvers, rendezvous and re-docking. We achieved those things on Apollo, so we have become celestial travelers and there is no need to duplicate them at Mars just to verify it can be done. Also, since the moon is only two to three days away, it made sense to take it one step at a time; not too much time was needed compared to taking these steps with Mars, which has a one-way travel time between six and nine months, more akin to 10 weeks of Columbus' journey.

Learning to survive

As lunar bases are built up with the international and commercial partners, NASA could conduct extensive environmental control and life support system improvements and address long-term deep space effects on the human body. The most detrimental effects are due to radiation outside the Earth's radiation belts and the lack of gravity. NASA could place the proposed long-duration habitat, which would have the required radiation protection and provisions for artificial gravity in high Earth orbit. A crew could occupy this hab for a year. Although this would not be the exact conditions for the long trip to Mars, it would lend a verification lab to gain confidence that the long-term exposure and trip to Mars can be done with known effects on the human body.

Once a "good" hab is established, it would be wise to have a spare hab in space for use in transfer to and from Mars in an emergency, akin to Columbus' multiple vessels. It's worth noting that weeks after reaching the "New World," his command vessel Santa Maria ran aground on the coast of Haiti and had to be abandoned. Columbus left 39 men behind and sailed back on La Niña. This first voyage started the long series of exploration voyages that opened up the New World. Now it's time for us to "open up" a new planet. ★

Mike Helton is a retired aerospace engineer and a senior risk manager. He worked on the Apollo program for North American Rockwell and on early versions of the space station concept. At NASA's Jet Propulsion Laboratory, he worked on unmanned missions including Mariner 9, Pioneer 10 and 11, and Galileo; and he worked on Earth observing programs including Landsat and Seasat. He has taught classes in risk management.