Stepping Stones to Mars – A New Strategy, by James Oberg
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For more than thirty years, the only human space voyages have been going round and round, in the region of space called Low Earth Orbit – perhaps 500 kilometers above Earth's surface. Voyages beyond this zone, back out to the moon and ultimately farther, will require surmounting barriers both technological and conceptual.

Yet however hard it was to send astronauts to the Moon, that world now looks practically in Earth's back yard, in Solar System terms. Mars is so much farther away, needing so much faster and long-lived spacecraft, and so much more persistent political commitment, that the very idea of a human Mars expedition (and of its budget) has grown more intimidating year by year.

Early in 2004, the White House released a 'Vision for Space Exploration', a long range commitment to venture again beyond LEO, out towards the Moon and beyond. It was an inspiring vision, but how it would be accomplished took a long time to come into focus – and then it looked, in one official's words, like "Apollo on steroids".

By coincidence, a new strategic approach to space exploration – a piece-by-piece "bite size" plan that incorporates and expands on similar earlier suggestions – had been under development, and in 2005 appeared in public. The engineering and cultural challenges of sending astronauts to Mars are broken into segments that still provide significant scientific and political payoffs. A consensus is forming – this still poorly publicized approach might just be 'do-able'

There are useful historical analogies. Only on his third voyage to America did Columbus actually reach the mainland, replicating a pattern of voyaging set by the first Norse explorers of Vinland and precursing the pattern of later European voyages to Antarctica. And all these trans-oceanic voyages had been preceded by smaller expeditions to islands just off the European coast.

For other worlds, in a sample size of one, the same pattern holds. Only on the third manned flight to the moon, and after two dozen sorties into low earth orbit, did Apollo astronauts actually attempt the landing.

Reasoning both by analogy and by unique Martian logic, for decades some space planners have recommended that the next human expeditions beyond low earth orbit scout out the 'offshore waters', then nearby islands, and only then aim for Mars. And the first spaceships sent there would not land on the planet itself, but rather go into orbit around it and visit its two small moons Phobos and Deimos.

Step by step

Now a new strategy has emerged that lays a concrete theoretical foundation for such a step-by-step approach. The arguments are no longer by analogy, or from aesthetics and instinct – they rest on solid reality.

Wesley Huntress, emeritus space scientist for NASA, President of the 'Planetary Society', and now director of Carnegie's Geophysical Laboratory in Washington, DC, had originally disclosed details of the new study in his testimony before the Senate committee overseeing space, in October 2003.

"America has the right stuff, but today's human space flight program isn't giving the public what it wants," he began. "The whole point of leaving home is to go somewhere, not to endlessly circle the block."

Huntress described a private effort he was then involved in, under the auspices of the International Academy of Astronautics, called "The Next Steps in Exploring Deep Space". Its purpose, he explained, "is to provide a logical and systematic roadmap for the long-term scientific exploration of the solar system beyond low Earth orbit with a goal to land humans on Mars sometime in the next 50 years." The study, he continued, "envisions the establishment of a permanent human presence in space using an evolutionary approach to the development of space transportation infrastructure utilizing well-defined intermediate destinations as stepping-stones to Mars."

Space history already shows us two extremes of 'space strategies'. At one end is Apollo, a magnificent science mission whose infrastructure collapsed immediately after it had provided brief access to the lunar surface. At the other end is the International Space Station, which has offered magnificent promises that have been delayed year after year by the need to assemble immense infrastructure prior to beginning significant science returns.

In the most common conceptions, a human mission to Mars would be "the worst of both worlds" -- an "ISS-class" infrastructure in the extreme, with many, many years (stretching over several different presidential administrations) of hardware development and testing prior to the return of the first science, and ending soon afterwards.

A set of destinations

However, this new study describes a more attractive approach. It identifies several specific "destinations" beyond LEO but short of the ultimate Mars landing. First is a 'gateway' zone at the Sun-Earth Lagrangian Point 'L2' (about 1.6 million kilometers 'down sun' from Earth). Then are sorties to one or more of the small asteroids known as 'near-Earth objects'. Next are visits to the two moons of Mars, Phobos and Deimos. Reaching the surface of Mars is at the limit of its vision. "There is no single destination for human exploration, as was the case during the Apollo era," the report explains. "There is a set of destinations that is scientifically and culturally compelling."

In this view, such as approach is not only technically superior to an all-or-nothing Mars landing mission, but is more practical in political terms. "We assert that a 'brute force' approach that would jump directly to Mars from our current limited human capability in low-

Earth orbit is untenable," the report stated, "and that the annual investment and mission risk required for such a leap are simply too great to be tolerable in today's environment."

Instead, the report calls for "a logical series of steps that will lead humankind progressively deeper into the solar system and ultimately to Mars, with significant scientific discoveries possible at every destination along the way." Each step, taking a number of years, will bring its own rewards: "[I]n the process, they provide important opportunities for scientific discovery while they stimulate the development and validation of the infrastructure to support permanent human presence throughout the solar system."

According to Huntress, the intermediate destinations "comprise a progressive approach to the long-term objective", the surface of Mars. "There is a logical progression to successively more difficult destinations," he explained. Each new destination has value on its own, and is "scientifically and culturally compelling" in the words of the final report.

And in one of the study's most innovative creative leaps, for each step, the development of only one fundamentally new type of space vehicle is required. "This approach requires incremental investments to maintain progress, rather than huge new budgets," he explained to the Senate committee. It would allow the program to exist under a relatively constant 'budget roof', not requiring peaks (and valleys) or roller-coaster funding.

Bite-size chunks

Buzz Aldrin, Apollo-11 moon walker, believes that breaking a "20-year space plan" into bite-sized chunks may also offer profound political advantages. "You have no idea how important I really believe [this approach] to be," he told me. Because space goals are set by whoever is in the White House, he believes that "we should design a series of four-year programs" as part of long-range strategy. From time to time, he continues, "you may slide some of the objectives due to delays, wars, politics – but you can't slide who makes the decisions, and that's the President." Projects with well-defined short-term goals would be politically much more advantageous than one big project with a far-distant single goal.

How do we get there from here? How do we fulfill the fundamental truism expressed in the report, that the "critical first step in a long-term program of human exploration of the solar system is to finally get out of low-Earth orbit." And this is not to say that we would abandon that region, since the International Space Station will be operating for decades even after Space Shuttle missions complete its assembly about 2010-2011.

Going to L-2

The ISS can be useful for research and testing, but despite NASA's initial claims it cannot serve as a jumping-off point for more distant missions. "Its orbit inclination creates a severe penalty for station-launched missions to the Moon and planets," Huntress explained, referring to the sharp north-south flight path necessitated by making it accessible to Russia's spaceports. Combined with a crippling 25-30% performance penalty of US space shuttles launched into the station's inconvenient orbit, these considerations guaranty it will remain a space voyage dead end.

In contrast, the IAA study focuses first on a region of empty space as the first human destination beyond LEO. It is located about 1.6 million kilometers from Earth (four times the distance to the Moon), away from the Sun, and is designated “SEL2”, or Sun-Earth Lagrange-2. It is a gravitationally ‘neutral zone’ where spacecraft are metaphorically swept along in the gravity wake of Earth, and thus can maintain position there at very little cost in steering rocket firings.

Space astronomers have already had their eyes on this region. This is because of the unrestricted view of most of the celestial sphere, and of the benign thermal conditions (no rapid day-night cycles as in LEO), and of the uniform gravitational forces that allow widely-scattered spacecraft to maintain very precise relative positioning. NASA’s Webb Space Telescope will be located here, as well as its Constellation-X and Terrestrial Planet finder instruments. The European Space Agency is developing a range of observatories – named after scientists Herschel, Planck, and Darwin – that are also to be deployed in this region.

These scientific instruments are all self-contained, unlike Hubble, and they have been designed to operate untouched by human hands. But in years to come, as these pioneering SEL2 telescopes uncover new secrets of the Universe, the need may grow for human servicing and even human-assisted deployment and calibration for follow-on instruments such as those now being imagined to map the surfaces of extrasolar planets.

By lucky coincidence, this region also offers a unique view of the Earth. The angular size of Earth at this range is nearly the same as that of the Sun, providing properly positioned observatories with a continuous annular eclipse that backlights Earth’s atmosphere whose profile can be monitored. And since objects in the zone are not really in orbit around Earth, they can transition from it into orbits around Earth with ANY desired inclinations, to access, inspect, repair or otherwise control any object in Earth-moon space.

Getting there

A human mission to SEL2 would involve launching a spacecraft just a little faster than the Apollo missions during the Moon Race, and would take about 15 days to get there. The velocity change, or delta-V – the propulsion maneuver – to stop in the zone, and later to depart it for the return to Earth, would be about 20% greater than that needed by Apollo-8 in December 1968 to enter lunar orbit and then head back to Earth a day later. In hardware terms, this would take a rocket just a bit more powerful than Russia’s ‘Proton’, perhaps a souped up version of the new generation of Delta or Atlas boosters now entering the US inventory. It would NOT need a massive Saturn-V-class behemoth from the Apollo days.

“What is being proposed is wonderful,” noted Apollo-14 moon walker Dr. Edger Mitchell. “We need to be doing something like that – but we have to find enough excitement at any given mission to make it fun, to make it self-motivating.” Although the main purpose of going to SEL2 would be just to acquire capabilities and knowledge, Mitchell told me it would be important to add enough ‘sizzle’ to make such a mission attractive.

The IAA plan calls for the development of a crew-carrying spacecraft with capabilities similar to those of an Apollo command module, or perhaps an upgraded Soyuz or Shenzhou vehicle. This capsule would end its mission by aerobraking in Earth's atmosphere. In many ways this vehicle resembles some proposed variations of NASA's new 'Crew Exploration Vehicle', or CEV – the designated successor to the space shuttle.

The US would also have to build a reusable 'Service Module' for the propulsion and power. Between missions, this vehicle would be parked in low Earth orbit. There, it could be serviced and refueled. As mentioned, the step-by-step goals have been selected because each NEW step requires the development of only a single NEW spacecraft, along with evolutionary upgrades of vehicles already developed for earlier steps.

Furthermore, such a new spacecraft opens a multitude of doors. Once Earth builds a spacecraft for human access to SEL2, small modifications could also support missions to lunar orbit, or for servicing of constellations of communications satellites in 24-hour geosynchronous orbit – the delta-V and mission duration requirements are similar. It could also serve to support later human lunar landing missions, if this goal were selected.

Huntress explained to me why the IAA plan prefers a first step so different from any other strategy yet developed. "SEL2 only makes sense if you know you're going many times," he admitted," and it's NOT what you'd do if your only intent is to do it once or several times."

NASA plans, in contrast, looked at basing in the Earth-Moon L1 point. "It's closer, it's in the line-of-sight of the Moon," Huntress explained, "but when you look at the energy requirements it is NOT the best place if you're going to go elsewhere."

Surprisingly, this IAA strategy does not require a lunar landing phase on the way to Mars. Huntress had testified that the Moon itself "is not necessarily on the critical path to Mars," and the draft report elaborated on this theme: "The Moon is a destination with important scientific and cultural benefits that make it worthy of human exploration," it stated, "but from a technical standpoint it is not necessarily in the critical path to Mars." Furthermore, it continued, "it is debatable to what degree the development of tools and habitats for the Moon will provide substantial benefits to eventual Mars exploration. . . . [T]hey require development of surface exploration capabilities that may be substantially different from those required for Mars."

So there could well be good reasons for humans returning to the Moon, the report concludes – but preparation for Mars is not among them.

Gateway post to the asteroids

The term 'gateway' as applied to the SEL2 zone means that objects parked there – and it does take significant propulsive energy to get there – can trade that energy back in to be applied to pathways to other destinations. A vehicle could depart SEL2, dive back towards Earth, and while swooping by it, fire its engine again to attain an extremely efficient escape trajectory.

Because of this initial energy advantage, vehicles departing for more distant destinations would not face an excessively challenging velocity requirement. They would be easier to build, since much of the preliminary work would already have been accomplished just to get to SEL2.

For humanity's first sortie beyond the Earth-Moon system, Huntress and the IAA team had a consensus – visit a passing asteroid: "There is no doubt that a one-year human mission to a Near-Earth Object [NEO] would serve as an excellent intermediate step before any mission to Mars," he told the Senate Committee five years ago. The full report elaborated: "NEO's are ideally situated to provide an important stepping-stone to Mars. They are accessible with flight times that are intermediate between SEL2 and Mars, and will provide us with an opportunity to exercise many of the required transportation elements in a relatively low-risk manner."

Again, the notion that the next solar system object to receive human footprints could be a small asteroid is not new, but the study provides novel justification for it. Reaching an asteroid and spending several weeks exploring it (but not 'walking' on it – its gravity would be far too low) would provide a double bonus – a stepping stone for farther travel, and an immediate object of intense scientific and practical interest.

There are powerful reasons for stand-alone interest in these particular objects. For planetary geology, determine if these are burnt-out comets with surviving residue of very old ice deep inside. For resource exploitation, find out if they contain materials susceptible to in-place industrial exploitation, from water to perhaps metal ores. And for the ultimate 'down home' justification, for threat mitigation, determine what is their typical consistency and internal structure, and how they would it react to propulsive forces designed to alter their orbits.

"I find it a very refreshing approach," noted Apollo astronaut Rusty Schweickart. "I am especially supportive of their recognition of the critical role asteroids will likely play in our future in space." The incremental approach also appealed to him: "The step-by-step logical progression leading to real capability for human presence in deep space will also be more attractive to the public than one-shot grasp for a human Mars landing."

"Much of the required investigation can be done robotically," the IAA report concedes, "but it may ultimately be important to enable human explorers to use their powers of observation, intuition, and active testing to fully understand the detailed physical nature of NEO's and to validate impact mitigation techniques."

An important feature of NEOs that argues for the advantage of moving directly to human on-site presence is the very long time between revisits. This is at first counter-intuitive -- these objects are 'near' Earth, with orbital periods very similar to Earth's. But 'launch windows' only occur at intervals in which two objects 'lap' each other around the sun – and if their periods are very similar, that 'overtake interval' can be a decade or more.

In practical terms, this feature offers little chance of robotic precursor missions to provide data that can be studied leisurely while planning a subsequent human visit. If there is a window for a robot mission, this means that the next window for astronauts could be many, many years in the future. So instead, once an asteroid is selected as a target for a human mission (based on observations from Earth), small probes could be dispatched on faster trajectories, to arrive a few weeks or months prior to a human crew already on its way.

Bridge to Mars?

“By far the strongest imperative for human missions to NEO’s arises from consideration of their utility as an intermediate step to Mars,” the report argues. “Their locations and physical characteristics will stretch the capabilities of human exploration just enough to greatly reduce the risk of the Mars missions to come. NEO’s will thus play an important architectural role as a bridge between Earth’s neighborhood and Mars.” And later, if the choice at Mars is to first visit its moon Phobos, “a precursor mission to a near-Earth asteroid would allow demonstration of almost the entire mission at a destination closer to Earth, with ample solar power availability, high communications rates, and relatively short return-to-Earth flight times that provide an extra measure of safety.”

In plotting the paths from Earth to asteroids and back, one has to ask just how hard is it to get from ‘here’ to ‘there’. It turns out that this questions depends on how you define ‘here’ (that is, where near Earth will you start from) and ‘there’ (which asteroid do you want to visit?). This IAA study provides a revolutionary definition of what ‘here’ means, and thereby greatly facilitates the transportation challenge. Here’s why:

Numerous studies have been made over the past three decades of round-trip missions to passing asteroids., with the total delta-V and total flight time calculated. They all start in the familiar ‘low earth orbit’ where today’s space station flies. For long flight times – on the order of two years or more – there are numerous opportunities that require only 6 to 7 km/sec delta-V added to a vehicle in LEO. For missions under one year duration, the delta-V requirement goes up to the 9 to 10 km/sec range or higher.

Mission requirements

This is a pretty big challenge. In comparison, an Apollo lunar orbital mission required about half that much -- 4.6 km/sec delta-V (from both the Saturn S-IV-b upper stage and the Apollo’s own Service Module). This Apollo figure compares to the delta-V capability of the space shuttle orbiter of only one tenth that amount, or the multi-spacecraft Apollo lunar landing and return delta-V of about twice that amount. A round-trip mission to Mars orbit (not landing) is estimated to require a little less than twice that amount (about 7 km/sec). All of these high-velocity missions required multiple vehicles with very high fuel-to-payload rations – a daunting engineering and funding challenge.

To underscore this, here’s a ‘typical’ asteroid visit-and-return mission. The target would have been asteroid 1982DB, and the vehicle would be launched on Feb 12, 2004. It could spend a month at the object and return to Earth with an expenditure of only 7.5 km/sec – but the mission duration would be 986 days. Flights of less than a year are possible but only at delta-V costs of 13 to 14 km/sec. At best, perhaps, asteroid 1991JW would allow a May 16, 2009 launch, five weeks at the object, and a return after 363 days, all for a delta-V of 5.9 km/sec. But figures in the 9 to 11 km/sec range are much more common.

In the face of this formidable delta-V challenge, the strategy proposed in the IAA report is to stage such a mission from the SEL2 gateway. There, reusable space tugs initially developed for access to that point can deliver the asteroid-bound space vehicle and, in the end, its crew. The energy required to assemble the vehicles here is acquired piecemeal through reusable tugs over a period of months, and is then expended efficiently during a brief launch maneuver in which the total required delta-V has already largely been 'pre-invested'.

As a result, in a typical 1-year mission (to asteroid 1999AO10 in 2025), the additional delta-V is only 5.5 km/sec from the SEL2 point. By changing the meaning of 'here' from low-Earth orbit right at the edge of Earth's deep gravity well) to the SEL2 gateway (way out on the 'lip' of Earth's gravity field), the 'next step' becomes much more manageable. The mission isn't free – this isn't trajectory magic – but the steps are much more 'bite sized'.

The interplanetary transfer vehicle

Since the flight time increases from a few weeks to many months, neither a modified Apollo vehicle nor the SEL2 human-access spacecraft could keep a crew alive long enough for an asteroid round trip. So the elegance of the IAA plan pays off again. Following the principle of 'one major new vehicle per step', it calls for development of an 'Interplanetary Transfer Vehicle' to carry a crew for a long mission (a year or more) with a delta-V capability of about 6 km/sec (to be increased to 8 for later Mars missions). This spacecraft "is most significant development that will be required for this step," the report states. "This will represent a substantial investment and must be designed with the ultimate destination (Mars) in mind."

In terms of hardware, designers would be looking at a booster perhaps half the size of a S-IV-B upper stage from the Apollo era, and a human spacecraft no heavier than the Apollo multi-module combo of Command/Service Module, Lunar Module. We know how to design and build something like this.

The vehicle's engines will use tried-and-true chemical propulsion. "Although there are certainly other propulsion technologies that can provide better performance, at least on paper," the report explains, "in our view the risk and expense of those developments would only serve to further delay the first human journeys into the solar system." As new propulsion technology comes on line later, it would only enhance transportation capabilities already pioneered by these vehicles.

The report does not expect there to be only a few missions to a few asteroids, and then a cessation of such exploration. The missions would likely continue and expand in scope and sophistication, independent of Mars activities. Different types of asteroids would be visited, so the full range of geology, mineralogy, and internal structure could be assessed. But once the initial year-long asteroid sorties had validated the life-support hardware, the next big interplanetary step becomes feasible.

So, with the first two stepping stones now achieved – SEL2 with its fleet of science observatories, and the variety of passing asteroids now also within reach – and with a Mars landing the ultimate goal, where next will human footprints be planted?

Falling back upon the design principles of the IAA strategy, it's clear that the last step is still too great a leap. Too much remains to be designed and built, and too much material (shelters and equipment and supplies) needs to be sent towards Mars, to be accomplished under the relatively constant level of funding and engineering challenges envisioned.

Cargo

So in the IAA plan, one other major space vehicle is needed even before the new human Mars landing craft itself can be built. This final intermediate step is to develop hardware to provide a means to get large cargoes to distant destinations where future astronauts can use them. As the report states, "a robust cargo delivery capability is a key element of a sustainable human exploration program." In more human terms, this means that techniques used by polar explorers a century ago now show the way to Mars – emplacing significant caches of supplies along the routes to be taken, so when the human travelers finally make the trip, they are not overburdened with life-critical baggage.

"The principle of separating crew and cargo makes it possible to view the transportation challenge in a new way," the report explains. The key to doing this economically is to realize that inert cargo isn't in as much hurry as people.

This plan suggests developing high-efficient low-thrust engines – probably powered by nuclear reactors – to send most of the mission's cargo out ahead of the crew. This concept, again, isn't unique to the IAA study, but it is in keeping with the study's philosophy: "Only one major new capability is required for each step, coupled with evolutionary progress in existing capabilities."

"Our philosophy of incremental development as a means of managing cost and risk suggests that a human mission to one of Mars' moons, Phobos or Deimos, may be an important precursor to a mission to the planet's surface," the report continues. As the next stepping stone, this mission would be launched from SEL2 back near Earth, use crew transfer vehicles tested on asteroid missions, and would rely on finding major components and supplies already waiting for the astronauts when they got near Mars.

To Phobos?

Dr. Fred Singer, now in his 80's, was a pioneer in the development of rocket and satellite technology, and was the first director of the US Weather Satellite Service, now NOAA (Dept. of Commerce). Among his lifelong space science interests has been a passion for human missions to the martian moons. "I've personally been concerned with Phobos and Deimos for last 40 years," he told me.

"The moons are not too difficult," he explained, and "the main reason is because their landing velocities are zero. They are actual space stations in Mars orbit, you just tie up." His proposed research program, named 'PhD' (after PHobos-Deimos) pioneered the concept that it was worthwhile to make an interplanetary journey while not actually landing on Mars itself. Now the IAA strategy has endorsed this viewpoint.

Phobos has value both for future Martian missions (is there extractable water there? Can a radiation shelter be built using local regolith?) and intrinsically (what is its origin, and when will it fall onto Mars?). And if a handful of ‘martian meteorites’ have been recovered on Earth, they must have left Mars in great numbers and many would have impacted on Phobos, for retrieval by explorers.

Being close to Mars has many scientific advantages. “The removal of the light-time delay to Earth would make it feasible to actively manage experiments and react to discoveries,” the IAA report points out, “thus helping to define the role of humans when they eventually reach the surface.” A human-in-the-loop real-time control of the recent twin Mars rovers, for example, could have increased their surface speed by a factor of 50, and allowed the months of science investigations to be accomplished in a few days. Instead of creeping along at inches per hour, and taking days to properly align instruments over rocks of interest, surface rovers (as well as flying vehicles) directly controlled by people on Phobos could operate at astonishing speeds and thus harvest even more astonishing results.

With refueling on Phobos, spacecraft based there can make sorties into lower orbits around Mars to rendezvous with robot payloads sent up from the surface with carefully-collected samples. Such samples can initially be studied and catalogued in the habitat imbedded safely under the radiation-shielding dirt of Phobos.

Astronaut James Lovell, how orbited the Moon on Apollo-8 and flew past it on the failed Apollo-13 landing mission, sees no psychological problems with an expedition that goes all the way TO Mars, but doesn’t land ONTO Mars. “That would be well accepted by the public,” he predicted, and as for the crew, “their attitude would be fine.”

“They would feel they were the pioneers who were the first to reach Mars,” he speculated, based on his own crew’s experience in circling the Moon without landing. “They would be elated, they’d be satisfied – as we were.” Despite the long trip, he continued, they’d be happy to play a part in what he agreed was a logical strategy: “I concur – it has to be step by step,” he told me, “you have to build on previous experience, and each advance relies on past work.” And the work of the humans who only orbit Mars will lay the groundwork for the next big step.

Colonel Buzz Aldrin, who was on the first mission to walk on the Moon, agrees. “I want to be strong about emphasizing that we should not be in a hurry to go the surface of Mars,” he told me. “We can go to its moons,” he continued, “and we should go down to its surface only when we’re ready to work for permanent presence there.” As an astronaut, he admits that “being that close to Mars could be frustrating,” but if your primary mission is setting up a shelter on Phobos, it’s plenty satisfying.

How soon?

How long will human visitors to Mars have to wait before going down to the surface? Some of the constraints of space travel give clues.

Opportunities to fly from Earth to Mars open up about every 26 months, the ‘interplanetary window’. The window after the first human Mars orbit mission is too soon, and probably the window after that, too, since the discoveries and the equipment operational experience will need to be studied in the fabrication of the next new space vehicle, the surface lander (and returner!).

“Having completed exploration Steps 1, 2, and 3 prior to the first mission to the surface of Mars, a large suite of very capable hardware elements will have been developed,” the IAA report states. “These will have been progressively evolved through each destination, so that by Step 4 the common elements should have the required capabilities. There will, however, be a large number of unique elements that are required for the Mars surface mission.”

Funding their development, and testing them – including space tests, perhaps near the Moon, perhaps even at Mars – will take a long time. It could be a decade or more between the arrival of humans at Mars, and the first human footsteps ON Mars.

The logic of this strategy may be persuasive, but as of now it still goes counter to ‘conventional wisdom’. For many spaceflight theorists this ‘stepping stone’ approach is nothing but an overcautious temptation that distracts from the main goal, Mars itself. Instead, it replaces it with what could become a series of ‘stumbling blocks’ that would bankrupt a space budget and stretch out flight schedules beyond the attention spans of the public and political leadership.

“Besides”, goes the main objection, “who could imagine going tens of millions of miles to look down on Mars only a few thousand miles below, and then turn around and head back for Earth?” As it turns out, many people can – and their arguments in favor of such a strategy have gained both new urgency in light of the ‘New Space Vision’ from the White House, and new credibility with the development of carefully designed and rigorously quantified strategies.

“Some crewmember candidates will say ‘If I spend years in preparation and then a couple of years in space, I must go to the surface to justify my time investment’,” pioneering space station astronaut Owen Garriott has admitted. But he suspects that other potential crewmembers would not: “Other fully qualified candidates will be just as anxious to contribute to this magnificent opportunity to make a meaningful, early contribution to our exploration of the solar system and to the Mars vicinity,” he continued. “This is a case in which ‘self-selection’ provides a quite valuable discriminator.”

Garriott appealed to historical precedent, to which he was a direct eyewitness. “Consider selection of the early Apollo crews in the 1960s,” he explained. “Probably everyone in the Astronaut Office would have wanted to go to the moon's surface. But some more than willingly accepted roles in lunar orbit or in LEO, or as back-up crews which were essential to the moon landings, or even reached for other important objectives, as in Skylab. I would expect Mars to be a similar situation.”

And considering the length of time between the first human missions to the martian moons and the actual first footsteps on the martian surface, there might even be time for some of the early crews to return to Earth and spend a few years retraining for the landing mission itself.

Building capacity gradually

The details of that final step is another topic entirely, since what is most innovative about the new strategic plan is how people get to that point. “This architecture gradually builds capability to explore the solar system through a series of carefully selected steps, each one designed to eventually enable humans to reach the Martian surface,” the IAA study concludes. “This by no means implies that the first human mission to the planet will be easy. Even with the significant investments made in the earlier steps, this fourth and final step will be the most challenging, and the time at which we will be ready to undertake it is uncertain. Ultimately it will be the continuing sense of exploration, along with the scientific discoveries and technical progress of the preceding steps, which will sustain public interest and international political support and make human presence on Mars a reality.”

Looking back on the process of developing, critiquing, and disseminating the report, Huntress told me that the peer review process had been surprisingly smooth. “We received about a dozen reviews from all over the planet,” he explained, “and they were uniformly excellent.” In 2003-2004, Huntress presented the strategy at international space conferences in Houston, Bremen, Paris, and Vancouver, receiving “a uniformly good reaction.” He also stayed in regular touch with the ‘NASA Space Architect’ whose responsibility it was to develop long range plans: “Our interactions with NASA were very, very good,” he said.

“Our study is unique,” he continued, “in establishing goals, and then deriving destinations”, rather than past practices of picking destinations or favored hardware, and then shaping a strategy around them. “Hopefully,” he concluded, “our document will help.”