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Next stop: Mars

by Richard A. Lovett

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What will it take to plant booted feet on Martian soil? And what will it take to keep them there indefinitely? We set our sights on the Red Planet.

THE DREAM OF VISITING MARS is as old as the fantasies of sci-fi authors Edgar Rice Burroughs and Ray Bradbury, but it took a giant step forward in January 2004, when U.S. President George W. Bush announced America's intention of returning to the Moon, and using that as a springboard to the Red Planet.

The proposed U.S. program – still in its early design stages – kicks off with a series of robotic missions to the Moon, followed by more manned lunar missions around 2020. It also involves a new spaceship, called Orion, based on a combination of technology derived from the space shuttles and the venerable Saturn V – the booster used 38 years ago to launch Neil Armstrong, Buzz Aldrin and Michael Collins on their historic voyage to the Moon.

That's the Moon taken care of, but it's yet to be determined when the U.S. program is due to crank it up a notch and set its sights on Mars. With top priority and a liberal budget, it could be done within a decade – or it could take considerably longer before we have astronauts gaping at red-dust sunsets. "I think it's at least 40 years away," says Chris McKay, a planetary scientist with the U.S. space agency NASA's human exploration program at its Ames Research Centre.

Furthermore, there's currently a conspicuous lack of funding. The work is expected to proceed on a piecemeal 'pay as you go' basis, with funds extracted from NASA's normal operating budget, recently running at about US$16.4 billion. Yet nobody knows what a 40-year mission to Mars might cost. Estimates range from tens to hundreds of billions of dollars. To put this in perspective, this is considerably less than the U.S. has spent in Iraq, but is equivalent to 10 to 50 per cent of Australia's annual gross domestic product.

THE BIGGEST FEAR is that the program, ambitious though it is, will get bogged down on the Moon and never make it to Mars. But there are also plenty of other potential obstacles. Right now, we simply don't have the space chops we had 35 years ago, says Scott Hubbard, NASA's one-time Mars tsar, now a professor at Stanford University in California.

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To start with, we have to rebuild all that Apollo-era expertise, much of which has been lost as the scientists and astronauts involved have retired or passed on over the years. Space buffs dream that such a program will proceed with the same sense of urgency that characterised the Apollo project after President John F. Kennedy's 1961 pledge to put a man on the Moon by the end of the decade.

But that's unlikely. "A lot of my colleagues want to live in the past," says Hubbard. "That was a Cold War-driven effort, and is unlikely to be seen again unless there is some similar type of national emergency." Or perhaps an unequivocal discovery of life by one of our current robotic probes could give us the shove we need to make the journey to the Red Planet. "That would do it, too," he says.

Such a revelation would also quite likely spark an enormous debate about how we handle the newly discovered life. It's very unlikely the Martian life would have tentacles, bug eyes, or speak Klingon; more likely it would resemble bacteria. But Hubbard predicts the discovery would spark an international scramble over which country leads the mission. Meanwhile, he says, the airwaves would be filled with talking heads endlessly debating what the discovery meant. Had 'incompetent NASA engineers' somehow managed to contaminate our neighbouring planet with Earth life hitchhiking on their probes? Would the Martian bacteria kill us all if it somehow got back to Earth? Or is this simply the proof we've been looking for that we're not alone in the universe? Whatever the outcome, Hubbard's sure of one thing: "humanity would go take a close look – maybe with people in orbit at first and robots on the surface".

HIGH-PRIORITY OR LOW-PRIORITY, getting to Mars presents major technical challenges. Not only do we need the Orion launch vehicle, we also need a spacecraft capable of supporting astronauts in reasonable comfort during a nine-month-long flight. Then we need to land them on Mars, preferably without broken bones.

Currently, the easiest way to land small probes on Mars is to use air resistance to brake them from interplanetary speed high above the surface, then parachute down using airbags to protect against the thump of landing. This has worked fine for small probes, such as the current Mars rovers. However, with a bigger ship, we can still use the atmosphere for the first step (as we do on Earth for space shuttle descents), but parachutes and airbags alone aren't going to cut it to get us safely down: the atmosphere is just too thin. That probably means we're going to need rockets – and everything we're 'probably' going to need adds unwanted kilos to the spacecraft, which means many more kilos of fuel to get it there, and potentially back again.

But there might be a way to minimise all the heavy lifting. It's a bold plan called 'Mars Direct', championed by the lobby group, Mars Society, and its vocal leader, Robert Zubrin.

Mars Direct means just that: skip the Moon and go straight for the end zone. Furthermore, while many plans for a journey to Mars require a monstrous ship to carry all the required fuel, components and crew – a ship that is so large and complex it would need to be assembled in space – Mars Direct does away with this requirement in a most ingenious way. It does this by splitting the mission across two ships – both of which are kept to a minimum in size, weight and cost by foregoing the fuel necessary for the return trip.

Whoa. But this isn't a one-way mission. No problem, because we're not travelling to a total wasteland; Mars has ample indigenous resources which would allow you to brew your own fuel. "Shipping rocket fuel to Mars is like shipping oil to Saudi Arabia," Zubrin says. "In fact, it's crazier because it's much more expensive to ship rocket fuel to Mars."

The first phase of the mission consists of a robotic craft. It can be launched on a booster comparable to the old Saturn V, and carries the astronauts' return vehicle plus a small nuclear reactor. Once safely on the ground, it sends out a robotic rover, which deploys the nuclear reactor behind a hill, or a pile of rocks – anything that can provide rudimentary radiation shielding. An electrical cable then connects the reactor to the lander. The reactor then fires itself up – and the ship uses the electricity to manufacture rocket fuel by combining hydrogen carried from Earth with carbon dioxide extracted from the Martian atmosphere. The result could be thought of as a sort of nuclear-powered spaceship: the fuel simply serves as a battery to store a year's worth of accumulated nuclear energy.

More importantly, Zubrin says, you get 18 tonnes of rocket fuel for each tonne of hydrogen carried from Earth – a huge advantage since fuel for the return journey is a large fraction of the mass of a conventional carry-everything-with-you mission.

By the time the next Earth-to-Mars launch window opens, two years after the first ship departed, the return vehicle is fuelled and raring to go. Only now do the astronauts launch, again on a relatively small booster. "You don't need a Battlestar Galactica spaceship because the return ride is waiting for you on Mars," Zubrin says.

At the same time, another self-fuelling return vehicle is launched separately, so it can be preparing for a subsequent mission while the astronauts are still on the first.

HOWEVER, NOT EVERYBODY is on-board with Zubrin's vision. Hubbard thinks it's too risky. "I like Bob and applaud his enthusiasm," he says. But, "I think Mars Direct is a bridge too far…Bob's scenario piles a lot of what-if statements on top of each other."

He compares it to climbing Mount Everest without oxygen. We now know this is possible, but Sir Edmund Hillary took bottled gas. "There's taking risk, and taking foolish risk," Hubbard says. If nothing else, he'd like to see the Mars Direct approach tested first, with an unmanned probe, possibly on a sample-return mission. "That sets the stage for knowing what's reasonable."

Even some former Mars Direct believers have re-thought the scheme. One is NASA's Chris McKay. He still thinks Zubrin's self-fuelling lander might be the way to go when the time arrives, but he's reluctantly come to the conclusion that bypassing the Moon just doesn't work unless our only goal is a prove-we-can-do-it 'sprint' mission. If we're going to do more than touch down, look around, and say "far out," he's decided, we can't afford to bypass the Moon.

McKay and others have a whole shopping list of things that need to be done before astronauts will be prepared to leave their boot tracks in Martian dust. One is the boots themselves – and the spacesuits to which they're attached. We need spacesuits we can "wear like coats," he says, day after month after year: something a lot more manageable than the motion-hampering monstrosities of the Apollo era.

Another problem is the dust. Moon dust is nasty stuff, smelling like spent gunpowder, says Harrison Schmitt, one of the last Apollo astronauts, who had to breath it in each time he came back into his lander. Not only are there potential health dangers, but the fine grains also penetrate like graphite lubricant – though of course they don't exactly lubricate. "You have to protect moving parts," he says.

Steven Squyres, principal investigator for NASA's tremendously successful Mars Exploration Rover mission, has noticed the same thing on the Red Planet. "The dust is incredibly fine-grained," he says. "It's clingy stuff that's going to get into everything."

Luckily, it carries a static charge (that's what makes it so clingy), which means it should be possible to develop an electrostatic vacuum cleaner to get rid of it. Thus armed, Moon and Mars dwellers will simply have to be meticulous about dusting themselves off before going indoors. "You learn that in kindergarten," says McKay. "I don't think it will be a fundamental problem."

The durability of rovers is another issue. The timing of launch windows gives astronauts 18 months on the Red Planet before they can return. They're going to want a well-tested and robust rover that's guaranteed to not break down and leave them high, dry and immobile (perhaps something like the MarsCruiserOne, Cosmos 16, p32).

And on a more mundane level: they need a workable, portable drill for taking core samples and looking for fossils and water. "Harrison Schmitt tried to operate a two-metre drill on the Moon and ran into serious problems doing it with a spacesuit," McKay says.

And the list goes on. "I think we're looking at 20 years on the Moon before we have all those things in hand," McKay says.

SCIENCE FICTIONAL HEROES swing a quick jaunt to Mars in a matter of days – or even hours. But that requires rockets that can accelerate all the way without running out of mojo. In the real world of science fact, we can expect travel time to be about nine months, each way. That's a long time to spend cooped up with a small bunch of people. Radiation and weightlessness are also going to make it potentially tough on the travellers' long-term health.

Radiation is the bigger problem. In principle, the solution is simple: make sure the ship's walls are thick enough to block it. But conventional radiation shielding is, unfortunately, heavy.

Ram Tripathi, a researcher at NASA's Langley Research Centre, adds that deep-space radiation doesn't simply plough into shielding and stop, like a bullet hitting a bucket of sand. Rather, it smashes into individual atoms, blasting them into just-as-lethal nuclear shrapnel. "You do not want a heavy material that produces debris," he says.

This makes hydrogen – the lightest of all elements – a prime candidate for shielding because it produces the least, most easily restrained shrapnel. Not that it's possible to build spaceship walls from hydrogen, but in March 2007, at a meeting of the American Physical Society, Tripathi suggested that they could be built of filaments of a material like carbon nanotubes, enriched with hydrogen.

Weightlessness is easier to deal with. One approach is to equip the spaceship with a gymnasium. A full-fledged spa and step classes aren't necessary; all that's needed is some multi-purpose workout widgets like the ones sold on the late-night telly by Chuck Norris. Even better would be to simulate gravity with a spaceship that spins, like a giant gerbil wheel, or is tethered to a burned-out booster engine and swung like a big bolas.

Science fiction author Kim Stanley Robinson, who has spent years thinking about Mars, suggests that during the flight the spin might even be decreased to acclimatise the astronauts to the lower Martian gravity – reducing the risk of unhappy mistakes such as bounding off a cliff when all you intended was to admire the view. On the way home, the ship could be progressively spun up, so the astronauts don't wind up as couch potatoes once they get back.

AN ASTRONAUT'S FIRST impression of Mars will be strongly dependent on the time of year when he or she lands. "Winter's my favourite time because the skies are so clear," says Squyres. "You get crisp views with beautiful, wispy clouds. Summer is hazy. It's also when you could get a global dust storm."

Experiencing a Martian dust storm wouldn't be like being flayed by a Saharan sandstorm. It would probably be more like finding yourself trapped in thick red-brown smog. "At its worst, you can't really tell where the Sun is," Squyres says. "I think the greatest effect would be psychological. It would get hazy and dim for months. That could get to you after a while," he speculates.

And then there are the dust devils. Squyres likes to refer to them as "a summertime phenomenon and a lunchtime phenomenon". Translation: they kick up at about 10 am, and last until 2 or 3 pm. They're not quite tornadoes – though they might pack enough punch to carry off loose sheets of plastic –and they have the beneficial side effect of blowing dust off solar panels. "They're one of my favourite things on Mars," he says. That's because Mars is normally very static. "You go along and kick a rock, and that rock may have been there for a billion years." With dust devils, "you actually get to see something move."

Once the initial excitement subsides, however, astronauts may feel very isolated. Earth will be a blue speck, about as bright as Venus appears from Earth, simultaneously reminding them of home and telling them just how far away it is.

On the other hand, in the days before radio, explorers survived worse isolation in the Arctic and Antarctic. "Plus, as scientists, you are on an alien world that's never been explored," says Squyres. "I don't think boredom is going to be an issue."

Gravity, however, may continue to be a problem. "We have no experience with 38 per cent Earth gravity," says Robinson. "[But] we know perfectly well that microgravity is bad for you and you have to exercise your butt off to counteract it." One of the advantages of going to the Moon first is that by the time we get to Mars, we'll have had lots of practice coping with even lighter gravity. It's likely, though, that the health-conscious will need long, daily stints on treadmills or exercise bikes.

The first explorers will live in their landers, which Zubrin envisions as two-storey tuna cans on stilts, capable of housing four to six people. His group has even tested such structures in the Utah desert and on Canada's Devon Island, whose sere, Arctic plains are among Earth's closest analogues to Mars. The mock-up habitats are 8.2 metres in diameter, giving them a bit more than 211 square metres of living and workspace: about the size of a large flat or small townhouse. The upper deck is split between tiny bedrooms and a common living/kitchen/dining area. The lower deck has a workroom, bathroom, and utilities. Despite the cramped quarters, Zubrin says, "We found them quite liveable."

The habitats even have mock landing legs and an airlock. Crews living in the habitats have simulated Mars conditions in which they can't go outside without putting on a "spacesuit," and communications with the outside are by email with a built-in time lag to simulate the speed-of-light delay in radioing from Mars to Earth. "If you've got a question, you'll wait at leat 45 minutes for the reply," wrote science fiction author Wil McCarthy, who described a two-week stint in the Utah habitat in a 2005 article for Analog science fiction magazine.

Because the habitats aren't return vehicles, they will gradually accumulate on Mars, providing nuclei for expanding bases, or possibly strings of yurt-like huts within rover-range of each other.

ALL THESE VISIONS are well and good if we only hope to venture to Mars for limited scientific expeditions. But what about the next step; the next giant leap for humankind? What if we want to embark on a longer-term colonisation effort?

To achieve this we'll need to start sending more than just a handful of astronauts every couple of years. This will require either lots of trips at each launch window, or the use of a much bigger ship: more like a spaceliner than a runabout.

One concept for a Mars hauler is the Aldrin Cycler, proposed two decades ago by Apollo astronaut Buzz Aldrin. The Cycler takes advantage of Aldrin's discovery that it's possible to put a spaceship – or even something more substantial, such as an asteroid – into an orbit around the Sun that strategically swings past both Mars and the Earth on a regular basis, keeping on course via carefully adjusted gravity slingshots around each planet. The result is a ship that can be as big as you like because it requires virtually no fuel and never has to land. Instead, crews rendezvous or descend from the Cycler each time it passes one of the planets.

One fly in the ointment is that the best Cycler orbits for outbound trips zip past Mars fast enough to make it hard for shuttles carrying home-bound astronauts to chase them down. (Mars-bound astronauts can simply jump off and use the Martian atmosphere for braking.) Also, the Cycler's return journey may take considerably longer than its outbound one. The solution may be two (or more) Cyclers – one for the trip out, and another, on a different orbit, for the return journey.

The Cycler can also be extended over the course of time as depleted boosters or other components are added to it, making it ever larger and more luxurious. It could be spun for gravity, provided with good radiation shielding, and stocked with the latest in entertainment for the long journey ahead.

Meanwhile, Mars bases would continue to expand. And so too would their demand for resources. Yet this is one of the things that makes Mars such an attractive destination for manned missions. As Zubrin puts it, "precisely the same features that make Mars interesting can make it attainable". This is because Mars has abundant natural resources just waiting for an enterprising colony to tap into them.

For example, water comes from ice melted out of the subsoil or 'regolith'. With solar or nuclear power, the water can be broken into hydrogen and oxygen. More complex chemicals, including rover fuel, come from those plus the atmosphere's carbon dioxide and nitrogen.

Meanwhile, McKay says, it would be nice to find out if we can grow plants in Martian soil. That might be easy, or it might be difficult if the soil proves too salty or otherwise toxic. Recent studies led by Sushil Atreya, at the University of Michigan in Ann Arbor, and Gregory Delory, at the University of California, Berkeley, have found that static electricity from Martian dust devils might be generating hydrogen peroxide snow from the atmosphere that accumulates in the soil at bleach-like levels. If this is the case, it may be necessary to purge toxins from the soil before attempting to grow anything.

What won't be needed is a totally closed ecology, like that tried in the early 1990s in a project called Biosphere 2 (Earth itself was considered to be Biosphere 1). That project, carried out near Tucson, Arizona, involved an attempt by eight 'bionauts' to live for two whole years in a 1.3 hectare sealed habitat, like a giant terrarium. They survived, but their habitat's ecology teetered, hunger reigned, and the experience wasn't exactly what you'd want on an alien planet where you couldn't escape simply by opening the doors and walking home.

The bionauts saw themselves as practising for space. But it wasn't a realistic experiment, says Robinson. True Mars colonies would undoubtedly make heavy use of recycling, but they wouldn't have to recycle everything. "You would do the best you could, then supplement as needed," he says. In fact, that's the whole point of looking for water and finding out how to make useful chemicals from the Martian atmosphere. Still, greenhouses will obviously play a role, even if just for farming. "I think they'd get into the grooviest little greenhouse lives you can imagine," Robinson says.

BUT THERE'S STILL ONE MAJOR PROBLEM: the Martian surface is a dangerous place, not just because you might asphyxiate if your habitat blew a seal, but because the atmosphere is too thin to block the lethal bombardment of cosmic radiation. Unfortunately, Robinson says, the cancer risk from radiation coming through the thin transparent roof means that you're not going to want to spend a lot of time in that greenhouse. This is not such a problem for the more radiation-resistant plants, but you wouldn't want to idle away too many hours gardening in there without wearing a lead hat.

And there's the rub. Living in one of Zubrin's tuna cans for 18 months might not be any worse than a lifetime of smoking cigarettes. But for permanent colonists? Somebody had better come up with either an easy cure for cancer or some extraordinarily effective – and easily manufactured – radiation shielding. Otherwise, colonists are going to have to live underground – not quite as glamorous as jaunting across Martian hills gazing on red sunsets.

The result is that true long-term colonisation is unlikely in the absence of some kind of terraforming (see "Turning the Red Planet green", p62). Instead, most experts believe the set-up will be more like Antarctica, where scientists go to pursue specific lines of research, revel in the unearthly beauty, and then return home (and have a nice, cleansing hot bath): a once-in-a-lifetime trip they will remember forever, but few would care to repeat. Mixed in with that might be tourists and wealthy retirees willing to accept the radiation danger in exchange for spending their golden years in a truly unique environment.

Still, the dreamers want to go. Some offer utilitarian reasons: each dollar invested will potentially spur many more in technological spin-offs; it's an opportunity for nations to work together peacefully for the benefit of all humankind; if the U.S. and Europe don't do it, the Chinese will; and the more we learn about Mars, the better we'll understand the Earth.

All of these are valid, but ultimately, it's a bit like Edmund Hillary trying to explain Everest: you either get it, or you don't. "It's a symbolic act," says Robinson. "It suggests that a whole civilisation agrees to do something just for the beauty of it. It's like building a cathedral was for the Europeans. It unifies people and gives them a symbol."

It's a symbol that – until we finally go there – will beckon in the night-time sky, like a distant, dusky lantern. It's a symbol that conjures fantasies of dust-red deserts, rock-rimmed craters, and taking the ultimate bushwalk.

Richard A. Lovett is a regular contributor to *Cosmos* based in the U.S. city of Portland, Oregon.

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