Mars on Earth: The NASA Haughton-Mars Project

Preparing for Mars in a unique public/private — and international — setting.

By Pascal Lee, SETI Institute

A thousand miles or so from the Earth's North Pole lies our planet's largest uninhabited island, Devon Island. To the Inuit of Nunavut in this part of the Canadian high Arctic, the island is known as Taallujutit Qikiktagna or Jaw Bone Island. Devon Island is home to one of the highest-latitude impact structures known on Earth, Haughton Crater. At 20 kilometers in diameter the crater formed 23 million years ago, at the beginning of the Miocene, when an asteroid or a comet collided with our planet.

Every summer since 1997, I have journeyed to Devon Island with colleagues and students from many horizons to study the natural wonders of Earth—and Mars, by comparison. We also test out new technologies and strategies that will help us explore Mars and other reaches of space in the future, with both robots and humans. Our research project is called the NASA Haughton-Mars Project or HMP.

Little imagination is required to believe oneself on Mars when exploring Devon Island. Many features and sites there are strikingly reminiscent of the Martian landscape, from barren rocky blockfields to intricate valley networks, from precipitous winding canyons to recent gully systems on their slopes. We come here to understand whether this resemblance is merely a coincidence or whether there are common underlying causes. Did some of the processes that shaped Devon Island also operate on Mars?

Marco Lee (left) and Pascal Lee rappelling down a cliff face in simulated spacesuits (made by Mars Society volunteers) for a TV documentary sequence.

Setting The Stage

It is hard to tell when Devon Island became an island, but the rocks that form the landmass today are mostly ancient seabed material ranging from 570 to 35 millions years in age. The sediments (mostly carbonates) are resting on an even older crystalline basement 2.5 billion years old. Taking this into account, the Haughton impact was a recent event. During the Miocene, the region's climate was much warmer than it is today. Boreal forests of conifers and birch trees covered the land. Giant rabbits and small ancestral rhinos roamed. Local streams and lakes teemed with fish.

All of this changed in an instant.

The object that struck Devon Island was perhaps 1 kilometer (0.6 mile) in diameter. Coming in at cosmic speeds, the impactor delivered a pulse of energy equivalent to 100 million kilotons of TNT. In so doing, it produced a blinding flash of light followed by a monumental air blast that flattened the surroundings, obliterating almost all life several hundred kilometers around. As the dust cleared, a smoldering hole filled with a vast pool of chunky molten carbonates appeared. Haughton Crater was born.

In Search of Mars Analogs

To be sure, no place on Earth is truly like Mars. Antarctica is the coldest and driest continent on our planet and remains in many ways of unique value to Mars analog studies. But no positively identified impact structure is known to exist there. Alaska, Arizona, Hawaii, Utah, Iceland, the Atacama Desert, the Altiplano, the Negev, the Sahara, the Gobi, and the Tibetan Plateau, to name but a few classic sites, all present Mars analog aspects. However none of these locations possess the full gamut of Martian characteristics.

The NASA Haughton-Mars Project

Early research efforts at Haughton focused on studies of the crater itself with investigations into a possible Mars analog angle remaining unexplored. I approached Chris McKay at NASA Ames Research Center to do just that. With his visionary support, I obtained in 1997 a grant from the National Research Council to visit Haughton Crater. As a result, a four-person team traveled to Devon Island in August of that year. Comprising this initial field party were James W. Rice, Jr. (at that time based at NASA Ames, now at Arizona State University), John W. Schutt (chief field guide for the U.S. Antarctic Search for Meteorites program), Aaron Zent (NASA Ames), and myself. The site proved interesting beyond our wildest dreams. Not just one, but also several features were found that might serve as potential Mars analogs.

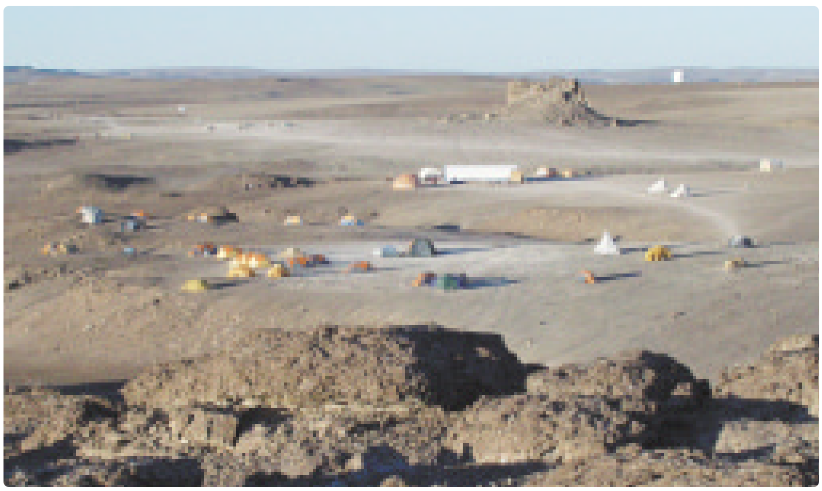
This initial reconnaissance trip led to what is today the NASA Haughton-Mars Project, an international interdisciplinary field research project comprising both a science and an exploration program. The HMP science program focuses on learning more about Mars and the Earth, impact cratering on planets, and life in extreme environments. Astrobiology might be the best term summing up the focus of our science studies at Haughton. The HMP exploration program, built around the science program, seeks to develop new technologies, strategies, and experience with human factors that will help plan the future exploration of Mars (and other planets too) by both robots and humans.

The HMP, now in its sixth year and with five consecutive field seasons in the Arctic, continues its research activities on Devon Island. The project draws its core funding from NASA but is actually a collaborative government-private joint venture with substantial support (almost half) contributed from non-NASA sources. It should be added that NASA-funded research on the HMP is not specific to preparing a human mission to Mars. While the science program has a strong Mars flavor, the exploration program is generic in its applicability to planetary and space exploration.

The HMP is managed by the SETI Institute, my home institution and the largest private space research organization in the world. Co-investigators and other participants from a wide variety of government agencies in the U.S., Canada, and other countries, universities and research institutions, private industrial partners, corporations, space interest groups (including the NSS) and exploration societies contribute each year to the project's field activities.

Each summer, tens of researchers, students, support staff and visiting media join in on field activities. At any given time only 30 people or so are admitted at the field site. A core team of ten individuals spends the entire summer on Devon Island while other co-Investigators and visitors rotate in and out for shorter stays.

Substantial logistical support is also provided by the United States Marine Corps who view the HMP in part as a valuable training opportunity. Since 1999, Marine C-130 crews have supported the NASA HMP with the successful transportation and delivery of tens of tons of mission critical cargo including all manner of expeditionary gear, research equipment, exploration vehicles, and field supplies. This is done via the airborne delivery of parachute-equipped cargo pallets. These "paradrops" on Devon are among the highest latitude drops ever performed by the Marines and are often done under extreme conditions. Twin Otter cargo airplanes chartered from local flight operators are also used to fly cargo and personnel from the hamlet of Resolute Bay (on Cornwallis Island) to the HMP Base Camp and back.



NASA HMP 2000/Mark Webb

General view of the NASA HMP Base Camp, with "Tent City" in the foreground and "Downtown" in the middle ground. The prominent rock feature beyond Downtown is known as "The Fortress". In the distance (upper right in photo), on Haynes Ridge, is the Mars Society's Flashline Mars Arctic Research Station.

Background image: NASA HMP 2001/Kelly Snook

NASA HMP 2000/Mark Webb

Airborne synthetic aperture radar image of Haughton Crater.

Ground Ice: An Enabler of Human Exploration

The ground-ice on Devon Island and indeed across the high Arctic represents an important repository of freshwater and, as suggested by known examples from Siberia, might even trap a biological record covering several million years. Recent neutron spectrometry data from the Mars Odyssey spacecraft provide startling possible evidence that ground-ice is abundantly present at shallow depth in the Martian subsurface (within the top few meters), particularly at high latitudes. While the findings of the orbiter's science team remain preliminary, it appears that ground-ice might also be found at shallow depth at low latitudes in specific areas. If confirmed, this could have important implications both for the search for life on Mars and for planning future human endeavors on the planet. Our studies of ground-ice on Devon could help plan for these exciting activities.

Ancient Hot Springs and Lakes

In addition to subsurface ice deposits, Haughton Crater also offers remnant signatures of ancient hydrothermal activity—evidence for which was only recently uncovered by our HMP team. These hot spring features were powered by the tremendous amount of heat dumped into the surrounding rocks at the time of impact. While the impact-induced hydrothermal activity has long ceased, the hydrothermal sites are preserved in almost pristine condition, having been spared substantial weathering due to the increasingly frigid climate that has prevailed in the Arctic since the Miocene.

Understanding the nature, evolution, location, and preserved record of impact-induced hydrothermal activity at Haughton Crater helps us assess the biological potential of similar sites on Mars as well as on other planets. Impact-induced hot springs would have been places where liquid water and warmth would have coexisted, if only for short periods. As such, they are places where life, perhaps imported from elsewhere, might have gained a foothold and thrived.

Haughton Crater also once contained a lake—or, to be more precise—a network of water bodies whose shapes evolved over the course of time. These bodies of water formed very shortly after the crater's formation and may have lasted only a few million years. Although the lake waters are long gone, sediments were laid down that are beautifully preserved. These paleolakebeds represent the only sedimentary record of the Miocene preserved on our planet in the Arctic. As such, they provide us with a unique view of what conditions in the Arctic were like 23 million years ago.

Using Haughton Crater To Reveal Ancient Martian Climate

Taken in a broad context, the overall amount of erosion we find at Haughton Crater might be telling us something important about Mars. In spite of Haughton's young age compared with that of many similar-size craters on Mars, it is far less well preserved than its Martian counterparts, most of which are probably between 2.5 and 3.8 billion years old. At the very least, the cumulative effect of erosion on Mars in the past 2.5 billion years appears to have been less than that experienced by Haughton in the Arctic over the past 23 million years.

Thus, average erosion rates have probably been over 100 times slower on Mars than in the Arctic on Earth. This would lead one to expect that if Mars was ever wet and warm at any point over the past 2.5 billion years at least, it was probably not so for very long. Otherwise, more erosion would be in evidence on Mars.

Water and ice on Mars

Many features outside of Haughton Crater itself are also contributing to solving, and sometimes deepening, the mysteries that Mars presents to us.

Networks of channels found on Devon Island bear similarities to the so-called Martian small valley networks. On Mars, most of these features date back to the end of the "Heavy Bombardment" (a period of high impact rates early in the history of the solar system). Some of these features are also found on more recent Martian terrains such as the flanks of relatively young volcanoes.

The surface of Devon Island has been carved by a multitude of small valley networks that bear an uncanny resemblance, including in their bizarreness, to the many small valley networks on Mars. Curiously, when you consider the classical explanations for Martian small valley networks, the Devon Island networks formed neither by rainfall, groundwater or ground-ice release, or mud flow. Rather, they were formed by the melting of vast ice covers that once occupied the land above the material exposed at the surface today.

While not settling the mystery of past climates on Mars, our work on Devon Island is offering new interpretations for many of the planet's so-called "fluvial" landforms. Our research suggests that surface ice deposits on Mars may have played a much greater role throughout Martian history than has been suspected in the past.

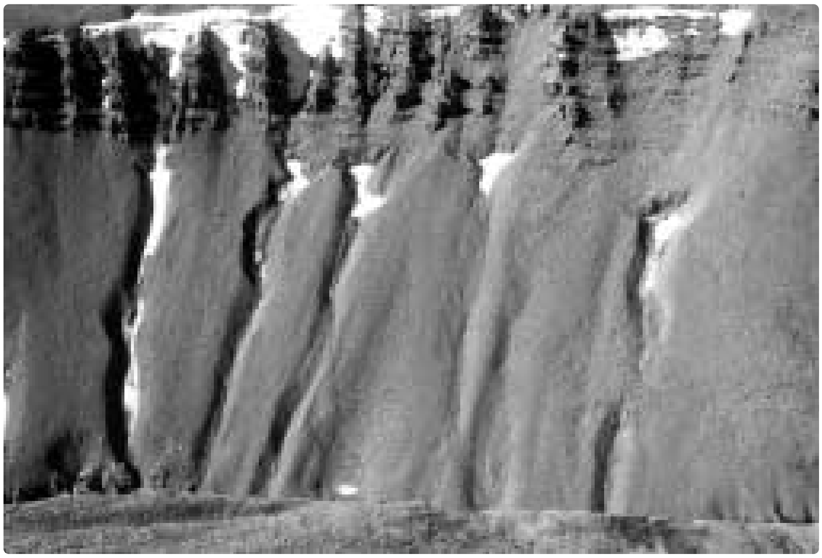
There are many other features on Devon Island with eerily similar counterparts on Mars, including vast canyons and small gullies. In the end, it is perhaps not any single parallel that should impress, but the convergence of so many in a single small area of our planet. Without loosing sight of the fact that no single Mars analog on Earth can be considered ideal (it depends a lot on what one wants to study), Devon Island has come to be described by many as, and granted with much exaggeration, "Mars on Earth."

LIFE AT THE EDGE

Devon Island is also astonishing by virtue of the resilience of the life that can be found there. Life in polar deserts usually persists at the edge of what is possible. Liquid water is rare—as are essential nutrients. Our studies of microbial life at Haughton Crater, led by HMP chief biologist Charles Cockell of the British Antarctic Survey, are revealing stories of survival and adaptation with potential implications for our search for life on Mars and elsewhere.

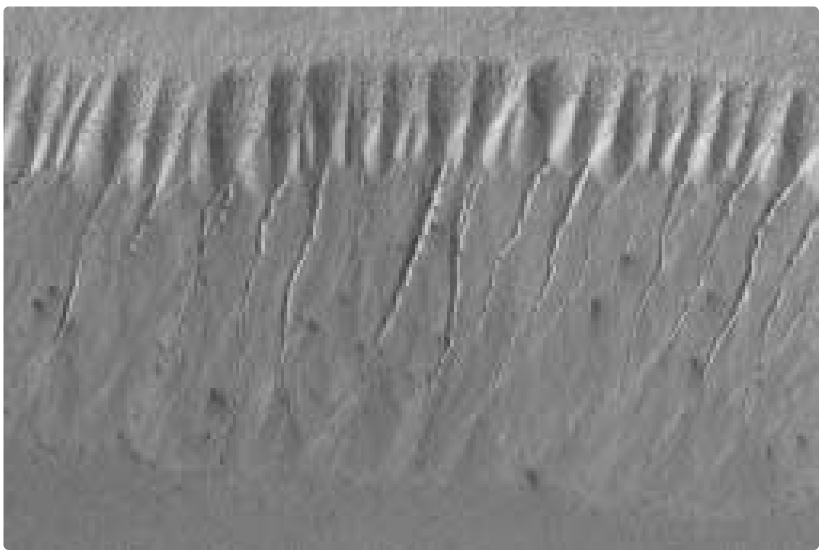
For example, in spite of the high ultraviolet (UV) radiation environment prevailing during the summer with its 24 hours of unrelenting sunlight, microorganisms are able to avoid radiation damage by remaining shielded. Many do so by simply colonizing sheltered areas underneath rocks or in soils. Other organisms, such as algal mats living at the bottom of open shallow ponds and puddles, have evolved natural sunscreens.

Just as humans don a spacesuit so as to survive in an otherwise lethal environment, these microbial colonies coat themselves with a gelatinous pigment-rich UV-screening compound that is secreted to form a protective biofilm. Long after the microorganisms themselves have died, the biofilms they produced can remain intact. This could serve as the basis for one of the ways we might search for past life on Mars. Through high-resolution remote sensing, instruments could search for the telltale signatures of resistant biological compounds, which putative microorganisms might have evolved to survive in the planet's harsh UV-drenched near-surface environment.



NASA JPL/MSSS

Gully system on Devon Island [above] similar in morphology, scale, and context (they form preferentially along the cold, north-facing walls of valleys) to some of the recent gully systems reported on Mars [below]. The gullies on Devon result from the repeated melting year after year of seasonal snow or secular surface ice deposits that accumulate and linger in the nooks and crannies of rocky bluffs along the top part of canyon walls. Might the gullies on Mars not have formed by groundwater seepage or ground-ice melting (prevailing hypotheses), but by a mechanism similar to that observed on Devon instead.



NASA JPL/MSSS

NASA HMP 2000/Mark Webb

An ejecta block resting near where it landed during the impact event that formed Haughton Crater. Over time, the fractures within the rock induced by the impact have become a habitat for microbial colonization.

Impact Events: They're Not Always Bad News

The HMP team has also found that the inside of Haughton Crater's battered rocks can serve as a host location for colonization by cyanobacteria. The existence of so-called "endolithic" microbial communities (microbes living inside rocks) is not new. Such colonies were first identified more than 20 years ago by Imre Friedmann in sandstone rocks found in Antarctica's Dry Valleys. Until now, these endolithic colonies had only been found in more porous and translucent sedimentary rocks—not in crystalline rocks, which are typically very compact and opaque. At Haughton Crater, however, crystalline rocks have been so heavily fractured and rendered porous by the impact that they are now home to thriving colonies of cyanobacteria.

The usual tone of any description of large impact events and their effect upon life is "bad news." This may not always be the case. Large catastrophic impact events certainly threatened highly evolved and narrowly adapted species such as dinosaurs and mammals—organisms that relied upon complex and vulnerable food chains below them. Curiously, however, large impacts could also have offered microbial life shelter and warmth when they needed it the most, that is, on early Earth and possibly early Mars. They can also create habitable zones—albeit transient ones—in otherwise hostile (cold) locations.

Mars on Earth: Being There

During our first season on Devon Island in August 1997, it became clear that the Haughton Crater site offered a unique opportunity to learn more about not only Mars and the Earth, but also about how actual humans will explore Mars and other planetary destinations in the future.

In addition to presenting us with a polar desert setting, Devon Island is also rugged, vast (20 times the area of the Antarctic Dry Valleys), diverse in terrain types, unpopulated, radio-quiet, tree and power line-free (important for aircraft operations), remote, isolated, and still poorly mapped. All of our activities on the island have to be carried out with attention to potential life or death consequences. Small mistakes can become big problems quickly. The isolation and remoteness of the site render medical help difficult to access. This will also be the case, to a greater degree even, for humans on Mars.

While quite a bit of thinking has already gone into the question of how to get humans to Mars and back, much less thought and virtually no dedicated field studies have addressed what Mars travelers will do once they get there.

How will humans live and work on Mars during surface excursions that could last for weeks, months—perhaps longer? What instruments, tools, and robotic devices would they need to accomplish their tasks? How often will EVAs be performed and how far away from base camp should they go? What sort(s) of surface vehicles should they drive? How much time will be set aside to analyze data and samples compared with the time required collecting them? How will the Mars crews on the surface (and/or in orbit) communicate with each other and with Earth? What information should they have available to them during EVAs?

Lessons can be drawn from the Apollo missions, but only in a limited way. Humans on the Moon had very little total surface time. EVAs were few and were scripted in detail. Little deviation was possible. Also, being located only 1.5 light-seconds away, Mission Control had almost instantaneous situational awareness and followed and supported the explorers essentially "live."

On Mars, the situation will be very different. Extended sojourns are envisaged while the time barrier associated with the much greater Earth-Mars distance (4 to 20 light-minutes each way) will preclude any true live interaction with Earth. Mars explorers will be to a large extent on their own. Mission Control becomes something fuzzier, "Mission Support," with lesser ability to control things directly because of the delayed situational awareness, but with a role still likely to be critically important to enable mission success.

On Devon Island we are faced with an opportunity to investigate how field exploration is done, how it can be optimized for field safety and science yield, what effects specific constraints associated with Mars exploration might have (limited EVA time, need to remain within walk back distance to survival shelter and supplies at all times, etc.), and how new technologies and strategies can help enhance exploration.

FROM ROBOTS ALONE TO ROBOTS WITH HUMANS.

Over the years, a number of exploration research activities have taken place under the auspices of the HMP. A regular partner in these efforts has been the Robotics Institute of Carnegie Mellon University (CMU). In 1998 and 1999 the HMP worked with Omead Amidi and his team on the performance of autonomous and teleoperated helicopters in support of field research activities. In 1999 we also worked with Dimi Apostolopoulos and his group on field studies to define the requirements of future robotic roving assistants for human explorers. Most recently, in 2001, CMU researchers led by David Wettergreen and Red Whittaker conducted the highly successful field trials of the sun-synchronous (sun-tracking) “Hyperion” rover at Haughton Crater.

These efforts in robotics development have an immediate application for the design of more capable autonomous systems that will soon find their way on new robotic spacecraft bound for Mars or other destinations in space. But as robots improve in sophistication, their ability to interface with humans in complex ways is also making strides. A tight partnership between humans and robots may in the end emerge as the most powerful exploration system we can develop, one that would see not robots exploring Mars in place of humans or vice versa, but one in which humans and robots explore in tandem.

In 1999, a communications network set up on the HMP by Rick Alena from NASA Ames Research Center and Stephen Braham from Simon Fraser University allowed initial field tests of wireless high-bandwidth communication systems in support of robotic and human exploration. Once established, the network was used to support embryonic interactions with the Exploration Planning and Operations Center (ExPOC), a newly-created mission control center at NASA Johnson Space Center designed to serve as a simulation testbed for future advanced human space exploration missions.

For a period of two weeks that summer, field activities reports and science findings were downlinked daily while future science requests, troubleshooting tips, weather forecasts, and news were uplinked in exchange. In all these exchanges, one-way time delays of up to 20 minutes were introduced to simulate the time barrier that would exist between the Earth and Mars during an actual Mars missions. The experiment was a success and led to a higher fidelity simulation in 2000. Among the key lessons learned was that unless comprehensive automated procedures are in place, the need to convey adequate situational awareness to Mission Support back on Earth will place a heavy time burden on any crew on Mars. While this was suspected going in, the HMP simulation allowed actual and quantitative operational experience to be gained.

NASA HMP 2001/Pascal Lee

Carnegie Mellon University's autonomous sun-following Hyperion rover during field testing on Devon Island in Summer 2001.

Related to this research are studies performed by Bill Clancey, director of the Human-Centered Computing research group at NASA ARC. Clancey’s research has focused on the specific interactions and information exchanges between humans engaged in exploration (with one another in the field and with their peers back at Mission Support), their tools (computers, robotic assistants, rovers, rock hammers), and their living space (habitats, tents, furniture). The information collected, akin to data gathered by ethnographers, is analyzed by Bill and his team and then fed into computer simulation models designed to eventually help plan and optimize future human exploration missions.

GETTING AROUND

Perhaps one of the most far-reaching findings emerging from our HMP exploration studies is the confirmation of the key role that ATVs (all-terrain vehicles or “quads”) could play as personal mobility systems in support of the surface exploration of Mars (or the

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Moon). The use of individual motorized vehicles is not new *per se*. Personal astronaut motorcycles were designed and tested during the Apollo program, but never made it to the Moon. Still, the idea of having spacesuited explorers drive individual ATVs had never gone far beyond the concept stage.

Our use of ATVs on Devon Island, sponsored by Kawasaki Motors USA, combined with the prior experience of some of our team members with snowmobiles in Arctic and Antarctic field research, is allowing operational benefits of such mobility systems to be evaluated. ATVs offer a high degree of flexibility and reliability, through redundancy in particular, in field exploration activities.

Any ATV-like vehicle taken to Mars will need to be optimized for safety, power consumption, performance on different terrain types (dunes, rock fields, salt flats), and ride comfort. They will also need to be robust, equipped with redundant systems, and most of all, easy to repair. Range of use also needs to be understood. Our studies suggest that ATVs are best used for activities within a few miles or so from a local base (a shirt-sleeve haven such as the base habitat or a pressurized rover). Beyond that distance, exploration is safely and effectively conducted likely only by pressurized rover. The best mix of short and long range capabilities will probably be provided by a trailer (with several ATVs aboard) towed behind a pressurized rover. When necessary, astronauts would go EVA from the pressurized rover and conduct local explorations using the ATVs.

Out for a Stroll

The spacesuit that will be used on the Martian surface will be one of the most complex pieces of hardware that will need to be developed in order to enable effective human Mars exploration. A spacesuit should be viewed as a wearable spacecraft. Compared to spacesuits in use today, the Mars surface suit will need to operate for much longer periods of time, be easily and repeatedly cleaned and repaired, comfortable to wear for many hours at a time on difficult terrain, and be capable of supporting its wearer in a wide variety of conditions. The suit will also have to support information systems that will allow astronauts on Mars to communicate and handle data effectively.

It is important to note that current EVA suits in use on the International Space Station and Space Shuttle can only be used for a matter of tens of hours before requiring a complete overhaul. Apollo Lunar suits were rendered almost useless by lunar dust after only a few excursions onto the lunar surface. Moreover, they were bulky and tiresome to use. While a few days of hardship inside a stiff suit can be adapted to, exploration activities over the course of several months on Mars would suffer greatly if a poorly designed suit were to be used repeatedly.

Current estimates of the target “felt weight” on Mars of a future Mars suit are in the 50-70 pound (~25-35 kg) range, i.e., the spacesuit’s actual mass might be 130-185 pounds [~65-95 kg]. While this weight may seem high, these numbers should be compared to the mass of the current Space Shuttle/ISS EMU spacesuit system: over 300 pounds [150 kg]. Because of its use in zero g, Shuttle and ISS astronauts are still able to wear their suit relatively comfortably, but such a suit would be inadequate on Mars. Its felt weight would be 115 lbs, an impractical burden to bear, not to mention the fact that the EMU suit was not designed for walking to begin with.

As such, doing work on the design requirements for Mars surface suits now, even at moderate pace, may provide an important headstart. NASA JSC is currently leading an advanced spacesuit development effort that will help pave the way for a future Mars suit. Realizing the importance of advancing suit system development now as well, the aerospace company Hamilton-Sundstrand has also been devoting some internal R&D resources to develop a concept spacesuit for advanced planetary exploration.

In coordination with ongoing efforts led by Joe Kosmo at NASA JSC, Ed Hodgson’s team at Hamilton-Sundstrand has conducted a series of field tests on Devon Island of various components of the 65-lb non-pressurized concept suit. The specific focus of the studies using the HS concept suit is the development of new information technologies interfaces in support of field exploration. Working with Steve Braham and several HMP field geologists, the HS team began tests during the 2001 field season of wearable computers in support of field exploration EVAs. The hardware used in these simulations was sponsored by Xybernaut, Inc. Such EVA-related studies will continue at Haughton

NASA HMP 2000/Mark Webb

Baruch Blumberg, Nobel Laureate and Director of NASA's Astrobiology Institute (third from left, standing) examines a sample while Pascal Lee (third from right, kneeling) collects additional specimens.

during upcoming field seasons, in particular through the generous support of the National Space Society.

One highlight of the field tests performed to date is the establishment of multiple-relayed wireless links and the remote control of field computers on geology-driven simulated EVAs. Control was established over distances in excess of 2 km. Use of integrated information systems in support of EVAs will be critical for ensuring the safety and productivity of future human exploration activities on Mars—and indeed at any other location in the solar system.

NASA HMP 2000/Bill Clancey

Pascal Lee doing geological field work in Hamilton-Sundstrand's concept spacesuit for advanced planetary exploration.

THE HAB

A recently added element to the HMP is the Flashline Mars Arctic Research Station (FMARS). The project has its genesis back in 1998 when I suggested to Robert Zubrin (who was then in process of forming the Mars Society) that this new organization should look at contributing a simulated Mars habitat to our ongoing efforts on Devon Island as its first project. The premise was that such a habitat would provide a more constrained framework for carrying out some of our studies of how humans will live and work on Mars, and at the same time serve as a visible and tangible symbol of the society's stated goal—help send humans to Mars.

Through the efforts of many, the Flashline Mars Arctic Research Station (named after an early major sponsor) was eventually established near the HMP Base Camp on the rim of Haughton Crater in July 2000. During the 2001 field season, a rotation of six crews, each comprising between 5 and 7 people, lived and worked out of the "Hab" for 5 to 10 days at a time, allowing a first wave of valuable operational experiences to be logged.

For the simulated EVAs performed out of the Hab, Mars Society volunteers had produced simulated spacesuits. While these suits were of low fidelity in many respects (they weighed only 25 pounds [12 kg], were not pressurized, and did not restrict motion significantly), they were nevertheless good to have for three reasons. First, the suits took 25-35 minutes to put on, requiring that a checklist be followed and the buddy system be used. Thus, their use imposed an operational burden that was not unrealistic for an actual suit that might be used on Mars. Second, the suits restricted the wearer's vision in a relatively realistic manner. Thirdly, the suits, by virtue of their good looks, served as an effective and important tool for public outreach.

EVAS AND SCIENCE OPERATIONS

While public outreach continues to be an important aspect of the FMARS activity, HMP science and exploration programs were also brought into the mix in support of FMARS research. During the shifts I participated in (I served as crew commander on 4 of last summer's 6 crews), we performed field work with specific operational constraints and procedures defined in consultation in particular with the Exploration Office at NASA JSC.

The underlying assumptions for these simulated EVAs included simulated pure oxygen prebreathing time prior to egress so as to simulate specific cabin pressure and air composition conditions. We also limited the duration of our EVAs so as to adhere to plausible life support system operation times. These time limits were usually 2-3 hours on a backpack, which would be used while walking, and 2-3 additional hours assumed to be carried on the ATV and used while riding the vehicle. For simulation of safety margins, 30 minutes of "don't use it" time were added to both suits and ATVs for all EVAs. We also made use of (imaginary) pre-positioned caches of supplies (including auxiliary oxygen) in the execution of extended traverses.

Field traverse planning, science implementation, and in-hab data analysis were carried out in consultation with an experimental "Science Operations Center" established at NASA Ames Research Center by Michael Sims, Kelly Snook, and Carol Stoker. Jeffrey Moersch of the University of Tennessee, Melissa Lane of the University of Arizona, and James Rice of Arizona State University served as the Earth-based science team.

One lesson emerging from the field traverse simulations performed to date is a quantitative assessment of the duration of EVA cycles in support of exploration activities. Extended exploration EVAs on Mars will require that substantial amounts of crew time and Mission Support resources be spent on the careful planning (including possibly reconnaissance robot deployments and the pre-establishment of caches), implementation (the actual EVA), post-EVA data analysis, and communications with Earth. While pre-mission crew training, robotic reconnaissance and caching, and the development of effective EVA planning tools will clearly help streamline EVAs, extended exploration traverses on Mars will, in a true sense, remain expeditions within an expedition, mobilizing each time a substantial fraction of the crew.

FUTURE ACTIVITIES

Upcoming seasons will see the addition of new research elements to the NASA HMP. One of these will be the "Arthur Clarke Mars Greenhouse," a 12 x 24 feet long experimental facility recently donated to the SETI Institute for the HMP by SpaceRef Interactive Inc. Slated for initial deployment in 2002, this greenhouse will allow HMP researchers to carry out a variety of astrobiology and space biology experiments in the field, and also test out advanced life support system technologies for future Mars exploration (*see "Greenhouses for a Red Planet," on page 14*). On another front, a specially modified Humvee, sponsored to the SETI Institute for the HMP by AM General, may also begin service on Devon Island in 2002 as a long-range field exploration roving lab. Through its use in support of actual field research, the rover will be used to help define over time the requirements for long-range pressurized rovers to be deployed by humans on future Mars missions.

Humans to Mars

As a planetary scientist, I am a strong supporter of the human exploration of Mars, which I view as the most effective means of learning more about this and other planets and the possibilities of life. But there are many other reasons why humans should go—many of which may be unrelated to science. In the end, rather than science alone, it is likely to be the broader factor of national interest that will drive a nation—or a group of nations—to undertake a human mission to Mars. Going to Mars now would serve our national interest in an ideal way as it would be a powerful investment in our future on Earth, regardless of what we are to find on Mars.

But why Mars? Why not the Moon, asteroids, or Pluto, or a technology program with universal applicability but no specific focus? It is here that the specific scientific potential and complexity, and the undeniable public appeal of Mars kick in: a) Mars might have once harbored life and might still; it is a world promising new knowledge and potential revolutions in the life sciences and many other disciplines; b) Mars is a planet bearing clear similarities to the Earth and is more directly able to help us understand and manage our own planet; c) Mars is a planet actually accessible to human exploration and its exploration would be much better done by humans on site rather than remotely from Earth; d) Mars represents a goal that would provide a clear and well-defined focus for the nation's space program, the latter being a capability that needs to be sustained anyway as a matter of national interest in its own right.

If our micro-scale experience on the NASA HMP analog project has been any indication, going to Mars, if initiated through a government effort, would likely draw in significant participation from the private sector. It would also provide an ideal opportunity for international cooperation, building on the ISS experience and binding allied and friendly nations in a positive, forward-looking enterprise that would help promote world peace, education, human knowledge, and a more secure global future.

And did I mention that going to Mars will also be exciting?

Dr Pascal Lee is a planetary scientist at the SETI Institute. He is Project Lead and Principal Investigator for the NASA Haughton-Mars Project.

For more information on the NASA HMP, visit www.marsonearth.org.

MODULES

space community

NSS Website

Have you checked out the NSS website lately? You may notice that the website has undergone a number of revisions and we hope you like the new look. Be sure to check out some of the new features, which include a downloadable version of the "Roadmap for the Settlement of Space," this can be used by you to educate your friends, family and colleagues as a way to move forward in humanity's greatest odyssey—the settlement of Space.

You'll also find a link to the archives of *L5 News* where you can download (for free) back issues of the *L5 News*. The *L5 News* was published from September 1975 until April 1987, at which time the L5 Society merged with the National Space Institute to create the National Space Society.

NSS Online Report

Are you receiving the NSS Online Report? This free, monthly newsletter is a way to keep connected to the latest happenings at the National Space Society and contains interesting space news that you may not have seen in other newsletters or read about on the World Wide Web. If you are interested in receiving this great member benefit then send an e-mail to nssas st@aol.com with your name and e-mail address and we will sign you up for the next issue.