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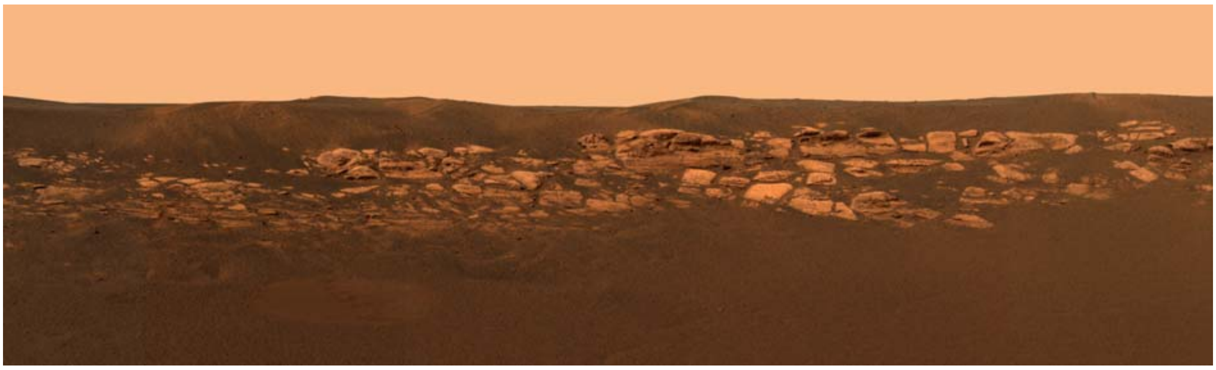
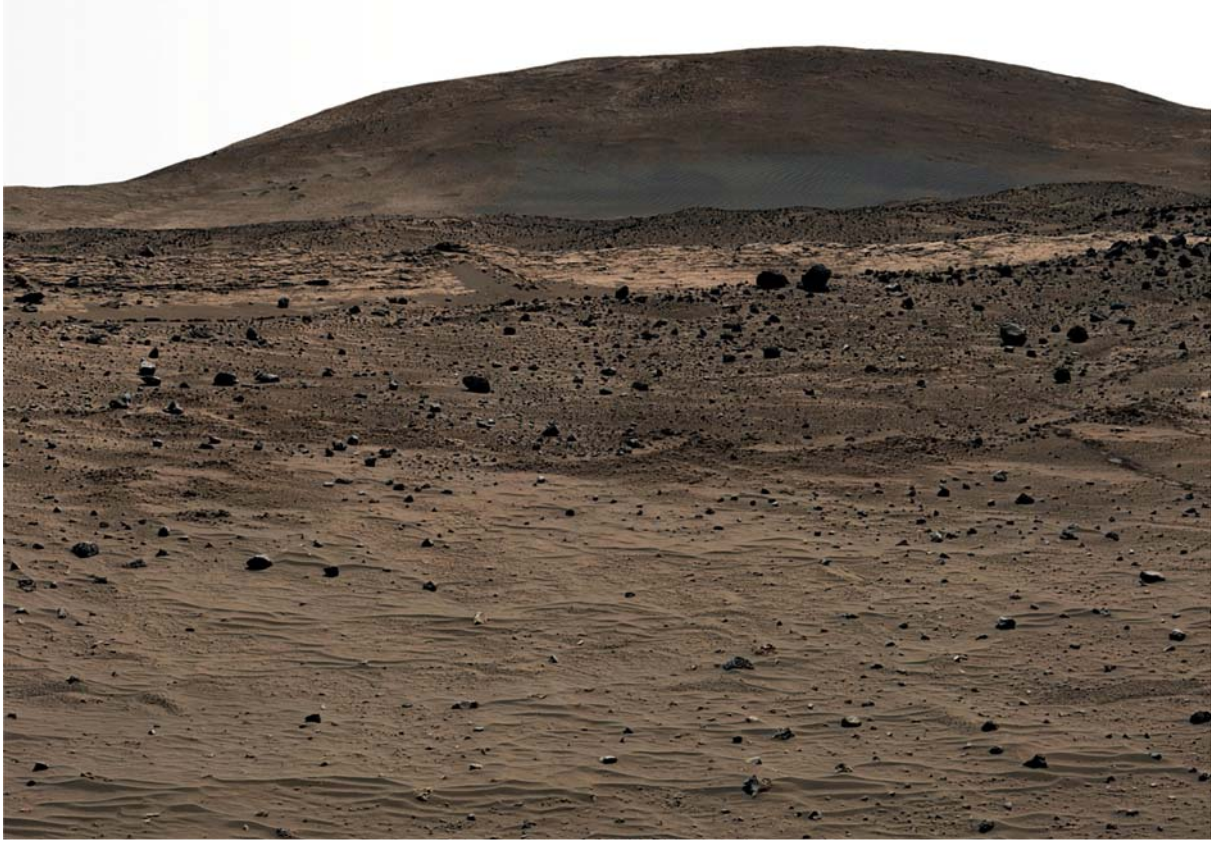
Proceedings of the 8th Australian Mars Exploration Conference

AMEC 2008

Adelaide, South Australia, 4 – 6 July 2008

Editor: Colin Pain





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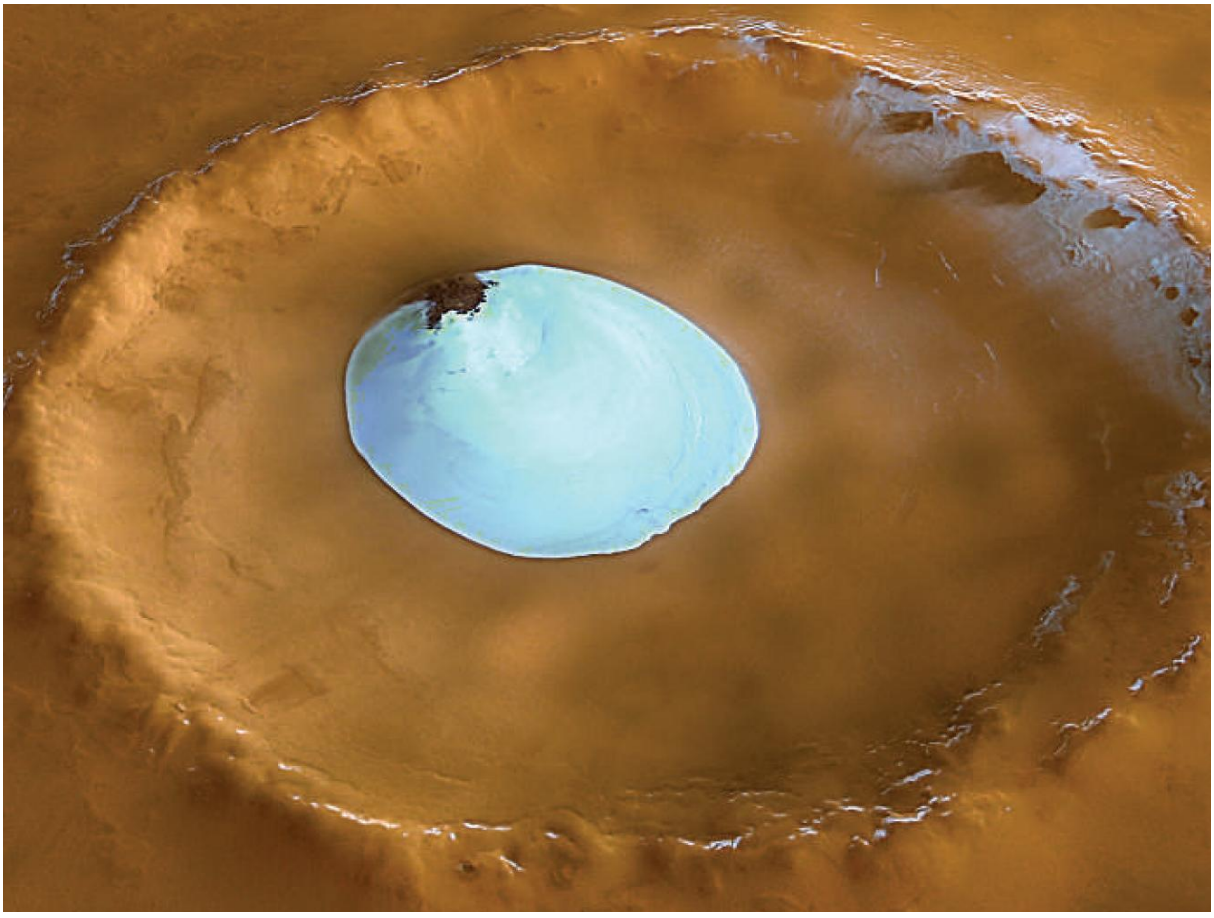

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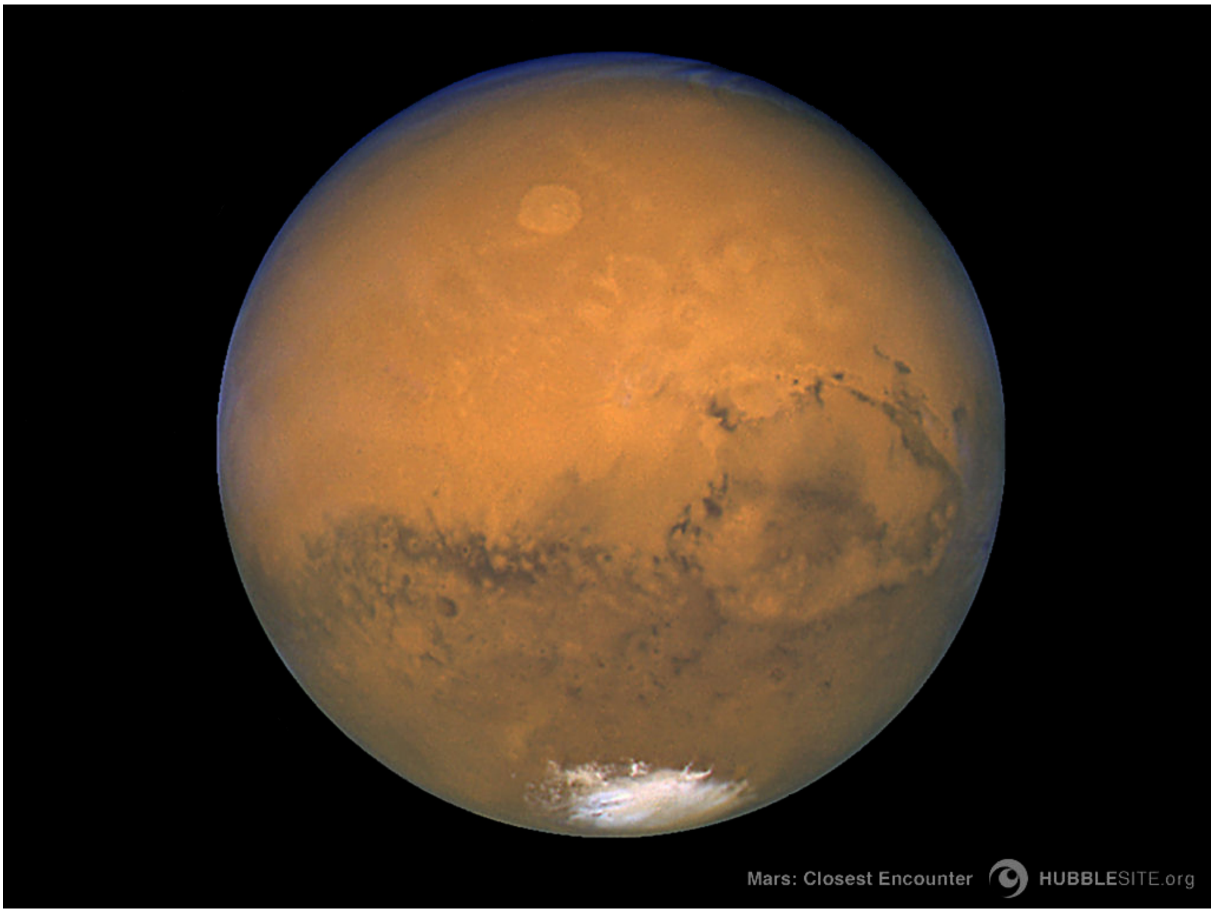
Mars: Closest Encounter
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Phoenix*

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The Phoenix mission gets its name from the fact it is made from components of two abortive missions to Mars, the 1998 Mars Polar Lander and the 2001 Mars Surveyor mission. Most of the questions Phoenix is designed to answer were framed during the Viking missions 30 years ago, although several earlier missions have attempted to answer them, all have failed. Phoenix is the first spacecraft to successfully land at the martian poles. A NASA funded mission, Phoenix has contributions from Canada, Germany, Finland, Denmark, and the United Kingdom. Phoenix successfully touched down at Scaandia Colles on Mars, 68.22°N 234.25°E, on May 25th, 2008. The design mission is 90 sols, although the lander may last 60 or 70 sols more. Phoenix uses a robotic arm to sample to the landing site, studying the physical and chemical properties of the martian surface, as well as imaging the area and collecting atmospheric data. Phoenix has already shown a landing site characterised by polygonal patterns indicative of polygons. The exhaust blast of the landing rockets exposed massive ice beneath the lander and excavations by the robot arm have shown ice cemented materials subliming on exposure to the atmosphere. Detailed results were not available at the time of writing, but the Phoenix mission is expected to greatly improve our understanding on the nature of the martian surface and atmosphere at high latitudes, the physical and chemical properties of globally distributed fines, and how water ice is occurs in the regolith. The results are expected to be especially significant for human missions by better quantifying potential hazards and resources.

Keywords: Mars, rovers, exploration, human missions

* Clarke, J.D.A. 2008. Phoenix. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 1.

Crewed Vehicles for Mars Exploration – Towards a Set of Requirements*

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Abstract. Vehicles are essential for the exploration of Mars beyond the radius of pedestrian sorties by astronauts and to carry out a number of field engineering roles associated with the establishment of Mars stations. A range of vehicle designs have been proposed, both pressurised and unpressurised. This paper reviews the type of vehicles required to support the Mars Oz reference mission from the perspectives of safety, technology base, and mission requirements. Drawing lessons from existing commercial off-road vehicles and the small legacy of successful Moon and Mars surface vehicles we conclude that two basic vehicle types can meet all the mobility and support requirements for the first few Mars missions, a 0.5 tonne unpressurised and a 3 tonne pressurised vehicle. The vehicles can be operated manually, remotely, or semi-autonomously, as required. They will need to be able to operate before, during, and after the period the crew are on Mars. Reconfigurability is highly desirable and should be able to be carried out with a minimum of effort. The vehicles need to operate safely at extended distances from the Mars station. Beyond walk-back distance a minimum of two vehicles will be needed to provide backup in the event of an emergency. Pressurized vehicles should be able to dock with the Mars station. This will facilitate crew transfer under normal operations and may be the only means by which injured crew members can be transferred. An airlock appears desirable for pressurized rovers to minimize loss of gases and heat, reduce the introduction of sand and dust into the interior of the vehicle, and to allow field maintenance of space suits. Other options such as suit ports may also be viable. We identify a number of unresolved questions for future study, many of which could be answered, at least in part, with the Starchaser Marsupial rover, now being constructed.

Keywords: Mars, vehicles, exploration, human missions

Introduction

Long range surface mobility is essential to the exploration of Mars. Determining the vehicle details and mass estimates to be landed on Mars is a key part of determining the overall mission architecture mass and spacecraft design needs.

Human missions exploring beyond the walk back distance of an astronaut (~10 km) will require vehicles. In addition to transport the vehicles will also be needed to perform a range of field engineering tasks like towing and deploying equipment, act as sensor platforms, and provide life support and habitable volumes on extended traverses. The vehicles must be capable of being driven by astronauts but also operated remotely by astronauts in orbit and on the surface, and semi-autonomously, with only limited supervision [1, 2].

In this paper we will outline issues and possible mission requirements for the two main types of Mars vehicle proposed: small unpressurised vehicles for local use and large pressurised vehicles for long range use. These requirements and design and operation issues will be based on considerations arising out of the Mars-Oz reference mission [3], our involvement with previous vehicle-related studies by Mars Society Australia [4, 5, 6], mission requirements from NASA-based studies [7, 8, 9], and some 25 years personal experience by the lead author in driving off road in remote parts of Australia. Specific areas covered will be:

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* Clarke, J.D.A., Mann, G. and Willson, D. 2008. Crewed vehicles for Mars exploration – towards a set of requirements. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 2-13.

- Maximisation of crew safety;
- Mission requirements as they affect vehicle systems;
- Technological capability to deliver the mission requirements; and,
- Design and operations issues arising for future study.

The paper will recommend approaches and serve as a basis for two future studies, the forward engineering of the Starchaser Marsupial simulated Mars vehicle design [6], and to develop a list of questions to be answered using the Starchaser Marsupial vehicle, when completed.

Mission Assumptions

Mars surface mission requirements are driven by assumptions about the nature of the mission. Will the surface stay be short (<60 sols) or long (500-600 sols)? How much mass is landed on Mars, and how much of this can be allocated to vehicles and associated equipment)? Will *in situ* produced propellants be available (determining the design of the power plant and the extent of the vehicle traverses)? How many crew will be on the mission, and how will this affect the EVA sortie rate and the size of EVA parties?

This study will work within the assumptions of the Mars-Oz reference mission [3]. This features a long-stay surface mission (500-600 sols), a total landed mass of over 70 tonnes, of which up to 5 tonnes will be devoted to vehicles. In Situ Resource Utilisation (ISRU) will provide very high range through the provision of electricity for recharging batteries and/or reactants for fuel cells. There is a crew of four. The mission can be compared to Mars Direct [10], albeit with a much greater endowment of vehicle assets, and is roughly two thirds the mass of the NASA Design Reference Mission version 3.0 [7]. The 5 tonnes devoted to vehicles in the Mars Oz reference mission is be divided between three small multipurpose unpressurised vehicles and one large pressurised vehicle (Table 1). The vehicle fleet listed in Table 1 are to work as an integrated team either in manned or unmanned modes providing for long range exploration, short range transport and civil and erection work. The integrated team and multipurpose vehicle design maximizes the capacity of the 5 tonnes payload vehicle mass allowance.

Safety Issues

Safety must be the first consideration for a crew carrying out operations on the Martian surface. Complex, even hazardous tasks must be carried out in such a manner as to keep risk to a minimum. There are many hazards involved in exploring Mars, including systems failures [11], environmental hazards [12, 13], and human error. Physical safeguards must be designed-in and field-tested before incorporation into the flight hardware, while procedural safeguards must be field-tested and, once adopted, trained to the point of routine habit by the crew. Complete sets of recovery gear must also be carried, was with long range desert and polar travel on Earth, and the crew trained and experience in their use. Possible failure modes are listed in Table 2 leading to a 'Safe travel analysis' for the pressurised vehicle listed in Table 3. Table 3 is based on foot or unpressurised vehicle travel being unsafe at night. The outcomes of table 1 & 2 drive the detail design, the mass, and operating envelopes of the vehicles. Table 3 links the surface exploration limits with the number and type of vehicles. This in turn provides mission planners a means to estimate the payload mass required to undertake specialized surface expeditions from the Mars Station.

Technology base

There is a considerable technological base that can be drawn on by would-be designers of Mars vehicles. These include both terrestrial vehicles and number of planetary vehicles.

Terrestrial

The terrestrial technology base includes the wide range of off-road, all wheel drive vehicles that have been developed for military, transportation, agricultural, mining, private, and polar use. There is more than a century of design, construction, and operation of such vehicles, resulting in highly proven concepts. Careful consideration should to be given to this heritage when designing Mars vehicles. Of particular value will be the design of chassis, steering, and suspension systems. Drive trains will be less relevant, however electric, hybrid, and fuel cell technology will also be increasingly used in terrestrial vehicles, including for off-road transport.

Table 1: Vehicle Functional Description Adopted from MARS-Oz Mission Architecture (modified slightly from Reference 3)

<table>
<tr><th>Vehicle</th><th colspan="2">Functional Description and Details</th></tr>
<tr><td>Pressurised Vehicle</td><td colspan="2">A 3 tonne (dry) 4 or 6 wheeled vehicle with a pressurized cabin used to travel with normally 2 passengers for 10 sols or in an emergency 4 passengers for 5 sols. It consists of a pressurized front cab and a rear tray. A detachable habitation module can be mounted on the tray
Can tow up to 45 tonnes mass of wheeled spacecraft for up to 10 km at low speed as part of the assembly of the Mars Station process.
Operating range up to 1000 km. Can tow 4 wheeled trailer that can carry up to 1 tonne of equipment and tow or carry an unpressurised vehicle.
The vehicle can dock with the Mars Station enabling the passengers to transfer without space suits.
The vehicle can be operated manually, remotely, or semi-autonomously
The drive system is electric from LOX/LCO powered fuel cells.</td></tr>
<tr><td rowspan="4">Unpressurised Vehicle chassis</td><td colspan="2">A 0.5 tonne unpressurised multipurpose vehicle that can be adapted for different roles
Electric powered from either rechargeable batteries or O2/CO fuel cells
The vehicle can be operated manually, remotely, or semi-autonomously
The basic vehicle will arrive on Mars in one of the three following versions</td></tr>
<tr><td>Version 1: Transport</td><td>Can carry two suited astronauts and up to 100 kg of cargo. An additional two astronauts can be carried in an emergency
Has a plug in space suit environmental control unit
Has a minimum operational endurance of 1 sol or 100 km (preferably 200 km).
Vehicle not intended for overnight use but has lights and navigation facilities for night travel in an emergency.</td></tr>
<tr><td>Version 2: Front end loader</td><td>Equipped with attachments for detachable buckets, blades and a crane extension arm for civil engineering work and can tow a trailer.</td></tr>
<tr><td>Version 3: Solar array erector vehicle</td><td>Primary function to clear an area (with small dozer blade and then lay and peg down a solar cell carpet with a manipulator arm for the ISRU plant</td></tr>
</table>

Table 2: Pressurized Vehicle General Possible Modes of Failure

Mode of Failure	**Options and Comments**
System Failure	
Wheels	Vehicle must run with one damaged wheel (two if six wheeled). Must carry 1 spare wheel
Drives	Vehicle has 1 drive per wheel and must run on a minimum of 2 out of 4 or 4 out 6 drives Vehicle must have 3 independent fuel cells and run on 1 fuel cell.
Loss of propellant	Vehicle must have 3 separate propellant tank systems.
Cabin environment	Vehicle must have environment system with backup equipment as per spacecraft.
Loss of air pressure	Vehicle must have spacesuits for crew. The crew can use separable

	pressurised module (with independent controls) if main cabin looses air pressure.
Structural failure	Vehicle cannot operate with a major structural failure. Crew must be able to return using backup vehicle
Navigation and communication failure:	
Loss of electronic navigation equipment	Crew must be able to navigate using stars and maps.
Loss of communication equipment	Vehicle and crew must be able to operate independent of mission control.
External/ travel and environment incidents	
Vehicle rolls	Vehicle has a roll bar. Vehicle equipped with several hatches to ensure crew can exit.
Vehicle bogs in sand	Vehicle is equipped with winches, wire ropes and anchors to pull machine out of bog.
Loss of propellant. Vehicle becomes stranded.	Vehicle life support system must be able to operate for extended period from solar cells either on the roof or unpacked from storage and erected.

Table 3: Safety Analysis for Pressurised Vehicles

Travel Range	**Procedures**
Up to 10 km from Mars Station	In the event of Vehicle failure, crew return to the Mars station on foot or in accompanying unpressurised vehicle . Walking must be completed in remaining daylight hours.
1 sol travel from Mars Station	In the event of Vehicle failure, crew return to the Mars station in an unpressurized vehicle towed or accompanying the vehicle. Unpressurised vehicle travel must be completed in 1 sol.
Greater than 1 sol travel from Mars Station	A second pressurised Vehicle must travel with the first vehicle. In the event of Vehicle failure, crew return to the Mars station in the second vehicle. The travel range is based on the range of the vehicle carrying twice the normal crew number. Range could be 3 sols travel.

Planetary vehicles

There have been three main examples of planetary vehicles, the NASA Mars Rovers, the Soviet Lunokhod lunar rovers, and the Apollo Lunar Roving Vehicle (LRV). Each offers different lessons for designers of vehicles to support crewed missions to Mars.

All NASA Mars rovers, from the 10kg Sojourner, to the 180kg Mars Exploration Rovers (MERs), and the forthcoming 800kg plus Mars Science Laboratory (MSL), use essentially the same design with a rocker bogie suspension [14]. The suspension and drive systems of the MERs have been optimized for very low speed operations. However, the many years of operational experience with these rovers are invaluable in providing information to the trafficability of the martian surface, environmental hazards, and wear and tear over long periods.

The Soviet Lunokhod rovers are the largest, most instrumented and, in terms of distance travelled, the most successful unmanned rovers to date [15]. As with the NASA Mars rovers, the Lunokhod drive systems are designed for a slow operational speed. Furthermore the differences between the lunar and martian environments may require some different solutions. However, the Lunakhods provide the best examples of long range teleoperated rovers to date.

Boeing's LRV was a masterpiece of innovative effective design [16]. A updated, slightly larger version of this rover, adapted for Martian conditions, would be ideal. Assuming a nominal 2-person crew, the basic alterations should include:

- The horizontal wishbone, torsion bars and damper suspension elements to be strengthened and use of a 400We motor on each wheel to allow for 0.38G.
- Highest energy density available rechargeable batteries, or fuel cells (supplying at least 80kWe)
- Greatly strengthened dust fenders over the wheels (these broke on two of the three Apollo expeditions that used them)
- The addition of a short, walled tray behind the seats for improved cargo carrying
Increase maximum speed to 30km/h
- Increase range from approximately 100 km to 200 (300 km allowing for margins).
- Extension of payload capacity to include the provision for on-board oxygen, water, food and power for both crew for the total 1 sol endurance.

Additional desired capabilities for teleoperated and semi-autonomous operation and an instrument and sensor platform are discussed below.

Analogue studies

There have been a number of studies using terrestrial vehicles to test concepts for pressurised Mars vehicles. Most of these have been at the Mars Desert Research Station in Utah (MDRS) [4, 17, 18] and at the Haughton Mars Project [19]. To date these studies have involved low fidelity simulations based on modifications to existing vehicles, to test issues associated with navigation [19] internal layout [18] and crew usage [17]. MSA's Marsupial rover currently under construction [6] is a medium fidelity simulation, involving a more complete reconstruction of an existing chassis to explore more fully internal and external layout and utilization issues.

Requirements for vehicle sorties

Key questions

We can best understand the roles to be taken on by the three vehicles supporting the Mars-Oz reference mission by asking a series of questions about exploratory activities that would be carried out at the surface. The following sections ask and answer some of these questions.

How will vehicles be controlled?

Contemporary approaches to robot control call for three possible options: *teleoperation*, in which a human operator manages individual robot motions at a detailed level; *high-level commanding*, in which the operator provides and *full automony*, in which the operator provides desired goals, leaving the robot to plan a series of actions and carry them out with minimal supervision. Previous planetary vehicles have operated in one or two of these three "adjustable autonomy" [20] modes. Unmanned vehicles have been either teleoperated (Lunokhod) or controlled by a mixture of teleoperation and high-level commanding (NASA Mars Rovers). Full automation of the kind required is technically difficult and is at present seen only in high-technology competitions such as the DARPA Grand Challenge [eg 21], but is developing rapidly. The Apollo LRV was driven by the crew but the TV camera was controlled from Earth. Vehicles supporting human Mars missions will need all three modes.

Teleoperation will allow the vehicles to be controlled from Earth, Mars orbit, from inside the habitat, or even from portable units outside the station. Cameras on the vehicles would allow external inspection of scouting of sites without the crew having to perform an EVA. Armlike manipulators and specialised, readily detachable tools would allow the vehicles to carry out a wide range of tasks.

A promising approach is to think of the vehicles as members of a team of agents which includes special-purpose robots, and the astronauts themselves. In this view, vehicles and other robots arrive at the surface first, deploy themselves and begin preparing the way for the astronauts. They set up the solar power and ISRU equipment, take photographs and possibly perform earth-moving or hazardous boulder removal. In the past few years, remarkable demonstrations of the capabilities of robot teams have been made by the combined efforts of NASA's Ames Research Centre and Jet Propulsion Laboratory [22, 23]. Wirelessly connected robots controlled by human-monitored, high-level planning software can be interrupted during their work by voice commands from astronauts or distant controllers. The robots will re-plan their activities based on a prioritising policy, and be able to resume their lower level tasks once the help has been rendered. The benefits of such a system for a Mars expedition are very high, and once perfected would be a unrivalled asset to the mission.

For what tasks will the vehicles be needed?

Within the Mars Oz operational scenarios, key tasks for which the vehicles will be needed include:

- Personnel and equipment transport
- Field engineering
- Field science
- EVA support
- Shelter and extended life support

Personnel and equipment transport is the simplest task the vehicles can carry out. In the Mars Oz reference mission the typical EVA team would be two people. Depending on the size of the vehicle, an additional payload of 100 kg for the unopressurised vehicles and 1 tonnes for the pressurized vehicle would be a reasonable requirement. Note that, because of the low gravity and low speeds, a Mars vehicle can carry much more mass than a similar-sized vehicle on Earth.

Field engineering tasks would consist of deploying equipment, site preparation, and ISRU inspection, servicing and repair. Equipment deployment would include unfolding, pitching or unrolling solar arrays, pegging them down, uncoupling and towing modules such as portable garages, and unrolling and connecting cables. Possible site preparation tasks are leveling and clearing obstacles in heavily trafficked areas. Potential ISRU tasks might include excavation and transport of water-bearing regolith to an extraction plant that supplies the Mars station [24], or rotation of gas tanks on an atmospheric oxygen extractor.

Field science tasks will extend well beyond that supported by the Apollo LRV. A wide range of lightweight sensors can be now be carried to document field sites, prioritise features to visit and characterise otherwise inaccessible objects. These could include video cameras, Laser Induced Breakdown Spectrometers (LIPS), and multispectral scanners [9]. The vehicles could mount or tow a wide range of geophysical instruments, including neutron beam sources, ground penetrating radars, electromagnetic instruments, magnetometers, hand drills and gravity meters [9]. Manipulators and specialised sampling tools would allow the vehicles to collect samples while being teleoperated or in semi-autonomous modes.

The same also applies to EVA support. In the 1970s, the only EVA support the LRV was able to perform beyond transport was through a teleoperated colour TV camera. Mars vehicles will also need to be able to carry instrumentation, as described above, provide communications links, and, if need be, transport incapacitated astronauts back to the Mars station. Considerable work has been done on robotic field assistants [22, 25] and human-robot cooperation [26, 27]. We suggest that such specialised robots are not efficient mass items, and it would be better to design the vehicles to carry out such a role. A good terrestrial analogue would be the R-Gator, a light vehicle based on the John Gator light off-road vehicle being trialed by the US Army [28]. R-Gator carries a range of sensors as well as two soldiers and cargo. It can be driven by hand, by remote control, or operate in a range of semi-autonomous modes, including following an infantry detachment. Such capabilities would be very appropriate for providing EVA support on Mars. Additional and specialized lightweight robots may be needed for maintenance work at the Mars station, but are not included here.

Lastly, both kinds of vehicle provide additional life support during single-sol missions and pressurised vehicles can provide complete shelter during multi-sol missions. Life support consumables weigh much more on Mars than they do on the Moon. The ability to store most of a sol's consumable supply – plus a substantial reserve – on an unpressurised vehicle will greatly facilitate surface exploration. During multi-sol traverses the pressurised vehicle needs to function as a small, independent Mars station and provide the minimal requirements for shirt sleeve habitation including volume for sleeping, food preparation and toilet facilities.

How far will vehicles need to travel?

Critical to the successful use of vehicles is the distance they are able to travel. As noted above, this is determined by safety issues. The most important of these is the ability of the crew to be able to return to the Mars station in the event that their vehicle is completely and irretrievably immobilized. For single vehicles this is the walkback distance, a maximum of 10 km based on Apollo experience. To venture further from the Mars station, a second vehicle is needed. For unpressurised vehicles and two-person EVAs this could be achieved in two ways. The second vehicle could be towed behind the one with the EVA team on board, or follow it autonomously. Alternatively each vehicle could carry a single astronaut. In either case, if one vehicle is irretrievably immobilized the EVA team could return in the other.

Unlike on Earth where exploration radii for ground vehicles are determined mainly by fuel consumption, and measured by distance, on Mars what matters most is life support capability, measured in time. Therefore exploration radii on Mars resemble those of an aircraft or submersible and need to be measured in hours rather than kilometers.

An additional limiting factor for open, unpressurised vehicles under normal operating conditions is daylight. Even though additional consumables may be carried on the vehicle, to allow for a safe margin the nominal duration of an unpressurised sortie will be of the order of about 8 hours, similar to present-day EVAs and historic Apollo sorties, with life support capability for at least 12 hours in emergencies.

How far they could travel in that time would depend on the trafficability of the surface. Typical going on Mars might be the Viking and Pathfinder sites, and could be traversed at speeds of no more than 15 kph, allowing for the lower gravity. Smooth surfaces like Meridiani or parts of the floor of Gusev crater, might be traversed at up to 30 kph. With one hour stops at the extreme limit of the traverse, this could allow unpressurised EVA sorties to a distance of 50 km from the Mars station, perhaps 100 km in exceptionally good travel conditions.

Pressurised vehicles would not be limited by the need to return each sol (martian day) and can be expected to have endurances of several sols, as a minimum. How far they could venture from the Mars station depends on the nature of the second vehicle. The pressurised vehicle of the Mars Oz reference mission could expect to be accompanied by a single unpressurised vehicle. The unpressurised vehicle would have a one sol range of eight hours, between 100 and 200 km. This defines the approximate maximum operating radius of a single pressurised vehicle. The unpressurised vehicle must be able to return immediately to the Mars habitat day or night.

A second Earth-to-Mars expedition sent to the same landing site could provide an additional pressurised vehicle. No longer limited to the one-way range of an unpressurised vehicle, exploration traverses could then venture to much greater distances. The exploration radius of two pressurised vehicles would be limited by the consumables needed to return the two crews to the landing site in an emergency. Until the capabilities of the pressurised vehicle for the Mars Oz reference mission have been calculated this distance is not known, but, for benchline purposes the Starchaser Marsupial prototype is required to support four persons for two sols, during which time it could travel 490km if it averaged 20km/hr for 24.5hrs, and much further if the policy of night travel was relaxed [6].

The remaining safety constraint on operating radius is the risk of exposure to a solar particle event. At a minimum two hours warning (compared to one hour for Earth) is probably available for such events

[29], unpressurised vehicles should be able to return to the more shielded Mars station within this time if such an event appears likely. Pressurised vehicles will need sufficient shielding to protect the crew from the radiation. The vehicle structure itself should provide about 5 g/cm^2 of shielding [30], while the Martian atmosphere will provide another ~15 g/cm^2, for a total of 20 g/cm^2. More shielding could be provided in an emergency by moveable plastic water bladders.

In what order will the vehicle carry out its tasks?

Vehicle utilization in the Mars Oz reference mission [3] will occur in distinct phases.

Phase 1: The cargo vehicle arrives some two years prior to the crew. A small unpressurised vehicle will level and clear the ground sufficiently to unroll and peg down a 25-30 kWe carpet (556-667 m^2) of solar cells to run the ISRU plant. It will also unroll the necessary cabling. When these tasks are completed the vehicle should be able to jettison the carpet deployment mechanisms and scout the landing site environs preparatory to the arrival of the crew. The vehicle will need to be able to recharge its batteries or refill its fuel cells from a port on the Cargo lander These operations will be done autonomously under terrestrial supervision. Two other vehicles are stored in the garage section of the Cargo Vehicle - the unpressurised vehicle fitted out for earth moving and the larger pressurised vehicle. These vehicles can also be deployed in Phase 1, if required.

Phase 2: When the crew arrives aboard the Habitat Vehicle they will bring the third unpressurised vehicle and use it to travel the few kilometers from the their landing site to the Cargo lander. These historic events will be videoed by one of the unpressurised vehicles that accompanies them. There they will unload the earth-moving vehicle and the pressurised vehicle, if this has not happened already and use the pressurised vehicle to tow the garage section of the Cargo vehicle to the Habitat Vehicle and dock them together. The earth-moving vehicle will be used for site preparation and route clearing. It could also place a layer of regolith on a platform covering the module connecting the habitat and the garage to provide a shelter during intense solar particle events, if required. The earth-moving fittings should be easily attachable and detachable, so that the machine can double as an ordinary unpressurised vehicle when required. These operations will be controlled by high level commanding and teleoperation from the Habitat.

When these operations are complete the vehicles can be used for exploration and, if need be, maintenance. Un-crewed, the unpressurised vehicles can still scout the region, drive EVA teams directly to sites of interest, carrying out geophysical surveys semi-autonomously, and provide EVA support. More distant sites will be explored by crews in the pressurised vehicle, accompanied and supported by an unpressurised vehicle. Both classes of vehicles would also be able to carry drilling equipment, when required.

This phase shows the highest intensity of operations and vehicles will experience the greatest wear and tear during it. Down time for maintenance and repair will need to be included in scheduling.

Phase 3: After the crew leaves the vehicles will be able to perform two roles: follow-up missions to sites of interest and environmental monitoring, by high-level commanding under terrestrial control. The second would be to prepare for the next human crew, should it be decided to send them to the same site.

Issues arising

New designs, or terrestrial heritage?: Initial studies for the next generation of crewed planetary vehicles, such as ATHLETE [31] and CHARIOT [32] involve highly complex chassis that have been designed from scratch rather than relying on previous designs. While these designs may offer innovative and flexible capabilities (such as CHARIOT'S ability to move sideways when required), conventional vehicle technology used by military and civil off-road vehicles appears adequate for almost all tasks and, being simpler, may be more reliable and maintainable than less tested approaches.

How will EVA teams egress and enter the pressurised vehicle?: A second design issue relates to how EVAs will be carried out from pressurised vehicles. There are several possibilities. The simplest is that adopted during EVAs from the Apollo LM when the entire cabin was depressurised and repressurised. Consequently dust and sand will be brought into the interior of the vehicle. Sensitive equipment will need to be sealed and was provided to clean up the material. It could also present risks to the crew, if martian regolith is judged hazardous [12]. This approach requires accepting high rates of gas and heat loss every time the cabin is depresurissed, assuming the cabin gas is vented to the outside each time. Given that daily EVAs are highly likely during an extended traverse in a pressurized vehicle the extra consumables entailed by such an approach may be considerable. Pumping the cabin down to near external pressure would reduce this loss, but require a much longer time, period, reducing that available for external work.

Suit ports [2] have been advocated in some studies. They would require minimal additional volume and eliminate the need for pressurisation and depressurisation. They would also exclude sand and dust almost completely from the vehicle. However, they do require suit exteriors to be permanently exposed to the martian environment, and, in the case of long stay missions such as the Mars-Oz reference mission (00-600 days on the Martian surface), they may experience considerable extra degradation from abrasion, UV exposure, and reactive chemicals in the regolith. The vehicle would still need to be capable of depressurisation to allow normal entry should the suit port fail, or an injured astronaut need to be brought inside. Suit ports are not compatible with carrying extra crew in an emergency, as the number of suit ports is fixed. The vehicle would still require a backup airlock or be depressurized to carry extra people. Suit ports also cannot be used with Mechanical Counter Pressure (MCP) suits [33], only with conventional gas pressure suits. This is because the porous nature of MCP suits construction (other than the helmet) means that an MCP suit attached to a suit port would not be able to maintain vehicle pressurization.

An airlock would help exclude dust and preserve heat and gases, but would require extra volume and mass. However, because this option keeps suits out of the Martian environment when not in use and allow field repairs the suits to be easily carried out, we suggest they are the preferred option unless minimizing volume and mass becomes critical. Use of airlocks also takes advantage of the extensive airlock heritage of the Space Shuttle, Mir, ISS, and other programs to be used. However, airlocks also have a larger penalties with respect to mass, volume, power, consumable, and time, compared with suit ports.

How will crew transfer between the Habitat and pressurised vehicles?: Experience of simulated vehicle operations during Expedition One at MDRS [4] showed that while crew transfers between the Habitat and pressurised vehicles were possible, they were impractical. These experiments assumed that the astronauts would undergo a depressurisiation-repressurisation cycle every time a transfer needed to be made. This was time consuming, and, in a real-world situation would mean wastage of gas and heat. Some form of docking tunnel that allowed shirt-sleeves transfer between the two was seen as highly desirable as a result of these experiments. Docking tunnels would not be necessary with suit ports. However, transferring an injured astronaut from the vehicle to the Habitat might be impossible with a suit port, make docking still a necessity in such an event, so no advantage is really gained.

It is our opinion therefore that it is highly desirable that pressurised vehicles be able to dock with the Mars habitat. This has been assumed in the Mars Oz reference mission. Designing a docking system that could work on the Martian surface has been briefly reviewed previously [34]. The review suggests the vehicle will need a flexible coupling in the transfer tunnel, a ramp for the vehicle to assist alignment with the habitat docking hatch and ensure the vehicle is parked on a solid base while docked. In addition the ramp would need to be fitted with buffers to prevent the vehicle ramming the habitat. After docking the vehicle would need to be fixed to prevent it from rolling away. However considerable work is still required to ensure a safe docking system design.

Can vehicles be reconfigured without human presence?: This paper argues that modularity and reconfigurability are very attractive features, a conclusion supported by other researchers [35].

However, although converting a small unpressurised vehicle from an earth-moving to transport configurations is comparatively simple for an astronaut crew, it may be challenging to do remotely.

Can vehicles be refuelled and recharged autonomously?: The vehicles will need to recharge and refuel. Many desired operations, for example earth moving and towing, are power-hungry operations and vehicles performing these tasks will need to be refulelled or have their batteries recharged. While this would be a straight forward operation for an astronaut crew, this will also need to be carried out autonomously before the arrival of the crew. This capacity needs to be demonstrated.

What is the best crew placement for pressurized vehicles?: Moving crew in and out of pressurized vehicles is demanding of time and resources. It may be desirable for the crew of a pressurised vehicle to operate it from the outside, going into the pressurized volume only at the end of the day [36]. Alternatively a pressurised vehicle could be dispensed with altogether, with unpressurised vehicles towing a pressurised trailer of "camper" [37]. While this would simplify many operations it would require crews on extended traverses to spend most of their time in space suits. The safety and feasibility of these concepts need to be tested.

Are the many desired semi-autonomous operations for site preparation and equipment deployment feasible: Can semi-autonomous vehicles clear ground, level sites, unroll solar cell carpets, and two modules?

What suspension and running gear are best suited to the Martian environment?: Although direct electric drives from batteries, fuel cells or from a internal combustion engine-powered generator seem most likely, many details remain to be worked out. Issues that need investigation include likely operating speeds, wheel design, terrain, substrate, and steering and braking issues.

Conclusions and Further Studies

We conclude that two basic vehicle types can meet all the mobility and support requirements for the first few Mars missions. The two types are: 1) A 0.5 tonne unpressurised vehicle that can be adapted for different roles, and 2) A 3 tonne (dry) 4 or 6 wheeled vehicle with a pressurised cabin.

The vehicles can be operated manually, remotely, or semi-autonomously, as required. They will need to be able to operate before, during, and after the period the crew are on Mars. Reconfigurability is highly desirable and should be able to be carried out with a minimum of effort. Three primary roles are identified for the unpressurised rover – transporter, loader-earth mover, and solar carpet deployer – have been identified as required in the Mars-Oz reference Mission. Similarly the unpressuised rover will need to operate as a long-range exploration vehicle, as a tug for towing station modules, and as a light truck for specialized equipment.

The vehicles need to operate safely at extended distances from the Mars station. Beyond walk-back distance a minimum of two vehicles will be needed to provide backup in the event of an emergency. Pressurised vehicles (and trailers) should be able to dock with the Mars station. This will facilitate crew transfer under normal operations and may be the only means by which injured crew members can be transferred. An airlock appears desirable for pressurised vehicles to minimize loss of gases and heat, reduce the introduction of sand and dust into the interior of the vehicle, and to allow field maintenance of space suits. Other options such as suit ports, routine external operation of even pressurised vehicles, and the use of pressurized "campers" rather than fully pressurized vehicles may also be viable, but need to be evaluated.

Future work planned by the authors include a forward engineering study of a 3-tonne pressurized vehicle and field trials of the Starchaser Marsupial Rover. The forward engineering study will be of a vehicle designed to support the Mars-Oz reference mission. Completion of the Starchaser Marsupial Rover will enable evaluation of a range of operational concepts associated with the design and operation such a vehicle.

Acknowledgements

This paper has arisen through discussions with a great many people over the past seven years. We would particular like to thank Matt Bamsey, Anna Clarke, Stan Piechocinski, Anna Paulson, Chad Rowland, Shannon Rupert and Nancy Wood The responsibility for how we have used their input is, of course, our own. We also gratefully acknowledge the contribution of two anonymous reviewers who provided many helpful comments.

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Spaceward Bound: Training the Next Generation of Explorers*

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Spaceward bound is an educational program developed at NASA Ames Research Center in California. The mission of Spaceward Bound is to train the next generation of space explorers by having students and teachers participate in the exploration of scientifically interesting but remote and extreme environments on Earth as analogs for human exploration of Mars. Spaceward Bound supports the second major NASA education goal to attract and retain students in STEM disciplines through a progression of educational opportunities for students and teachers. Undergraduate and graduate STEM students; pre-service and in-service STEM K-12 teachers; and STEM education faculty contribute to the science mission and goals by becoming members of science expedition teams. While learning STEM content, concepts and skills they become immersed in the conduct of scientific research and experience first-hand the intrigue, excitement, collegiality, and challenges of terrestrial analog field research. A growing body of evidence indicates that these experiences are unique and exceptional in their ability to inspire and motivate participants into dual roles of scientist and teacher. This paper will present in-depth information about the program, previous and current expeditions, outcomes from expeditions to the Atacama Desert, Mojave Desert, Pavilion Lake, North Dakota and Lassen Volcanic National Park and descriptions of future expeditions to the Arctic and Australia.

* Coe, L. 2008. Spaceward Bound: Training the next generation of explorers. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 14.

Exploring Knowledge beyond the Rutted Path: Aligning Computer Based Technologies with New Curricula for Teaching and Learning High School Science and Mathematics*

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This paper provides a critical review of the reasons for the lack of acceptance and integration of computer based technologies into mainstream high school education ,specifically mathematics and science, given that research recognises the importance to teaching and learning of the those technologies. This paper then proposes a framework for a new exploration based curricula and supporting case study.

Keywords: Anchored instruction, exploration based learning, virtual learning environments, modelling and simulation, computer based technologies, Bloom's taxonomy and technology.

* Darby, M.L. 2008. Exploring knowledge beyond the rutted path: aligning computer based technologies with new curricula for teaching and learning high school science and mathematics. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 15.

Creating the Next Generation of Space Explorers Now*

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Do your students dream big, have their heads in the clouds, are often caught out looking into space?

This is not a bad thing. Turn their imagination into reality through exciting new space science initiatives. Examining the new MSA and NASA Spaceward Bound connection, this paper will highlight activities that will utilise expeditions to develop skills and prepare for off-world exploration.

This paper will discuss classroom and local initiatives, arising from the recent completion of Spaceward Bound-Mojave that connects classroom, research and development. The mission of Spaceward Bound is to train the next generation of engineers and scientists by having teachers and students participate in the exploration of scientifically interesting but remote and extreme environments on Earth as a simulation for human exploration of the Moon and Mars. A range of practical activities and student excursion and expedition scenarios will be presented, all to stimulate the next generation of explorers.

Keywords: Spaceward Bound, Outcome Based Education, STEM, excursions, student expeditions, student fieldwork, space science education, practical projects and investigations, scientific journaling, Bloom's taxonomy and exploration based learning.

Mark is the Science Coordinator at St Joseph's School, Northam, in Western Australia. He has been in Science Education for over 15 years and has been in various Middle Management positions for most of that time. He is an active member of the Science Teacher Association of WA (STAWA) and the Australian Science Teachers Association (ASTA) and has been providing sessions, curriculum and course materials and professional development opportunities in space science related areas to other educators for many years. He is also a member of several educational planning committees and is an Education member of the American Institute of Aeronautics and Astronautics (AIAA), Mark recently participated in the April Spaceward Bound Mojave 2008 Expedition and this will provide the thrust of his presentation.

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* Gargano, M. 2008. Creating the next generation of space explorers now. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 16

Project MAST - Mars Analogue Simulation Trainer*

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One of the key ingredients for planning any expedition be it on Earth or off Earth into outer space and out ward to another planetary body is pre-mission reconnaissance and familiarisation training capabilities. All of The Mars Society's analogue research stations (FMARS, MDRS and the soon to be deployed EuroMARS and OzMARS) are missing this capability. Yes, incoming crews can look back over several years worth of web shots and reports for MDRS and FMARS, but that only gives the new crew a peep through a key hole at selected tiny areas of the HABs and the surrounding terrain who's exploration they are about to undertake.

Project MAST is a Virtual Reality simulator was conceived and developed by Hugh S. Gregory, Spaceflight Historian, as a solution to this problem. From 2005 to 2007 Project MAST gathered data at MDRS (both inside and out) and over a series of five missions to the MDRS area, also recorded its surrounding network of ATV trails and exploration routes.

The interior of the FMARS HAB was added to Project MAST over the winter of 2005-2006 with data gathered for Project MAST by the FMARS 10 crew. A demo available of Project MAST - The FMARS Version, in which one can in a limited manner "walk around" inside the FMARS HAB. It is now available on request to the author.

Project MAST visited the EuroMARS deployment area in Iceland in June of 2006 but was only able to document the approaches to the intended HAB deployment site as a late season snow storm dropped over 2 meters of fresh snow across the area only 2 weeks before the recon visit. The initial version of Project MAST for EuroMARS was released as a shareware demo during EMC-6 in Paris in October of 2006. It to is available on request to the author.

It is intended that the EuroMARS version of Project MAST be implemented for it when that HAB is ready to go into service.

Project MAST will be visiting the Arkaroola site in June 2008 to perform an initial recon and documentation of the surrounds of the OzMARS deployment site. It is intended that the OzMARS version of Project MAST be implemented for it when that HAB is ready to go into service.

Currently the Project MAST VR software will enable first time members of incoming crews to train for their rotation for FMARS and MDRS analogue HAB's in the comfort of their own home on their personal computer. It will also allowing returning veterans to refresh their memories of what is where and help them plan their next analogue HAB mission. Annual updates will enable the latest version of the MAST VR simulator to reflect which foot and vehicular (ATV or mule) travel routes are currently open or closed to travel and what new exploration areas have been authorised for investigation. Finally it will graphically represent any changes have been made in a HAB since their last crew rotation.

The initial test of the MAST VR software using data gathered on MDRS Crew 35 in Feb-March of 2005 was a complete success. Two privately sponsored data gathering missions to MDRS were approved and mounted in June and October of 2005 Project MAST was invited to join The Artemis One Expedition Moon Base simulation by Moon Society President Peter Kokh (MDRS Crew 45) to complete it's initial data acquisition for the MDRS version of Project MAST. In April of 2007 a third privately sponsored data gathering mission to MDRS was approved and mounted to update the project with the significant interior and external engineering changes to the MDRS HAB area since March of

* Gregory, H.S. 2008. Project MAST - Mars analogue simulation trainer. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 17-18.

2006. The access to Lith Canyon West was documented during the University Rover Competition in June of 2007.

The Project MAST VR simulator is being sponsored, funded and produced in house by SpaceBase™ © - A Not For Profit Astronomy & Space Sciences Educational Information Service based in Vancouver, Canada with "in-kind" support from Sagewood Software of Burnaby, BC.

Hugh S. Gregory is Spaceflight Historian, Chief Documents Editor, Chief Cartographer and WP Database Curator for MDRS and FMARS Research stations. Engineering Judge for the University Rover Competition, Comdr. MDRS Crew 35 (and Crew Scientist - Project MOSS), Crew Scientist-Surveyor MDRS Crew 45 (Moon Society Artemis One Expedition) also Crew Scientist-Surveyor for off season crews at MDRS, FLAME-1, MAST 1 (2005) and MAST 2 (2007).

Keywords: cartography, simulator, training Arrkaroola

Colouring Mars: Revisiting Historical Spacecraft Imagery*

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The electronic age has brought about a revolution in spacecraft imaging. For the first time, digital manipulation tools that were the domain of major institutions are now readily available to individuals. The author has applied 21st century imaging techniques to historic Mars imaging data from early US and Soviet missions. This has led to the ability to reprocess imagery originally released as monochrome into colour.

Keywords: Mars, Mariner, Phobos 2, Colour

A 21st Century look at Historic Martian Images

They flew past Mars years before man first set foot on the moon. Their low resolution television cameras helped shatter forever the myth of an advanced civilization on the Red planet, almost wiping our future space exploration in the process. Forty years later, their original monochrome images are shown here in colour (Figure 1).

Mariner's 6 and 7, like their predecessor Mariner 4, were the first unmanned spacecraft to return images of Mars, revealing a cratered moonlike world, apparently inhospitable to any form of life, past or present (Figure 2). By sheer bad luck, all three space probes had flown by the most uninteresting part of Mars and it wasn't until the arrival of Mariner 9 that the towering volcanoes and fossilized outflow channels of today's Mars were discovered (Figure 3).

Nevertheless these early Martian images represent an important milestone in space exploration's history. Mariner's cameras contained red and blue filters which changed sequentially as the probes photographed the surface of Mars. Following conversion from NASA's native image format, overlapping two-channel imagery from these filters were created, then a green channel was synthesized out of a combination of the red and blue channel. These three channels (red, blue and green) were combined to create a colour image. Further enhancements based on subsequent Mars observations were made to approximate Mars' true colours, while still preserving the integrity of the raw data. A similar process has been used for the Mars Global Surveyor (MGS) imagery. The MGS cameras also lacked a green filter. New details of the Martian pole can be seen, as well as atmospheric haze on the planet's limb.

Most original colour Mariner pictures that may have existed have since been lost to antiquity. The computer processing power at the time was barely sufficient for the task of colour processing, making it impractical for all but a few images to be released in anything but black and white. By the time the processing power had become available the early Mariner images were buried under superior products returned by later Mars probes.

Now, however, computer imaging technology has advanced to the extent that the average home PC is capable of achieving what mainframes had to be used for decades ago. Figure 1 depicts a colourised overlapping frameset from Mariner 4's returned image data. These frames, seven and eight out of twenty one in total, surprised scientists by revealing moon-like craters on Mars. A simulated Martian colour gradient was applied to most of the frameset however the central overlap allowed for true colour processing. Figure 2 represents a significant improvement in imaging technology from the Mariner 6 and 7 missions. This image shows frost and ice covered craters over the Martian Pole. Finally, over a generation after first release, colour has been added to Mariner's Mars.

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* Hobbs, S. 2008. Colouring Mars: revisiting historical spacecraft imagery. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 19-24.

A similar process was used to revive other Mars mission imagery. The Soviet Phobos 2 mission returned the highest quality pictures of any Russian Mars mission, returning red and blue filtered images before a sleeping technician allegedly caused its failure just before entering Martian orbit. Figure 4 is one of a series of frames returned from Phobos 2 as it approached Phobos, one of Mars' two small moons.

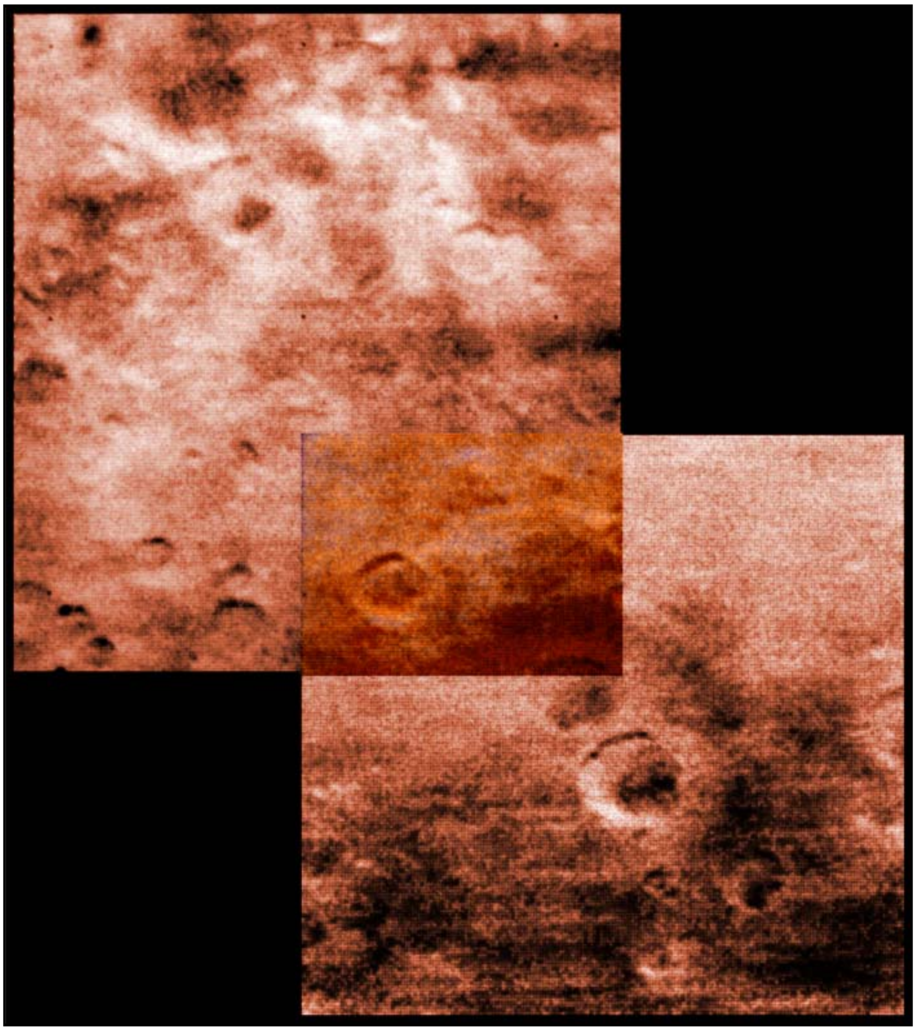

Figure 1. These Mariner 4 frames represented the first ever close-up views of the Martian surface. Each frame was shot in a different filter, enabling the overlapping region denoted by the central square to be reprocessed into colour. A generic colour gradient has been applied to the rest of the frames.

NASA's Viking lander imagery was transmitted as three separate channels, negating the need for channel synthesis. However a number of higher resolution monochrome Viking images were returned during the mission. These were colourised by combining the original channel with lower resolution colour channels from another image of the same area (Figure 5).

Mariner 9 proved the only disappointment. Despite discovering the great Martian volcanoes and a valley system many times larger than the Grand Canyon, its filter wheel jammed, making colour imagery impossible. A simulated colour scale based on colours from later orbiter missions was used as made for a stand in, based on colours from later orbiter missions, as shown in Figure 3.

These colour images are intended to provide a new look at the historic Mars and it is hoped to preserve the heritage of these early missions for the future.

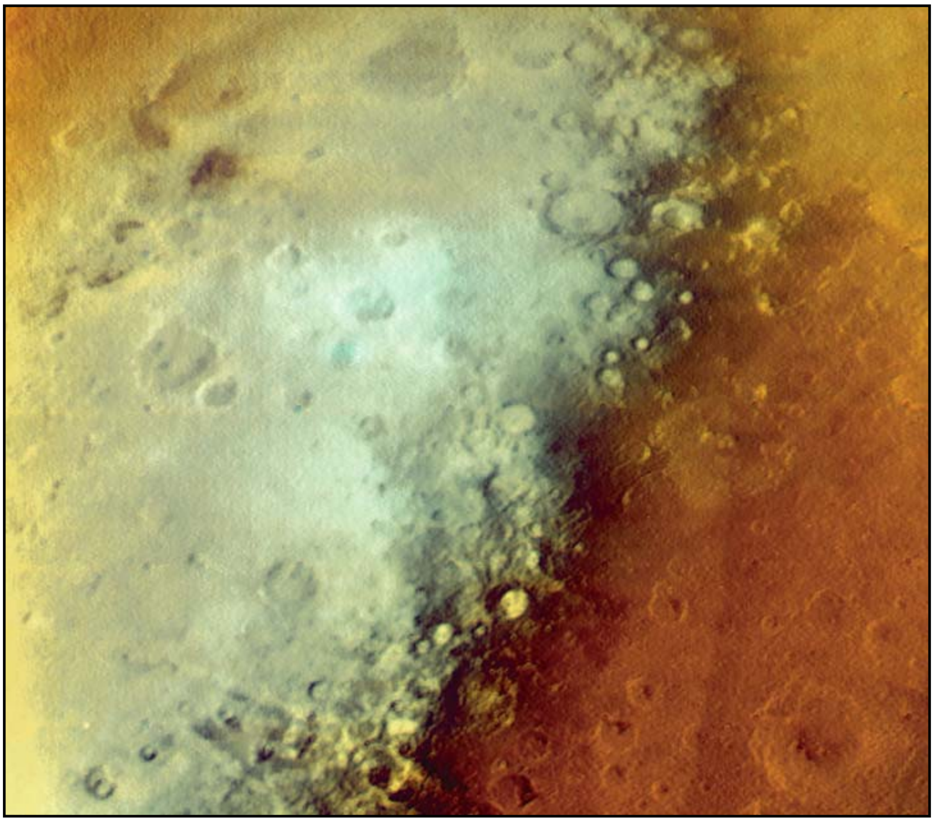

Figure 2. This Mariner 7 image of the Martian pole was created using overlapping red/blue filtered imagery returned by the spacecraft. A green 'channel' was created from a mixture of the red/blue images and then all three channels (red, blue and green) were combined to create a colour image.

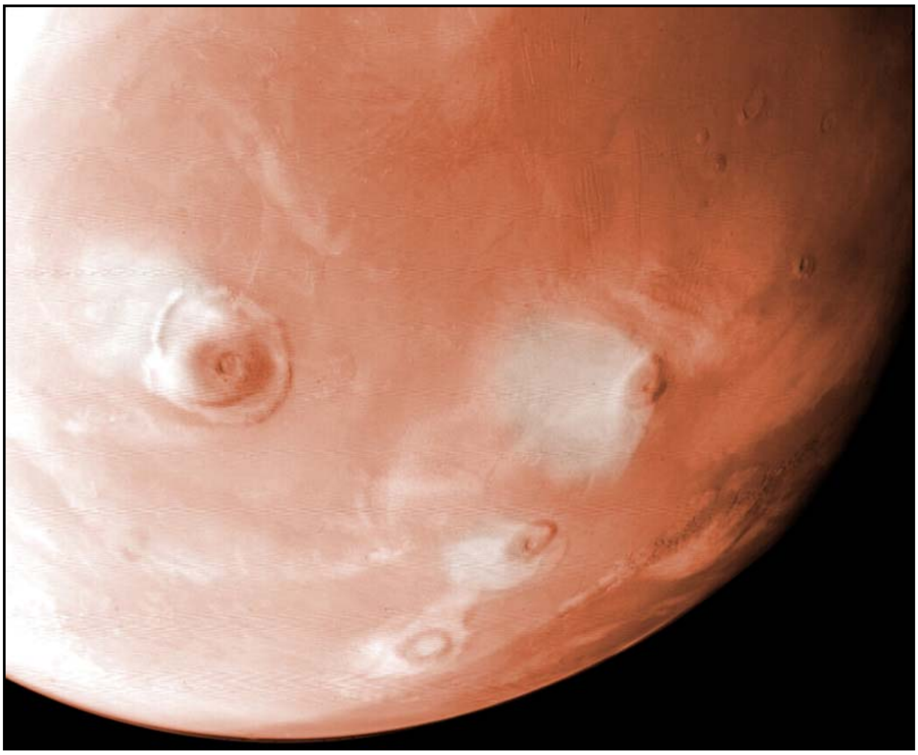

Figure 3. A wide angle view of the great Martian volcanoes imaged by Mariner 9's wide angle camera. Few Mariner 9 colour images exist due to a jammed filter wheel. This image was converted from NASA's native format, then a simulated Martian colour gradient was applied to approximate what a human observer would see.

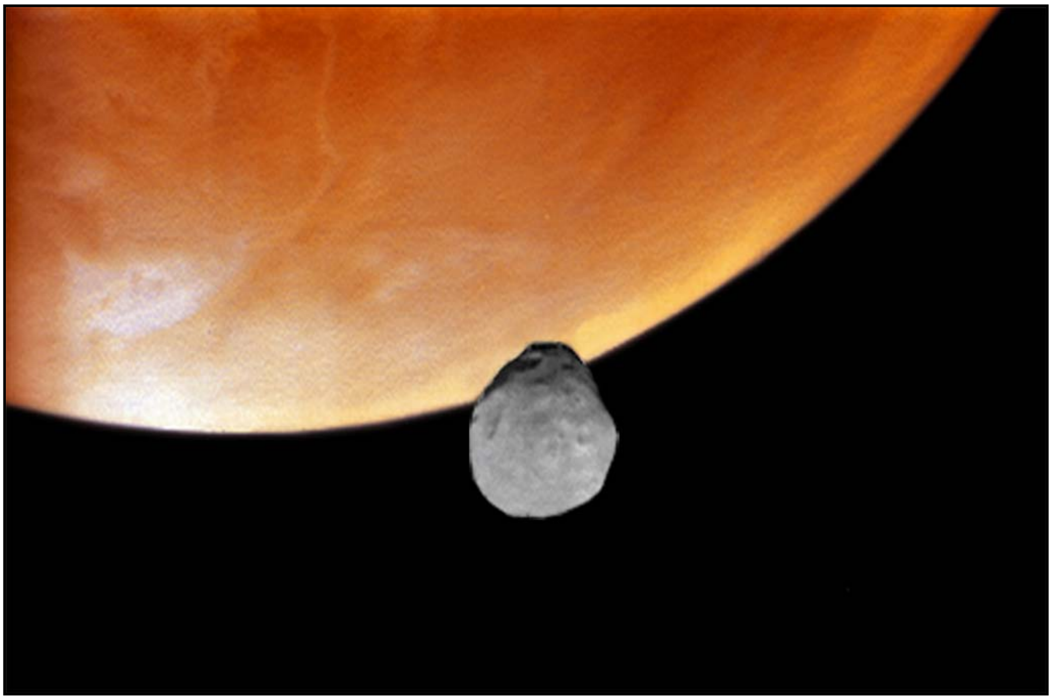

Figure 4. The Soviet Phobos 2 imaged Mars and Phobos during its approach to the innermost Martian moon.

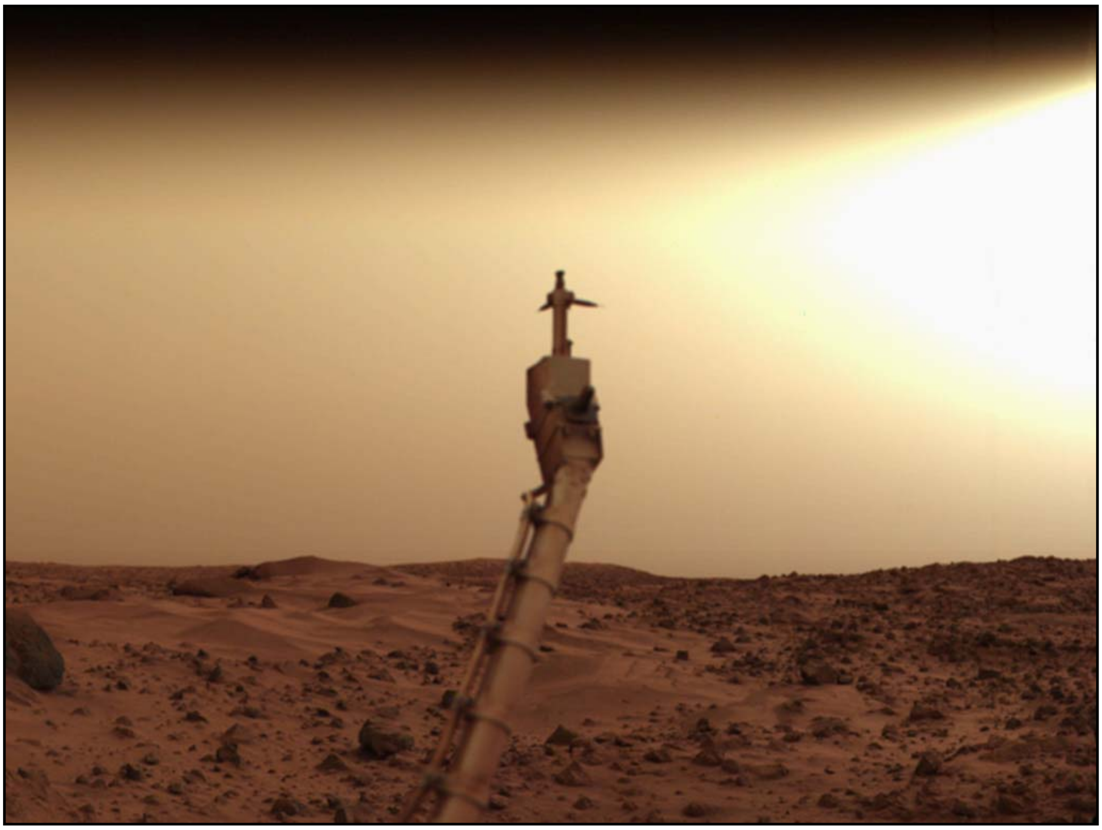

Figure 5. The Viking landers transmitted images using three separate filters, red, green and blue. This negated the need for creating an intermediate channel. The three images were processed to reduce noise and line dropouts and then combined. The colours in the resulting image were tweaked to accurately portray the colours of a Martian sunset.

Scientific Artwork

Mars Global Surveyor returned highly detailed elevation data of Mars, tracing the heights of geological features as never before. Combining this with orbital imagery in specialized visualization software made it possible to create scenes simulating low Martian orbit. The scene in Figure 6 approximates what a future Marsnaught would see, hovering a few hundred kilometers above the surface. This style of artwork is also useful for visualizing what Mars may have looked like billions of years ago, when Mars probably had oceans of freely flowing water. For Figure 7, water was added to an aerial view of Chryse Planita to approximate an era of torrential flooding from Valles Marineris.

The more traditional artwork pieces utilize the latest scientific understanding of Mars to create realistic impressions of the robotic Mars missions in action (Figure 8). From Mariner 9 to the Opportunity Rover, these man-made explorers are shaping the way we understand Mars and also of our own planet, its origins and future.

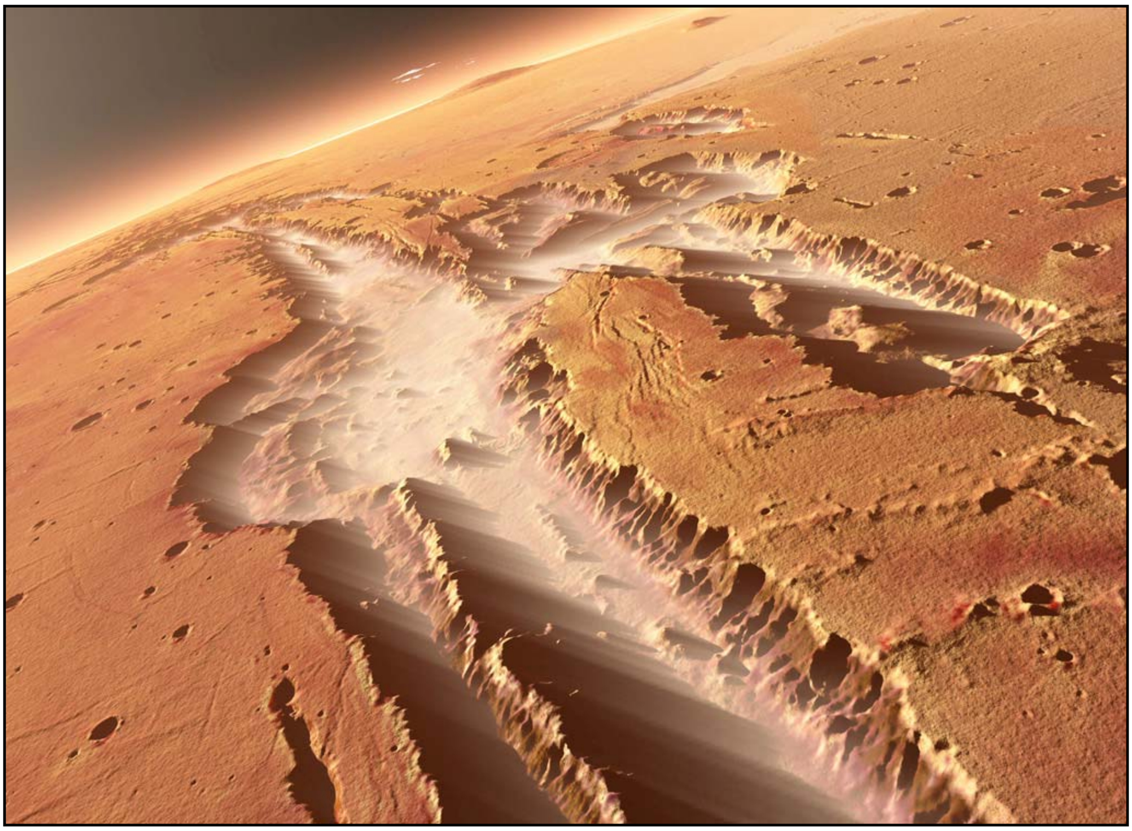

Figure 6. Mars Global Surveyor returned highly detailed elevation data of Mars. A Viking colour overlay was registered in visualization software with the equivalent elevation map. Sunlight angle, atmospheric conditions and planetary curvature were all adjusted to create a view above the Valles Marineris canyon system.

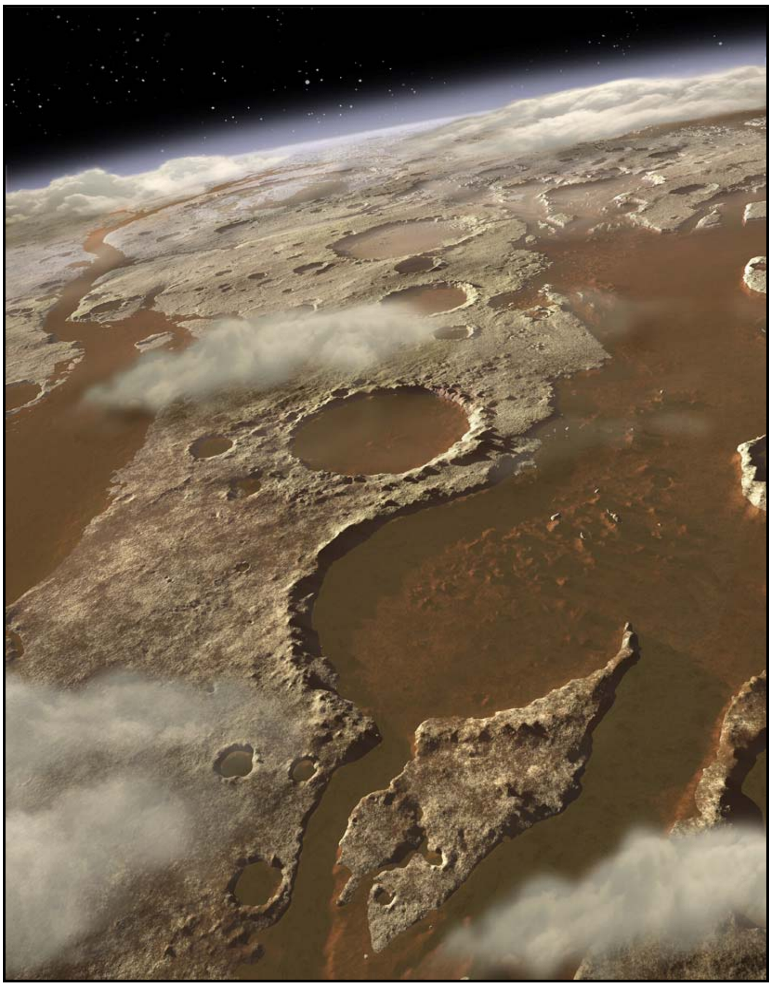

Figure 7. Most scientists believe early Mars was covered by freely flowing water. This is how the Chryse Planita region may have appeared billions of years ago.

Figure 8. The Martian sun rises over the Opportunity Mars Exploration Rover (MER). The sun will soon rise high enough to provide enough power for the solar panelled rover, lying dormant during the night, to wake up. The rover and elements within the scene were modelled in 3D and are based on actual spacecraft photographs from NASA.

Modelling the Martian Subsurface in Search of Water*

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Our current knowledge of life on Earth indicates that life requires liquid water. A first step therefore in identifying the environments on Mars which are most favourable to current life is to locate where there is liquid water. On Mars stable liquid water must be confined beneath the surface. It is important to locate the shallowest potential liquid water environments as they may be the most easily accessible by future missions. We are developing a model to estimate the range of subsurface depths on Mars at which the temperature and pressure conditions allow water to be a liquid. The depths to liquid water on Mars can be constrained by developing and improving models of the geothermal gradients and heat flow in the Martian subsurface. This method relies on the measured physical parameters of Martian materials (such as thermal inertia) which have low spatial resolution and are indicative of the thermal characteristics of the top surface layers. An important complication in these models is the shallow temperature gradient (within several meters of the surface) which is strongly influenced by diurnal and seasonal surface temperature variations. We use a simplified solution to the one-dimensional, time-dependent heat conduction equation to determine how periodic surface temperature variations affect temperatures below the Martian surface. Using estimates of the range of Martian surface temperatures and the plausible range of thermal diffusivities of Martian materials we can constrain the maximum variation in temperature that could occur at a given depth below the surface. This will allow us to determine if liquid water can ever occur transiently at shallow depths. Such a result has important implications both for the explanation of shallow putative water flow features on the Martian surface (such as gullies) and for the exploration of environments hospitable to microbial life, which may be of significance for a future shallow drilling mission. In this talk our model will be discussed and preliminary results presented.

Keywords: Mars, liquid water, biosphere, astrobiology

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* Jones, E. and Lineweaver, C. 2008. Modelling the martian subsurface in search of water. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 25.

Quantitative Evaluation of Human-Robot Options for Maintenance Tasks during Analogue Surface Operations*

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Due to the scarcity of human labour plus the harsh conditions at any human Mars base of the foreseeable future, robots are likely to be employed in to assist with at least some assembly, deployment, transportation, inspection, servicing or repair tasks. By the first human landing, robotic technology is expected to have made possible the use of robot teams already on the surface to prepare the landing site, ensure the functioning of ISRU equipment and survey the local area for the arriving astronauts. Robots are also likely to assist them during their stay and after their departure. Today's researchers are increasingly interested in the question of how to systematically choose the best combination of robots and/or humans for particular tasks, and how to actually demonstrate and measure teams performing these tasks in realistic simulations. This paper critically examines a quantitative method developed by Roderiguez and Weisbin of JPL for computing performance/resource scores for a range of human-machine systems on a variety of tasks. It then proposes a practical experiment, to be conducted at a future Mars Society surface operations simulation, that will apply the method to quantitatively compare human maintenance task scores with those of a hexapodal service robot that the author is currently building.

Keywords: Mars analogue studies, field robotics, evaluation, sliding automation.

Introduction

It is now commonly envisiaged that due to the scarcity of human labour and the harsh conditions at any human Mars base in the foreseeable future, teams of robots will assist with assembly, deployment, transportation, inspection, monitoring, maintenance, mapping, science and safety tasks. By the time humans are ready to land, perhaps around 2020, the technology is expected to have advanced to the point where robot teams already working on the surface will prepare the way for the arriving astronauts - checking equipment, surveying the site, moving boulders, etc. Later, robots deployed on the surface will join a cooperative network, communicating with and working alongside the humans in flexible ways to get the best out of both agencies.

Mission planners and engineers are increasingly interested in the question of how to choose the best teams of robots and/or humans for particular tasks, and how to actually demonstrate and measure teams performing these tasks in realistic simulations. Human teams are constantly being evaluated in ever more realistic surface simulations, involving sophisticated electronic communications, planning, recording and monitoring. For example, a team lead by William Clancey demonstrated the value of their Mobile Agent Architecture at the Mars Desert Research Station (MDRS) in Utah in April, 2003 [1]. Once the necessary physical communications infrastructure had been made reliable, this voice-driven software proved capable of acting as an intelligent 'CapCom', automatically monitoring, route planning and generally assisting its human agents, transferring large volumes of logged data such as maps, models, photographs, voice logs and other science data around the local area, and communicating this remotely to distant "back office" teams for later analysis.

In the past few years, several remarkable demonstrations of the capabilities of robot teams have also been made by the combined efforts of NASA's Ames Research Centre, Carnegie-Mellon University, the Jet Propulsion Laboratory [2, 3]. For instance, the Collaborative Decision Systems (CDS) Demonstration that took place at Ames in September, 2005 showcased an integrated network of cooperating human and robot agents. The scenario included 'K9' a highly autonomous, six-wheeled MER-class wheeled rover; 'Grommit', a smaller, four-wheeled high speed personal assistant robot,

* Mann, G.A. 2008. Quantitative evaluation of human-robot options for maintenance tasks during analogue surface operations. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 26-34.

one space suited individual in the test area, a remote coordinating ‘habcom’ and a crewmember remotely commanding each robot, as if from a habitat. The test field was a sandpit scattered with rocks, and pieces of equipment serving as landmarks. The task was a science sampling EVA, in which the robots, in the process of performing their own exploratory tasks, could be requested by an astronaut to interrupt their work, and assist with another task, which request would be granted conditionally according to a policy that prioritised tasks.

Such demonstrations depend on the accumulated efforts of dozens of paid government researchers, costly equipment and the expenditure of substantial sums of money and time. The key consideration for the purposes of this paper, are then: without such resources, what answers to the question of robot usage can the Mars Society Australia hope to answer? It will be argued here that a niche opportunity exists for rigorous experimentation in this domain using what resources are now available to MSA. This work learns from the prior experiments. It would be a mistake to deny the value of JPL’s cooperative agent network (team of communicating robots and humans) so this basic concept will be accepted in what follows. The approach taken here is to develop a specific offering for such a network: a machine oriented toward maintenance tasks instead of field science (the justification for this is given in Section 3).

Once a prototype robot has been built, it will be field-tested during a Mars simulation in order to answer questions such as: How does a maintenance robot compare with humans performing maintenance? Is a robot-human combination preferable? What are the requirements for a suitable maintenance robot? What are the best mode(s) of control (assuming “adjustable autonomy” [4]) for a eminence robot - teleoperation, high-level commanding or full automation? How simple and reliable could a robot be made that still served a maintenance role? What other tasks could a maintenance robot be expected to perform?

Answering these questions will require:

- A good evaluation method for quantifying the contribution or “value-added” expected from a human, robot or human-and-robot system for a given category of task
- A suitable example task(s) that can be modeled in a realistic surface simulation
- A human work team capable of performing the example task(s) in simulation
- A robot capable of performing the example task in simulation

The remainder of this preliminary paper will attempt to provide these four requirements. Section 2 critically examines an interesting quantitative method developed by Roderiguez and Weisbin [5] for evaluating a range of human-machine systems on a variety of tasks. Section 3 justifies the choice of maintenance as a category tasks suitable for these experiments, and analyses these tasks into independent task primitives as a step toward applying the Roderiguez and Weisbin method. Section 4 introduces the Mascot experimental field robot, currently being developed by the author, as a robot system potentially capable of inspection, servicing and maintenance tasks. A sliding automation control system is planned for the Mascot, i.e. it will eventually be capable of being teleoperated by a remote human, commanded at a high-level by a remote human or operating fully autonomously. Section 5 then proposes a practical field test, to be conducted at a future Mars Society surface operations simulation, that will apply the remaining steps of the method to compare the value added by a human performance of the task with that of the Mascot robot system operated in one or more of its modes.

Roderiguez and Weisbin’s method

I choose to focus on a method developed by engineers Guillermo Roderiguez and Chuck Weisbein of JPL for evaluating the performance of different agentive systems on particular tasks [5]. The method is interesting in that it allows measurements taken on very different systems, using almost any suitable criteria and metrics, with different units, to be directly, quantitatively, compared. It can be also be applied at any scale. Briefly, the method consists of the following steps:

1. A scenario involving the tasks of interest is analysed into a complete set of *functional primitives*, i.e. physically independent operations an actor might perform in carry out the task, such as Plan Path, Traverse, Find Rocks, Carry Rocks or Sense Atmosphere.

2. For each functional primitive, define one or more *performance metrics* to be used in evaluating each candidate system. E.g. for Traverse, one would include distance to be travelled, as well as degree of difficulty of the terrain to be negotiated.

3. Specify a set of *agent systems* to be evaluated: these can be particular robots, humans or a combination of both.

4. For each agent system, specify the *resources* needed to deploy it on each functional primitive. E.g. for Traverse, the mass and power of individual agent systems might be measured. This keeps the comparison fair, by compensating for the differences in performance which might be due to different classes of machine or human tackling the operation.

5. Either by analysis, simulation or experiment, the performance of each agent system is then evaluated on each of the functional primitives and a composite score s(m) is computed that estimates the aptitude of each agent system for each operation. This is combined with a composite score r(m) estimating the resource consumption to form a comparative ratio called *value-added* v(m).

Values of v(m) are the output of the process and may be interpreted as "the ratio of additional performance due to system m to the additional resources needed to implement this system when compared against the performance and resources of the reference system [5, p.173]. They can thus compare any of a number of competing systems.

From a practical perspective, it could be difficult to specify the input parameters for the calculations. In particular, Step 1 could require some effort to create new functional primitives and ensure that they are independent, although the total possibilities for these should be limited, and a common pool of "standard" primitives would soon become available if these were always well-described in publications. In Step 4, appropriately characterising resource requirements would be difficult for some tasks. Would the dollar cost of a system be an appropriate parameter? Do these also have to be independent? Once chosen, it would generally not be as conceptually difficult to decide on appropriate metrics, but this could still present some difficulty: how would one account for the resources expended in a human or robot system that opportunistically used an existing measuring device to gather extra data? The difficulty is not one of differences between the units of measures because the method is specifically designed to use a multiplicity of measurement units and reduce them to standard units of the bit by the final step. It is rather, about understanding the abstract relationship between inputs and outputs well enough to make good choices.

Is the method theoretically sound? Most of calculations involved in the method are straightforward and uncontroversial. Mathematically speaking, a potential problem arises from the choice of an information-theoretic measure. In [5], Equations 4 and 7 describe task growth and resource growth, respectively, as base 2 logarithmic functions, drawing inspiration from the human performance work of Fitts [6]. That work proposed an Index of Task Difficulty (ID) for experiments involving human placement of limbs at a target position:

$$ID = \log_2(2A / W) \qquad \textbf{(1)}$$

where A is the size of the motion required to place the limb at the target and
W is the width of the target.

The unit is bits, because Fitts was interested in quantifying the information processing capacity of the motor nervous system and wanted to apply Shannon's information theory [7], where the bit is the fundamental unit of complexity. However, according to MacKenzie [8], Fitts may have erred by adopting a simplified variation of Shannon's work. MacKenzie argues on theoretical and experimental grounds that, unless A:W >> 1, the behaviour of Equation 1 will depart from Shannon's well established model of the information capacity of a channel as limited by its signal-to-noise ratio, and that Shannon's original formulation ([7], Equation 17, p.100-103) should have been used instead. According to MacKenzie, in some applications of the Index of Task Difficulty, the ratio has been observed at unity or less, which condition would have invalidated the measure.

Our concern is that Roderiguez & Wiesbin, in adopting Fitt's idea, may have inadvertently made the same error. Now combining Equations (1) through (3) from their paper and replacing a product of ratios with a ratio of products, one of the two affected corresponding measures for our purposes is the performance s of system m

$$s(m) = \log_2 (|P(m)| / |P(1)|) \qquad \textbf{(2)}$$

where each P(m) is the product over all performance measures of system m and system m=1 is arbitrarily chosen as a standard reference.

A second measure, r(m) is similarly defined, but for resource consumption. The question becomes: are these ratios likely to approach unity? The answer is clearly yes, since any system m might return very similar performance measurements to those of the reference system 1. The same would be true of resource consumption. Fortunately, the solution is at hand; as MacKenzie points out, there is no reason why Shannon's original equation may not be used instead. In the case at hand, that would amount to replacing Equation 1 in the Roderiguez & Wiesbin paper with

$$p(k,m) = p(k,m)+p(k,1)/p(k,1) \qquad \textbf{(3)}$$

as well as the corresponding alteration to the c(k,m) resource ratio. If the proposed field trials can be realised, calculations using both variations can be compared to gauge the actual magnitude of this problem.

Another problem is one common to econometric analysis of this kind: that it could be focused too narrowly on achieving readily-measurable outcomes at the expense of less tangible, but still real, outcomes. Suppose an analysis based on science productivity measures such as number of sites visited, hypotheses generated, etc. [e.g. 9] returned a finding that the optimal science could be done by leaving human astronauts in Mars orbit and conducting the exploration by controlling robots on the surface (as is actually proposed by Landis [10]). Choosing this option might well be a cheaper, safer and more efficient way of doing science but from a broader, cultural perspective such a mission is clearly deficient, both for the human crew and for the taxpayers vicariously experiencing it. They would be "spared" the experience of landing, ascending, living and working on another planet - and nothing of these important matters would be learned. The remedy to this drawback is to find a way of properly valuing the less obvious benefits of human presence so that it can be input to and accounted for by the Roderiguez and Weisbin method. This would be the equivalent of efforts by environmentalists to revolutionise business accounting so that it does not undervalue the contribution of natural resources or a clean environment as inputs. But although theoretically feasible, deciding how to include intangible benefits in the Roderiguez and Weisbin method would complicate the already difficult matter of how to choose and weight the component primitives[1].

Despite these problems, the potential usefulness of the Roderiguez & Wesibin method can scarcely be overstated and so it should be refined and applied by all means.

Choice of task

The chosen demonstration scenarios for most of the robot development at NASA centres over the past decade still reflects the prevailing funding environment prior to the Bush administration's commitment

[1] One of the example primitives offered by Roderiguez & Weisbin, called "Be There", accumulates risk to the human astronauts over the time taken in an EVA. It is zero for robots and apparently all negative for humans.

to a return to human spaceflight in 2002: a culture of Earth-controlled robots doing exploration and science. As the emphasis moves to human spaceflight, the trend now is toward cooperative human-robot teams, but the focus is still on glamorous field science. This category of task is therefore quite well studied, and probably not worth revisiting for our purposes.

Fig. 1. Maintenance tasks will represent a considerable, ongoing burden for future Mars explorers, unless the workload can be reduced by robots. Here engineer Matt Bamsey repairs a collapsed water pipe support outside the Mars Desert Research Station, Utah during a 2003 simulation. .

On the other hand, taking care of the base has not received so much attention. Monitoring and maintaining all the equipment required to support human exploration in optimal condition over a many months will represent a lot of work. Examination of actual crew workloads on the International Space Station (ISS) reveals that a substantial proportion of even the science crew's time is spent on planned and unplanned maintenance tasks [11, 12]. From the author's experience at the MDRS [13], maintenance work on for small crew at the first Mars base is likely to be even more demanding (Figure 1).

An Ames Research Centre study of human versus robot rover science returns in a Mars simulation suggested that human beings are 1-2 orders of magnitude more productive than robots at field science[9][2]. But even if it were shown that human astronauts were inferior to robots at this category of task, it is difficult to imagine a realistic scenario in which they took the trouble to fly to Mars but did not actually take a lead role in exploratory science (see Section 2). Once humans arrive, it is far more likely that robots will be cast into supporting roles, not the least of which would be relieving the astronauts of the burden of servicing and maintaining the other equipment, and themselves. For many outside tasks that did not deserve the direct attention of humans, the time, effort and risk reduction of robot work would be highly desirable.

For convenience, I shall categorise tasks into three levels of increasing difficulty for a robot, depending on the nature and predictability of the task.

Level 1. Location-based non-manipulation tasks (e.g. still and video imaging; transport of tools and consumables; instrument positioning) It is only necessary for the robot to navigate accurately to a location such as a possible trouble spot and take high-resolution photographs of the equipment

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[2] This is actually a claim of the kind that should be better quantified using the method described in Section 2.

concerned for transfer to an engineer's station. In teleoperation, the machine is guided by the human operator; in high-level commanding and full automation, the robot must plan a path between waypoints that avoids obstacles. Such a robot also could fetch and carry tools, equipment and samples on command.

Level 2. Use of manipulators for planned, structured tasks (e.g. repair-by-replacement; spraying of paint, lubricant or sealant; changeout of a dust filter or replacement of a gas cylinder; staking or pegging structures such a solar panels or antennae; connecting and tightening electrical or stay cables; loosening or tightening bolts and nuts; sweeping or blowing dust off solar panels, instruments or cameras). This task requires in addition to accurate navigation the provision of one or more manipulators and/or specialised tools and the skill to bring those tools to bear on a particular work item. In teleoperation, the skill is that of the remote human operator; in high-level commanding it requires sophisticated sensors and intelligent control software. Scheduling would come from human-supervised, overrideable, automated scheduling software working to a routine maintenance schedule (both off-board the robot).

Level 3. Use of movement and manipulators for unplanned, unstructured tasks (e.g. repair on demand, given a diagnosis; disassembly and assembly of machines according to manufacture's procedure; repositioning of fallen or displaced equipment; opening or closing stuck valves, doors and panels; unfreezing pipes; simple testing of electronic and mechanical components). These tasks require everything required in Level 2, but also presuppose a certain degree of problem-solving, and error recovery. This would come from human intervention, planning and reasoning overriding automated routine maintenance schedules. A larger selection of tools, probably more sophisticated sensors and probably a greater amount of applied force from the manipulators would be required. Such skill is difficult, but not impossible, to demonstrate [14]

From an evaluation point of view, what functional primitives would be involved in the performance of such tasks? Because it is advantageous to have a small, standardised set of these available to all, the first step in any such specification should be to examine the existing primitives and try to use what is there. New primitives should be created reluctantly, and only if there is nothing suitable on the shelf. From the list of examples in [5] we see that Traverse (moving from one specified location to another, characterised by distance, speed, and terrain difficulty), Recover From Mishaps (overcoming relatively simple operational mishaps such as a fall and verify that no damage has occurred) and Carry Rock, renamed as Carry Equipment, (characterised by mass, volume and distance carried) could be used. Similarly, Find Rocks should be renamed as Find Jobsite (speed and accuracy with which vision systems could locate, recognise and project a working calibration onto a specified object of interest). To this we should add Grasp (ability to apply force to turn or lift an object, characterised by force/torque applied and mass and dimensions of object). Skilled Tool Use should also be added, to capture the need to apply human and machine skill to the use of a specific tool (correct selection of tool, speed and accuracy of placement, time to completion).

Mascot field robot

A team of two (simulated) human astronauts working on specific maintenance tasks would form one agent system to evaluate (and would probably be chosen as the reference system). The Mascot field robot (Figure 2), currently being developed by the author, is another. It is designed as a service robot and could be adapted to serve as a simulated maintenance machine for Mars explorers. This machine is designed to demonstrate that six-legged locomotion can provide good speed, traction and stability in uneven or broken terrain that cannot be matched by wheeled machines. However, in order to avoid the well-known problem of unreliability in complex, jointed leg systems, the mechanism has been greatly simplified. Inspired by a similar machine called RHex [15], the Mascot has six, simple passive spring legs, each mounted on an independent revolute axis (6 DoF in total) and driven by an 18V Metabo 100W DC motor fitted with a 150:1 planetary gearbox. The six motors are driven by Jeffrey Kerr LLC PIC-SERVO control boards connected to a 32-bit RS485 multidrop network controlled by an onboard Sony Viao laptop running Windows XP.

This configuration is simple, reliable and robust, yet provides remarkable agility and control. The machine is 590mm long, 570mm wide at the middle legs and 700mm from the ground to the top of the current camera mast. It weighs approximately 14kg. As with insects, the machine moves by “tripod walking”: at any instant three legs are on the ground, and these alternate between the sides of the robot. The machine is steered by altering the phase relationship between the tripods on either side. Although not yet measured, the machine is expected to be able to achieve a speed of at least 0.5 m/sec. on uneven ground. The main power supply for the motors consists of two 18 volt, 13Ah Lithium-Ion battery packs with built in voltage regulators and thermal shutdown circuitry. A 12v 2Ah Lithium Ion battery supplies logic power. The camera and control receiver are both independently powered by small NiCd battery packs. The camera platform is designed around a pair of EO5-380

Fig. 2. Prototype of the Mascot field robot being developed by the author.

CCD cameras mounted on a tilt-pan head. Each camera is capable of transmitting 380-line PAL colour video over at 2.4GHz wireless link. At this stage the cameras are not used by the robot as a vision system, but only as part of a low-cost teleoperation control system. This also depends on a commercial 6-channel 36MHz FM wireless remote control system, designed for model aircraft. Two channels of this control the effective left and right steering, and two channels control the tilt and pan motors of the camera head. When completed, the system will enable a remote operator to control high-speed motion of the robot while viewing real-time video from the cameras on a small LCD monitor. Depending on the performance of the machine, the project may progress to a high-level commanding mode or even to full automation.

What tasks could a robot like the Mascot take on while setting up and operating a surface base, and in exploratory work? The answer depends on the task, the mode of control required (teleoperation, high-level commanding or full automation) and the provision of hardware and software for the total robot system (see Table 1). We will restrict our attention to maintenance tasks for the reasons discussed in Section 3. This table should be interpreted as showing increasing, cumulative demands on the equipment and behavioural competence of the robot as we move from the lowest demands in the top left of the table to the greatest demands in the bottom right. Thus simplest operational form of Mascot would be capable of Level 1 tasks if teleoperated, because those tasks only need accurate navigation and photography. At the other extreme, a long, well funded research effort would be required to provide the all requirement specified in the table, including real-time planning and error-recovery software in order to automatically cope with unplanned, unstructured repair jobs.

Table 1. Cumulative requirements of the Mascot field robot relative to developed control mode and level of task.

	Teleoperation	High-level Commanding	Full Automation
Level 1 Tasks	functioning basic system allows inspection, photography, fetch and carry	add compass, GPS and obstacle- detecting sensors; add software planning layer on behaviour based reactive layer	connect cameras to vision system; add vision software to frame photographs, recognise humans
Level 2 Tasks	add at least one 6 DoF manipulator arm; routine maintenance manuals for operator	add specialised, detachable tool ends; vision software and touch sensors to guide tool use algorithms	add human-interruptible maintenance scheduling software off-board); algorithms for selection of tools
Level 3 Tasks	Provide more force at manipulator, tool end; more manipulators; detailed troubleshooting manuals/software for operator	add more and better sensors depending on task; voice command software	add best available real-time planning software (off-board); error recovery software

Table 1 also suggests a research direction for future work on the Mascot robot: left to right and top to bottom. It makes sense to try to add high-level commanding only once teleoperation is perfected, and progressing to full automation will be easier once high-level commanding is perfected. For example, the necessary skilled motions for the robot to open an access panel and remove the circuit board inside on its own might be able to be acquired by a learning algorithm in the robot while it is being guided through these actions in teleoperation. If more resources can be made available to the robot, such as better sensors and lightweight, multi-jointed arms with manipulators for the front of the machine, it will be possible to progress down the table to the higher levels of functional skill.

A Possible Experiment in the Field

How can the use of the Mascot robot be tested in an analogue surface simulation, such as those conducted by the Mars Society and how can its performance be evaluated quantitatively in comparison with human astronauts on maintenance tasks like those described in Section 3? Conceptually at least, if we choose a simple Level 1 task - maintenance photography - we now have the four requirements of Section 1: a good evaluation method, a suitable task, a human team that can do the task in simulation and a robot that can do the task in simulation. At a minimum, the Mascot robot will be able to carry out this task at the next Mars Society simulation, at which it is also extremely likely that a volunteer human astronaut team of two could be found for the comparison.

Physically, the task would require each agent system - the pair of astronauts, and the teleoperated Mascot, and a combination of the two - to take a series of high-resolution photographs at a number of key equipment sites at various distance from the habitat. A taxing list of real or dummy equipment panels, bolts, connectors etc. would be nominated or set up in the vicinity of the habitat. The amount of time, resources, risk taken as well as the quality of the resulting photographs would be assessed. These data would then be processed using (both variations of) the Roderiguez & Weisbin method to decide how they compared.

The Mascot robot can probably be modified to carry out Level 2 tasks, but Level 3 tasks are expected to require a more massive, better engineered machine. It is, however, neither necessary nor wise to tackle all levels of tasks at once. In developing robots to tackle ever more complex tasks, it might also be possible to assess an important matter about maintenance by robot: to what degree does extra complexity need to be added to the system in order to carry out the higher level tasks, and at what point do the maintenance needs of the robot itself begin to impose more of a burden on the mission than they are worth?

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Trust me, I'm a Science Communicator!*

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In this presentation, Dr Rob Morrison explores the relationship between science and the media, how to get science into the news, and why scientists should bother doing so.

The presentation analyses a typical science news report, explores the news angles that are good (and bad) for scientists, examines the relative benefits of TV, Radio and Print and demonstrates how to prepare a Media Release that works.

Increasingly people are choosing to get their news through the internet, and the presentation examines the particular challenges and hazards facing those putting out science news through the web.

Science Communication is a developing field, and the presentation deals briefly with some of the professional guidelines that have emerged to help scientists deal with the media, and the role of the Australian Science Media Centre, which is transforming the ways in which the Australian media handle science stories.

Rob is a freelance Science Communicator and broadcaster, and holds the position of Professorial Fellow at Flinders University.

Rob has written 34 books on science and natural history, and is co-author of 13 more, as well as dozens of articles. A science and environment broadcaster for forty years on television and radio, he co-hosted the long-running national television program *Curiosity Show*, which screened in 14 countries. He was for ten years the environment and science correspondent for Channel Ten TV News and produced the science segments on *NEXUS*, the television program of the Australia Network, Australia's Asia Pacific Service, which screens in 41 countries.

He has won many national and international awards, including the Michael Daley Award for Science Journalism, the Skeptics Eureka Prize for Critical Thinking, The Australian Government Eureka Prize for the Promotion of Science and the inaugural SA South Australian Government award for Excellence in Science Communication. In 2004, he was awarded the Order of Australia for Science Communication and Conservation.

Rob is currently Patron of National Science Week SA, Interim Chairman for *SciWorld*, South Australia's interactive science and environment centre, Vice-President of the Australian Science Communicators, a member of the Board of the Australian Science Media Centre, and Chair or a member of many Boards and Councils of environment and conservation organisations. He is the South Australian Senior Australian of the Year for 2008.

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* Morrison, R. 2008. Trust me, I'm a science communicator! In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 35-40.

A Charter for Public Service Research Agencies

Soem Issues in Science Communication

Dr Rob Morrison

Framing a Story

Is the story framed so that:

- a news event is made out of a study's release?
- it is attached to a hard news peg?
- it is part of cyclical events?
- it is a human interest story or has that context?
- it highlights the biggest, most expensive, first……?
- it emphasises the paradoxical, ironic, quirky etc?
- it highlights differences, controversy (esp. expert)?
- it revolves around well-known personalities?
- it reflects current media agenda of 'important' issues?
- it is an exposé (fraud, plagiarism, theft, cover-up etc)?
- it is little more than the Media Release?

Are Scientists Becoming Media Tarts?

Stories that are not Stories

- The PR Machine must be oiled
- Institutional Demand
- Hyperbole – "Breakthrough" and other Swearwords
- Promise is not Achievement
- Clouding the Issues

Some examples………

Eurekalert "Stem Cells"

10 Most relevant stories (88% - 85%)

3 Factual
call for public comment, Congressional briefing ;
stem cell injections helped Lupus sufferers.

7 speculative
stem cells might one day cure ….
spinal cord injury, Alzheimer's disease, Lou Gehrig's disease, strokes, diabetes, immune disorders, cancers, Parkinson's disease, heart failure, spinal paralysis, multiple sclerosis, other therapeutic applications

One story … "this experimental procedure 'may work in humans, but there is still a long way to go."

Eurekalert 2006

“Press Release” = 5229

“Breakthrough” = **2206**
“Cutting-edge” = **1127**
“Groundbreaking” = **783**

How might we do it better?

Media training?

Codes of conduct?

Guidelines?

ASC Guidelines for Science Communication in the Media

http://www.asc.asn.au/ Resources

1. Don’t confuse demonstrated research results with speculation about where research might lead.
2. Avoid the clichés of science communication.
3. Evaluate how many media releases you send and their real newsworthiness.
4. Use terminology accurately, and provide a science style guide or ensure ready access to one.
5. Encourage direct communication between journalists and scientists, and discourage attempts to channel comments and communication through a corporate or media spokesperson.
6. Be forthright with the bad news as well as the good.
7. Seek to place the information in context.
8. Ensure that internal as well as external communications are effective.

ASC Guidelines for Science Communication in the Media

http://www.asc.asn.au/ Resources

9. Include appropriate media training and induction for staff.
10. Build relations with specialist science, environment, technology and medical journalists.
11. Encourage communication strategies to be a dialogue between the provider and recipient, rather than a monologue exercise.
12. Where possible, make the focus of your communication one of empowerment, not education.
13. Observe accepted practices for science communication, such as protocols for electronic distribution of releases.
14. Encourage appropriate ethical standards for the release of science news.
15. Develop an in-house set of written induction procedures, guidelines and standards.
16. Publish your policy and appendices, encourage comment on them and revise them periodically to keep them up to date with technological and professional developments.

ASC Protocol for Posting Media Releases via Email

http://www.asc.asn.au/ Resources

- Don't send media releases as attachments
- Send media releases in the body of your email without complex fonts or additional included material such as colourful headings, elaborate signatures etc.
- Don't attach photographs or other documents to emailed media releases, even if the releases themselves are in email form.
- Make photographs (and similar) available through a dedicated website.
- Suppress the list of recipients of your emailed media releases
- If publicising an event or similar, identify the state where it is to take place in the subject heading of your email.

The Australian Science Media Centre

A determination that journalists have **DIRECT** contact with scientists

Where does that leave institutions which insist on a **go-between?**

Scientists and their institutions are:
less **preferred;**
less **contacted;**
less **featured;**
less **authoritative.**

“Scientists Need To Accept…..”

(From Science Media Centre, UK)

- A short time frame for comment
- A bias toward conflict and controversy *
- A concentration on negative bad news *
- A penchant for the lone voice speaking out against authority and the mainstream *
- The need for soundbites (grabs)
- The need for yes-or-no answers*
- Lack of specialist knowledge on the part of the journalist *
- Pressure to address the wider political and social consequences of the science in question*

* Depending on whether journalist is specialist or not

Messages for the Future
The concept for a first human landing marker on Mars*

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A human landing on Mars is the ultimate goal of many working within the broad field of space exploration. However, the enormous costs associated with such a mission causes problems for government-funded space agencies as governments look for indications of public support before sanctioning such expenditure. Reports suggest that some form of involvement of the public in the mission would be necessary.

This paper presents research being undertaken to develop a framework for an artwork-inspired First Human Landing Marker on Mars incorporating a time capsule of digital recordings from the people of Earth. The basis of this research is to offer a means of involving the global population in a science and technology venture, thereby creating an environment for support through a shared mission.

Keywords: Land art, time capsules, public participation, monuments, Mars mission.

Introduction

Science and art, once partners in the evolutionary development of humankind have, for some time, gone their separate ways. However, for a major human expedition from our terrestrial base to Mars it may be advantageous to once again join forces.

> Science and art are two things most uniquely human. They witness to a desire to see beyond the seen. They display the crowning successes of the objective and subjective view of the world. But while they spring from a shared source – the careful observation of things – they evoke different theories about the world: what it means, what its inner connections truly are, and what we should judge as important. [1]

My research is focussed on creating a framework for the world community to be involved in the first human landing on Mars via the device of a First Human Landing Monument. This monument would be the art component within the framework and, as such, would be conceptually underpinned, designed and fabricated to fit within the Mars mission parameters and contain the capability of storing, in digital format, the contributions of the people of the world.

As a starting point for research purposes the monument can be referenced as having two components. A physical artwork and a digital Space Time Recording based on the concept of a time capsule. However, conceptually they would interlink, the Space Time Recording being an integral part of the artwork and the artwork standing as a symbolic representation of cultural exploration and human achievement.

Background

There are enormous costs associated with human space missions and going to Mars, without doubt, would be the most costly we are yet to undertake.

As planetary scientist Jim Bell puts it:

> ... the post-Apollo decline in public interest in space exploration reverberates today in the debates over NASA's budget and the general scepticism about the agency's future relevance,

* Rodwell, T. 2008. Messages for the future. The concept for a first human landing marker on Mars. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 41-49.

> especially among the generation now entering the workforce. Further triumphs of the robotic missions will be possible only if public and political interest is rebuilt and sustained by a reinvigorated program of human exploration. [2]

For the moon this is looking quite promising, however, for Mars things are not looking quite so good. Regarding NASA, Administrator Michael Griffin recently commented at the 39th Lunar and Planetary Science Conference that after the report by the National Research Council, NASA has "rebalanced the planetary science portfolio accordingly". This meant less funding for a human Mars mission but with regard to this he did hope that other countries would participate with NASA. "Our human space flight efforts are centred around that partnership", he concluded. [3]

However, it is generally acknowledged that any partnership with other government-funded space agencies would require public support, or at least the public not to be opposed to such a venture. Unfortunately though, the public seems to have a general lack of comprehension as to the benefits of such an expensive mission. In a recent report issued by Dittmar Associates of Houston summarising their field research, surveys and polls over several years on behalf of NASA, found, among other things, many people, especially those in their mid to late twenties, were fairly disengaged from the space program and that to become interested they would need more interaction. [4] This is not a new revelation, as Louis Friedman – Executive Director of the Planetary Society stated that in the Society's formative years in the 1980s their outlook was:

> ...that it was the people of planet Earth who were exploring the planets, not just the United States, the Soviet Union, or some space agency, but the entire population of the planet. [5]

However, space programs to date have never really delivered on the idea of a shared venture.

Research

To develop a framework for an artwork inspired First Human Landing Monument on Mars I have researched historical time capsules, time capsule-like events in space, historical monuments and Land Art.

Historical Time Capsules

Time capsules evoke a sense of mystery for those finding them. For those contemplating creating them there is a desire to tell those in the future about us as we see ourselves. As Carl Sagan put it, there is:

> ... something graceful and very human in the gesture, hands across the centuries, an embrace of our descendants and our posterity. [6]

Many time capsules were not originally conceived as such, for instance tombs, from which we have learnt much about our past. But some in the ancient past did realise that their history would be written by people in the future and so made provision for their story to be told. One such person was Esarhaddon, the king of Assyria, Babylonia and Egypt, 2700 years ago, who

> ...had a conscious interest in presenting not just his military glory but his entire civilisation to the future, burying cuneiform inscriptions in the foundation stones of monuments and other buildings. [7]

Most of the more contemporary time capsules have a definite expected retrieval date. These fall into two broad groups. The commemorative type that are sparse in content and have a short scheduled duration (usually less than 100 years) and time capsules that are, in effect, miniature museums and long term archives such as the 'Tropico Time Tunnel', a 10,000 cubic foot mine shaft in Rosamond, California that was sealed in 1966 for an expected re-opening in 2966. The Japanese Osaka Time Capsule No 1 that is filled with over 2,000-cultural artefacts. The high-tech capsule, weighing over two tonnes was buried in the Osaka Castle Park in 1970 with a 5,000 year retrieval date. The Crypt of Civilization, a large underground chamber filled and welded shut in 1940 is impressive in its contents.

Not only containing a broad range of artefacts it also has more than 640,000 pages of microfilm from over eight hundred works on the arts and sciences. It is scheduled for re-opening in 8,113 AD. At the New York World's Fair in 1939 a torpedo-shaped container sponsored by Westinghouse Electric and Manufacturing Company was lowered into the ground for 5,000 years. The original proposed name of the "time bomb" was changed before its burial to "time capsule" which is the first recorded use of this term. [8]

Carl Sagan concludes:

> For those who have done something they consider worthwhile, communication to the future is an almost irresistible temptation, and it has been attempted in virtually every human culture. In the best of cases, it is an optimistic and far-seeing act; it expresses great hope about the future; it time-binds the human community; it gives us a perspective on the significance of our own actions at this moment in the long historical journey of our species. [9]

Time Capsule like events in space

Space time capsules, by their very nature of being extraterrestrial are very contemporary. These are an interesting type of time capsule as their contents are not only known, but because of contemporary methods of communication, are accessible to everyone. The uniqueness of these time capsules is where they are. The first of this type was left on the Moon by the two astronauts who made the first human landing on 20 July 1969. Attached to the leg of the landing module was a plaque that proclaimed "Here men from Planet Earth first set foot upon the Moon, July 1969 AD. We came in peace for all mankind."

This was not the only message the crew left on the lunar surface, they also carried a small silicon disc, just under 4 cm in diameter, etched with 74 goodwill messages from heads of states around the world and inscribed "From Planet Earth – July 1969". The Australian message from then Prime Minister, John Gorton, reads

> Australians are pleased and proud to have played a part in helping to make it possible for the first man from earth to land on the moon. This is a dramatic fulfilment of man's urge to go 'always a little further'; to explore and know the formerly unknown; to strive, to seek, and to find, and not to yield. May the high courage and the technical genius which made this achievement possible be so used in the future that mankind will live in a universe in which peace, self expression, and the chance of dangerous adventure are available to all.
> John Gorton, Prime Minister [10]

Of course, the goodwill messages written by world leaders were as much for the people of the time as to people of the future. Nevertheless, it was the first time anyone from our planet had had the opportunity for their words to be taken to and left on the surface of another terrestrial body.

Later, other messages were sent out into space, the first of these left Earth on 3 March 1972 aboard the Pioneer 10 spacecraft. It was realised that both Pioneer 10 and Pioneer 11 (launched on 6 April 1973) would be the first human made object to leave our solar system. The message engraved on a gold anodised aluminium plate 15cm x 23cm was a graphics image containing a diagram of our solar system, a pulsar map to locate our position in the Milky Way galaxy and the figures of a man and woman, standing in front of the spacecraft for scale. A duplicate plaque was placed aboard Pioneer 11. [11]

On 16 November 1974 a short radio message burst into the cosmos sent from the Arecibo radio telescope in Puerto Rico aimed directly at the Great Globular Cluster in the Hercules constellation, named Messier 13, 25,000 light years away. The signal, which took 169 seconds to transmit, can be transcribed into a simple pixel type graphic design, giving information of our form, make up, mathematics and where we are. [12]

Because of various factors, the information contained on the Pioneer plaques and the Arecibo transmission were very limited and told any alien species capable of translating the messages little beyond what we looked like and where we came from.

A bigger challenge came several years later in 1977 with the launch of the Voyager 1 and 2 spacecraft. Destined, like the Pioneers before them, to eventually leave our solar system on a one way voyage to the stars, a decision was made to incorporate a message to whoever may find them in the future. By then, technology had made the recording of information more efficient, however, the longevity of the recording medium was still of primary importance, so for both Voyagers the information to travel into deep space was recorded on gold coated copper phonograph records, complete with needle and visual instructions on how to play it engraved on the outer metal case.

By opting for a speed of 16 3/8 revolutions per minute and making the record double-sided a large amount of recording time became available on this 'Extraterrestrial Time Capsule'.

The challenge then was what to include that would be representative of humankind; our history, our culture, our great achievements, our aspirations, our worst moments? And who would decide? From the writings of Carl Sagan, the team's co-ordinator, the process was very demanding, sometimes frustrating and always occurred around a sense of overlooking something vital. With regard to the visuals that were to be included, Sagan said the

> ... principal focus of the pictorial segment was information that might in some sense be unique to Earth: information on geochemistry, geophysics, molecular biology, human anatomy and physiology, and our civilization. The more specific the information is to Earth, the more anecdotal or idiosyncratic, the more difficult it may be for extraterrestrials to understand – but also the more valuable the information will be, once understood. [13]

At its launch the contents of the record comprised 118 pictures, greetings from the President of the United States and the Secretary-General of the United Nations, other greetings in 54 languages, various sounds of earth, 87.5 minutes of music and whale song. Also, in the run out groove on the record a recording technician had added his own personal message – "To the makers of music – all worlds, all times". Such is the unquenchable desire of the individual to communicate.

The Voyagers were dispatched as a one way mission; we will never see them again. But others, alien to us may, in time, pick them up. Commenting on this, Timothy Ferris, a team member summed up the endeavour like this:

> The record says: However primitive we seem, however crude this spacecraft, we knew enough to envision ourselves citizens of the cosmos. It says: However small we were, something in us was large enough to want to reach out to discoverers unknown, in times when we shall have perished or have changed beyond recognition. It says: Whoever and whatever you are, we too once lived in this house of stars, and we thought of you. [14]

Since those times other efforts to launch written and visual documentation of ourselves into space have occurred. For a fee, Bigalow Aerospace included personal documents inside their inflatable space station, Genesis 2, put into earth orbit in June 2007. [15] The Planetary Society is also quite active in the time capsule department, sponsoring the 'Wish upon the Moon' project with people's names and a very short message etched into a foil attached to the Japanese SELENE space craft now orbiting the moon. [16] Their latest project 'Messages from Earth' is a specially produced silica glass DVD incorporated onto the Phoenix science laboratory now carrying out experiments in the northern polar region of Mars. The DVD contains around 250,000 names, messages from visionaries of our time, including Carl Sagan and Arthur C Clarke and a number of classical works of Martian literature. [17]

Historical monuments

Sculptural artworks can be read as conceptual or narrative structures of representation. As an example of this we can examine three different monuments that have been erected to pioneers in the past. The first is at Glenelg in South Australia and marks the site of the landing of the pioneer settlers and the announcement by Governor Hindmarsh of the establishment of the government on 28 December 1836. The structure is a tall, monolithic, square sided marble column. At the top is a bronze model of the sailing vessel *Buffalo* which brought the settlers from England and on the two broadest sides are carvings depicting the establishment of the colony and its development a hundred years later, when the monument was erected. Text, in English, is incorporated into the fabric of the structure. This monument presents a classical narrative reading. The carved figures of the first settlers are represented realistically in authentic dress and are depicted in a ceremonial scene. The other image is of a hundred years later, where a number of stereotypical people reference past events that have shaped the character of South Australia. The bronze model of the *Buffalo* is also realistic and sits in a position atop the monument where its sails are still silhouetted against the sky.

The position of the viewer, once near enough to see the detail in the images, is one where the monument exerts its greatest authority. The vertical element is the element of power and in towering over us with its great mass it is designed to humble the viewer into recognising the great achievements of the pioneer settlers. This is reinforced by the carved images being above head height so that the viewer has to literally 'look up' to the people depicted.

The second monument is of Captain James Cook on Poverty Bay, Gisborne, New Zealand. This monument, like many of its kind, features a realistic, larger than life sized bronze figure of Cook. He is standing on top of a granite sphere, part of which has been cut flat to include the text about his landing at the site. It begins: "A fine seaman, an outstanding captain and an honest man. Captain Cook was one of the last of the great explorer-navigators and the first of the scientific expedition leaders".

The depiction of Cook is one of authority. Hand on hip he gazes above our heads at the horizon and the challenge ahead. And because of his elevated position we can never meet that gaze with our own eyes; he is beyond our reach, his pedestal separates him from the immediate environment and so enhances his status as well as indicating that we cannot see what he sees from our lower position.

Like the points of the compass in the tiled representation on the ground, this monument is designed to be viewed from all sides, with each view providing a complementary reading aimed at enhancing our understanding of the man and his achievements. The readings are designed to be literal and the artist has refrained from including any ambiguous visual information.

The third example is a contemporary monument at Victor Harbor in South Australia that acknowledges the meeting of English Captain Matthew Flinders and French Captain Nicolas Baudin in the Aboriginal waters of the Ramindjeri Ngarrindjeri people. Visually this monument is very different from the previous two and was commissioned as a public artwork.

The three slender poles forming the major components of the sculpture deviate from the concepts of solidity and realistic representation to one of metaphor. The three poles represent the masts of the English and French ships and the indigenous Knobby Club Rush and present the meeting of three cultures at this geographical point. The sculpture is not intended to be dominant over the viewer and this is achieved by presenting the best view from a distance. From this position it can be seen that the height of the three elements is the same, giving no supremacy to any culture. And although the rigging of the French and English masts overlap, they do not touch, keeping the three elements separate. This steel rigging does, however, vibrate in the wind producing an Aeolian sound, giving the sculpture an audio and kinetic element.

It can also be seen that the three elements are equal distances apart, which could indicate the three cultures were equal in the domination of their own space. However, within the study of social semiotics this interpretation must be questioned, for distance and space have to be viewed in the context of other signifiers which can act as transformations of physical distance and space. Therefore, because the poles representing the two masts are smaller than the actual ship's masts but the representation of the Knobby Club Rush is massively enlarged from the real thing, we could conclude the artist is deliberately distorting the aspect of space for other aesthetic reasons.

The introduction of colour into this monument is also one key to understanding the artwork. The colours red, white and blue are the only ones on both the English and French flags, but the proportions and spacing of these colours tells us which is which. But with this type of sign there is an assumption of knowledge of the two flags. Without this familiarity a certain amount of meaning is lost, as it is with the Knobby Club Rush if the viewer has no knowledge of this grass and its uses by the local indigenous population.

The title of this artwork *On Occupied Territory* gives a clue to the time of this encounter, for debates relating to whether this country could be deemed to be occupied or classified as Terra Nullius relates to the earliest days of English exploration of Australia. It also helps to know the English and French were at war at the time, which makes this peaceful meeting even more extraordinary. The abstracted form of this artwork can produce numerous interpretations, making it not only visually strong but conceptually very interesting.

The analysis of historical monuments of exploration on earth can be utilised in the conceptual framework for the design of a significant Mars First Landing Monument. An awareness of the implications associated with visual interpretations could greatly enhance the design development of the monument in any effort to be neutral of any individual culture or, more desirably, to represent a global culture. To be generally acknowledged as a significant monument the artwork would need to be recognisable as visually different from the rest of the human infrastructure left behind on the Mars surface.

Land Art

The site for a first human landing on Mars will be new territory. We may have satellite images and we may have even dropped robots to do an initial reconnaissance, but no human will ever have been there. For a sculptural monument on Mars the artwork would have to respond to a landscape never before utilised for this purpose. Along with the different physical conditions on Mars and the fact that installation would have to be done in a space-suit would produce an interesting challenge for the artist/design team. Also, the Mars First Human Landing Marker, once installed, will only ever be seen in its actual location by astronauts. Could a copy on Earth, physical or virtual do justice to the artwork, especially being out of context?

The nearest situation to this is artists working in the area of Land Art, where often their work is in isolated and, in some cases, almost inaccessible environments. Documentation, in some form or another, is usually the only way the public will view the work, especially if it is also ephemeral. To many of these artists the environment in which their work is situated is critical to the concept and understanding of the work. It is this factor, the intimate link between artwork and environment, where the environment is an integral part of the artwork that would make a Mars First Human Landing Monument ideally suited to this artform in an extraterrestrial version.

Much of my own art practice lies within the area of Land Art (Figure 1).

Land Art is an artform that can encompass both simple and profound ideas on the linking of humanity and environment. The framework that is being developed through this research will define the idea of Extraterrestrial Land Art and encompass issues of aesthetics and ethics in relation to international views on extraterrestrial land use.

It should also be emphasised that Extraterrestrial Land Art is not a matter of transferring terrestrial concepts, ideals and techniques to another planet. Some conceptual issues that artists working in the area of Land Art focus on are to do with terrestrial environmental problems. For example: the degradation of wilderness areas, urban sprawl or contamination of waterways. Other issues reference the plight of indigenous cultures, the extinction of animal species, the arbitrariness of land borders or the historical aspects of migration and land settlement. These are big issues that can be understood locally and, in some cases, globally but would have little application on the surface of Mars. They are internal to planet Earth.

Figure 1. Written on the Land [18]

To relate meaning within a cosmic environment, concepts would have to relate more to how we perceive ourselves as space beings, our ambitions as a human race towards expansion into the solar system or our quest for knowledge from the stars. These are concepts for anyone, anywhere on Earth who has ever looked up into the night sky and wondered about its meaning.

Public Participation

The benefits of public participation in large space ventures have already been touched on in this paper. My current research focuses on one practical way to engage the public on a global scale.

Time Space Recording

The time capsule component of the Mars marker is the main device for global participation. However, the popular notion of time capsules is for the storage of artefacts which, because of volume and weight restrictions will not be possible on space missions. Time capsules sent into space so far have been either etched messages on suitable material or recordings. Therefore, to differentiate between traditional time capsules and time capsules in space, I intend to use the term Time Space Recording.

In a digital format the thoughts, writings, pictures, poetry, family histories, stories, music etc of the participants would be stored on Mars indefinitely. Each person who wanted to be involved could be allocated a set amount of input space which they could fill in any way they chose. This uncensored data could be taken to Mars on pre-recorded devices.

Formatted as read only, nothing further would be added after completion of the recording but, more importantly, the device would not be capable of downloading, and no copies would be kept on earth thereby providing complete security for participants. Access to this information would be available only by returning to Mars and physically removing the data device. The information contained would be a snapshot of life on earth at that particular time as recorded by the people of earth, unmediated by editors, politicians, corporations etc. It would, in effect, be raw data for future cultural historians.

Electronic Communication

With the advent of the internet and the wide distribution of personal computers, communication has been transformed. It is now easier than ever before to form global networks and participate interactively in events around the world. This interactivity would be vital within the framework of a Mars monument incorporating a Time Space Recording.

The willingness of people to engage in what is effectively a major art and social project can be gauged in the work *Vectorial Elevation* by artist Rafael Lozano-Hemmer. First shown in the Zocolo Plaza in Mexico City for the millennium celebrations, the artwork consisted of 18 robotic searchlights placed on top of buildings around the Plaza. These searchlights could be controlled via a program downloaded from the Internet. People were invited to design a light sculpture then watch in real time over the net the resulting light beams in the night sky. More than 800,000 people from 89 countries visited the website in the two weeks the installation was active. Since 2000 the work has been set up three more times, the last in Dublin, Ireland for twelve days in 2004 when 522,000 visitors, from 100 countries downloaded over 19 million pages of documents and images and over 14,000 light sculptures were created. [19]

Conclusion

The concept of linking a sculptural First Human Landing Monument with a public Time Space Recording serves the purpose of introducing art onto Mars and enabling people of the world to feel part of a major historical event. This, I propose, would be as important to the population of Earth as any scientific experiment on Mars.

In the document *LunAres: International Lunar Exploration in preparation for Mars*, a project by the International Space University, these concepts were touched on under the headings 'Civilization Mission' and 'Humanity Mission'. The civilisation mission emphasised how humanity throughout the ages has left monuments, many of which are now considered great works of art, that mark new stages in the path of cultural development. The humanity mission talks about how people have thought about space and how they have communicated their ideas and messages. This segment concluded that the technology is available for the mass of humanity to compose their own message to be installed by humans on the next landing mission. [20]

My research also indicates that public support could be crucial to any major space endeavour. An example is the British Beagle 2 Mars lander. Colin Pillinger, consortium leader and lead scientist commented regarding the finances for the project:

> It needed a million voices pressing the case, organisations and individuals, who by their very existence would convince the authorities to contribute to the budget, or persuade sponsors to back their judgement with contributions, advertising revenue or donations. So it embarked on a publicity campaign. Public opinion was to be Beagle 2's strongest card. [21]

Enlisting the help of pop group Blur and internationally recognised artist Damien Hirst to bring Beagle to the attention of the mainstream public resulted in the British government putting up a substantial amount of money for the project.

It is therefore justifiable to look at the benefits that might come to us now for creating a Mars First Human Landing Monument. Certainly, it would provide a great opportunity for the most amount of people to be involved in what will probably be this planet's greatest space endeavour. The Time Space Recording element could get people thinking about what is meaningful to them, what they would want to leave as an imprint of this on Mars. Schools might organise their students to produce a production for inclusion on the recording, thereby introducing the subjects of space science and communication in a very practical way.

And as far as the Mars mission consortium is concerned, any activity that raises the profile of the venture in a positive and meaningful way can only help in securing the vital funding that will be needed for our leap into the solar system.

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A Geological Study of Two of the Potential Landing Site for Mars Science Laboratory*

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As my honours degree at Monash University I am comparing the geology and landing potential of two areas on Mars that have been selected as potential landing sites for the Mars Science Laboratory rover (MSL). The aims of the MSL are to determine the planet's biological potential, both past and present, by looking for things such as organics and biosignatures; study the geology and geochemistry; determine past processes that influence habitability; and study the varying processes affecting the area at present, including many types of radiation and the water cycle. The rover will mostly do this by studying the rocks, soil and the local geological setting via remote sensing and direct contact as well as through the use several other instruments.

MSL will be launched between September and October of 2009, aiming to arrive at the red planet in October 2010. It is approximately twice the size of Spirit and Opportunity and has a much different landing system (sky crane). The MSL payload weighs 75kg, with an allocated total rover mass of 775kg, compared to the MERs payload weight of 9kg and total rover mass of 170kg. The range of MSL is much more significant than previous rovers as well, both in how far it can drive (>20km), plus in the latitudes and altitudes it can reach: 45°N to 45°S, and <+1km MOLA height.

The two sites I am focusing on are Mawrth Vallis (24°N, 340°E) and Nili Fossae (21°N, 74°E). Mawrth Vallis is currently the most likely location for the rover's landing; Nili Fossae, one of five other possible sites, I chose as my comparison site. Mawrth Vallis is mid to early Noachian in age and was chosen as a candidate site due to the presence of phyllosilicates, which is a subclass of silicates that forms in sheets. One common phyllosilicates is clay, which has been identified at both sites. Evidence suggests that the clays at Mawrth Vallis formed early in the areas history, and that they formed as a result of sedimentary processes, most likely aqueous (excluding deep marine). This means that they have a higher chance of containing evidence of life, as life would have required water and have evolved early in the planets history. Plus, given the nature of clays, they generally have a higher chance of preserving evidence of life, if there was any life to leave evidence of course.

Nili Fossae is a potential MSL landing site as it has fan deposits, which also contain phyllosilicates. Clay is present in the form of smectite. These clays and the formation of Nili Valleys are also Noachian in age. This sites also presents a high chance of preservation of evidence of life, because of the presence of the old clays and because textural features could be preserved in the sedimentary deposits. The clays may be either lacustrine or hydrothermal in origin, but which is the case has not yet been determined. There is also not a lot of dust present at the site, and a number of clear outcrops have been observed, which means, over all, getting to the rocks is that much easier. The rocks observed so far are strongly layered from unaltered Noachian crust to altered material (phyllosilicates). In addition, there is a transition from Noachian to Hesperian material within the landing ellipse, which will be beneficial in studying the geological history of the area.

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Keywords: MSL rover, Mawrth Vallis, Nili Fossae, Geology

* Sharp, J. 2008. A geological study of two of the potential landing site for Mars Science Laboratory. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 50.

Revival Possibilities of Dead Planet Mars*

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Abstract

Earth's internally produced energy (hot mantle) constantly sends submerging seawater back (through Mid Oceanic Ridges/MOR) to the surface by vaporization and thus hot mantle also keeps effluence of huge amount of CO_2 (Dissolved Inorganic Carbon/DIC) and other dissolved gases alive, from submerging seawater to the Earth's atmosphere. In this way, Earth's active internally produced energy (hot mantle) prevents the entire surface water from getting submerged into its subsurface along with the huge amount of DIC and other dissolved gases and is responsible for constant existence of surface water, atmosphere and greenhouse effect on Earth.

Diminished internally produced energy of early Mars would have resulted into cold mantle. While getting cold the volume of Martian liquid mantle would have reduced because of constriction due to solidification. Then the solid Martian crust might have had adjusted itself over the cooling mantle creating many crakes in the crust and gaps at many places between Martian cold mantle and crustal base while shifting of crust on the mantle. These gaps and crakes would have acted as sufficient reservoir for submerging Martian surface water. Therefore, diminishment of internally produced energy of earlier Mars would have resulted in gradual submersion of the entire Martian surface water into its subsurface and some interior (which could not return back to the surface due to cold Martian mantle) along with a large amount of DIC, breaking the efflux of CO_2 from submerging seawater to the early Martian atmosphere, however its influx remain continued. It would have caused disappearance of Martian surface water and poorer green house effect further cooling the Martian atmosphere.

Similarly other dissolved gases might also have submerged along with Martian surface water resulting in thin atmosphere and very low surface temperature on Mars. Melting of Martian polar and subsurface ice by increased green house effect, bombardment of asteroids, etc. would make liquid water available on Martian surface but this melted water will again get submerged gradually, with the dissolved gases into Martian subsurface and will not return back due to diminished internal energy production (cold mantle) of Mars. Hence terraforming Mars will be possible only when its diminished internal energy production is got regenerated or reactivated to make its mantle hot again. Only then, the submerged water (subsurface ice), trapped CO_2 and other gases will return back and exist constantly on the Martian surface and in its atmosphere.

Without this all the efforts to terraform or revive Mars would ultimately result in failure. But such technology which can regenerate or reactivate the diminished Martian internal energy production has not been developed so far and its possibility in near future also seems to be negligible. So, to terraform or revive Mars, we should first think that in future, can we ever reactivate or regenerate the diminished Martian internal energy production? As this is an impossible task with in the present frame of knowledge. In future Earth will have to encounter similar conditions like present day Mars, when Earth's internally produced energy will also get diminished.

Keywords: Internally produced energy, internal water cycle, Loss of water, Depletion of CO_2 & atmosphere, Terraforming.

* Shrivastava, M.K. 2008. Revival possibilities of dead planet Mars. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 51-57.

Introduction

Discovery of life on any other planet will undoubtedly be one of the greatest achievements in human history and is the prime underlying motivation for exploratory spacecraft missions to Mars, have revealed that water is absent on the Martian surface and very low in abundance in the form of ice, but have discovered surface features strongly reminiscent of dry river valleys and dry sea trenches [1, 2, 8]. Average temperature is about - 55^0C [3] and has very low atmospheric pressure at Martian surface, amounting to just 0.7% of that of the Earth, liquid water cannot presently exist on the Martian surface, as it would evaporate [4]. Mars was geologically active at some time in its past and had an internally produced magnetic field [10] volcanoes and possibly even some apparent crustal mobility**.** But at present Magnetic field [5], volcanism [6], plate tectonics activities [7] are absent on Mars. The atmosphere of Mars consists mainly of CO_2 (95.32%) with lesser amounts of N_2 (2.7%), Ar (1.6%), O_2 (0.13%), CO (0.07%) and H_2O (0.03%) [4]. So, if certain surface features of Mars really were formed by flowing liquid water [8], then two fundamental questions arise: Where the water vanished and how did the previously more-dense atmosphere became very thin? I address both of those questions in this article by comparing Earth and Mars

Earth's Internally Produced Energy

Earth's internally produced energy by Core radioactivity [9] or core dynamo [10] or geodynamo [11] or proto-planetary energy of compression [12, 13] or other unknown process, generates hot magma producing convection current [11] cycles (from outer layer of core towards inner layer of crustal plates and vice versa) which controls the plate tectonics activities, quakes, volcanism and also generates large magnetic field around the Earth.

Earth's Internal Water Cycle

Earth's crust has infinite number of small, large holes and cracks and most of the plate boundaries are on the ocean floor. The cumulative length of mid oceanic ridges (MOR) is more than 60,000 km [14]. The total power dissipated from the Earth (heat flow) has been measured to be 44.2 TW and from the mid oceanic ridges has led to a lower TW. [9], (31 TW heat energy can increase the temperature of about 7.5 million Kg of water from 0^0C to 100^0C in one second). The heat coming out from MOR is responsible for hydrothermal circulation. This circulation effects the composition of the Earth's oceans and indeed, atmosphere. [15]

I suggest, surface water moves down to Earth's subsurface through the holes, cracks and plate boundaries (mid oceanic ridges) but the entire submerging water and dissolved gases are recycled again into the sea or surface by evaporation due to the heat coming out from MOR. Similarly continental active volcanoes and many hot springs also send infiltrated water and dissolved gases back to either surface or atmosphere because of hot magma. Thus hot magma keeps internal water cycle and effluence of dissolved gases (from subsurface to surface and vice versa) alive and prevents the seawater from submersion with (Dissolved Inorganic Carbon / DIC) and other dissolved gases making liquid water exist on Earth's surface and gases to the atmosphere constantly (See Figure 1, A and B).

Causes of Water Loss from Martian Surface

Various dry river-valleys and dry sea trenches on Martian surface clearly suggests that earlier Mars was a very wet place [16]. Now the question arises that how such enormous quantity of water disappeared and where did all the water go? I suggest the factor mainly responsible for that is the diminished internal energy production of Mars. Mars is thought to have possessed a core dynamo that ceased 0.5 b.y. after the formation of the planet [17], resulting its mantle to get cold. I suggest, while getting cold the volume of liquid mantle would have decreased because of constriction due to solidification. Then the solid crust might have had adjusted itself over the cooling mantle creating sufficient crakes in the crust and gaps at many places between the cold mantle and crustal base while shifting of crust on the mantle (Figure 1, C and D). These gaps and cracks would have acted as sufficient reservoir for submerging seawater. Thus entire surface water gradually submerged into subsurface or interior through many small - large holes, cracks and plate boundaries present on

Martian crust and could not return back to surface by vaporization due to the mantle being cold breaking the internal recycling of surface water. This submerged water would certainly have deposited in the form of ice due to extremely low temperature of Mars (average –55^0 C [3])**.** Recent findings of huge quantity of subsurface ice on Mars [18] prove this.

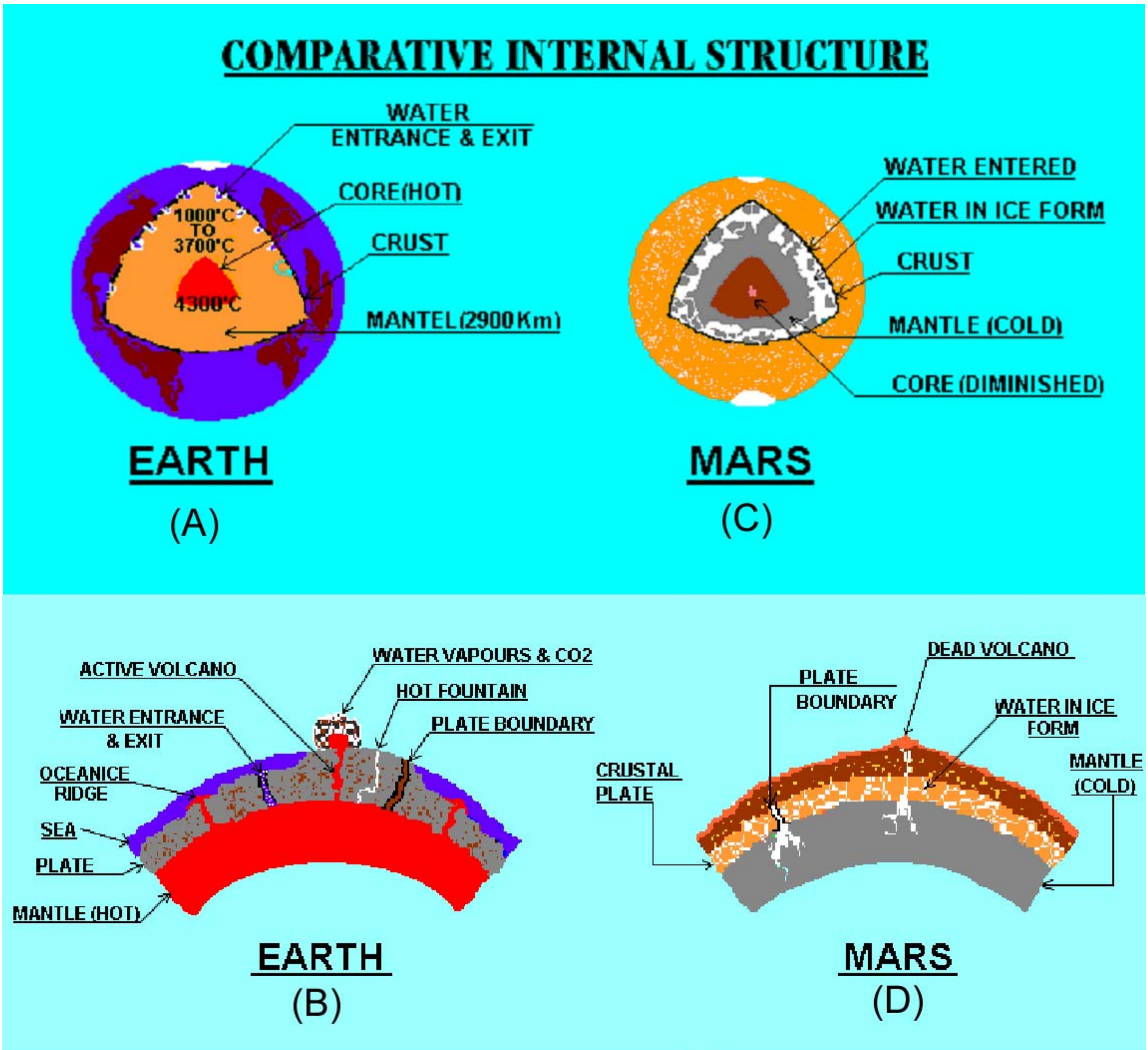

Figure 1. A and B show the hot magma of Earth keeping internal water cycle and outflow of CO_2 and other dissolved gases alive from submerging seawater to Earth's surface and atmosphere. C and C show the diminished core and cold mantle of Mars ceasing internal water cycle and outflow of CO_2 and other dissolved gases from submerged seawater to its surface and atmosphere. All the surface water has been submerged into its interior and has been deposited in form of ice.

As the orbital plane is inclined by 25^{0}19' sunrays fall slanting on Martian poles, so here temperature always remains below 0^{0}C, like Earth's poles. This is the reason for presence of ice caps on the Martian poles even today [19] and being in the solid state the polar ice could not submerge.

Scientists are planning to reflect Solar rays on Martian polar ice caps by establishing huge and larger sized mirrors in space and to enhance green house effect [20] for increasing Martian temperature by terraforming [21] to melt the polar ice and bombardment of asteroids to melt the subsurface ice. These methods will make liquid water available on Martian surface. But I suggest, this melted water will again get submerged into subsurface of Mars with DIC and other dissolved gases and will not return back to surface again due to absence of hot magma**.** In this way it is impossible to establish Earth like independent biosphere on Mars, until and unless Martian diminished internal energy production is got regenerated or reactivated in order to melt the subsurface ice. Only then the submerged water with huge amount of trapped gases would be made appear constantly on its surface again.

Causes of Poor Quantity of CO_2 in Martian Atmosphere

Scientists believe that Martian atmosphere was once denser, warmer and wetter at least 3.5 Gyr ago predominantly composed of CO_2 [21]. Now the question arises that how did Martian atmospheric CO_2 deplete. It is believed that Martian internally produced energy diminished million of years ago [10] ceasing the plate tectonics [7] and volcanic activities [6]. Thus the CO_2 deposited in carbonate rocks could not be recycled into its atmosphere resulting in the poor green house effect.

But I suggest that there is one more major factor mainly responsible for poor quantity of CO_2 in Martian atmosphere. Diminished internally produced energy would have caused submersion of entire Martian surface water along with a large amount of DIC into subsurface. Thus the submerged DIC could not be recycled again resulting discontinued efflux of CO_2 from submerging seawater to the atmosphere however its influx continued to subsist. Therefore over a prolonged period of time, amount of atmospheric CO_2 lessened making the green house effect gradually poorer and further decreasing temperature. Simultaneously, the temperature of submerging seawater also depleted increasing the solubility rate of atmospheric CO_2 into seawater continuously making green house effect poorer and further cooling the Martian atmosphere. Such a process might deplete the Martian atmospheric CO_2, can be appreciated by recalling following facts that:

1. CO_2 solubility in seawater of Earth increases with depleting water temperature and reduces as water temperature rises (Figure 2). Hence the oceans on Earth when heat up they emit CO_2 to the atmosphere and as they cool, adsorb more and more CO_2 [22, 23]. That is why the warmer parts of oceans on Earth are poor in CO_2 whereas the colder parts are CO_2 rich.

2. The weight of water in all the oceans of the Earth is about 1.40 billion billion metric tons [24]. Earth's oceans contain more than about 50 times as much Carbon in the form of DIC (38000 Gt or 38000 x 10^{12} Kg) than in its atmosphere in the form of CO_2 (700 Gt or 700 x 10^{12} Kg)) [25, 26, 27]. Such a ratio of carbon and DIC might also have prevailed between earlier Martian sea and its atmosphere.

3. Ice made from frozen ground water on Earth contains very large amount of CO_2 [28].

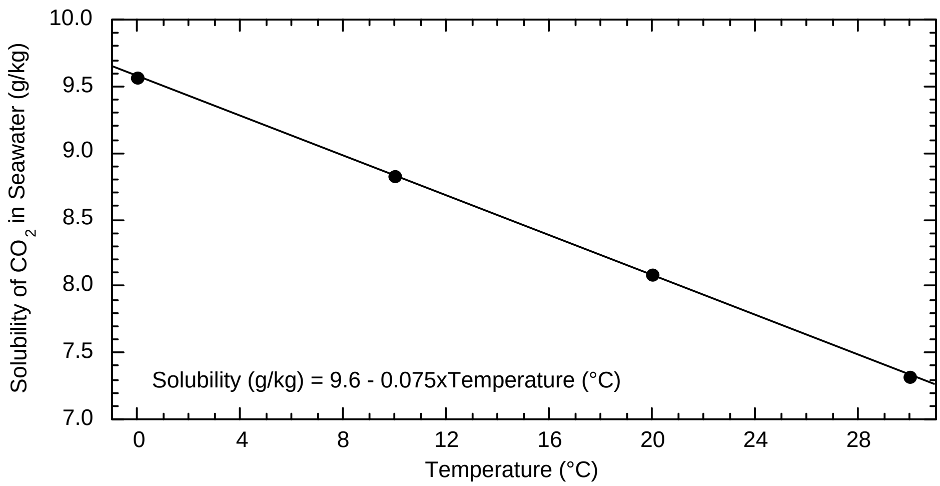

Figure 2. Solubility of CO_2 in g/kg of seawater as a function of temperature for surface seawater [23]

Causes of Thin Martian Atmosphere and Low Atmospheric Pressure

Terrestrial oceans of composition similar to the present ocean developed in early history, so it is possible that aqueous bodies such as lakes and oceans that developed on Mars may have had a composition similar to Earth seawater [8]. Oceans on Earth consist of N_2 (62.6 %), O_2 (34.3 %), Ar (1.6 %), CO_2 (1.4%) etc [29]. If early Martian oceans had a composition similar to Earth seawater then not only these gases but also the whole earlier Martian atmosphere would have depleted just like CO_2

mentioned above. It would have resulted in thin atmosphere and very low atmospheric pressure on Mars.

Table 1. Gases in air and dissolved in earth's sea water at equilibrium with air.

Gas	Chemical Symbol	Percentage in Air	Percentage in Sea Water
Nitrogen	N_2	78.08	62.6
Oxygen	O_2	20.95	34.3
Argon	Ar	0.934	1.6
Carbon Dioxide	CO_2	0.033	1.4
Neon	Ne	0.0018	0.00097
Helium	He	0.00052	0.00023
Methane	CH_4	0.00020	0.00038
Krypton	Kr	0.00011	0.00038
Carbon Monoxide	CO	0.000015	0.000017
Nitrous Oxide	N_2O	0.000050	0.0015
Xenon	Xe	0.0000087	0.000054

Table 2. The chemical composition of sea water on Earth [30]

Gas	ml/l (at 25^o C) sea water	mg/kg (ppm) in sea water
N_2	10	12.5
O_2	5	7
CO_2	40	90
Ar	—	0.4

Discussion

The popular prevailing theory of Martian water and atmosphere loss is based upon the idea that Martian water and atmosphere was eroded away into space from the outer atmosphere (exosphere) by the solar wind [16], fails to explain the followings:

1. HRSC images from the ESA Mars express spacecraft (2004), have found evidence consistent with a presently existing frozen body of water with surface pack ice, around 5 degree latitude and 150 degree east longitude in southern Elysium of Mars. It measures about 800 km x 900 km and averages up to 45m deep similar in size and depth to the North Sea [18]. This and many other recent finding of water- ice in such a huge quantity in Martian subsurface proves that water vapours did not escape into space but water submerged into subsurface of Mars.

2. To have such severe atmospheric erosion, the solar wind would have had to have been considerably more intense in the distant past after formation of flowing-water-sculpted surface features. One might wonder what effect such a super-intense solar wind might have had on the Earth as there it would have been about 2.3 times even more intense at the region of the Earth's orbit [4].

3. Lacking magnetic field [31] like Mars and being about three times closer to Sun than Mars, the solar wind would have had many times more intense on Venus than Mars. But Venus still has much denser atmosphere of CO_2 **[**32].

4. Temperature of Earth's troposphere depletes at the rate of 1^0C /165 m and reduces up to 0^0C at the height of 4800 m. So water vapours get condensed before reaching at this height and returns back on Earth's surface in form of rain. The same phenomena would also have existed in Martian atmosphere in past. So it seems to be impossible for water vapours to reach up to the Martian exosphere and eroded away into space.

5. Being heavy gases CO_2 and H_2O are restricted up to lower height due to their heaviness in Earth's troposphere. Earth's exosphere starts from height of 600 km. and ends in the space and so these heavy gases are not found. Such atmospheric conditions might have had prevailed on Mars also. So it seems to be impossible for CO_2 & H_2O to reach up to the Martian exosphere and eroded away into space.

6. Water cycle existed for millions of years in Martian past. Thus oxidation of chemical substances of Martian surface and subsurface would have reached up to saturation point. In this way planetary surface sinks for oxygen seems to be impossible.

Conclusion

1. Internally produced energy is the most important factor for life on any planet and can be considered like heartbeat of the planet as it keeps internal water cycle and chemical cycle of CO_2 as well as other gases alive.

2. Martian surface water has been submerged into its subsurface and interior due to the lack of internally produced energy and would have been present in form of ice. So all the efforts and planning made by the space scientists for revivification of Mars would finally result in failure until and unless its diminished internally produced energy is got regenerated, which seems to be impossible in near future.

3. Submersion of earlier Martian sea water due to diminished internally produced energy, with a large amount of DIC and other dissolved gases (having the tendency of greater dissolution in seawater with depleting water temperature) is the main reason of the poor quantity of CO_2 and other gases in Martian atmosphere.

4. We consider only pollution, depletion of ozone layer, remaining life of sun etc are the agents for destroying the biosphere on Earth completely in future. But it is also equally important to know, that how long internal energy will be produced in Earth's core. This factor also determines the duration of existence of surface water, green house effect (atmosphere) and life on Earth in future. Because in future Earth will also have to encounter similar conditions like present day Mars when Earth's internally produced energy will get diminished.

5. Before the search for water and life on Mars or on any planet or satellite of Universe, we must concentrate on the fact that whether the internally produced energy of the planet still exists or not.

6. To terraform or revive Mars, we should first think that in future, can we ever reactivate or regenerate the diminished Martian internal energy production? As it is an impossible task in the present frame of knowledge.

Acknowledgement

I thank Dr. J. Marvin Herndon (Geophysicist, Geochemist and Senior Scientist, Sandiego, California, USA) for his precious suggestions, constant encouragement and his kind help in reference collection.

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Technological Heritage on Mars: Towards a Future of Terrestrial Artefacts on the Martian Surface*

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For the past 45 years the red planet has been the focus of human space exploration. Commencing with the crash landing of Mars 2 some 35 years ago, humanity has left a range of traces on the Martian surface. This paper provides an overview of the successful landing missions and the material culture these missions deposited on the surface of Mars. Environmental conditions on Mars are also considered, as these differ from those of the Earth, and have important implications for the future integrity and management of these sites. This essay is the first step in a systematic appraisal of the cultural heritage values these sites possess for humanity at large and how such sites should be managed for the benefit of humankind.

Keywords: History of space exploration, extreme environments, space heritage, Mars, interplanetary probes

Note: This paper was first presented at the 6th European Mars Society Convention (EMC6) in Paris, 2006, and then published in the *Journal of the British Interplanetary Society***,** Volume 60, pp 42-53, 2007.

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Growing up: Bonding the Mars Societies Worldwide together in a Renewed Internationally-shaped Mars Society*

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Over the last ten years, the Mars Society has enjoyed phenomenal success in many areas: the Mars Analogue Research Station programme has reached a global audience, the Society is now recognised as a world leader in organising and running major Mars-related conferences around the world (USA, Europe, Australia), and we have created a truly international presence.

It is in the latter regard that the Mars Society has reason to celebrate its greatest success in spreading the vision of human missions to Mars. From humble beginnings in Boulder Colorado, the Society has grown into an international network of organisations, many of which are independently incorporated as legal entities within their particular country of origin.

All organisations naturally evolve throughout their lifespan – adapting to new challenges and opportunities, positioning themselves to make sure their message is clearly heard on the international stage, and so on. In this regard, the Mars Society is no different to any other global institution. With ten years of steady growth under our collective belt, the time is now right to review issues of international cooperation and support: to develop a framework that not only builds on the past, but positions us to face the challenges of the next 10 years.

The Mars Society worldwide should be about:

- Facilitating equal and open communication between all national Mars Societies.
- Providing a single unified portal for information about the activities of Mars Societies world-wide.
- Providing a moderated forum in which international policies, projects and campaigns can be determined.
- Providing a conflict resolution mechanism should any disputes arise in joint projects between international societies.
- Being a source of innovation and dynamism for the society.
- Being inclusive in seeking views and accommodating differences of opinion in determining possible future directions of the organisation.
- Encouraging fiscal responsibility and transparency in the operation of national Mars Societies and projects.
- Providing active encouragement and support to those seeking to establish new national Mars Societies

In short it should grow up and be a truly international corporation.

The Mars Society has a number of active projects right now. These are the two Mars Analogue Research Stations, Flashline Mars Arctic Research Station and Mars Desert Research Station. But also the University Rover Challenge held for the last two years at the MDRS attracts more competing teams each year contributing to outreach goals and university involvement around the world in robotic research as a tool to assist Marsonauts while on Mars.

* Westenberg, A. 2008. Growing up: bonding the Mars Societies worldwide together in a renewed internationally-shaped Mars Society. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 59-60.

In 2007, two years before the Roskosmos and ESA collaborate on the Mars500 project, TMS has sustained a 4 month Mars-simulation in the arctic at FMARS with crew of 7, which added tremendous knowledge and understanding what it means to sustain a group of people on Mars.

Over the last year restructuring of the Mars Society Inc. in the USA was taken in hand to meet the demands of the new decade and the rewriting of the By-Laws to express this new structure. The newly created position of Director International Relations, the appointment of an Executive Director at the head office in Boulder and the newly appointed members of the Board of Directors are examples of the new structure of The Mars Society.

This Hab is not Self-Cleaning. All that is needed to run Mars-simulations and how to make them count*

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More than 70 crews working at Mars Society's research stations have worked and lived testing life on analogue Mars, and doing so accumulated a substantial amount of science and operation information. These crews depend on the smooth operation of the Habitats to optimize time spend at the Mars Simulation Research Stations. To ensure the smooth operation the Mission Support team of the Mars Society monitors every crew on an almost 24 hour basis.

The management structure for the Habitats consists of the following groups:

- Mission Support led by a Mission Support Director
- The CapComs (=captains of communications) 'speaking' via internet to the crews each night also led by the Mission Support Director who is herself one of the CapComs.
- The Engineering Team led by a the Chief Engineer.
- The Science Team led by a coordinator.
- Local support person who can drive out to the Hab if need be and physically lend support.

With some exceptions all these groups find their members mostly among the former crewmembers of previous crews.

These people are distributed around the world, which incidentally makes 24 hour watch over the welfare of crews and buildings easier.

The goal of all these groups is uniform and clear: Keep the crews healthy, happy and productive and maintain the habitats to the best of their ability, while adhering to Simulation Regulations as strict as possible.

Background

Mars Society operates two Mars simulation research stations since 2001/2002: one in Devon Island (FMARS) and one in Utah (MDRS). The goal of these stations is to simulate human mission -work and life on the Surface of Mars. FMARS receives one crew each year while at MDRS crews change every second week except for the summer season. In the last 7 years 71 crews worked at MDRS. Their results are published in various forums: in peer-reviewed papers, conference abstracts, books, private websites or other publications [1] [2] [3] [5]. The actual work of all crews is documented as specialized daily reports together with images and are available at the MDRS website [4] (Figure 1, Figure 2.). Updated operation manuals and cartographic resources [1] are also available on the website.

Management

Management of the Habs is far more than just keeping machines and people alive and operating well within established parameters. The operation manuals of the Hab (96 pages! and growing) is at present the only guide for the mission support personal and the crews to manage the technical side of life at the Habs. But the knowledge accumulated at the Habs needs to be managed as well.

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* Westenberg, A. 2008. This Hab is not self-cleaning. All that is needed to run Mars-simulations and how to make them count. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 61-63.

Right now all knowledge is stored the webpages of the Daily Field Reports and in the aforementioned operations manuals. It is very hard to keep these manuals up to date as systems at the Hab are constantly adapted, upgraded or simply tinkered with, whatever makes them perform their task for the present crew. Therefore for quite some time there was a need felt to make the knowledge of the Hab-systems (generator, autoclave, bread maker, waterrecycling system, etc) easier accessible. This lead in 2006 to the creation of a Wiki 'Hablife' [6].

Figure 1. Mars Societies MDRS Daily Reports page

Plans for Australia and Europe

The Mars Society UK, The Mars Society France, The Mars Society Netherlands, with input from The Mars Society Spain have planned a EuroMARS (= European Mars Analogue Research Station) to be placed in Iceland.

They have found funds to build the structure in the USA and display it there. They have scouted Iceland in 2002 for an appropriate mars-analogue site and found one with the help of the Iceland minister of Science on the fresh lavaflows of the Krafla Vulcano. As finding enough funds to outfit the Hab and ship and operate it on Iceland has so far not been succesful enough the EuroMARS at present is still in its developmental stage.

The Mars Society Australia has had her own Mars-Analogue station planned. I will not go into the details of that as the Australian Mars Society is far more knowledgeable on that subject than I am.

This year the wiki will be enlarged in a collaborative effort between The Mars Society Hungary and the Mars Society Netherlands, ofcourse with added input of volunteers from around the world. The Hablife wiki will be available to everyone on the web, to function as a practical guide for present crews and future crews and an outreach tool for the general public.

Crews can insert new information, upload files and modify previous data if needed (correction, update etc). However the articles would not be open to the public for writing/modifying (or, only after registration), but would be open for reading all articles and writing to discussion pages (or for other Mars-simulation related information, like [1-5]).

This Wiki would ensure more continuity in the day to day handling of the systems at the Hab and would support both mission support members and crews at the research stations.

These articles could serve as a historical database how various crews saw the subject, collecting all information in an organized way. It would also prevent crews for trying to solve problems or get data that previous crews already did; giving them the chance to make one step ahead for a subsequent problem, using data from previous crews.

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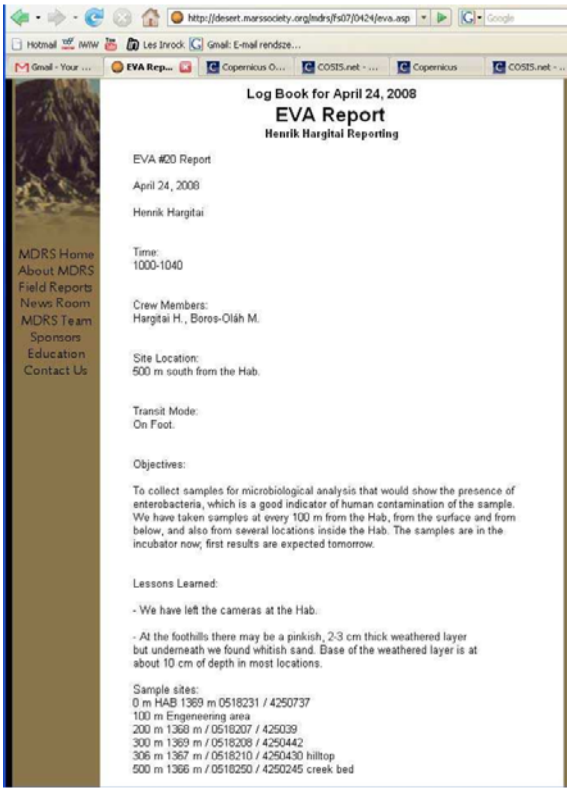

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Log Book for April 24, 2008

EVA Report

Henrik Hargitai Reporting

EVA #20 Report

April 24, 2008

Henrik Hargitai

Time:
1000-1040

Crew Members:
Hargitai H., Boros-Oláh M.

Site Location:
500 m south from the Hab.

Transit Mode:
On Foot.

Objectives:

To collect samples for microbiological analysis that would show the presence of enterobacteria, which is a good indicator of human contamination of the sample. We have taken samples at every 100 m from the Hab, from the surface and from below, and also from several locations inside the Hab. The samples are in the incubator now; first results are expected tomorrow.

Lessons Learned:

- We have left the cameras at the Hab.

- At the foothills there may be a pinkish, 2-3 cm thick weathered layer but underneath we found whitish sand. Base of the weathered layer is at about 10 cm of depth in most locations.

Sample sites:
0 m HAB 1369 m 0518231 / 4250737
100 m Engeneering area
200 m 1368 m / 0518207 / 425039
300 m 1369 m / 0518208 / 4250442
306 m 1367 m / 0518210 / 4250430 hilltop
500 m 1366 m / 0518250 / 4250245 creek bed

Figure 2: An EVA Report: this is how "collective knowledge" is now stored at the MDRS website

DESERT PAVEMENT

Deflation-made pebble fields (Desert pavement) / pavements of stone / gibber plains (AUS) / desert armour

Stony desert pavements stabilize the surface by furnishing protection to underlying desert soils. The pebble's source is varied: it may be the direct disintegration of conglomerates or can be deposited by flowing water. They are made of roughly similar size pebbles, the smallers removed by wind. Roundness pebbles originate from its paleoenvironment: they are round in the the original conglomerate, so their shape is not a result of subsequent weathering.

Formation of desert pavement

Pebble cover N of Shannons Range

On higher levels pavements of stone are clearly made of the disintegrated rocks (conglomerates), while on the lower levels fluvial activity may move or accumulate pebbles. During flooding pebbles can be complete removed from the levels below water level while in the higher ground (terraces) they are left unchanged, making islands of desert pavement.

This resembles desert pavement of Regs/Serirs (pebble deserts)

Conglomerates NW of Easter's Hill has a different erosional product: small crumby pieces, may be because the cementing material is stronger or fluvial processes have removed smaller grains.

Pebble field N of Lady Dunes, on a flat, plateau surface. Here rounded pebbles are clearly a remnant of weathered, disintegrated capstone conglomerates that could be found in a higher layer. (below)

Figure 3. Sample page from a publication on MDRS area geography [5].

MARS-Oz: A Proposal for a Simulated Mars Station at Arkaroola in South Australia providing an Inspirational Setting for Science Education and a Focal Point for Australian Planetary Science: A Presentation*

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The Mars Society Australia's MARS Oz project, 'Mars Analogue Research Station – Oz' has been developed during the last 6 years to provide a facility for practical education and research for planetary science in Australia. The education aim of the project is to:

> "Provide students and professionals an inspirational environment to explore the art of living on another planet encouraging students to develop and improve their science skills"

The project achieves this aim in two ways. Firstly, the station is located in an area that provides diverse geological and astrobiological Mars analogues. Secondly, the station design is a simulation of a horizontally landed bent biconic craft that could be used for a crewed Mars expedition. The combination of the location and realistic engineering design will give students and professionals an exciting and integrated approach to the issues of exploring another planet.

MARS-Oz could be used to undertake one to two week workshops for late primary school students, high school students, teachers, tertiary students and the general public. Practical and realistic 'Mars mission' scenarios can be created to explore questions such as: What do we need to travel and live on another world? Does life exist on other worlds? How do we find it or recognise it? What do we do when we find it? How can we live and work for long periods isolated from Earth and what kind of new society can we create on a new world?

MARS-Oz aims are similar to 'NASA's Spaceward Bound' educational aims. As such MARS-Oz will become a focal point of the Mars Society Australia's 'Spaceward Bound Australia' program being built in partnership with NASA Ames. The initial goal of Spaceward Bound will be to train teachers in the field of planetary science for teaching in the class though partaking field expeditions with professionals.

Finally, the presentation reviews the reasons for choosing the bent biconic vehicle and briefly covers the various technical arguments developed to adopt this vehicle as part of a Mission Architecture for an actual crewed Mars mission.

Keywords: MARS-OZ, Mars Base, Biconic vehicle, Arkaroola, Spaceward Bound

* Willson, D. and Clarke, J.D.A. 2008. MARS-Oz: A proposal for a simulated Mars Station at Arkaroola in South Australia providing an inspirational setting for science education and a focal point for Australian planetary science: A presentation. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, p 64.

Robotic Mission*

Colin Pain

The probe coasted into the planetary system from above the plane of the ecliptic, and began to survey the planets that orbited the rather ordinary star that sat in the centre of the system. It was looking for a particular kind of planet, one that showed the potential to produce intelligent life. The probe's makers were already an old race when this star began to form. They know that planetary systems were common in the galaxy, and although not so common, that planets suitable for life were also abundant. But they still knew little about the long term processes that led to intelligence, and so they had sent forth an armada of probes to search for planets that were suitable for life, but did not yet have intelligent beings. They knew that this could take a very long time, but they were patient, and long-lived enough to be able to see the results of their efforts. The probes were each designed to choose a suitable planet, and then gather data on its development. Only when unmistakable signs of intelligence were observed were the probes to send their observations back to their home system. In this way the scientists would not be inundated with data.

The probe noted that the system had the usual gas giants, although one was unusual in having a spectacular ring system. The system also had a number of rocky planets that orbited star-ward of the gas giants. This was promising, because many planetary systems in the galaxy seemed to be dominated by gas giants that orbited ridiculously close to their stars. After carefully comparing the characteristics of the rocky planets with the information and rules provided by its makers, the probe selected one of the rocky planets.

The planet it chose had an atmosphere thick enough and with a surface pressure high enough to protect life forms from harmful stellar radiation, and abundant surface water in oceans, lakes and channels and in the subsurface. The planet was also tilted relative to the ecliptic, which meant that it would have seasonal changes in temperature, wind, and water movement. It had two ice caps that would fluctuate with seasonal changes. It also had a number of impact craters, but this was common in young planetary systems. The planet met all the conditions for a pre-life planet, so the probe began to watch, record and wait. Only when it detected the presence of intelligent beings would it break its silence and make contact with its makers.

During the next four billion years major changes occurred on the planet, and all these changes were faithfully recorded by the probe. There were shifts in the distribution of land and sea, the polar ice caps waxed and waned, there was volcanic activity, large areas were eroded, and the resulting sediments laid down in lakes and seas, and along river valleys. Some places that were formerly wet dried out and became covered with wind blown sand. Lakes and seas dried up, and other areas were inundated. Glaciers formed, and carved valleys and moved rocks. Occasionally truly catastrophic events such as major floods occurred.

Then suddenly, about 4 billion years after it began its vigil, the probe noted the presence of the signs of intelligence, primitive artifacts orbiting around the planet and, in the blink of an eye compared with its long wait, vehicles orbiting the planet, and some landing, first with a few and than many intelligent life forms. It awoke from its passive observations, and began sending 4 billion years worth of data back to its makers.

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There was an air of excitement and anticipation in the control centre as the Astrobiologist entered the room. The previous evening a preliminary message had arrived on the sub-space communicator from Probe 672B indicating that it had detected intelligent life, and that it was about to begin sending the data the Astrobiologist had been waiting for nearly 4 billion years.

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* Pain, C. 2008. Robotic Mission. In Pain, C., (Editor), Proceedings of the 8th Australian Mars Exploration Conference, pp 65-66.

His First Assistant was already in front of the control screen on which a summary of the data would be displayed; the rest would be stored for leisurely study in the coming millennia. At a nod from the Astrobiologist he set the display in motion. The first images showed tiny and primitive vehicles orbiting the planet. These were soon joined by larger vehicles that contained the unmistakable signature of intelligent life. It seemed that these beings had at last escaped from the planet on which they had developed at the end of 4 billion years of evolution. It was time to look at the planet, and to see, first in summary, and then in great detail the steps that had led to their evolution. The Astrobiologist instructed the First Assistant to begin with the earliest images, and to step through the development of the planet at a pace that would allow them to see the broad outlines of its evolution.

The first images were encouraging. There was a dense atmosphere, and abundant surface water, with lakes and oceans. Precipitation meant the formation of drainage systems and in places the building of fans and deltas, the latter advancing out into lakes. There was also volcanism. All in all it was a most satisfactory setting for the development of life. But then, about 3.5 billion years ago things began to change and to become much less encouraging. The rivers dried up and the planet began to loose its atmosphere. Surface water retreated underground. There was still some volcanic activity, and occasionally there were catastrophic floods as underground water was suddenly released on to the surface. But by 2 billion years ago the planet was essentially dry, and the main activity was the formation of sand dunes, and the widespread movement of dust as storms built up and then dissipated in the thin atmosphere. Occasional volcanic activity interrupted a very passive period up to the present. During this long period the planet was clearly unsuitable for life.

Then, suddenly, the vehicles with intelligent life appeared. The Astrobiologist was by now quite agitated. This was intelligent life, but it cannot have arisen on the planet they were looking at. Where did it come from? The Astrobiologist watched with growing puzzlement as the last of the images of the dry and dusty planet were delivered from the probe.

Then suddenly he sat up. “Go back to that last image”, he instructed. The First Assistant did as he was told.

The Astrobiologist leaned forward. “Enhance that part of the image just above the hills on the left”, he said, pointing.

The First Assistant did so. A small white dot grew bigger as the high resolution enhancing capabilities of the screen did their job. As it grew the dot became blue, and then partly covered with swirling white areas. The image continued to grow until they were looking at a blue and white sphere against the black of space. Other sensors told them that the blue colour was mainly a result of water, and that the white swirling areas were made of water vapour clouds in an oxygen-rich atmosphere. There was also the clear signal of civilisations made by intelligent beings – intelligent enough to have built and sent vehicles to a neighbouring planet.

The Astrobiologist was devastated. The data the probe had collected would tell him nothing about the evolution of life and the development of intelligence, although there might be enough of passing interest to keep the geologists happy. He was almost at a loss for words. But not quite.

“That, that, that . . . . ROBOT!” he yelled. “It chose the wrong planet!”

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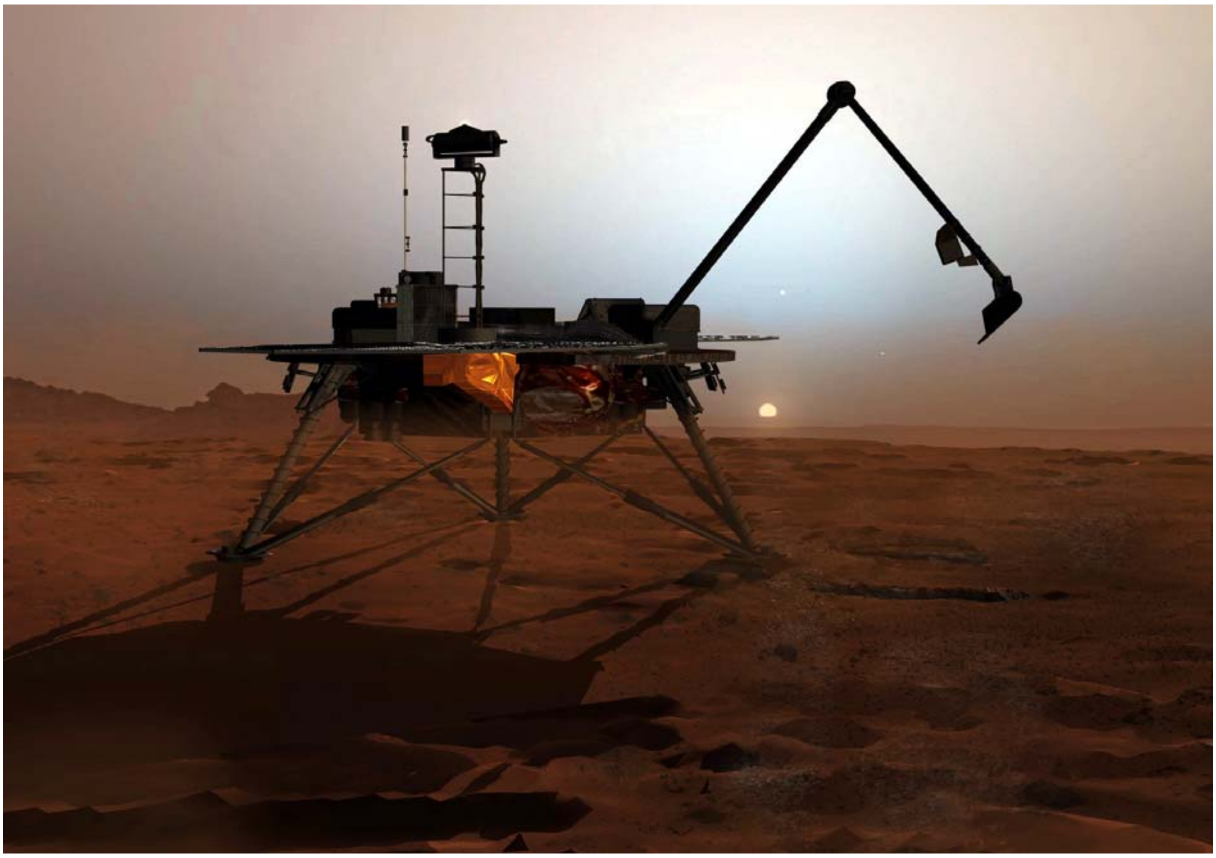

Images: NASA