

THE MARS QUARTERLY



PUBLISHED QUARTERLY (EARTH TIME) BY THE MARS SOCIETY

VOLUME 2, ISSUE 1 - WINTER 2010

Sign The Petition!

www.HumansToMars.org

Interviews:

- **Elon Musk**, SpaceX
- **Will Whitehorn**, Virgin Galactic

Drilling on the Moon & Mars

by Carol Stoker, et al.

**Phobos I and II, Red Russia -
Last Attempt on Mars**

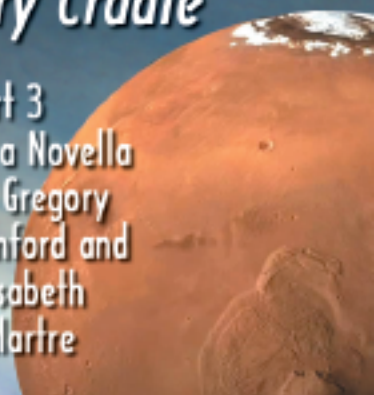
By Raul Colon

Mars Analogue Living

by Artemis Westenberg

*A Cold
Dry Cradle*

Part 3
of a Novella
by Gregory
Benford and
Elisabeth
Malartre



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On the Cover: Colorful Streaks

The HiRISE camera onboard the Mars Reconnaissance Orbiter is the most powerful one of its kind ever sent to another planet. Its high resolution allows us to see Mars like never before, and helps other missions choose a safe spot to land for future exploration. Thousands of images are available online at: uahirise.org. NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, Calif., manages the Mars Reconnaissance Orbiter for NASA's Science Mission Directorate, Washington. Lockheed Martin Space Systems is the prime contractor for the project and built the spacecraft. The HiRISE camera was built by Ball Aerospace & Technologies Corp. and is operated by the University of Arizona.

From the Flight Deck

By the time this issue goes to press, NASA's 2011 budget will be available at <http://www.nasa.gov/budget>. It is expected to include "innovation initiatives" that will place an emphasis on outsourcing the development of commercial launch vehicles to the private sector. In this issue, we offer interviews by outgoing Executive Director, Chris Carberry, with Elon Musk, CEO of SpaceX, and Will Whitehorn, President of Virgin Galactic. These two companies are uniquely positioned to take advantage of these new NASA initiatives.

In this issue we are also pleased to include articles by Raul Colon, President of the Puerto Rico Chapter of The Mars Society on the subject of the Russian space program, and by Artemis Westenberg, on the challenges met by those who experience a Mars analogue environment.

We hope you will join us at our 13th Annual International Convention which will be held in Dayton, Ohio, on August 5-8. Register early!

On to Mars,
- Susan Holden Martin

THE MARS QUARTERLY

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Publisher

The Mars Society
Headquarters
11111 W. 8th Ave., Unit A
Lakewood, CO 80215 USA
www.MarsSociety.org

The Mars Society

President.....Robert Zubrin
Treasurer.....Gary Fisher
Secretary.....Sara Spector
Executive Director
.....Lucinda (Weisbach) Land
Accounts Receivable Director
.....Patt Czarnik
Webmaster.....Alex Kirk
Director, Public Relations...Kevin Sloan
Director of Membership.....Patt Czarnik
Director, International Relations
.....Artemis Westenberg

The Mars Quarterly

Editor-in-Chief.....Susan Holden Martin
www.tmq-editor@marssociety.org
Art Director.....Keith Keplinger,
Keplinger Designs, Inc.
Contributing Editors.....Chris Carberry,
Artemis Westenberg, Josh Grimm,
Blake Ortner, Byron Wiedeman,
Gus Scheerbaum, Jean Lagarde,
Joseph Webster, Kevin Sloan,
Patt Czarnik, Alex Kirk, Debbie Foch

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Moving Forward

By Lucinda Land, Acting Executive Director

It has been said that 2010 will be the year for space, and our organization is committed to keeping Mars at the forefront of the space movement. As Acting Executive Director, I stand behind our cause to make sure that the exploration of Mars as well as the inevitability of a human mission is kept in the minds of space advocates and enthusiasts. In moving forward, it is imperative that our outreach goes beyond our normal circles of influence, and reaches those that may not have considered the possibility of sending humans to Mars.

This is why we do what we do, and why we depend on your dedication and persistence in communicating our message.

The Mars Society is a forward-moving collaborative, community and action-oriented organization that inspires many. We are this because of you, our members, and a handful of very devoted individuals who create our conferences worldwide, competitions,

and lobbying efforts in Washington DC. One committed individual, who has made significant strides for our organization over the last two years, is Chris Carberry, our previous executive director, and we are with heavy heart to see him move on. He has left us with a strong foundation on which we will continue to build a mighty political position on the Hill with our unending strive to go to Mars. We are grateful for his dedication and leadership to our organization and wish him well with his future space endeavors.

Augustine Commission's recommendations. We are asking you to participate in urging President Obama to set a course for Mars and give the US Space Program a goal, and that goal should be sending humans to Mars by the end of the next decade. Here is your opportunity in communicating that message, sign the petition, and send humans to Mars at www.humanstomars.org.

I am thankful for this organization, its members, and dedicated volunteers. I take great pride in being a part of our Mars community and moving it forward. I am also eternally grateful for my predecessors who have laid down a solid footing for me to stand on and want to create a path to take us to where we want to go... to Mars.

The Mars Society outreach initiatives for 2010:

- SEA Legislative Blitz, Washington DC, February 21st-23rd
- MDRS crew rotations Fall 2009 - Spring 2010
- University Rover Challenge, Hanksville, Utah, June 3rd-5th
- The Mars Society conference, Dayton, Ohio, August 5th-8th
- International Mars Society conference, Poland, October (TBC)

HumansToMarsPetition.org

In continuing to reach the general public, we have begun an international effort to convince President Obama to move Mars forward in light of the

-On To Mars,
Lucinda Land,
Acting Executive Director
The Mars Society



The Mars Society Launches a Humans To Mars Petition

by Robert Zubrin

Mars Society Launches Petition Campaign - "President Obama: Set the Course for Mars"

The failure of the Augustine Commission to provide the Obama administration with a worthy objective for the American human spaceflight program threatens to leave NASA rudderless. Under these conditions, those who believe that the space program needs a real goal - and that goal should be humans to Mars - need to step forward. For this reason, the Mars Society is launching an

international petition campaign, calling on President Obama to set the course for Mars. The petition is open to all to sign, regardless of age or nationality, because the question of whether NASA succeeds in doing what it can and should do to open the space frontier is a matter of vital concern to all humankind.

On July 20, 1969, Neil Armstrong

and Buzz Aldrin set foot on the Moon. In the 40 years since, no human has gone farther. Four decades of stagnation in human spaceflight is

more than enough. We do not need a fifth. It is time for the people to speak. Sign the petition. Spread the

petition. Post links to it on every website you can. Let the voice of the future be heard.

The petition can be found at
www.HumansToMars.org

Click Now!

Mars Analogue Living

By: Artemis Westenberg



Winter hit MDRS early and harshly this year, bringing problems of frozen waterlines and even water tanks to the crews. Truth be told it made the experience of being at our Hab a lot more Martian, or so crews reported. The intense cold brought home a deeper understanding of what humans will face on Mars: a hostile and dangerous environment that dares you to forget even the merest detail of the chores at MDRS aimed

at keeping all the systems alive. An unintentionally unplugged heat tape means a broken grey water line and heaps of trouble to fix that while the weather remains so cold. The outside water tank got insulated, but the water in the tank nevertheless froze for many inches. Only a livestock feeder heater was able to alleviate that. And that is what life on analogue Mars seems to be all about: every time we think we have a firm grip on the situation, Mars throws us a curveball and we need to get creative once more to remedy the problem.

We are in our 9th season at the Hab and we are already having many plans, and even agreements with 3rd parties, for the 10th and 11th season.

Full crews and individuals are applying for those seasons and if you feel that you want to be part of that, feel free to apply as well. Over the years we realized that the educational outreach of the station, like under the Spaceward Bound contract with NASA, but also in general, could be so much greater than what we are doing right now. Therefore we intend to widen the scope of the educational outreach. More levels of participation in duration, from a few days/long weekend, the normal crew rotation of two weeks, to even several months will be offered. All in order for our next generation of would-be scientist and engineers to get a taste and a hands on feel for the science and technology that is such a large part of our societies nowadays.

Halfway in this 9th season at the Hab you would think we know it all, but believe us when we tell you that there is scope for quite a bit of learning yet. We invite you to come and see for yourself. And until you do, follow us on:

<http://twitter.com/MDRSupdates> and <http://www.freemars.org/mdrscam>.



Drilling On The Moon And Mars: Developing The Science Approach For Subsurface Exploration With Human Crews

C.R. Stoker¹, J. Zavaleta¹, M. Bell², S. Direto³, B. Foing³, D. Blake¹, and S. Kim⁴,

(1 NASA Ames Research Center, Moffett Field, CA, 94035 carol.stoker@nasa.gov;

2 NASA JSC, Houston, TX; 3 ESTEC /SCI-S, Postbus 299, 2200 AG Noordwijk, The Netherlands;

4 Jet Propulsion Laboratory, Pasadena CA)

Introduction: DOMEX (Drilling on the Moon and Mars in Human Exploration) is using analog missions to develop the approach for using human crews to perform science activities on the Moon and Mars involving exploration and sampling of the subsurface. Subsurface science is an important activity that may be uniquely enabled by human crews. DOMEX provides an opportunity to plan and execute planetary mission science activities without the expense and overhead of a planetary mission.

Objectives: The objective of this first in a series of DOMEX missions were to 1) explore the regional area to understand the geologic context and determine stratigraphy and geologic history of various geologic units in the area. 2) Explore for and characterize sites for deploying a deep (10 m depth) drilling system in a subsequent field season. 3) Perform GPR on candidate drill sites. 4) Select sites that represent different geological units deposited in different epochs and collect soil cores using sterile procedures for mineralogical, organic and biological analysis. 5) Operate the MUM in 3 different sites representing different geological units and soil characteristics. 6) Collect rock and soil samples of sites visited and analyze them at the habitat.

Approach: A crew of 6, comprised of 3 scientists and 3 engineers, was deployed for 14 days at the Mars Desert Research Station (MDRS) November 14-28, 2009. The MDRS is a unique facility that is designed to look like a Mars lander from the Mars Direct architecture[1]. The facility houses a 6 person crew, providing their habitation needs, and laboratory space for sample analysis including wet lab, refrigeration, autoclave, oven, basic laboratory equipment and instrumentation. Ingress/Egress is provided through simulated airlocks and EVAs can be simulated using mockup spacesuits. MDRS is located in an important Mars analog site in South-central Utah. The area hosts exposed and nearly vegetation-free sediments deposited during the late Jurassic and Cretaceous geologic periods. Layered sediments were deposited from environments ranging from seafloor, floodplane, massive dunes, and evaporite sequences. The area exposes a rich array of mineralogies including sulfates and phyllosilicates and many types of concretions of particular interest as Mars analogs[2].

Equipment: Instrumentation used to support our mission included key instruments developed for flight use with support from the MIDP program including the Moon Mars

Underground Mole (MUM)[3], the CRUX Ground Penetrating Radar[4], and the Terra X-Ray Diffraction Analyzer [5]. The MUM is a subsurface penetrometer designed for penetration through regolith using an internal hammering mechanism. The device contains a hammering front end, a rear optical compartment with light collection optics for a fiber optic Raman spectrometer, and a tether management system (Figure 1). The CRUX GPR (Figure 2) is a small ground penetrating radar consisting of an antenna system mounted on a sled that can be towed. It returns radar echoes diagnostic of subsurface structure to a depth of 10m. The Terra XRD analyzer (Figure 3) is a commercial instrument, ruggedized for field use, that is the prototype of the CHEMIN instrument on the Mars Science Laboratory[5]. In addition, we used a manually operated soil coring system to obtain sterile soil cores.

Other: Detailed timing records were maintained of all crew activities. Audio records were acquired before and after each major traverse activity describing goals and accomplishments. Daily reports written by the crew summarized each day's activities.

Results: At mission start the crew performed a regional survey to

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Figure 1. MUM operation in the field.



Figure 2. Collection of GPR data in the field during a simulated EVA operation.



Figure 3. Terra XRD instrument operated in the field during a simulated EVA operation.

INTERVIEW WITH ELON MUSK

By Chris Carberry [October 19, 2009]



Carberry: Can you give us an update on Falcon 1 & 9 as well as Dragon and what the next year will bring?

Musk: Falcon 9 will begin final vehicle integration at Cape Canaveral in January 2010. The first flight of Falcon 9 will have a stripped down version of Dragon - basically our Dragon spacecraft qualification unit. This is the actual article used to qualify Dragon for flight loads, so it is identical to a flight vehicle as far as the core structure and mold line, but will not carry engines or avionics.

The second flight of Falcon 9/Dragon will be under the NASA COTS program and will probably take place the middle of next year -that flight will have an almost fully functional Dragon. It will maneuver around, communicate, re-enter and get recovered.

And then by the end of next year is when we hope to get to the [International Space] Station. As for human space flight, there is a lot up in the air and we only control

part of it. The real decision is going to be with The White House with respect to commercial manned space flight. I think it is going in the right direction, but of course, you don't know until it happens.

Carberry: If all goes well, when do you think you could get a human crew up to ISS?

Musk: I believe we can do it within three years of receiving the NASA contract - that is allowing for a year of margin. Our internal schedule is two years, but add a year in there for unknown issues.

Carberry: I know that it can be a complicated process to get "Human-Rated." Do you foresee any problems getting your vehicles human-rated?

Musk: There is no question that it will be challenging to achieve an official human rating, but it is not going to be as hard as for say an Atlas or a Delta. We built the Falcon 9 and the Dragon spacecraft to meet the NASA human rating requirements, as currently defined, from the beginning. There may be some things here and there that we missed, but all in all, we've probably got 99 percent plus of the requirements satisfied. Also, our Dragon spacecraft - for the portion of that it is in the facility of ISS - is human-rated because you have humans on the space station, and if something were to go wrong with Dragon, you could destroy the whole space station, which is a \$100 billion asset. In many ways, for that portion of the flight, Dragon is already human-rated. The parts that will have to be

...there will be huge opportunities for entrepreneurs to figure out how we make it work on Mars.

addressed will be reentry and ascent. Ascent really being rocket related - the core booster, the escape system, and then reentry. We should be okay in reentry, really. We have redundant parachutes,

redundant drogues and mains, and the g-loading is very light, so I think we'll be fine with reentry. I think ascent will be the real tricky one. The thing that affects our schedule is the escape system.

Carberry: What challenges does the escape system pose? Is it based on systems that have been used before?

Musk: We are considering going in a new direction that has not been done before, but assuming we do some sort of NASA contract, we need to do a careful study between traditional methods and the new method that we've created. But I don't want to talk too much about it because it is not something that we've decided on and we may find that it is

not feasible. So, I prefer not to discuss that right now.

Carberry: Assuming all goes well with the funding of COTS, and you continue to get other contracts, where do you hope to see SpaceX in 10 years?

Musk: Well, that is hard to predict. SpaceX didn't even exist 10 years ago - we're only seven years old. At the current rate of progress we'll probably be on Mars, but as you tend to get bigger, the rate of progress tends to slow down.

Carberry: What can the advocacy community or other small groups do to help promote the cause? I know we can always do political efforts, but do you see any technical projects that could be done by the advocacy community that might help us get to Mars?

Musk: Convincing NASA to go commercial; but beyond that, there is not that much because it is fundamentally about the booster, which is a huge capital project. If we can make the transportation system work, there will be huge opportunities for entrepreneurs to figure out how we make it work on Mars. But you need the transportation system. It is like having a railway--Union-Pacific. What I would like to see happen is to extend life to Mars, making life multi-

planetary. I certainly didn't found SpaceX because I think this is the easiest way to make a buck.

Carberry: If you had the option to mount a mission to Mars through SpaceX, or through NASA or some other combination, and you were the one choosing the mission architecture, how would you do it? And, do you think NASA's plans could do it, or would you do something like Zubrin's Mars Direct?

Musk: I think NASA's plans are constrained by budget. Congress is not going to appropriate the money to do that. I remember reading Zubrin's book at one point, but all I recall is the use of ISRU propellant. Was there more to it than that?

Carberry: [Mars Direct in a nutshell: ISRU, return vehicle first, then crew, no in-orbit assembly, etc.]

Musk: I think there is some logic to that.

Didn't someone else come up with that? Wasn't that part of the Mars working group, or something like that?

Carberry: A lot of these concepts had been thrown around for years and then Zubrin put the pieces together in a way that no one else had. He also had some great innovations that he added to the plan. Then there was the NASA Reference Mission which was a variation on what Zubrin had proposed with Mars Direct.

Musk: I think Zubrin has some pretty high costs for the humans to Mars missions - multiple billions. In reality, we have to do this mission per passenger in the lowest



[individual] billions. If you want to make life multi-planetary, that's the only way to afford it. Eventually costs will come down, but I think the long-term approach will be having people go there to stay and maybe go back once or twice after they get there - but much further down the road.

Carberry: You have also been running other interesting companies, such as Tesla. Do

you see a connection between Tesla and SpaceX? Could you use the technology from Tesla on Mars? A Mars pressurized rover perhaps?

Musk: Yes, I think Tesla would be the perfect company to do a Mars rover. Electric cars work just as well on Mars as they do here on Earth.

Carberry: I seem to recall reading a statement in support of the preliminary report of the Augustine Commission, but what are your general thoughts about their recommendations?

Musk: I think the realistic options involve the use of commercial crew services.

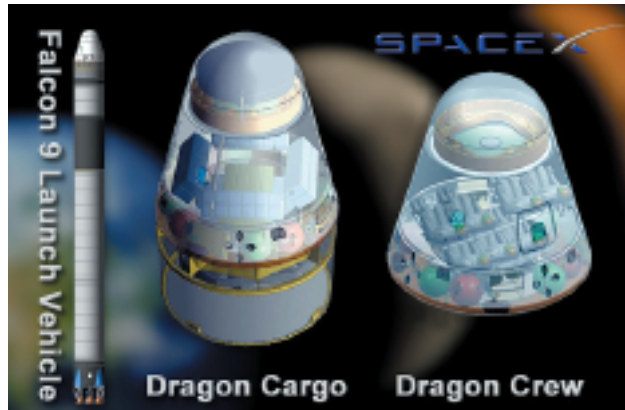
Carberry: So you don't think NASA's going to get us to Mars?

Musk: Not doing things the way they've been doing them. And, it's not about going to Mars and doing the "Flags and Footprints" thing. That's nice, but do you really want to spend \$100-\$200 billion on that? What matters is a system that is going to [breath] life into Mars and has a very low cost of transport. NASA's not currently set up for that.

Carberry: Is there anything else you would like to say to the readers of this magazine concerning your goals and hopes for the future of space/Mars exploration?

Musk: What I think is really of great

importance is to make life as we know it multi-planetary. This is the first time in our four billion year history that it is possible. Who knows how long that window will be open? It might be a long time - and I think it probably will be a long time. I'm quite optimistic about the future, but it may be that there is some sort of calamity waiting around the corner and this is insurance for life. I think we should



really try to promote that idea as something that is worthy of a portion of our economic resources. SpaceX will do as much as we can to help further that goal, but we certainly can't do it alone. There will have to be a lot of other companies doing things - particularly when you get the transport system working; and trying to figure out how to create a self-sustaining, growing ecosystem on Mars is going to be very difficult. I honestly do hope that there are others who will develop space transport systems [that are] competitive with SpaceX.

Carberry: Do you see any out there right now that may give you a run for your money?

Musk: I don't. I don't see anyone even close.

Elon Musk is CEO and CTO of SpaceX. SpaceX has developed two launch vehicles, and has been awarded COTS funding by NASA to demonstrate delivery and return of cargo to the International Space Station. For more information, please visit: www.spacex.com.

Continued from page 5

identify major geologic units that were correlated to recognized stratigraphy and regional geologic maps. Several candidate drill sites were identified. During the rest of the mission, successful GPR surveys were conducted in four locations. Soil cores were collected in 5 locations representing soils from 4 different geologic units, to depths up to 1m. Soil cores from two locations were analyzed with PCR in the laboratory. The remainder were reserved for subsequent analysis. XRD analysis was performed in the habitat and in the field on 39 samples, to assist with sample characterization, conservation, and archiving. MUM was deployed at 3 field locations and 1 test location (outside the habitat) where it operated autonomously for 2-4 hours at each site. Depths achieved ranged from 15 to 70 cm depending on the soil compressive strength and the presence and depth of subsurface indurated layers. Subsurface samples weighing 0.5 to 1 g were collected at the deepest depth encountered at each of the sites using the MUM automated sample collection system, and subsequently analyzed with XRD. Downhole inspection of holes produced by MUM with the Raman spectrometer was acquired on two of the holes and spectral features associated with selenite were identified in specific soil layers. Previously unreported fossilized remains of vertebrate fauna from the Jurassic era were discovered during our mission. Analysis of mineral biomarkers associated with this discovery are underway.

41st LPSC Abstract 2697 2010

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Acknowledgements:

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Mojave 2009 MS NorCal Report

By Boris Debic,

Northern California Chapter of the Mars Society

The Northern California Mars Society chapter rover team participated in a field science expedition to the Mojave desert organized by Chris McKay of NASA Ames for the NASA Spaceward Bound program [1][2]. The field expedition, also known as Mojave 2009, took place on locations near the Zzyzx Desert Research Station on the weekend of October 23rd. Joining the team was a small group Space Science students from Swedish Universities.

The main goals of the expedition from our group's perspective were:

- Field testing the Senseta rovers.
- Gathering imagery and video for future documentation, teaching materials and presentations.
- Field testing the MDRS rover base design.
- Field testing the new open source linux/java based control software.
- Assisting and documenting the Ames group in testing the desert mat imaging rover.
- Assisting Senseta staff in setting up communication hardware and experiments.

Field testing

The testing part was based on a testing plan agreed upon before the Mojave 2009 expedition. Here's a summary of observations performed.

In total, we brought three rovers to Mojave, two for Mars Society testing (a J and an R, one running MaxKernel, one running MSRS) and one for the Ames group (an R running MaxKernel)[3]. All rovers were up and running simultaneously on the same rover. There were only a few issues while setting up the rovers. For one, the MSRS software was a little unstable and video would cut out every once in a while. It should also be noted that rovers have to be secured during transportation. We had one of them shear a screw on the roll cage during transport. These were all resolved prior to field testing. The

rovers definitely proved their field worth - in pretty rough terrain as well.

Rover Setup

Setup proceeded smoothly. No problems were reported. It takes about 30 minutes to unpack the rovers, boot the station and setup basic wifi to get them going. We decided to skip some of the detail documenting at this point as we wanted to get an early start on the physical testing. Documenting the setup is easier to perform in the lab with controlled lighting and plenty of time for photography and video. We have already filed this as a TBD with Andrew Klofas of Senseta.

Rover Physical Testing Base Course

Performing basic driving operations at close range under visual guidance was not a problem. Sun glare is a factor when using the controlling laptop as the only navigational aid. Early on we moved the laptop into the shade of the van. Simple screen shades should be brought for field operation. The VMO rover was driven as well, while inherently less stable than the standard J and R rovers due to its oversized camera boom, control of it proceeded smoothly on the base course.

The rovers didn't appear to have any problems with operating in the hot temperatures, but the ground station carried in a backpack did get quite hot. If we're expecting to do a lot of visual operation of the rover with the ground station in a backpack, we might consider a bag with better airflow to

keep the laptop cooler.

The test on the rover ramp at various inclinations proved the vehicle can climb it at 20 degrees of inclination. The first run was done on the smooth board without any sand on it, the second run was performed after the rover kicked some sand on the ramp. In this second run the rover could not climb at higher than 10 degrees, and this only with the initial speed being somewhat excessive. The ramp will need a redesign, with steps installed to minimize the interference

of sand and dust and provide better traction at a safer speed.

A Course

The A course selected was a patch of relatively flat terrain, presence of desert crust was noted. The crust is an indication of the presence of organisms that live in dry

(Xerophytic) conditions and have implications for locating life[4], or even terraforming[5], in another extreme environment - Mars. Though cyanobacteria are among the most primitive living things, they have developed sophisticated skills for dealing with an environment where water is both scarce and transitory. These bacterial communities are of interest to scientists ranging from exobiologists to climatologists and will become a focus of more research and monitoring in future years [6].

The tests didn't find loose sand to be difficult at all to drive on on flat terrain. The soft tires of the rover helped in gripping loose sand. Preliminary accelerometer data shows the rover did not experience acceleration of over 2Gs on any axis.



Situational awareness showed itself as an issue for rover drivers. The test drivers at Mojave complained they had a hard time telling where they were when driving. A very wide angle lens on the camera would go a long way to help drivers drive safely. We had a rover tip over when it was driven into a dried out bush and a too high speed. Factors which led to the rollover were; speed, inclination, communications lag and situational awareness. On the other hand the rover was very stable when crossing over alluvial terrain features in the sand of up to 12 cm.

Driving fast on loose sand kicks up a great deal of sand/dust in the air that can get into ports and vents of the rover, as well as potentially coating the camera lenses. This could make driving by camera difficult and cause other problems. We need to recommend bringing some canned air and a brush to clean the rover vents and camera lenses of dust occasionally. Towards the end of the testing on the A course when the batteries were getting low, we noted an unusual noise from the gear box. This was corrected by replacing the batteries. We need to followup on the exact cause of the noise as it didn't seem too healthy for the rover. We also found the rover very useful when driving under visual control over desert mats. It did not leave any marks on them and proved itself as a very useful tool for gathering field data with minimal or no impact to the desert floor. This is an important consideration for any long term studies to be performed in the future.

B Course

The B course testing was split in two parts. One in a sand pit to test the climb ability on sandy terrain and the other on a rough patch littered with volcanic rock varying from 3 - 40 cm in size. The rover had a hard time climbing any hills made of loose sand and would dig its wheels if not properly controlled. Backing out and driving at full speed with some

momentum helped to clear loose sand hills of a meter high or so, but any hills taller than that will be a problem. If the rover is driven through such terrain a combination of visual and distance assessment data displayed on the controlling screen would be very helpful. It may be possible to generate a feature, an inclination display, based on processing the data the rover gathers to aid the operator. In addition a future survey of MDRS area is highly recommended based on the limitations we found in this



exercise although the primary goal will be to enable the rover to classify some of the obstacles itself [7].

Both rovers handled quite well on difficult lava terrain at moderate speeds.

The larger lava rocks were particularly difficult to climb over and the rover would frequently get stuck "bottoming out" on rocks over 10 cm. Driving the rover at full power generally had more success forcing itself over rocks, but this was very hard on the rover and caused a couple of rollovers. It was also responsible for losing a carter pin holding the batteries in. We conclude that this task would have been much more difficult when driving by camera. At the lava bed we ran both rovers to test tough terrain capability. The ability to traverse this terrain between the two was striking. While the 5R was controlled by MSRS from the van the drivers had limited situational awareness. Despite this they were able to traverse about a few meters before getting stuck on the lava rocks. Alternately, the other rover was

operated visually on top of the mesa and very successfully driven around the surface - even able to rescue himself out of tough spots without damage to the rover. The rover did a pretty amazing job of rock traverse on a terrain which is even hard to walk through.

Important to note for field work: The better the awareness the operator has of the rover surroundings the better they will be able to successfully navigate the terrain.

Two things to note for future development of the control package. In order to clear some of the tougher obstacles the power level had to be set to a maximum. Having more torque at a lower power setting would help significantly clearing out object while maintaining a lower speed resulting in less risk to the vehicle. While we have proven the rover's ability to traverse areas covered with large

rocks this should generally be avoided for safe rover operation in this configuration. If the rough

terrain is limited to a few meters, it is probably safe enough to pass through. But for longer traverses we need to develop a more robust control mechanism and power characteristic.

The Ames team tested the VMO configuration rover and gathered imagery and operational data. While the current version of the camera has stability limitations the rover managed to collect imagery at the desired millimeter resolution in a real world setting. The team gathered valuable experience for further design improvements of the camera boom. In addition, We need a planning session to identify and acquire a small set of field service parts for the rovers to have handy on future field trips.

Control network performance

We had several different setups for the control network; standard wifi with sector antenna and narrow field antennas, the Meraki mesh network. The primary means of controlling the rover was the standard wifi setup. Its

performance was adequate, the sector antenna easily covered the few hundred meters we needed for testing coverage. The narrow field was tested at the A course and distance-wide performed better than the sector as expected, though we did note a drop of the signal when descending the rover into the gully terrain which put the rover through a loss of visual contact



situation at the level of its wifi whip. Out of visual range should not be recommended for future expeditions, furthermore, may need to consider a higher whip on the rover to obtain better range when traversing lower spots. Towards the end of the testing wifi range was tested with the narrow field antenna on flat terrain. The rover stopped responding to control inputs at the distance of about 1.2 kilometer (3/4 of a mile).

The Meraki nodes were powered up and came online in their basic configuration. They need to be setup before any field work as their configuration requires internet access in order to boot up the network.

Conclusion

The majority of tests and field documentation we intended to collect were addressed. Logs, imagery and video were collected on which we will continue analysis in the coming weeks[8]. Enough material was recorded to cover properly the documentation which will accompany the rover to the MDRS and other missions. We decided to skip the setup imagery and video in favor of field sequences as the former are easily recorded in the Bay Area. Rover performance was as expected and we did try out a number of important real world scenarios which should aid us greatly in providing the right level of documentation and field support. The Senseta rovers are very capable of carrying out science tasks in the field.

Their setup and operation is not too complex and it is user friendly. It can be easily handled by scientists or teacher and students who are not necessarily robotics experts. It takes a reasonably short time to get them prepared and going so the bulk of it

can be allocated to science or teaching. Starting from scratch we had the rovers and network going in 30 minutes, in a teaching

laboratory environment with a preset wifi, it should take about 5-10 minutes to prepare the rover and control console for operation.

The rovers handled well terrain of varying degrees of roughness, and are resilient to rollover over obstacles of moderate size, up to 20 cm on one wheel and up to 15 cm on both. On flat terrain the rover cleared alluvial terrain features up to a meter in height with slopes of up to 35 degrees at a high power setting.

We also recorded accelerometer logs on various terrain configurations to aid in planning what kind of science packages can be safely deployed on the rovers and on what terrain configurations. On flat terrain we did not observe forces in excess of 2 g, however on the rough lava they did climb several times into the 3.5 g range. This should be a consideration when planning missions on difficult terrain. In addition we gained valuable experience with the new kernel software, the initial observation is that it is much more responsive and it gives us a level of control which surpasses the previous versions. Planned future improvements to the control console in terms of visibility, the display of additional navigational and situational factors, and the addition of certain autonomous modes will greatly add to the control characteristics of the rover. This will undoubtedly increase further the reach and usefulness of the rovers as

scientific platforms. The Senseta rovers proved their worth as versatile science platforms on the scientifically important type A terrain, in addition they can traverse shorter stretches of type B terrain greatly increasing their field value and range.

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Interview with Will Whitehorn, President of Virgin Galactic

by Chris Carberry [November, 2009]

Carberry: Thank you for speaking with me today. We thought it would be interesting to do an edition on private sector space exploration and the implications for Mars exploration.

Whitehorn: I think that is relevant in the context of the Augustine Commission. Obviously the initial conclusions of the Augustine Report on human space flight clearly laid out some of the issues in the NASA budget for space exploration outside of orbit.

Carberry: Yes, and it seemed to focus a lot on private sector options.

Whitehorn: I was in Washington last week meeting a lot of people in the US administration and on Capitol Hill, and also met with the Commercial Space Flight Federation Board. I got a copy of the Augustine Report and I

thought the conclusions were interesting in one respect. It was very honest about reality. If you are going to run any large, long-term project - and I have never run a project quite on the scale of say the Shuttle Program or the Apollo program - but we've done some pretty significant ones at Virgin where we have a 10-15 year time scale and a lot of technology introduced and a lot of infrastructure work. I can think of one in particular that I worked on which was the introduction of a train into the UK in the private sector, funded by the public and private sector. When you get into a project with that kind of scale, you've got to be incredibly realistic about budgeting. It is quite clear that the budget availability doesn't match the ambition at the moment of what the shareholder or

the stakeholder or the owner - if you want to call the US government that in the case of NASA.

Carberry: It is true that the past administration didn't provide appropriate funds for the program and perhaps underestimated what it would cost. However, I think the Augustine Commission may have overestimated what it would cost, which could also hinder the overall program.

Whitehorn: I do think, the more that I have learned about it over the past decade, is you look how industries develop - how aerospace developed. There will come a moment when there are certain things that the private sector can regularize and do better than an exploratory, research and development organization, which is what NASA was



Spaceport America designed by SRS/Peter + Partners.
Conceptual image courtesy of Virgin Ltd.

originally established to do. I think that a lot of low Earth orbit functions can be taken over in a cost effective manner by the private sector over the next decade or so.

Carberry: So where do you see Virgin Galactic in the next 10 years as well as the private sector in general?

Whitehorn: From our point of view, we have a real opportunity on our

hands. Virgin began this project with a piece of technology. A vision of what a technological approach to a problem could yield. SpaceShipOne and White Knight 1 are an example. In addition to using carbon composites, some extremely ingenious ideas by Burt like the feathering device for suborbital reentry. And they gave the

prospect of a safe operating system to allow people to get up in space and get a taste of seeing the planet Earth, experiencing weightlessness, and many of the elements that we've generally regarded traditionally as the human experience of going to space. The exciting thing was that with this technology we could do quite a bit more than that. So, from the very beginning, we planned our approach to being: let's look at the space tourism market, let's look at what that market would really want as opposed to what people are going to try to give them, and let's do some real work on market research - let's go out and sell tickets and find out what people want. Some people told us, back in 2004-05, that they weren't prepared to put their \$200,000 down unless they get the experience of weightlessness. That really sealed for Virgin that we were

going to need to take a technology development project to a new scale from what we had originally envisaged.

The original plan was to rebuild SpaceShipOne and get it into commercial operation quickly and then build a more sophisticated system later. But, it was quite clear to us we needed build a more sophisticated system to start with. If

people wanted to experience weightlessness, we needed a big enough cabin that we could carry more than just a couple of people that SpaceShipOne would have carried. And we needed to build a spaceship and space launch system for it in White Knight 2, which would be capable of doing more. So we designed SS2 with features that would make it a very useful

human in-the-loop space science vehicle. And we designed WK2 with a greater carrying capacity for weight to altitude than our SS2 design required. That extra bit - 35,000 pounds of weight - or 17 tons in metric terms - We could get a satellite of up to 200 kg into LEO.

With Virgin Galactic, we've moved ahead in the space tourism business. We embarked on work on the space science market with humans might look at with a cheap enough vehicle - with regularity and safety of flight. Then, in this last six months as a result of with the new investments that have come in, we have been given a budget to produce a business plan to look at developing a satellite launch vehicle. So a lot has happened to Galactic in the last six or seven months. It's allowed us to refine what we're doing and also bring forth our

planning as to we'll be able to do it. So certainly, what we envision over the next 8-10 years is that we will establish the space tourism business successfully.

We'll operate at our main base, Space Base America in New Mexico. We'll experiment with that system operating out of different locations - places we could conduct occasional flights from such as Kennedy Space Center or Kiruna in Sweden, or Abu Dhabi, subject to regulatory approval. We will also embark in the next six months - and we've actually undertaken in the last week or two to bring this forward - to develop an unmanned satellite launcher. We've actually recruited a Dr. Adam Baker from Surrey Satellites to be the manager of that project for us.

In the longer term we clearly have a vision that this approach of air launch, using the new materials technologies now available in aviation - the kind of really good power-to-weight ratio turbo fan jet engines for a mother ship to launch. With increased use of composites, we believe we can develop an even bigger White Knight in the future so that we could use an air launch system very flexibly to get human beings into orbit.

What this system can't do - but there's another ambition for us in the future - is the right type of engines be developed that could be the beginnings of hypersonic flight around the planet. But for the next decade, our ambitions at VG are not to go beyond that type of scenario. However, having said that, I still believe there still is a vision for the private sector doing deep space. But that is really is the place where NASA really needs to lay its next generation of vision on. I do think it is going to be quite possible for companies such as SpaceX and VG and other launch vehicles that exist to take up a lot of the work that is currently undertaken by NASA in LEO.

Carberry: Can programs like COTS or similar future programs stimulate this process?

Whitehorn: I think the need for these programs to stimulate it - there

...they gave the prospect of a safe operating system to allow people to get up in space and get a taste of seeing the planet Earth, experiencing weightlessness, and many of the elements that we've generally regarded traditionally as the human experience of going to space.

is no doubt. I think the analogy that was made by several people about the beginnings of the airmail system in the US in the 1920s, and what happened to air and space generally - and looking at aviation in Britain - many things are similar in the way that the government often ended up as the customer. A very good example, actually, is the first transatlantic air service between Southampton in England and New York. The first non-stop flights were undertaken with an aircraft called the Boeing 214 Clipper. Pan Am purchased that - the early Imperial Airways purchased that aircraft. They used a guaranteed minimum number of government seats to kick the service off in early 1939. And besides the fact the tickets were an equivalent price to \$70,000-\$80,000 U.S. dollars, they managed to fill all the rest of the seats with entrepreneurs, bankers, business people, etc. who just wanted to fly across the Atlantic. Of course the beginning of WWII ended that service, but did help the beginnings of real aviation industry that kicked off after 1945.

It was during WWII that there was a government incentive to build long runways all over the world that really allowed aviation to move from its flying boat era into an era of infrastructure, which had been largely funded by the military during WWII. So, there are analogies and I think that NASA could take that role. But I do think - and I'm a huge NASA fan - I think that NASA has a potential vision, but it needs to be given the parameters for that vision. If you wanted a personal view of what I think would be exciting for the general public, I am a believer that the Moon can eventually be commercially developed if there is a real demand for it - like for Helium 3 for example. If there is a reason to do it's not beyond the commercial sector to be suitably incentivized to go after that kind of role.

I find it quite intriguing that if you look at one of the ideas for NASA which is to do a deep space project, such as [hooking] up with an asteroid and doing science around an asteroid,

it is something that would capture the public's imagination in a major way - then to go to Mars based on that experience as well. I think just having one plan of just going back to the Moon when it can't be funded, and then go to Mars isn't necessarily - there needs to be an awful lot of out-of-the-box thinking. I'm sure that is being undertaken at NASA as we speak.

I personally think, and I was asked just last week, that you have to give back to the public that ultimately funds space, be it in Europe, the United States, the Far East, or Japan. The public/the taxpayers ultimately fund space work. They need to believe that what is being done is really exiting and really relevant. It is quite difficult to believe that going back to the Moon. If you ask a decent survey of people in the United States or the UK, something tells me - and I have a bit of a marketing background in my past - that there is huge interest globally in the science of our planet and NASA has been at the forefront of that science, which we now understand much better. But it is generally accepted because of the study of paleontology all the way to Earth science - archaeology, that we suffer extreme risk on the planet from incursions from space objects - we have a much better understanding of that than we even did a decade ago. It would really inspire the public that we would create a mission to do something like that. My personal view is that NASA undertaking a mission of that nature would be of great interest.

I am a great believer that humans have to go to Mars. I've become convinced of that not only through the polemic of individuals who have argued for it for many years, but also just because I think when you get people like Prof. Stephen Hawking saying that this is essential - not a maybe - and you get other leading scientists of many different disciplines - some of whose predecessors would have said that we could do this through robotics. But when you get the generation that is saying we know enough about the planet - we know enough about civilization now in 2010

to know that we will suffer severe risks to our civilization structure if we just remain on this planet. And then you take the emotional polemic argument - we also need to dream - we need to have a place to go. If we say we're stopping right here and we are never leaving this place, it doesn't exactly create the enthusiasm for the generations to come. I think if you combine those arguments - learning how to get off this planet is something that mankind needs to undertake. A logical way to do that is to go to Mars. That's the way we will learn to get off this planet. And we'll develop technologies to do so.

I do think one other thing in the Augustine Commission summary which I've seen - which I hope will be fleshed out a lot more in the larger document - is that NASA also needs to be an R & D organization - to get back to its R & D roots which it doesn't do much anymore. That is not an easy role for the private sector. There are very few people who will take the kinds of risks that Richard Branson has taken and is prepared to back what is effectively a commercializing R & D project with SpaceShipTwo and White Knight 2. It is thanks to his vision that we've been able to build that business plan and show that we can make this work commercially. But, without the initial money to undertake this project, it would never have gotten anywhere. R & D at that level - when you are really looking at a new type of motor for the future - is not best for the private sector. NASA needs to be there, and going to Mars will help to do that, but I think it should also be undertaking much more serious hypersonic engine work.

We need to find after forty years that Holy Grail - that we're going to do things in very low Earth orbit around the planet. We need to find the motor that can breathe air and work outside the atmosphere as well. It has been one of the tantalizing things where there have never been sufficient seed core investments in those concepts. And yet, what the aerospace world can now give is that we can create vehicles with composite technology now - which can benefit and provide a

lot of industrial work in space - much more efficiently, with an engine of that nature. There was something that Burt Rutan said to me many years ago when we first started on this project when Sir Richard asked him if it was possible - why can't we fly SpaceShipTwo around the planet? Burt said that he thought that the main thing holding us back - reentry is an issue but initially can be overcome - is that kind of vision from the 1960s where you could leave London or New York or Washington and two hours later be in Australia. Some of the LEO stuff can only really get the right economics if we can find a new kind of motor. NASA should be looking at R & D in some of those areas and of course a well-funded, well thought out deep space project that leads to Mars.

Carberry: With Virgin pursuing this type of R & D, have you found that it has inspired other companies to do similar R & D projects?

Whitehorn: Certainly there are a handful of companies that have sufficient funding to really take things forward in the private sector, but I think the three that have had sufficient funding to do a proper job at this have been Bigelow, SpaceX, and Virgin Galactic. Interestingly, none of us are competing with each other in any sense, shape, or form. SpaceX would probably never go into the satellite market below 200 kilos, but with the technology we are developing, we don't intend to go above 200 kilos. We certainly would look at the technology that they are developing - the rocket motor technology for Falcon 1 - in terms of what we might do with a launcher. I think that Bigelow has done an inspiringly good job with the project that they have developed. One day SpaceX could have a good start at fulfilling a marketplace for that if they can develop a commercial crew vehicle for the ISS - they can certainly do the same for Robert Bigelow. We, one day, might even be able to take a second version vehicle from that with an air launch system, which could lower launch costs yet again. I think some of the other private sector space

companies have got some really good ideas and really good technologies.

Carberry: Would you collaborate with any of those companies in future projects?

Whitehorn: Sierra Nevada Corporation is doing a lot of work with us on rocket motor two at the moment. XCor, we're not doing anything with right now, but one day in the future you can envisage - White Knight 2 could launch other vehicles as well. They've got some interesting motor technology there, but we haven't collaborated with them yet. A lot of the other private sector space companies have been looking for something out of NASA projects. That's one of the things that hasn't held back Virgin Galactic, SpaceX or Bigelow.

Interestingly enough, I'm speaking to you about the Augustine report, but it's directly relevant to our company. We may be able to provide services to NASA, but if the Augustine Commission report had come here or there about human space flight, it wouldn't have affected the work we might be doing with NASA in things like suborbital space science or astronaut training in the future. So, we're not relying on the outcome of the deliberations of NASA's budget over the next year, but there are probably a few private sector space companies are relying on that.

One of the things that I think is so crucial at the moment is that the rest of the world's space industry does look to NASA for leadership, and the current NASA leadership is waiting for leadership from Congress - where NASA finally tells them, 'Tell us what to do and we'll find a way to do it - and tell us how much money we're really going to have and give us a chance to plan and give us certainty.' I've got a feeling that's what is needed. There has been a long period where there just hasn't been that certainty. It they have certainly of purpose, I think

they can find a way to fund it within the budget constraints of the real world of 2010.

Carberry: Yes, it is difficult to make any progress if you are in constant threat that the goals may keep changing every 4-8 years.

Whitehorn: Indeed. If this report is taken in exactly the way that I think it was intended, I think it could be an opportunity for NASA. If it is just used in a way, in very difficult economic circumstances, to make an excuse for restricting budget or simply cutting budget, then it probably would not

have succeeded, but I don't think that was the intention of the piece of work.

Carberry: When do you expect to start service?

Whitehorn: The current time table is that we are unveiling SpaceShipTwo in December. We will start test flying soon after that starting with [captive] carry and then glide in flights. Then we start into the rocket motor fired up - then it goes supersonic. It will be one of the biggest test flight programs. When you take SpaceShipTwo and White Knight 2 together, it actually has a bigger test flying program than Concorde had in term of number of flights. Then we'll fly SpaceShipTwo to space a little over year after that. Then, of course, we need to get our license from the FAA. So, I think the year that we will be flying commercially will be 2011.

Carberry: I assume that you are planning on going up?

Whitehorn: I would love to go up on one of the last test flights if possible. That will all depend on the circumstances and what is needed at the time, but I would definitely fly on it. The question is when.

Virgin Galactic unveiled SpaceShipTwo at the Mojave Spaceport on December 7, 2009. www.VirginGalactic.com.

I would definitely fly on it.

The question is when.

BRSK Marsonaut Mechanism: Proposed Planetary Bioengineering

by: *Marsonaut - Dr. Balwant Rai*
Founder of Aeronautic Dentistry, India
Jasdeep Kaur, BDS, MS, SC-ADA

Corresponding authors: *Balwant Rai, drbalwantraissct@rediffmail.com*

From the perspective of biology, planetary engineering is the ability to alter the environment of a planet so that terrestrial organisms can survive and grow¹. The feasibility of altering planetary environments is clearly demonstrated by mankind's activities on the Earth and it is increasingly apparent that in the near term future mankind will gain the technological capability to engineer the climate of Mars. Current proposed experiments/proposals for the planetary engineering of Mars differ in their methodology, technical requirements, practicality, goals and environmental impact¹⁻⁴⁴. The planetary engineering of Mars may be divided into two distinct mechanistic steps, ecopoiesis followed by terraforming. Ecopoiesis in which the creation of a self-regulating anaerobic biosphere and terraforming refers to the creation of a human habitable climate⁶. Whether the creation of such biospheres are possible is not known^{8,10,12,14}. However, the majority of these planetary engineering models invoke the use of biological organisms, both during alteration of the planetary environment and in the regulation of the resulting biosphere. To best of our knowledge, no literatures published about planetary dental or oral micro-organisms of human model for creating earth-like environments or to test these micro-organisms' in both Earth and Mars environments. This article will briefly review the implications of the current Martian environment and assets for biology and then discuss the relationship between biology and planetary dental bioengineering.

I. Possible environmental evidences for no Human establishment

1. Low pressure. The atmospheric pressure on Mars is mostly due to carbon dioxide, and varies from approximately 7.4 to 10 millibar (mbar)¹.

2. Low temperature. The average diurnal temperature ranges from approximately 170 K to 268 K. These temperatures would completely freeze any organism and depending on the freezing process would cause cellular damage through the formation of ice crystals. Low temperatures would raise the activation energy for enzyme catalyzed processes and thus inhibit biochemical/metabolic reactions. Biochemical reactions occur in solution and the transport of metabolites would not occur efficiently in ice crystals².

3. Water. Liquid water which is a prerequisite for life (McKay, 1991; McKay and Stoker, 1989), under the current Martian atmospheric pressure is unstable. Such extreme dry conditions would cause dehydration, for example damaging DNA (Dose et al. 1995) and leading to mutation and cell/organism death.

4. Radiation. The main source of radiation at the Martian surface is ultraviolet (UV) radiation between the wavelengths of 190 and 300 nm. In the absence of an ozone layer, organisms can only escape the lethal affects of UV-radiation by living in protected habitats.

5. Oxidants. Due to UV-radiation the topmost layer of the regolith is thought to contain strong oxidants which are damaging for cellular components.

6. Oxygen and Carbon dioxide. Oxygen on Mars is 0.02%. The major atmospheric component is carbon dioxide. In organisms, the relatively high concentration of carbon dioxide would cause a low intracellular pH.

This may lead to damage for cellular proteins, cellular components and cellular metabolism³. Also, free radical induced damage is likely to biomolecules and cellular components.

7. No organic material. Because of the continuous bombardment of UV-radiation and oxidizing conditions, no organic material will be present on the Martian surface⁴.

II. Possible environmental evidences for Human establishment

1. Mars does contain sufficient volatiles to enable some form of colonization and perhaps planetary engineering, biomedical engineering, aeronautic dentistry and aviation medicine to render environmental conditions more clement for terrestrial life to survive and grow. Oxygen on Mars is 0.02% and free radical induced damage is likely to biomolecules and cellular components. Relative anaerobic environment will make bioengineering little difficult.

2. Analysis of Martian soil and shergottites, nakhlites and chassignites (SNC) meteorites has shown that all of the elements necessary for carbon based life on Earth are present on Mars⁵⁻⁶.

3. It is evident that Mars once possessed the liquid water and a dense carbon dioxide atmosphere⁷.

4. A number of compounds and elements are absolutely required for life; liquid water, carbon, hydrogen, nitrogen, oxygen, phosphorous and sulfur are the main elements which constitute amino acids and nucleotides and various minerals are also required. All of these elements/compounds are believed to be present on Mars⁸⁻⁹.

Going by evolutionary theories of life on earth that methane and nucleotides were first to evolve and water evolved much later, it is likely that similar mechanisms will be possible on Mars. What is important is consideration of existence of anaerobic environment for anaerobic flora and possible oxygen and nitrogen free radical attack.

Water. Currently, the surface of Mars is devoid of liquid water and the atmosphere only contains minute amounts of water vapour²,

Buried organic material⁶. It has been reported that organic material, either deposited by meteorites and/or remains from an earlier biosphere, maybe between 3 and 40 meters from the surface or perhaps be present in Polar Regions. These deposits could therefore be utilized by plants that have long root systems and/or by subsurface micro organisms.

Carbon. On first inspection the two main sources of "trapped" carbon dioxide are as a solid in the polar caps and adsorbed in the regolith⁸.

Nitrogen. No direct analysis of the nitrogen content on the surface of Mars has yet been conducted, the abundance of nitrogen on the surface of Mars has been estimated from analysis of SNC data and it would appear that there is proportionally less nitrogen on Mars than on the Earth⁵.

Minerals. Minerals are also essential for biological process, for example as co-factors in enzyme catalyzed reactions and components of vitamins. All of the elements necessary to support terrestrial life are thought to be present on Mars, although as with the CHNOPS elements their concentration compared to Earth are either slightly higher, lower or the same⁵.

Initial planetary biomedical and dental bioengineering-a new perspective

For Mars to be less hostile for pioneer organisms initial planetary engineering will be required to increase the atmospheric pressure. This will have a number of effects, including an increase in surface temperature; liquid water will be

stable (at least at equatorial latitudes) and an increase in ozone abundance that will reduce the amount of UV-radiation reaching the surface. Numerous of mechanism of warming of Mars such as runaway greenhouse mechanisms and greenhouse gases, Ammonia (NH₃) mechanism, Nanotechnology mechanism, Nuclear mining and alternative planetary engineering mechanisms, Ozone mechanism¹⁻¹⁸.

Planetary biomedical and dental bioengineering - This proposed mechanism is termed as BRSK (Balwant Rai Simmi Kharb) Marsonaut Mechanism:

Great claims are made to the potential exponential growth of nano-robots. We suggest that nano-robots could contain structures similar to those found in the human mouth because the mouth contains millions of types of bacteria such as Bacillus subtilis, microbacterium and Arthrobacter sp. In common with mouth microorganisms, nano-robots may have a huge growth capacity, i.e. doubling time, which for some bacteria, growing under ideal conditions, can be as little as 5 minutes. Ideal growth conditions for nano-robots are therefore likely to resemble those found for microorganisms. However, conditions on Mars will not be ideal for grow of either microorganisms or nano-robots. Nutrients/substrates may vary in abundance, there may be competition for resources etc. Therefore, growth is likely to be linear rather than exponential.

Oral cavity micro-organisms -

1. Biodiversity
2. Almost all types of bacteria
3. Easy available.

Candidate biological methods and mechanisms for adapting oral micro-organisms to grow on Mars

A number of pioneer micro organisms and plants have been proposed for introduction onto a partially altered Mars¹²⁻¹⁴. The first organisms will of necessity be

photoautotrophic, it means that they utilize sunlight as an energy source and do not require complex organic material for metabolism. In order to aid organisms to survive and more importantly grow as soon as physically possible on a partially altered Mars, two main mechanisms of adaptation can be utilized either individually or in concert, that of genetic manipulation and/or directed selection under simulated Martian conditions^{12,16,18}.

1. Genetic engineering on Mars. Genetic engineering is now common place and the ability to manipulate organisms for Mars, especially prokaryotes and also eukaryotes is entirely feasible¹. Such oral micro-organism would then be termed recombinant, or in this case a genetically engineered Mars organism. Exploitation of genetically engineered Mars organisms for industrial products could be another promising field.

2. Genetic selection. Alternatively, organisms could be adapted for growth on a partially altered Mars by growing them under simulated environmental conditions that increasingly resembles the climate on Mars at the proposed time of their introduction. In genetic terms, this process is called direct selection and is a well known Darwinian concept. In which adaptation results from the systematic relationships between genotype and phenotype and between phenotype and reproductive success in a given environment.

There are limits to increases in both physiological and metabolic processes using selection, and thus genetic engineering could be used to increase some of these. Because of their fairly rapid generation time, micro-organisms would best lead themselves to this type of adaptation.

Ramifications for the Martian environment of planetary dental bioengineering

During planetary dental bioengineering, geological features will change. Another important point to emphasize is that biology on Mars, at least during the initial stages of planetary engineering must always be

used to add CO₂/O₂ /N₂ /greenhouse gases to the atmosphere. It would be undesirable to reach a point where oral micro-organisms initiate a global freezing because all of the CO₂ has been re-sequestered as organic carbon. Plus artificial oxygen environment will influence bioengineering and principles of bioengineering can be different over Mars.

The introduction of terrestrial micro-organisms into the Martian environment, whether in greenhouses or for planetary engineering will obviously affect the search for any extinct, but especially existent Martian life.

Before planetary dental bioengineering commences, and during the initial stages, the very surface of Mars will be sterilizing for all forms of terrestrial life, whether genetically modified/adapted or not. However, if an oasis of life does exist, then such enclaves may be overrun by terrestrial organisms. Or perhaps if environmental conditions become more clement during planetary engineering such organisms will compete with terrestrial organisms. Therefore, a thorough search for "life" on Mars will perhaps be necessary before the wide spread introduction of terrestrial organisms.

Proposed model

The BRSK Hypothesis to explore that oral microflora can evolve the ability to survive and proliferate under low pressure atmosphere characteristic of the surface of Mars. And genetically modified Martian Microorganisms will have a promising role in bioengineering and genetic engineering. We will test this hypothesis using Mars atmospheric simulations and microbial community samples obtained from extreme "Mars analog" Earth environments.

Objectives:

1. Growth of oral and other microorganism on earth and Mars analog environments.

2. Cultivate selected model and environmental oral and other bacterial isolates from Objective 1 for multiple

generations under simulations approaching the defined Mars low-pressure limits, and selected variants that are able to survive on Mars.

3. To study the metabolic profile of these microorganisms grown under Martian environment and their biotechnological potential at Mars and on earth. These micro organisms will have diagnostic, therapeutic capability and dental bioengineering and biomedical engineering potential.



Balwant Rai did his BDS at Govt. Dental College, Rohtak, India, and is now working on his MS. He is Editor-in-Chief of four journals, and has published more than 100 articles in national and international journals, as well as five books. He is the Founder of Aeronautic Dentistry and the BR formula, and is an invited Jury member of NRF. Balwant was a member of MDRS Crew 78, and is a contributing editor of The Mars Quarterly.

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Space Exploration Alliance Announces February 2010 Legislative Blitz On Capitol Hill

From February 21-23, 2010, the Space Exploration Alliance (the "SEA") will be holding its annual Legislative Blitz. The February 2010 Blitz comes at a crucial moment in the formulation of space policy. The Final Report of the Augustine Commission stated that NASA simply can not accomplish the goals with which it has been tasked unless it receives an additional \$3 billion in annual funding.

Whether this is true or not, there is a strong possibility, given the current economic climate, that the United States will decide to choose far less ambitious goals.

The SEA firmly believes that it is a vital national interest for the U.S. to set ambitious goals that will free us from low Earth orbit and send us to destinations such as the Moon and Mars. According to Rick Zucker, Chair of the SEA Legislative Blitz, "More than ever before, it is absolutely critical that the voices of the space advocacy community be heard in the debate over the future of our nation's space program." Chris Carberry, Chair of the SEA Steering Committee, states, "We need to demand a space program that will captivate the public and will get us out of low Earth orbit as quickly as possible. We should never doubt how

much impact a small group of dedicated people can have."

Come join space advocates from around the country to let Congress know that there is strong constituent support for an ambitious space program. The SEA will provide an information/training session plus materials that you will need for the meetings. Please register for the Legislative Blitz online by going to the Space Exploration Alliance homepage (www.spaceexplorationalliance.org) and following the links.

For more information, contact Rick Zucker - Rick.Zucker@nss.org or 508-651-9936.



...join space advocates from around the country to let Congress know that there is strong constituent support for an ambitious space program.

THE MARS SOCIETY is a 501(c)3 tax-exempt non-profit organization with headquarters in Colorado, USA, committed to furthering the goal of the exploration and settlement of the Red Planet, via broad public outreach to instill the vision of pioneering Mars, support of ever more aggressive government funded Mars exploration programs around the world, and conducting Mars exploration on a private basis.

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Phobos I and II, Red Russia - Last Attempt on Mars

By: Raul Colon

It seems like ages ago, but once upon a time, it was the Soviet Union which took the early lead in man's exploration of outer space. The Moon, Mars and Venus were, among other celestial bodies, their main target. Of the three, it was Mars that became the USSR's biggest obsession. More than two dozen remotely controlled probes were sent to the Red Planet between the fall of 1960 and the summer of 1971. Most of them either failed to reach the planet or malfunctioned once they achieved their orbital destination. Their program began with the launching of the 1M-No.1 probe on October 10, 1960, and unofficially ended the morning of July 12, 1988 with the launch of the Phobos 2 spacecraft.

Back in the early 1980s, Russian plans for the exploration of Mars called for the use of orbital platforms feeding robotic systems or rovers, in a surface analysis and data collection effort. The blue print also stated that a complex Mars sample return project would be on the drawing boards by the early part of the '90s. Even the exploration of the Martian moon Phobos was conceived. Unfortunately, the Soviet economy collapse and a changing political climate placed enormous pressure on the countries under-funded space program. Within weeks of conceiving the Phobos missions, Moscow discontinued the sample recovery project - the rovers never happened, but the plan to study Phobos survived.

The Phobos spacecraft had a new design and the project reflected the Soviet Union's new sense of cooperation. When all was set and done, three European nations, Sweden, France and Germany, went on to collaborate on the project. Even the once hated Americans were incorporated on the adventure. In one of the first acts of glasnost, the United States allowed the Soviets the use NASA's advance Deep Space Network to communicate with the probes.

Each Phobos spacecraft carried up

to 24 different science instruments to study the atmosphere and surface of Mars, and to investigate Phobos, the bigger of the two Martian moons. At the time, this was the most advanced experimentation package the Soviet's had ever deployed on any space probe. The elaborated science package included a first generation photon laser intended to vaporize material from the surface of the satellite for analysis. Phobos 1 and 2 also carried a small lander aimed at cruising Phobos' surface. The rover was fitted with a mid-resolution camera and instruments to search for signs of seismic activity, as well as study soil composition. Phobos 2 was fitted two a landers.

Structurally, the Phobos platforms were rather similar. Both crafts were built with the same pressurized toroidal electronics section surrounding a modular cylindrical experiment section. Below these were mounted four spherical tanks containing hydrazine for attitude control and, after the main propulsion module was to be jettisoned, orbit adjustment. A total of 28 thrusters were mounted on the spherical tanks with additional units mounted on the spacecraft structure and solar panels. Attitude was maintained through the use of a simple, three-axis control system aligned with sun and star sensors. Power was generated via solar arrays.

The Mars orbit insertion maneuver was performed by a dedicated propulsion module utilizing used nitric acid and an amine-based fuel, with a 9.86-18.89 kN variable thrust chamber and eight helium pressurized

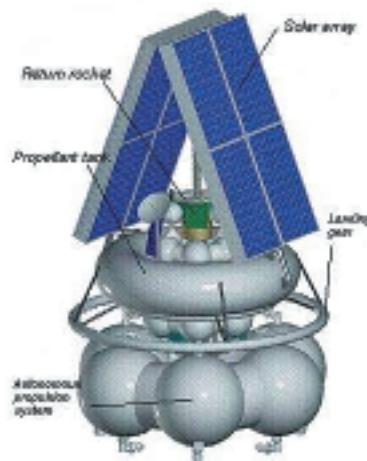
aluminum alloy tanks. After achieving the final orbit, the orbit insertion module was jettisoned, exposing the downward viewing instruments on the main structure. Mass was 2600 Kg in Martian orbit weight standard. Computer transaction capability was 30 MB memory of storage. Downlink was via a two degree-of-freedom

parabolic high gain antenna at 4 kbits/sec. The larger Phobos landers would have transmitted data directly to Earth at a higher rate of 4-20 bits/sec on 1.672 Ghz to 70 m.

The payload included a television imaging system, a thermal infrared spectrometer/radiometer with 1-2 km resolution; a near-infrared imaging spectrometer; a thermal imaging camera;

magnetometers; gamma-ray spectrometers; an X-ray telescope; radiation detectors; and radar and laser altimeters. The lander was designed to make chemical, magnetic and gravity observations at different locations on Phobos' surface. Phobos 1 carried the Lima-D laser experiment, designed to vaporize material from the Phobos surface for chemical analysis by a mass spectrometer, and imaging radar. Phobos 2 had the 'DAS' platform lander, which carried a panoramic stereo TV system, seismometer, magnetometer, X-ray fluorescence spectrometer, alpha particle scattering device, and penetrator.

In the end, neither probe gathered much information. One, Phobos 1, did not even reach Mars as an incorrect digit command sequence transition cut short the life of the spacecraft. The error cost mission control the ability to point the probe's high energy solar arrays toward the sun. Without solar power, the batteries were soon drained and Mars orbit insertion was impossible. The spacecraft was lost.



The newest Russian initiative is Phobos-Grunt scheduled for launch in 2011

Her sister ship enjoyed just a tad more success. It did manage to orbit the Red Planet and was able to study the planet and its moon for two months, but it never was able to deploy its prized landers. Another costly error ended the promising mission. The control center sent Phobos 2 a command to take photographs of the Martian moon. In order for the spacecraft to turn its camera toward Phobos, it had to turn its antenna away from Earth. When it was time for the spacecraft to return its signal, there was silence. It is assumed that a computer malfunction left Phobos 2 unable to rotate back to the correct position to communicate with Earth, but the exact cause of the failure was never determined.

Before data transmission ceded, one of Phobos 2's last images relayed to earth showed an elliptical form shadow on the surface of Mars estimated to be between 25-27 kilometers in length. The size of this object ruled out the possibility that it was a reflection of the spacecraft itself, as it has been suggested years after the event. Because of its position, its symmetrical shape, its size and its movement, no features on the surface of Mars in the area in front of the probe, or the satellite moons of Phobos and Deimos, nor the Phobos 2 spacecraft itself could account for this shadow pattern occurring in the very last frames of data successfully transmitted to earth.

The newest Russian initiative is Phobos-Grunt scheduled for launch in 2011.

For more information, please visit:
<http://smc.cnes.fr/PHOBOS/>

Raul Colon is a writer, sport reporter and columnist known for his practical research and insight. He has published over 400 articles and three major Current Systems Papers. He is the founder and chair of the Caribbean Chapter of the Cold War Museum, a non-profit organization that promotes a better understanding of the events and stories of that profound period. He is also the director of the Puerto Rico Chapter of the Mars Society, an organization that promotes the conquest of the Red Planet in our generation.

Currently, he is putting the finishing touches on his first book, titled: The Air War over The Somme, due for release on October 2010. Raul is a member of the Military Writers Society of America and the Football Writers Association of America. His work can be found on many internet sites as well as in trade magazines. He is President of the Puerto Rico Chapter of The Mars Society.

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A Cold Dry Cradle, Part III

by Gregory Benford & Elisabeth Malartre

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Gregory Benford is currently working on a novel that entwines both SETI and the Mars life we envisioned in Cold Dry Cradle (and then expanded into The Martian Race). It explores what such an ancient lifeform would think about...

She woke to the bitter tang of black Colombian perking in the pot, the scent mingling with a buttery aroma of pancakes, the sizzle of bacon in its lake of fat, all lacing in their steamy collaboration to make a perfect moist morning--

And then she snapped awake, really awake --on the hard rover bunk, hugging herself in her thermoelectric blanket. Once all her waking dreams had been about sex; now they were about food. She wasn't getting enough of either, especially not since Piotr's ankle.

The break would heal by the time they were on the long glide Earthward; their rations would not improve until they were back eating steak. She pushed the thought of meat out of her mind and sat up. First feelers of ruddy dawn laced a wisp of carbon dioxide cirrus high up; good. Today she got to burrow, at last.

"Hey Marc! I'll start the coffee."

No dallying over breakfast, though the hard cold that came through the rover walls made her shiver. A ruddy sunup was just breaking, giving them one final day of exploration. She peered out the viewport as she munched. They would run on in-suit rations today, no returning to the Spartan comforts of the rover.

They had set up the cable rig at the edge of the vent before sundown. By early light it still looked secure, anchored to three boulders. Marc didn't trust the soil here to hold so they had arranged cross-struts of their monofilament-based cabling to take their weight as they went down the steep incline. Metal cable was much too heavy to fly to Mars, and not

necessary under the lighter gravity.

The first part was easy, just backing over. The rock was smooth and of course dry. Even if vapor had spouted last night, it would never condense for long. The Martian atmosphere was an infinite sponge.

The vent snaked around and steepened as the pale light of late dawn from above lost out to the gloom. The rock walls were smooth and still about ten meters wide. They reached a wide platform and the passage broadened further. Every ten meters down they checked to be sure the cable was not getting fouled. They were both clipped to it and had to time their movements to keep from getting snarls.

They edged along the ledge cautiously, headlamps stabbing into the darkness. She was trying to peer ahead but her eyes were cloudy for some reason. She checked her face plate but there was no condensate on it; the little suit circulators took care of that, even in the cold of full Martian night. Still, the glow from Marc's suit dimmed.

"Marc, having trouble seeing you. Your lamp die?"

"Thought I was getting fogged. Here--" He clambered over on the steep slope of the ledge and shone his handbeam into her face. "No wonder. There're drops of something all over your faceplate and helmet. Looks like water drops!"

"Water...?"

"We're in a fog!" He was shouting.

She saw it then, a slow, rising mist in the darkness. "Of course! It could be a fog desert in here."

"A what?"

"Ever been out in a serious fog? There's not much water falling, but you get soaked anyway. There are deserts where it doesn't rain for years, like the Namib and the coast of Baja California. Plants and animals living there have to trap the fog to get water." She thought quickly, trying to

use what she knew to think about this place. In fact, frogs and toads in any desert exploited a temperature differential to get water out of the air even without a fog. When they came up out of their burrows at night they were cooler than the surrounding air. Water in the air condensed on their skin, which was especially thin and permeable.

Ann peered at the thin mist. "Are you getting a readout of the temperature? What's it been doing since we started down?"

He fumbled at his waist pack for the thermal probe, switched it to readout mode. "Minus fourteen, not bad." He thumbed for the memory and nodded. "It's been climbing some, jumped a few minutes ago. Hm. It's warmer since the fog moved in."

They reached the end of the ledge, which fell away into impenetrable black. "Come on, follow the evidence," she said, playing out cable through her clasps. Here the low gravity was a big help. She could support her weight easily with one hand on the cable grabber, while she guided down the rock wall with the other.

"Evidence of what?" Marc called, grunting as he started down after her.

"A better neighborhood than we've been living in."

"Sure is wetter. Look at the walls."

In her headlamp the brown-red rock had a sheen. "Enough to stick!"

"I can see fingers of it going by me. Who woulda thought?"

She let herself down slowly, watching the rock walls, and that was why she saw the subtle turn in color. The rock was browner here and when she reached out to touch it there was something more, a thin coat. "Mat! There's a mat here."

"Algae?"

"Could be." She let herself down further so he could reach that level. The brown scum got thicker before her eyes. "I bet it comes from below."

She contained her excitement as

she got a good shot of the scum with the recorder and then took a sample in her collector rack. Warmer fog containing inorganic nutrients would settle as drops on these cooler mats. Just like the toads emerging from their burrows in the desert? Analogies were useful, but data ruled, she reminded herself. Stick to observing. Every moment here will get rehashed a million-fold by every biologist on Earth...and the one on Mars, too.

Marc hung above her, turning in a slow gyre to survey the whole vent. "Can't make out the other side real well, but it looks brown, too."

"The vent narrows below." She reeled herself down.

"How do they survive here? What's the food source?"

"The slow-motion upwelling, like the undersea hydrothermal vents on earth?"

Marc followed her down. "Those black smokers?"

She had never done undersea work but was of course aware of the sulfur-based life at the hydrothermal vents. Once it was believed that all life on Earth depended on sunlight, trapped by chlorophyll in green plants and passed up the food chain to animals. Then came the discovery of sunlight-independent ecosystems on the ocean floor, a fundamental change in a biological paradigm. The exotic and unexpected vent communities were based on microbes that harnessed energy from sulfur compounds in the warm volcanic upwelling. Meter-long tube worms and ghostly crabs in turn harvested the bacteria. The vent communities on earth were not large, a matter of meters wide before the inexorable cold and dark of the ocean bottom made life impossible. She wondered how far away the source was here.

In the next fifty meters the scum thickened but did not seem to change. The brown filmy growth glistened beneath her headlamp as she studied it, poked it, wondered at it.

"Marsmat," she christened it. "Like the algal mats on Earth, a couple of billion years ago."

Marc said wryly, puffing, "We spent months looking for fossil evidence, up

there in the dead sea beds. The real thing was hiding from us down here."

The walls got closer and the mist cloaked them now in a lazy cloud. "You were right," Marc said as they rested on a meter-wide shelf. They were halfway through their oxygen cycle time. "Mars made it to the pond scum stage."

"Not electrifying for anybody but a biologist, but something better than individual soil microbes. It implies a community of organisms, several different kinds of microbes aggregated in slime --a biofilm." She peered down. "You said the heat gradient is milder here than on Earth, right?"

"Sure. Colder planet anyway, and lesser pressure gradient because of the lower gravity. On Earth, 1 klick deep in a mine it is already fifty-six degrees C. So?"

"So microbes could probably survive further down than the couple of clicks they manage on Earth. They're stopped by high heat."

"Maybe."

"Let's go see."

"Now? You want to go down there now?"

"When else?"

"We're at oxy turnaround point."

"There's lots in the rover."

"How far down do you want to go?"

"As far as possible. There's no tomorrow. Look, we're here now, let's just do it."

He looked up at his readouts. "Let's start back while we're deciding."

"You go get the tanks. I'll stay here."

"Split up?"

"Just for a while."

"Mission protocol--"

"Screw protocol. This is important."

"So's getting back alive."

"I'm not going to die here. Go down maybe fifty meters, tops. Got to take samples from different spots."

"Piotr said--"

"Just go get the tanks."

He looked unhappy. "You're not going far, are you?"

"No."

"OK then. I'll lower them down to the first ledge if you'll come back that far to pick them up. Then I'll come down too."

"OK, sounds fine. Let's move."

He turned around and started hauling himself up the steep wall. "Thirty minutes, then, at the first ledge."

"Yeah, fine. Oh, and bring some batteries, too. My handbeam's getting feeble."

"Ann..."

"See you in thirty minutes," she said brightly, already moving away. Marc kept going. The slope below was easy and she inched down along a narrow shelf. Paying out the cable took her attention. Methodical, careful, that's the ticket. Especially if you're risking your neck deep in a gloomy hole on an alien world.

She felt a curious lightness of spirit-- she was free. Free on Mars. For the last time. Free to explore what was undoubtedly the greatest puzzle of her scientific life. She couldn't be cautious now. Her brother Bill flashed into her mind. He took life at a furious pace, cramming each day full, exuding boundless energy. They went on exploring trips together as children, later as nascent biologists. He was unstoppable: up and out early, roaming well after dark. There was never enough time in the day for everything he wanted to see. "Slow down, there's always tomorrow," people would tell him.

But his internal clock had served him well, in a way. He was cut down at age 22 when his motorcycle slid into a truck one rainy night when sensible people were home, warm and dry. Looking around the church at his funeral, Ann felt he'd lived more than most of the middle-aged mourners. Bill would've approved of her right now, she was sure.

A flicker from her handbeam brought her back. She looked down, shook it. The beam brightened again. Damn, not now.

The mat was thicker here, as she'd guessed it would be closer to the elusive source.

She landed on a wide ledge, moved briskly across it, mindful of time passing. The floor was slippery with Marsmat but rough enough so she could find footing. Sorry, she said silently to the mat, but I've got to do this.

Her handbeam flickered again, died. She shook it, bent her head to look at it with the headlamp, then felt a sudden hard blow to her forehead, heard the headlamp shatter. She fell backwards, in slow-motion but inexorably, nothing to grab.

Her wrist hit first as she landed and she dropped the handbeam. She lay there for a moment, waiting for the surprise to go away. Must've run into an overhang. It was pitch dark. Where was her damned lamp? There was a faint glow to her left. That must be it. She started to get up, noticed a feeble luminescence ahead of her. Confused, she sat back down. Take this carefully.

All around her, the walls had a pale ivory radiance.

She closed her eyes, opened them again. The glow was still there.

No, not the walls--the Marsmat. Tapestries of dim gray luminosity.

She reviewed what bits she remembered about organisms that give off light. This she hadn't boned up on. Fireflies did it with an enzyme, luciferase, an energy-requiring reaction she had done in a testtube a few thousand years ago in molecular bio lab. Glow worms --really fly larvae, she recalled --hung in long strands in New Zealand caves. She remembered a trip to the rainforest of Australia: some tropical fungi glow in the dark. Hm. Will-o-the-wisps in old graveyards, foxfire on old wooden sailing ships...could there be fungi here? Unlikely. Wrong model. She shook her head. Waves breaking at night into glowing blue foam during red tides in California. Those are phosphorescent diatoms. What else? Thermal vent environments...

Deep sea fish carried luminescent bacteria around as glowing lures. That's it. The lab folks had fun moving the light-producing gene around to other bacteria. Okay. So microbes could produce light, but why here? Why would underground life evolve luminescence?

Bing bing. the warning chime startled her out of her reverie. She flicked her eyes up. The oxygen readout was blinking yellow. Thirty minutes reserve left. Time to go back.

As she picked herself up she

brushed against her handbeam. She picked it up but left it off. Navigating by the light of the walls was like hiking by moonlight.

Pulling herself up gave her time to think, excitement to burn in muscles that seemed more supple than usual. Yes, it was warmer here. She turned her suit heater down. Life hung out in the tropics.

Before she reached the tanks, she heard Marc's impatient voice. "Ann, where are you?"

"On my way. Pretty close." She rounded a jut in the vent walls, into the glare of his lights. The walls faded into black.

"Where were you? You're way late, damn it. The tanks were here on time --hey, where's your headlamp?"

"Ran into an overhang. Smashed it. Marc--"

"Handlamp too? What'd you do --grope your way back? Why didn't you call?" He was clearly angry, voice tight and controlled.

"I found, I found--"

"Ann, calm down, you're--"

"Turn off your lamps."

"What?"

"Turn off your lamps. I want you to see something."

"First we switch your tank."

She sighed. It was just like Marc to fuss over details. Looking down at the sidewalk for pennies and missing the rainbow.

When she finally got the lamps off he could see it too. There was a long moment of utter shock and he seemed to know it was better to say nothing.

Then she heard something wrong. The faint hissing surprised her. Mission training reasserted itself.

"What's that? Sounds like a tank leaking." Automatically she checked her connections. All tight. "Marc?--check your tank."

"I'm fine. What's the matter?"

"I hear something, like a leak."

"I don't hear anything..."

"Be quiet. Listen." She closed her eyes to fix the direction of the sound. It came from near the wall. She shone her handbeam on the empty tank, bent down low and heard a thin scream. Oxygen was bleeding out onto the Marsmat.

"Damn. Valve isn't secured." She reached down to turn it off. Stopped-- "What?"

The Marsmat near the tank was discolored. A blotchy, tan stain.

"Damn! We've damaged it." She knelt down to take a closer look, carefully avoiding putting her hand on the wall.

"What happened?" Marc took one long step over, understood at a glance. "The oxygen?"

"Uh-huh. Looks like it."

"What a reaction. And fast! No wonder there was nothing in the first vent. You were right about that."

"Oxygen's pure poison to these life forms. It's like dumping acid on moss. Instantaneous death."

He looked around wonderingly. "We're leaking poison at them all the time in these suits."

She nodded. Stupid not to see it immediately, really. Like SCUBA gear, their suits vented exhaled gases at the back of the neck, mostly oxygen and nitrogen with some carbon dioxide. A simple, reliable system, and the oxygen was easily replaceable from the Return Vehicle's chem factory.

Marc shook his head, sobered. "Typical humans, polluting wherever we go."

"If the stuff is this sensitive, we'll have to be really careful from now on." Ann straightened up carefully and backed away from the lesion.

They stood for a long moment in inky blackness, letting their retinas shed the afterimage of the lamps. Finally Marc asked, "Where's the light coming from?"

"Marsmat glows. Phosphoresces, is more correct."

"How can it do that?"

"Don't know. The more interesting question is why."

#

They knew now that time and oxygen would set the limits. They had this day and were to return to the ship tomorrow. Team loyalty.

"Plenty of oxy up there," Marc said as they rested and ate lunch --a squeeze-tube affair she hated, precisely described in one of her

intervideos as eating a whole tube of beef-flavored toothpaste.

"So we trade tanks for time."

"Piotr's gonna get miffed if we don't check in at the regular time."

"Let him." She wished they had rigged a relay antenna at the vent mouth. But that would have taken time, too. Tick tick tick.

"I don't want us to haul out of here dead tired, either."

"We'll be out by nightfall."

"We won't be so quick going out."

Field experience had belied all the optimistic theories about working power in low gravity. Mars was tiring. Whether this came from the unrelenting cold or the odd, pounding sunlight (even after the UV was screened out by faceplates), or the simple fact that human reflexes were not geared for 0.38 gee, or some more subtle facet--nobody knew. It meant that they could not count on a quick ascent at the end of a trying day.

"You want geological samples, I want biological. Mine weigh next to nothing, yours a lot. I'll trade you some of my personal weight allowance for time down here."

He raised his eyebrows, his eyes through his smeared faceplate giving her a long, shrewd study. "How much?"

"A kilogram per hour."

"Ummm. Not bad. Okay, a deal."

"Good." She shook hands solemnly, glove to glove. A fully binding guy contract, she thought somewhat giddily.

"Piotr's counting on using some of your allowance to drag back more nuggets and 'jewels,' y'know."

"It's my allowance."

"Hey, just a friendly remark. Not trying to get between you two."

Innumerable nosy media pieces had dwelled on the tensions between a crew, half married and half not, complete with speculations on what two horny, healthy guys would feel like after two years in a cramped hab with a rutting couple just beyond the flimsy bunk partition. All that they had scrupulously avoided.

So far the answer was, nothing much. Raoul and Marc undoubtedly indulged in gaudy fantasy lives and

masturbated often (she had glimpsed a porno video on Raoul's slate reader) but in the public areas of the hab they were at ease, all business.

There was no room for modesty in the hab, four people in a small condo for two years. So they unconsciously adopted the Japanese ways of creating privacy without walls. They didn't stare at each other, and didn't intrude on another's private space unless by mutual agreement.

Nobody had thought much about what the hab would be like if the newlyweds--well, it had been well over two years now, most of that time in space--got into a serious spat. Maybe on the half-year flight home they would find out. She would worry about that then; for right now--

"Hey, we're eating into my hard-bought hours."

#

They returned to the ledge where Ann had her accident, two hundred meters further in. On the other side of the fortuitous overhang they found a pool covered with slime on a ledge. It was crusty black and brown stuff and gave reluctantly when she poked it with a finger.

"Defense against the desiccation," she guessed.

Marc swept his handbeam around. The mat hung here like drapes from the rough walls. "Open water on Mars. Wow."

"Not really open. The mat flows down, see, and covers this pool. Keeps it from drying out. Saving its resources maybe?"

She scooped out some of the filmy pool water and put it under her hand microscope. In the view were small creatures, plain as day.

"My God. There's something swimming around in here. Marc, look at this and tell me I'm not crazy."

He looked through the 'scope and blinked. "Martian shrimp?"

She sighed. "Trust you to think of something edible. In a pond this small on Earth there might be fairy shrimp, but these are pretty small. And I don't even know if these are animals."

She hurried to get some digitals of

the stuff. She scooped some up in a sample vial and tucked it into her pack. Her mind was whirling in elation. She studied the tiny swimming things with breathless awe.

So fine and strange and why the hell did she have to peer at them through a smudged helmet? They had knobby structures at one end: heads? Maybe, and each with a smaller light-colored speck. What?

Could Mars life have taken the leap to animals--a huge evolutionary chasm? These could be just mobile algal colonies-- like volvox and other pond life on Earth. Whatever they were, she knew they were way beyond microbes. She bent down over the pool again, shone her handbeam at an angle. The swarm of creatures was much thicker at the edges of the Marsmat-- feeding? Or something else?

She couldn't quite dredge the murky idea from her subconscious. The arrangement with the mat was odd, handy for the 'shrimp.' What was the relationship there? Some kind of symbiosis? And how did the swimming forms get to the pool?

They climbed down from the ledge. As they descended, the mist thickened and the walls got slick and they had to take more care. The cable was getting harder to manage, too. She could not stop her mind from spinning with ideas.

On Earth, hydrothermal vent organisms kilometers deep in the ocean photosynthesized using the dim reddish glow from hot magma. The glow becomes their energy source. Could some Martian organisms use the mat glow? Wait a minute-- the 'shrimp' had eyes! Or did they?

"Marc, did you notice anything peculiar about the shrimp?"

He paused before answering. "Well, I don't know what they should look like. They looked sorta like the shrimp I feed my fish at home."

"Did you notice their eyes?"

"Uh..."

"The knobby ends, those had lighter specks, remember?"

"Yeah, what about them?"

"So you saw them too."

"Why, what's the matter-- Oh."

"Right!"
"I see, they shouldn't have eyes."
"Good for you. I'll make a biologist out of you yet. On Earth, cave-dwelling organisms have lost their eyes. Natural selection forces an organism to justify the cost of producing a complicated structure. You lose 'em if you don't use 'em."
"So if they have eyes--"
"On Earth, we'd say they were recent arrivals from a lighted place, hadn't had time to become blind."
"But that's impossible. The lighted parts of Mars have been cold and dry for billions of years. Where would they have come from?"
"I agree. So my next choice is that it's not dark enough here to lose the eyes. But the idea of some kind of transfer with the topside peroxide microbes is worth thinking about."
"That glow is pretty dim."
"To us, maybe. We're creatures from a light-saturated world. Our eyes aren't used to these skimpy intensities. Closest parallel on Earth to these light levels are the hydrothermal vents. There are light-sensitive animals down there, even microbes able to photosynthesize."
"Maybe they're not even eyes."
"They're light-sensitive. The critters clustered under the beam from my 'scope."
"Wow."
"I need more information, but at the very least it suggests that the glow is permanent, or at least frequent enough to give some advantage to being able to see. And that means there should be something that can use the glow as an energy source. Maybe the mat is symbiotic --a cooperation between glowing organisms and photosynthesizers?"
"Yeah...That suggests the glow is primary. What's it for?"
"Don't know, just guessing here."
"Curiouser and curiouser, as Alice said."
"I didn't know boys read Alice and Wonderland."
"It seems to fit what we're doing."
"Down the rabbit hole we go, then."

#

Below the level of the pool ledge, there were twisty side channels to the vent. These ran more nearly horizontal, and they explored them hurriedly, clumping along until the ceiling got too low. No time to waste crawling back into dead ends, she figured. They headed back to the main channel and then found a broad passage that angled down. It was slick and they had to watch their footing.

The mats here were like curtains, hanging out into the steady stream of vapor from the main shaft of the vent. Some seemed hinged to spread before the billowing vapor gale. She was busy taking samples and had only moments to studying the strange, slow sway of these thin membranes, flapping like slow-motion flags. "Must be maximizing their surface area exposed to the nutrient fog," she guessed.

"Eerie," Marc said. "And look how wide they get. There's a lot of biomass here --wonder if any of it's edible."

At turns in the channel the mats were the size of a man. She took a lot of shots with her microcam, hoping they would come out reasonably well in their lamp beams. The mats were gray and translucent. Under direct handbeam she could see her hand through one.

How did these fit in with the peroxide-processing microbes on the surface? Clearly these mats harvested vapor; did they somehow trade it with the peroxide bugs, water and methane for the racy stim of peroxide? She had a quick vision of an ecosystem specialized to use what it had: peroxides aplenty above, and ice below, awaiting a lava flow to melt it.

Did life negotiate between these resource beds? Oxides cooked by the searing sun, with microbes specialized to gather their energy. Those microbes must have evolved after the great dryness came, when UV sizzled down and drove deeper all that could not adapt to it.

Yet below, where water still lurked, dwelled forms that owed their origin to the warm, moist eras of the Martian antiquity.

The mats --and what else, in such labyrinths as this, all around the

globe? --transacted their own business with the peroxide eaters. They could harvest the moisture billowing from heat below, and perhaps melt the permafrost nearby. At the edges of Earth's glaciers lived plants that actually melted ice with their own slow chemistry.

The thermal vents and their side caverns could be extensive. With an exposed surface area as big as Earth's, there was plenty of room for evolution to experiment.

Nothing like this pale ivory cavern on Earth, ruled as it was by boisterous, efficient aerobic life. To escape the poisonous reach of oxygen, anaerobes retreated to inhospitable niches like hot springs and coal mines. In that infertile ground they survived, but remained as microbes, spawning no new forms. On Mars, any oxygen-loving forms would have died out when the planet lost its atmosphere. Here the anaerobes persisted, and evolved new forms; maybe the closest analogy was to the marsupials in Australia. Marsupials breed more slowly than true placental animals, and thus were eliminated all over the Earth except for the huge island of Australia. Free of competition, they populated an entire continent, evolving completely unique forms such as kangaroos, wombats and the duckbilled platypus. What were the equivalents on Mars?

Ann gently caressed a mat as it lazily flowed on the vapor breeze. Plants, flourishing in the near-vacuum. She could never have envisioned these...

Yet in the edges of her vision she sensed something more. She thought for a moment and said, "Turn off your lamps."

"Mine's getting pretty low," he remarked as they plunged into blackness.

The glow gradually built up in their eyes. "There's a lesion on the closest mat," said Marc.

She swung gently over, peered at it. "It's the same shape as the damage we did above." The mat around the wound shape glowed more brightly with pale phosphorescence. It seemed to be changing as she

watched. "Look at it out of the corner of your eye," she said. "See?"

"It's spreading downwards."

The mats were growing ever larger as they went lower. She leaned over into the vent and peered around. "The glow increases below." They looked down the vent.

"It's definitely brighter down there."

"Let's go." They descended carefully, playing out line. Their lamps washed the mats in glare that seemed harsh now. Twenty meters down she said, "Lamps off again," as they rested on a shelf.

When her dark vision came back her eyes were drawn to a splotch of light. "Damn! How--?"

"It's the same shape again."

"A mimicking image. Parrots imitate sounds, this mat imitates patterns imposed on it, even destructive ones. Why?"

He drawled, "I'd say the question is, how the hell?"

"The mat here learned about the wound above."

"Okay, they're connected. But why the same shape?"

She sighed. "It's a biological pictograph. I have no idea why, but I am sure that any capability has to have some adaptive function."

"You mean it has to help these mats survive."

"Right."

They descended again, quickly; time was narrowing. The image of the lesion repeated on successively lower mats twice more, five meters apart.

She gazed back up. The blurred gleaming above had faded. So it was not just a simple copying, for some pointless end. "It's following us down."

"Tracking us?"

"See for yourself, up there--the image is nearly gone, and the one next to us is brightening."

"Are you implying it knows we're here?"

"It seems to sense what level we're on, at least."

"This one is stronger than the others."

"I think so too. Brighter the deeper we go. The glow is purely chemical, some signaling response I would guess, and the denser vapor here

deep in the vent helps it develop."

"Signaling?" Marc sounded puzzled.

"Maybe just mimicking. Light would be the only way to do it here. It couldn't use chemical packets to signal downwards because of the updrafts of vapor. Sound could go either up or down, but it doesn't carry well in this thin atmosphere."

His voice was strained in the blackness. "There's got to be a simple explanation."

"There is, but it doesn't imply a simple organism."

"Maybe it's... signaling something else..."

"And if it's brighter the deeper we get, maybe that means... something below."

They went one more time down into the darkness. Her muscles ached and her breath came in ragged gasps. At the next ledge down the lesion image began to swell into a strong, clearer version.

Something beyond comprehension was happening here and she could only struggle with clumsy speculations as she worked. Somehow the mat could send signals within itself. There were many diaphanous flags and rock-hugging forms and somehow they all fit together, a community. They used the warmth and watery wealth here and could send signals over great distances, tens of meters, far larger than any single mat. Why? To sense the coming pulse of vapor and make ready? A clear survival value in that, she supposed. Could organisms evolve such detailed response in this harsh place?

And how did these fit with the peroxide eating microbes? Could they somehow work together? Darwin had his work cut out for him here...

With their lamps off she took video shots of the ghostly lesion images with her microcam, though she was pretty sure the level of illumination was too low to turn out. She would memorize all this and write it down in the rover. Careful notes...

"We're out of time."

She gazed down and saw at the very limit of the weak lamplight bigger things. Gray sheets, angular spires, corkscrew formations that stuck out

into the upwelling gases and captured the richness...

She blinked. How much was she seeing and how much was just illusion, the product of poor seeing conditions, a smudged helmet view, her strained eyes--

"Hey. Time."

She felt her fatigue as a slow, gathering ache in legs and arms. Experience made her think very carefully, being sure she was wringing everything from these minutes that she could. "How far down are we?"

Marc had been keeping track of the markings on the cable. "Just about one klick."

"What's the temperature?"

"Nearly ten. No wonder I'm not feeling the cold."

"The thermal gradient here is pretty mild. This vent could go down kilometers before it gets steam-hot. And we've just reached the cavern level."

"Ann..."

"I know. We can't go further."

"It'll be a long, tough climb out. Must be dusk up there by now."

Getting deathly cold on the surface, and fast, yes. Automatically she cut a small sample out of the closest mat and slipped it into the rack. A strange longing filled her.

"I know. I'm not pushing for more, don't worry. Biologists need oxygen, too."

#

They got the rover back just before they could've been accused of being late, tired and cold but still elated by their discoveries. Over a late dinner they briefed Piotr and Raoul, then squirted a summary Earthside, along with the digitized readout from her microcam. Now, whatever happened to them at liftoff, the information was safe.

Ann and Piotr made love one last time on Mars. Piotr had been worried about her: he held her close afterwards long after she drifted into sleep. After a few hours they were all up again, in a hurried rush to get ready. There was plenty more to do for launch, and months to cancel the

sleep debt.

As she worked alongside the others, she was struck again at how well they all worked together. Even under enormous time pressure they partitioned the duties with little or no overlap. It all went so smoothly that by noon they were just about finished. They celebrated at lunch, finishing up with a few saved delicacies.

Despite a mountain of last-minute details, Ann's thoughts kept flashing back. Something about the team related to the puzzle of the vent life, but she couldn't quite get it. Oh well, she'd have six months to think about it, starting in just a few hours.

Piotr made her stick to their deal on mass allowance. She spent pointless time worrying about which of her sample racks to leave and fretted and even begged Piotr (with no luck)...and then thought of a last trick.

Once they had the old hab stripped and their gear transferred, she did the last rites of sealing up the worn little apartment they had now lived in for over two years. She would be perfectly happy to never set foot in it again. Piotr had already set the power reactor to low, so it could still drive the communications with Earth. She made sure the TV microcameras were pointed to follow the liftoff. If they crashed at least Earthside would see what had gone wrong. She brought the last personal gear over and then -- her idea--had the men pass their pressure suits out through the ship's lock. Leaving the suits behind saved a hundred kilos, neatly taking care of all her sample racks.

They had to lift at night to make their launch window. Escape energy for Mars was less than twenty percent of Earth's, which made the entire process of making their fuel from Martian carbon dioxide workable -- they didn't need to make a lot. But even making the 5 km/sec escape velocity took a lot, so the entire flight plan, including the final boost to Earth, cut matters fairly fine. They had stayed the full 550 days to make this minimum energy window.

She was strangely calm, waiting in her couch in the cramped Return Vehicle hab when Piotr started the

engines.

"Pressurizing all OK."

"Flow regular."

"Max it."

"On profile."

Cottony clouds billowed outside, licking up past the square port. She could see their liftoff by turning her head and the hills seemed close in the deep blackness of Martian night.

They climbed quickly in a roaring, rattling rush, a feeling like being pressed down by a giant, yet she knew that meant it was all going well. Raoul called out altitudes, speeds, voice calm and flat.

She felt a sadness as they angled over at several kilometers up. Mars lay in its frigid night below. Then she saw it.

The entire moment lasted probably no more than five seconds. In memory it became a long, stretched syllable of time to which she was the sole witness.

Her microcam was irretrievably tucked away. The others were busy with the launch, shouting with relief and joy and the boundless releasing pleasure of knowing that after two years they were going home. No witnesses.

#

She had no time to think about what she had seen because the trouble started as soon as they were in orbit. It came through her earphones in Piotr's pinched voice: "Losing pressure, Tank 2."

The methane tank had a rupture. "Damn plumbing again," Marc said, trying to be casual, but they all knew this was bad.

In the end it was their teamwork that saved them again.

Resealing the tank using what few tools they had left from Raoul's kit was a tense, precise operation. She had to go outside in the light, full-vac suit and serve as general gofer while Raoul and Marc blocked the venting of methane, then made a makeshift repair. Meanwhile, Piotr made orbital calculations.

The story of those days would make Raoul into the true media hero of the

expedition. Not that she minded in the least, for indeed, he had saved them all.

But they had lost a lot of methane. Calculations showed they could boost for Earth, but would not have enough to fully decelerate once they got there. Burning up during aerobraking, in a desperate attempt to lose their incoming velocity, was a very real possibility.

So they rethought, frantically. Piotr was the first to see the only plausible solution: the booster fuel pre-positioned in high Mars orbit by their competitors, Airbus. He put together a sequence of five burns which took them into a long, elliptical matching orbit with the Airbus tanks.

Earthside was aboil with negotiations between the Consortium and Airbus, with lawyers angrily slapping writs on each other, over fuel four hundred million miles away. Airbus argued that the Consortium team failed if it could not get home without Airbus' help: they should at least split the \$30 billion prize money. This provoked a brief flurry within the government. NASA announced that the terms of the contest only specified that the first team returning successfully from Mars would be the winner. Anything else was between Airbus and the Consortium.

Intense public interest greased the negotiations. Airbus couldn't refuse the team their only chance home with the whole world watching. And none of the negotiators could have stopped the team from taking the fuel anyway. It was like piracy on the high seas two hundred years before.

Finally they agreed. Overnight, a billion dollars changed hands. Deep in the bowels of a Swiss bank, a dolly heavily loaded with gold bars was wheeled from one vault to another.

The two-bulbed booster looked surprisingly like a huge metal insect as they approached. Hanging below it was the rusty dry abyss of Mars, ripe for exploration.

Ann shot the docking sequence with her microcam, a concession to the publicity-mad Consortium. Ground Control had wanted her to take extensive footage of the whole

incident, but she had refused so far. It was too much to ask that they star in a home movie that might end in their deaths, and besides, she was too busy helping with the repairs.

The team offloaded tons of methane from the booster reserves. That did not leave enough for the Airbus crew to return, which meant that Airbus had to send a second, smaller methane tank to rendezvous --no mean feat of orbital mechanics and navigation. That drama would play out years later, of course, for the Airbus team had a year and a half, just like the Consortium, to explore the surface of Mars before risking return.

The refueling worked, though just barely. Bedeviling details such as incompatible couplings in the hoses and frozen joints in high vacuum cost them time and nerves. They alternately cursed the hardware and cajoled each other through the rough spots.

But they got the methane they could not live without. The entire return orbit had to be recalculated, and of course they had missed their optimum time to catch the lowest-energy trajectory. That would cost them more fuel at Earth rendezvous, but at least they had it to burn.

When they were under way they all slept most of the first week, not wholly from fatigue, but from the need to escape the sense of a closing vise around their lives. Recovery was slow. But then she had time to think, to recall those first moments of liftoff.

#

They had half a year of waiting before their aerobrake into Earth's swampy air. As soon as they could they got the ship spinning, using the last stage rocket as counter-weight. This brought back Mars-level gravity and in the months ahead they gradually spun it to higher angular speeds, building up for the return to Earth.

Ann thought a lot without talking to the others. Marc processed his data from the vent and they were all pleased to discover that the vapor boiling out had plenty of hydrogen

and methane--a ready resource for later expeditions. If somehow they could land a robot vehicle next to a vent and trap its exhalations, Earthside wouldn't even need to ship hydrogen to make fuel here.

Her samples were sealed away, her equipment on the planet below, so she could not work on the mat tissues or the 'shrimp' or any of the rest of it. A treasure for others, though of course she would get to direct a lot of the work. They sure as hell owed her that; better, it was in her contract. There was no place in the Return Vehicle hab to rig a sealed work vessel for even simple studies. So she was left to her hypotheses.

#

Back to basics, she decided. Try to see the whole planet from a Darwinian perspective.

She couldn't prove any of her speculations, of course. Not without knowing more about Martian DNA. She suddenly realized what to look for, once she reached the labs of Earth.

The DNA code might just hold the answer. Earth's code was degenerate: a mistake in the coding was like a change in spelling that didn't always alter the meaning. In a sense, there were alternate spellings for the same amino acid. And of course proteins themselves have regions where a substitution of a different amino acid doesn't really matter. Room for error, with no consequences.

She had always thought that was a response to a rapidly evolving planet with lots of mutagens: a Darwinian hotbox world. So a rich world struck a balance between conservatism and experimentation, achieved over billions of years on a planet where evolution's lathe was always spinning. Climatic fluctuations changed the rules of survival, flipping from warm to cold and back again. It led some to postulate the Red Queen hypothesis: you have to keep running to stay in the same place: the entire biota evolving in fast lock-step to avoid being left behind. The pace was grueling, and a species lasted on average only a million years or so

before running out of steam.

What would happen on Mars, where there may have been only one golden age of evolution, and a long twilight of one-way selective pressure? The environment got ever colder, ever drier, the atmosphere ever thinner. But there were also brief eras of warmth, when water or at least mud flowed on the surface. What then?

#

Ten days later they finally celebrated their victory over lunch. They had stopped holding their breaths and were beginning to relax in the tiny social room of the circular hab. The others had begun to write their memoirs. There would be four solid bestsellers out of this, no problem, already under contract with fat advances paid.

Amateur writers all, they were trying out titles on each other.

"I think I'll call mine Mars or Bust," said Marc.

That got a laugh from Raoul. "More like Mars and Busted, don't you think?"

"I know. Mars or Bust." They howled with laughter, delayed release from earlier terrors.

What about The Long Glide Home?" said Marc when they had calmed down.

"Together on Mars," suggested Piotr, grinning at Ann.

Something about the titles caught Ann's attention. Mars had a long cold drying out....

She sank back into her thoughts. Now that you can't grab any more samples, let the theory lead you...

#

On Mars, maybe the DNA code would become more conservative, simpler and more precise? After all, the direction of evolution for a billion years had been the same: colder and drier. Without sudden climatic shifts, the need for degeneracy disappeared.

Every error would be significant. The price was that evolution must be slower. Even on Earth, most mutations were unfortunate, spelled gibberish, and killed the organism.

Only a very few were useful.

On Mars, the chance of a successful mutation would be much smaller. Then what would happen if Marc was right, and there had been a few brief intervals of warmer, wetter conditions? Evolution couldn't work fast enough to take advantage of the new conditions.

So ...what else? Could cooperation have become the winning rule? She looked around the tiny room at her teammates. Four tough-minded types with different skills, fitting together into an efficient whole. They had survived two near-disasters and a grueling eighteen months in a freezing, near-vacuum rustbowl because of that efficiency. Piotr had finally been picked, instead of Janet, because his range of talents, his characteristics, were what the rest of the team needed. That's what her subconscious had been trying to tell her.

Could it work on a planet-wide scale?

Find a partner with the desired characteristic, instead of trying to evolve it yourself. A short period of wet and warm brought the mats out of the vents and into the lake beds, where they interacted with the peroxide forms, perhaps incorporating them into the biofilm. Photosynthetic organisms loosed from the mat -- those 'shrimp'?--could colonize the seas, making hay in the brief summer while the atmosphere lasted.

Life that found partners to help it maximize the wet-era opportunities would be successful. Glowing mats and photosynthetic microbes, free-swimming forms and protective films, peroxide-eaters and watery membranes, all somehow trading their resources.

An entire ecology, driven far underground, none the less finding a path through the great Darwinning...

She did some quick calculations and saw that the available volume of warm, cavern-laced rock below Mars was comparable to the inhabitable surface area of Earth. Room to try out fresh patterns.

But always meshed into the spreading network of organisms great

and small...evolution in concert. Organisms still died their pitiful deaths, genes got erased...but the system could be more interlaced, she saw, deep in the guts of a slumbering world.

Maybe that explained what she had glimpsed at liftoff.

#

Her last look down at the frigid Martian night had caught a smudge of light toward the horizon. A pale white cloud, linear, fuzzier at one end. It seemed to point downward. Then she saw that she was looking north, and the cloud glowed. A pale ivory finger of illumination spiked up from the surface, broadening.

From the vent, she knew instantly--an impossibly brilliant outpouring. Then the ship took them up and away and Mars fell into its long cold night again.

To poke such a glistening probe of light into the sky must have cost the matting enormous energies, she thought. To make it, the vent would first have to be expelling a gusher of vapor. Then the mats would all have to pour their energy into the pale glow, coherently.

What coordination...and what control, over the venting of vapor itself? Could life have attained such levels?

On Earth, the anaerobic forms had never evolved beyond simple forms, bacteria. They had been competing with the hefty, poisonous oxygen-users, of course. On Mars that was no issue; the creatures of methane and hydrogen had prevailed, for billions of years, beneath the steady, cruel press of a world slowly bleeding its air and water into the hard vacuum above.

Somehow, she knew intuitively, the anaerobes had done it. They had evolved an intricate network. Peroxide eaters somehow traded with the harvesters of vapor. And they communicated--surely, for why else would they evolve light signaling?

The pearly lance, jutting up: a signal? Celebration? Mating dance? With so much energy expended, there must be some purpose.

It was natural to see it as a pointed message, but there are many behaviors in biology which defy easy logic. She knew what she would like to believe, but... Science is a systematic way to avoid fooling yourself, after all.

So much to guess...

#

They were three weeks out before Ground Control sent the liftoff pictures from the microcams she had positioned. One had pointed nearly north, along their trajectory. The rocket plume had blazed across the hard blackness and then vanished from the cam's fixed view. But the cam kept on recording because there was still something to see.

They had caught it. The ivory plume, towering kilometers into the sky, mingling with the gleaming stars.

What's this? -- Earth wanted to know.

She smiled. Memory was always tricky, unreliable. That was why they trained you to observe and sample.

From the spectrum Earthside could tell that the gas was methane and hydrogen, with some sulfur. Useful stuff. But--what's this?

She knew then that she would return. Let Piotr sit in his estates, but she was a scientist. There was a whole vast world back there to fathom.

Not the seared surface, but the kilometers-deep labyrinth of ancient refuge.

In that last moment, she sensed, Mars had flashed au revoir, not adieu.

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