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TERRAFORMING - A MATTER OF DECADES?

Peter Dale *examines a fascinating proposal from an international team of researchers. Prepare to familiarise yourself with "nanorods" because they could revolutionise the emerging field of terraformation. Find out more!*

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FLIGHT 8 – COMING SOON

Let the nail-biting begin! All Starship flight tests are crucial but some are more crucial that others. Flight 8 might determine whether we see humans on Mars in 2028 or later.

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MARSWORLD – THE GOVERNNACE OF OF MARS

Owen Louis David continues his chapter summaries of his book Marsworld this time looking at the chapter on governance of Mars. What is the role of the Outer Space Treaty in the governance of Mars? If Mars becomes the home to a significant number of humans can it become independent*?*

Another fascinating set of questions are addressed by the book's author who makes a strong case for an independent Mars Republic. Creating a planet-wide system of government could release Mars's potential to the full.

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MARSWORLD – THE GOVERNANCE OF MARS

Owen Louis David gives an overview of Chapter 6 in his book Marsworld which is focussed on the governance of the planet. What legal principles will apply? What will be the realpolitik issues determining Mars's development.

This is the final substantive chapter in my book, Marsworld. It deals with the crucial issue of who is going to govern Mars and how. Some people argue that Mars will necessarily be ruled as a tyranny. The argument goes that whoever controls the life support system controls the people – the people will face a choice between death through denial of oxygen on the one hand and compliance on the other.

That seems to me a somewhat hysterical way of thinking about the issue of governance on Mars. However, we can all understand that there will certainly be limits on behaviour in a pressurised environment. In the same way that people aren't allowed to open the exit door in a pressurised aircraft in mid-flight owing to the risk posed to other passengers there will be limits on freedom of action within the colony. There will be a culture of acceptance that the individual cannot create potentially risks for others. So, that is the background. On Mars there may be, from the start, a greater acknowledgement of the individual's responsibilities to the community at large. Likewise the goal of terraformation may tend to reinforce the bonds of community.

All modern societies have, in some way, to balance the demands of the famous three goals of the French Revolution: liberty, equality and fraternity (or "community" as we might call it now). These aren't *necessarily* compatible goals. A more equal society may be a less free one. A society that prizes individual freedom may see that can cause negative effects within communities (do you really want to get rid of all planning restrictions?). A society that values the claims of community may find it stifles individual initiative. So, we can perhaps state in broad terms that a successful society on Mars will hold these three in some sort of delicate equipoise.

So what do we understand the legal status of Mars to be? Well, the only thing that is specific to Mars (while also applying to other celestial bodies) is the Outer Space Treaty (ratified by the vast majority of countries of Earth). This makes clear that signatories (states on Earth) cannot incorporate any part of Mars into their sovereign territory. That means for instance that the USA cannot plant the Stars and Stripes on Mars and declare it part of the US or "owned" by the US. This also applies to entities under the control of a signatory. So a US company cannot claim any part of Mars as their freehold possession.

On the other hand the treaty does allow fully for exploitation of the planet's resources. There is nothing in the treaty to stop you mining on Mars or using what you mine. However, there is a divergence of view between the USA and other signatories like Russia and China. The USA thinks commercial entities can not only mine but legally own what they mine. So I think

we can say there are tensions resulting from differing interpretations of the OST which might be magnified by Mars colonisation if some signatories feel one or more signatory is trying to make de facto annexations of territory.

I go on to examine in detail the case both for and against an independent Mars Republic. You won't be surprised to find that I favour the establishment of a planet-wide *Mars World Republic* at the earliest opportunity. This could happen at a much earlier date than many people suppose. There's a tendency to think you need to have millions of people before you can declare independence. But Nauru, a UN state has a population of only 11,000 and Texas became an independent republic (before joining the USA) when it had a population of perhaps 40,000 or so. Of course what 40,000 people on Mars today could do with the aid of robots, self-drive vehicles and highly automated factories is more like the equivalent of an average nation of one million people could do a few decades ago. Even a community on Mars measured in tens of thousands will be far down the road to self-sufficiency.

So what sort of government would suit a citizenry made up of highly educated and resourceful individuals. I argue for a genuinely democratic republic. The Presidency of this republic I would see as semi-symbolic in its role rather than being a "temporary elected monarch" of the kind we see in the US or indeed France.

There should certainly be separation of powers between the executive, judiciary and legislative assembly. Nevertheless, I would advocate for the executive members (the equivalent of the Cabinet in the UK) being drawn from the legislative assembly as is the case in many countries around the world. I envisage also that there will be a much bigger role for direct democracy on Mars as well. Think Swiss Plus. Incidentally Elon Musk has supported the notion of direct democracy having a big role to play on Mars.

I also propose in this Chapter that Mars needs a government that reflects all shades of opinion. So, I suggest a system whereby all parties that gain above 5% of the assembly seats have a right to take posts in the Executive. Some may query how this would work. After all, these are parties that one can think of as opposing each other. Is that really so bizarre? In Europe and elsewhere around the world, coalition politics is a reality. Sometimes parties go into an election in alliance. But, more often than not, they join together in government after the election, following negotiations. Really, my proposal would just improve on this by ensuring all significant parties have a right to enter government, and be appointed to executive posts on a proportionate basis.

I have yet to hear a coherent argument against establishment of a democratic world government on Mars. The Outer Space Treaty certainly does not ban it. Some think the UN should have control over Mars (though there is nothing specific in international law to support this outcome). The UN Charter in fact specifically references the right of people to self-determination. The human community on Mars will be as a much a "people" as any on Earth. As a planet-wide republic, there will be no need to worry about its borders. Arguments

against a world republic on Mars are really more often an extension of arguments against colonisation – based on the idea that we should focus on Earth's problems before colonising Mars or that we should not sully a pristine planet with human feet.

Once you accept the idea of there being a colony on Mars with long term and then permanent migrants, I think the arguments for the establishment of a democratic government are overwhelming. It is a natural right of people to associate freely and form societies. Human rights also assert that people should be able to form political entities in accordance with democratic norms. Given the UN Charter's recognition of the right to self-determination, it cannot be argued that basic international law prevents this development.

I would also argue that the establishment of a democratic planet-wide political community on Mars will be vital to the development of human civilisation on the Red Planet. With the establishment of a Mars World Republic will come the opportunity to establish a separate Mars currency, trade and taxation policy and a bespoke legal framework regarding property rights and the operation of corporations and other legal actors.

All this will aid the development of a strong Mars economy which will lay the basis for civilisational achievements on the Red Planet. Imagine how Mars may become a bright beacon in the solar system, showing how a planet can live in peace and prosperity with a government that they can influence directly.

PICK OF THE PICS

Credit: NASA

This is a beautiful image of the Martian landscape at Jezero crater taken by the Perseverance rover, from earlier this month. That's quite a romantic image isn't it, with a haze hanging over the distant hills? So many entrancing landscapes on Mars.

IN THE NEWS - CES

The Jet Propulsion Laboratory report (25 February) on recent research suggesting that one of the various iron oxides found in Mars dust – ferrihydrite - is the main reason for the reddish colour of Mars.

Ferrihydrite forms in cool water. This is taken as evidence of Mars' much wetter past when water flowed freely on the surface, thus potentially supporting life as on Earth. JPL refer to this being "billions" of years ago.

Quick track to Terraforming Mars?

By Peter Dale

Most commentators have generally held that terraformation (making a planet or moon much more Earth-like) is going to be a very long process to be measured in centuries and perhaps thousands of years. Consensus is pretty rare when it comes to Mars colonisation but this seemed to be one area where received opinion looked like it was right and no one thought it could be done any more quickly.

For one thing, terraformation is more than even a "mega project". In its planetary scope this engineering project far exceeds anything previously attempted by human beings. It will require, for instance, putting trillions of tons of new "stuff" into the atmosphere: oxygen, greenhouse gases, nitrogen.

To be able to produce or manipulate such massive amounts of gas on Mars will of course require the use of prodigious amounts of energy. That is one of the limiting factors in how quickly we can proceed with terraformation.

Occasionally suggestions have emerged about how we might accelerate the process, most notoriously by exploding nuclear bombs on Mars, particularly at the poles. Half-jokingly or half-seriously Elon Musk has mentioned this possibility. Personally, using nuclear weapons on Mars - albeit for a peaceful purpose - seems like it might sully the vision of Mars terraformation. Image isn't everything but it could count for *a lot* when you are trying to get people come live on your planet!

So, until now, it seemed unlikely that there would be any big breakthrough that might allow us to speed up the terraformation process. Suddenly, though, that opinion might be about to be cast to one side. It seems there might be a way to kick-start the process that is practical, cost-effective and able to produce results over a very short timescale – some 5,000 times faster it is suggested than through the release of greenhouse gases. Get used to the word "nanorods" because they are key to the whole idea.

The team of researchers behind the proposal comprises Samaneh Ansari and Hooman Mohseni from Northwestern University, Ramses Ramirez from the University of Central Florida, Liam Steele from the European Center for Medium-Range Weather Forecasts, and Edwin Kite from The University of Chicago.

The idea was to create metal nanoparticles on a scale similar to Mars dust particles. The team based their design on the MarsWRF global climate model along with a supplemental 1-D model. Using these models, the team found that their computer simulations showed that a sufficient number of metal nanorods scattered in the atmospheres "would amplify sunlight that reaches the Martian surface and block ground heat from escaping."

The nanorods would be manufactured from iron and aluminum found on Mars. Kite is credited with coming up with the idea in the first place – and what a great idea it is!

These nanorods (around 9 micrometres in length) would be ejected as artificial aerosols from ground-based machines on the surface.

The team indicate that *"Such nanoparticles forward-scatter sunlight and efficiently block upwelling thermal infrared. Like the natural dust of Mars, they are swept high into Mars' atmosphere, allowing delivery from the near-surface."* So we can rely on natural convection currents to carry the nanorods into the upper atmosphere.

One key difference from natural dust particles however is that their properties should help them settle 10 times more slowly, so enhancing the global heat retention effects.

According to the team's computer models, their manufactured metal nanorods could stay aloft for as much as 10 years. If accurate, this long lifetime combined with enough nanorods delivered over a protracted period of time could immediately start the most critical element to terraforming Mars: melting the planet's ice.

The average lifetime of a nanorod in the atmosphere would be about 10 years. With sustained release of something like 30 litres per second into the atmosphere. This could achieved by the equivalent of a vertical glitter canon, or perhaps as some suggest a garden sprinkler with a 100 metre high hose.

The aim would be to catch updrafts that would take the nanorods high into the atmosphere. If strategically placed to utilise the energy of a Mars equivalent of a Hadley Cell, then the nanorods could be dispersed over both northern and southern hemispheres.

Within a decade Mars's surface atmospheric temperature would increase by an incredible 30 degrees Celsius, leading to widespread melting of ice. The release of flowing water would result in a water cycle and a chain reaction (release of gases) that would accelerate the terraforming process.

Taken as a whole, this could mean the average temperature on Mars would be much higher at -32 degrees Celsius, with summer daylight afternoon temperatures becoming very warm perhaps in the 30 degrees plus range. There is no doubt that under those temperatures there would be significant melting of water ice across the planet.

Of course, the proposal would have to be subjected to a very detailed critical appraisal. For one thing we would need to plan for the re-emergence of large quantities of flowing water on Mars. At the very least we would need to ensure any human settlements were safe from flooding, or – if not – were relocated. Specialist researches would also need to develop an understanding of what gases would be released into the atmosphere under the influence of such rapid heating. How much water would end up as water vapour in the atmosphere and would it lead to rain – if so, how much and where?

This fascinating proposal really does change the way we approach terraforming. It's no longer appropriate to think of it as a game of millennia or centuries. Let's now think of it as something that can *possibly* be achieved in decades. It seems we might have a way to speed up the warming and ice-melting process. Next, we need to think of ways of accelerating the greening of Mars. A logical follow-up step might be to find quick ways of seeding the whole of the temperate and equatorial zone with cyanobacteria that can produce oxygen as a byproduct of photosynthesis.

I am now seeing something like a phased approach to atmospheric terraformation:

1. *Assessment phase.* This might last between 10 and 20 years. The key question to resolve here is whether

there is an existing Mars life, either generally or in isolated pockets. If the answer is yes and that life can be found across the planet, this may put terraformation on hold. But if it is found in very isolated pockets, we might be confident of our ability to proceed with terraformation while protecting those isolated pockets of original Mars life.

2. *First implementation Phase.* This would involve using the nanorod approach to raise Mars's temperature.
3. *Second implementation Phase.* Using cyanobacteria to begin the oxygen generation process.
4. *Third Implementation Phase.* Creating a terraformation industrial infrastructure which will allow us to "fine-tune" the atmosphere by adding greenhouse gases, nitrogen and other constituents. We probably need to increase the density of the atmosphere to around 40% of Earth's with a somewhat higher oxygen level. People could probably acclimatize to breathing this atmosphere. This phase would likely be powered by nuclear fission or fusion. Well it certainly looks like we have an exciting future ahead of us. Young people alive today will in all probability see the beginning of terraformation Mars and may well see rivers flowing on the Red Planet.

Flight 8 – The nail-biting begins.

By Mary Khan

It's time to trim those nails – with your teeth! Flight 8 is coming up fast, and is now scheduled for Friday, 28 February. Can our nerves withstand another Starship battering?

The disappointment of Flight 7 hangs heavy over this latest flight. I'm sure most of us remember when - despite a picture-perfect capture of the Super-Heavy booster in the arms of Mechazilla's chopstick arms - the Ship itself suffered a RUD (a Rapid Unexpected Disassembly, Space X's merry euphemism for a devastating explosion). I don't think it's the prospect of failure as such that makes me/us nervous. It's more that memory of debris coming down over the Caribbean and more specifically very close to inhabited areas (the Turks and Caicos Islands). A repeat performance with a more deadly outcome does not bear thinking about. Apart from the personal tragedy it could visit on people living in

the Caribbean islands, it might result in a serious setback to the Mars mission programme, possibly resulting in a delay of years. It was the loss of communication with the Ship that was perhaps the most worrying aspect meaning that the distintegration took place automatically ie blind.

Thankfully Space X now seem to have a good explanation of why the RUD happened. The company have now confirmed that: *"The most probable root cause for the loss of ship was identified as a harmonic response several times stronger in flight than had been seen during testing, which led to increased stress on hardware in the propulsion system."*

They went on to explain that *"The subsequent propellant leaks exceeded the venting capability of the ship's attic area and resulted in sustained fires."*

The attic is an unpressurised area in the aft section of Ship that is found between the bottom of the liquid oxygen tank and the heat shield. The fires led to engine shutdowns and eventually loss of communications with base. The loss of communication in turn triggered the automated break-up of the Ship (a design feature).

It's reassuring to know that SpaceX has taken a number of measures to avoid a repeat. There was for instance a prolonged static fire to provide more robust testing of the systems. Information garnered from the static fire has also led to hardware changes to the fuel feedlines to vacuum engines, adjustments to propellant temperatures, and a new operating thrust target that will be used on Flight 7.

Space X indicate that: *"To address flammability potential in the attic section on Starship, additional vents and a new purge system utilizing gaseous nitrogen are being added to the current generation of ships to make the area more robust to propellant leakage."*. Space X also note that installation of Raptor 3 engines due to take place soon if not on this mission will reduce the attic space and also reduce the number of engine joints (thus reducing the risk of leaks).

SpaceX has not yet given any specifics about the mission aims for Flight 8 but observers think that they are likely to be very similar to those for Flight 7 (a sub-orbital flight with release of dummy satellites and controlled splashdown in the Indian Ocean).

So get your fingers crossed for what is going to a nerve-wracking few minutes. I think we'll all be very happy once the Starship gets beyond 8.5 minutes of fllght

MARSWORLD

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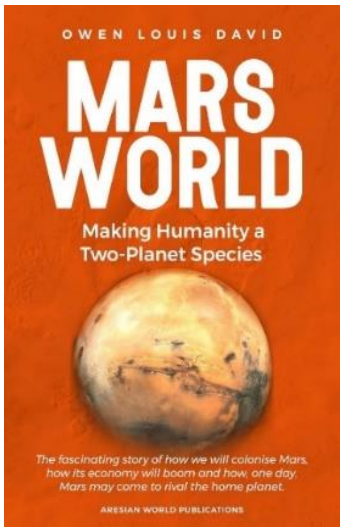

THE LATEST WEATHER ON MARS

Here's your update for the weather on Mars provided by the Curiosity Rover in Gale Crater.

For the nearest Sol to **19 February 2025** we have a *high* of **minus 23 degrees Celsius** (minus 9 degrees Fahrenheit),. The low for the same date, at **minus 75 Celsius** (or minus 103 degrees Fahrenheit) is a little colder than We're still short of the record low recorded on Earth (minus 89.2 Celsius) which was registered at Vostok on Antarctica in 1983. We're in mid-autumn now at Gale Crater so things are bound to get colder still!