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3D PRINTING – ALL ABOUT THIS KEY TECHNOLOGY

3D printing is going to be one of the key technologies that will enable Mars to develop full self-sufficiency by creating a small-scale manufacturing capability. In an article in this edition our contributor Victor Samuels takes a close up look at the issues.

Read about the fascinating history of 3D printing and what it can now make – everything from mugs to rockets to houses.

So how will 3D printing be used on Mars? Victor gives us his detailed analysis.

See page 2.

IFT 5 next up.

After a successful fourth flight, find out what's being planned for IFT5 – the fifth sub-orbital flight of the Starship system.

It looks like it will include a Booster capture on land which, if successful, will be a world first, a real Gold Medal win!

See page 6.

IS THERE LIFE ON MARS? IT'S ABOUT TIME WE DECIDED!

Well, NASA sent out a media release on 21 July telling the world they had found evidence of life on Mars…or maybe not. They're still not sure but it's an interesting development that we cover in this issue. ***See page 7.***

3D PRINTING - A WHOLE NEW WORLD OF INDUSTRY

By Victor Samuels

3D printing is going to be a keystone of Mars-based industry. Remember, the Mars colony – in the early decades at least – won't need vast factories churning out millions of items. It will need small scale and flexible production. That's where 3D printing comes in.

So let's be clear what is meant by 3D printing or additive manufaturing as it's sometimes called.

The story of 3D printing really begins, as with many advanced technologies, in the realm of science fiction. In the 1940s and 1950s writers began describing fictional machines that were basically what we now know as 3D printing. By the 1970s 3D printing moved into the realm of real applications with the first patent being granted in 1971. Gradually the basic concept of 3D printing became more mainstream and by the 1980s we saw the first commercial machines being developed. By 1984 US entrepreneur Bill Masters filed the first of several patents which set out the framework for modern 3D printing using sequential deposition. Other patents and technological innovations followed. One of the most popular technologies developed was fused deposition modelling (a type of plastic extrusion) – the first FDM machine being marketed in 1992.

Early machines were hugely expensive but unit costs started to fall dramatically from the 1990s onwards.

While the initial 3D printers were focused on thermoplastics, by the 1990s metal (with laser sintering or melting) was starting to be used.

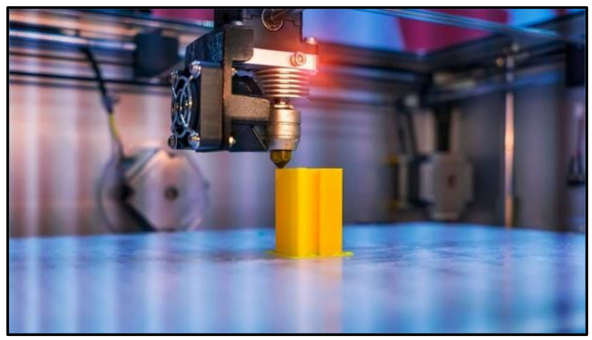


Image: 3D Printing in Operation

The 2000s saw the technology become available to individual consumers and also become used more widely in fields such as agriculture and medicine. By 2005 innovators were working on machines that could replicate themselves, if not 100% then maybe 70% of the final product.

The availability of open-source software for 3D printing and the lapsing of earlier patents, helped the sector grow rapidly and commercial models became readily available to the consumer.

By the 2010s, 3D, or additive, printing of metal items was really taking off. The advantages of using 3D printing for small-run design work became evident.

The technology began to penetrate new markets such as the aviation industry where 3D printing allowing for a huge proportional reduction in parts as 3D printers could craft extremely complex items such as engine nozzles as single integral pieces.

3D printing was also identified as having a potentially important role in the developing world, where remote communities would be able to produce small runs of vital equipment. The parallel here with industrial development on Mars is clear.

In recent years we have seen further technological refinements which allow for an amazing range of products to be produced. To illustrate just how wide a range of items can be produced here's a little list: prosthetic eyes, synthetic bones, clothing and footwear. In addition, Relativity Space have produced a rocket – Terran 1 – that has been launched from Cape Canaveral; it is 85% 3D printed and that should rise to 95% as the project proceeds. In China, WinSun Decoration Design Engineering Co., using additive manufacturing, was able to produce 10 houses in under 24 hours and has gone on to print a 5-storey apartment block. Size matters, it seems: the University of Maine has further demonstrated that objects as wide as 20 metres can be printed.

So I think we can see that 3D printing or additive manufacturing is going to be crucial to industrialisation on Mars. Put at its simplest, rather than building one big factory after another to produce a single product, we can use lots of 3D printers to produce 100s of different products, with each printer being used to manufacture a range of items.

This is going to be absolutely crucial in the drive for self-sufficiency on Mars. Perhaps we need 10,000 screws of a certain size every 100 sols, then we can put one or more printers to work producing 100 screws per day. Of course, the production run should allow for a slight over production with the balance being kept in storage. Eventually we will establish small factories staffed by industrial robots that can make screws and nuts but in the early stages of colonisation 3D printing will be invaluable.

3D printing will be absolutely essential in Mars being able to create a capability in small rocket manufacture. Such rockets will be vital in exploration of the planet and also in fast planet-wide travel (Mars's version of jet transport).

3D printing can also be used to manufacture batteries for energy storage and airlock mechanisms – both vital for successful colonisation. We have already spoken of the possibilities of 3D construction. Using Mars-produced concrete in an extrusion process might be one of the easiest ways in providing radiation-safe and resilient accommodation for the people of Mars.

Another area where 3D printing will be required is in building PV-panel manufacturing facilities. Initially such facilities will be imported whole from Earth but gradually, over time, 3D printed parts can replace imports.

The ability of 3D printing to create intricate and complex structures will have applications in the all-important communications industry eg in the field of microwave engineering. Multi-material printing is now well advanced, again allowing for much greater complexity in production. There is even something known as 4D printing being developed which allows for the product to incorporate potential for dynamic modification in certain circumstances, allowing for shape-changing.

Post-processing of items is often required e.g. to smooth down surfaces. That sort of work will likely be undertaken by AI-guided industrial robots on Mars.

Although a wide range of materials are now used in 3D printing, initially a lot of progress was made using polymers, based on hydrocarbons (oil and its derivatives). Given the absence of hydrocarbon deposits on Mars and the drive for self-sufficiency, polymers will like be less popular as a 3D printing material compared with back on the home planet. Materials such as glass will likely be much more favoured, particularly as the low gravity on Mars will mean that glass is far less heavy on the Red Planet. We can expect glass to be used in a wide range of contexts such as food storage, packaging and so on. The good news is that there are now 3D printers that can manufacturing glass objects using the additive process.

3D ceramics printing is also likely to highly favoured on Mars. As with glass, Mars needs to find alternative means of storage to plastic. Ceramics have been used for storage since the dawn of history. Ceramics too will naturally weigh much less on Mars meaning that ceramics are likely to be far more attractive a solution for storage on the Red Planet.

Concerns have been raised about gun control as we are now at a stage where guns (and other weapons) can be 3D printed. Most people expect the Mars colony to be a pretty law-abiding sort of place, so I am not anticipating any major issues. But it does probably argue the case for governmental authorities to have access to some weapons. Otherwise, they could face a situation where one person illicitly prints off a gun, or more worryingly several, and they might be powerless to prevent an anti-democratic coup or similar.

We can see how the use of 3D printers might go on Mars:

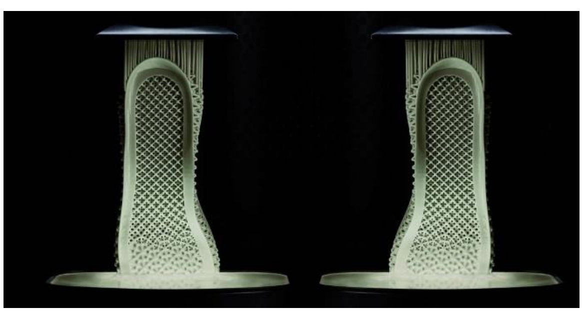
1. *Testing phase.* This will likely be the position for Mission 1 where the emphasis will be on proving

the machines can work well in the low gravity environment of Mars.

2. *Nuts and bolts.* For the first few missions producing basic parts such as screws, nuts and bolts plus a range of tools (particularly agricultural tools in the early stages) will be prioritised.

3. *Energy Generation and Food Production.* After 6 years into the colonisation process expect a shift towards energy generation and food production. 3D printers will be used to help build the vital PV Panel Production Facilities to ensure the colony's self-sufficiency in energy generation and also solid state batteries for storage of energy.

   In this phase 3D printing will also make a major contribution to achieving self-sufficiency in food production.



Credit: Adidas

Image shows 3D-printed lattice-structured mid-soles used in manufacture of trainers.

4. *Achieving Self-Sufficiency.* 3D printing will have an important role to play in helping the colony finally achieve self-sufficiency. After the first decade, the emphasis will likely be on creating stock of a wide range of items essential to a self-sufficient economy. This could include items like footwear for instance (Adidas are already well advanced with this technology). We shouldn't think that these will all be low print run editions. Chanel for instance already produce 1 million mascara brushes a month using 3D printing. We will also see 3D printing being at the centre of an indigenous rocket-manufacturing process on Mars.

5. *Relative Decline.* As the population of Mars grows to one million and beyond, we may see a relative decline as more traditional factory-based manufacturing (albeit highly robotised) becomes more economic.

3D printing will have a much bigger and more strategic role to play on Mars than on Earth, helping it achieve real self-sufficiency. Coupled with AI, the technology has huge potential even on the home planet. There will be many new fields of manufacturing where it begins to play a key role. 3D printing is one of the key technologies that will make Mars colonisation possible. ●

IFT 5 LATEST – ONWARD AND UPWARD (AND DOWNWARD)

By the Editorial Team

Ship 30 and Booster 12 are scheduled to undertake IFT 5. This will be the fifth test flight of the Starship rocket system.

There are some big changes this time around…

The word is that IFT 5 will include the first-ever attempt at an on-land capture of a returning booster. Reports suggest that a lot of work on the booster's shock absorbers has been taking place to ensure a soft landing – or should that be a "soft grab".

The other big news is that Ship 30 has had a pretty significant heat shield makeover.

The heat resistant tiles have been removed (and then returned into place) in order that a flexible ablative shield can be installed underneath the tile layer. The hope is that this added layer of protection will mean we don't see parts of the ship's structure going up in flames, as happened on the otherwise very successful IFT 4.

Elon Musk has suggested the launch will take place *no earlier* than 5 August. There has been some delay in Starbase operations

The thinking is that this time round the aim will be to capture the returning Booster in the "chopstick" arms of "Mechazilla", the fondly named return capture mechanism.

It is fascinating watching the step-by-step progression in the flight test programme, with each flight delivering incremental progress.

Credit: Space X

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 **17 July 2024** we have a *high* of minus 5 degrees Celsius (23 degrees Fahrenheit) which is quite a bit colder than last month but still something we can relate to in the UK. The low at minus 70 Celsius (or minus 94 degrees Fahrenheit) is pretty much on a par with last month. Very, very cold but not as cold as the record low on Earth (minus 89.2 Celsius) – registered at Vostok on Antarctica in 1983.

The Aresian makes sense of Mars.

Tell your friends about us!

ANCIENT LIFE ON MARS?

By the Editorial Team

The question of whether there is a life on Mars has been in play now for centuries. Even though both Viking Landers found evidence of life, the scientific consensus has tended to be far more sceptical. That might be about to change.

NASA have announced that their Perseverance Rover team think that the Rover's observations of a vein-filled rock nicknamed "Cheyava Falls" by the team, potentially provided evidence of ancient microbial life on Mars. The arrowhead-shaped rock holds clues to Mars's ancient history, pointing to the likely presence of microbial life.

In a media release dated 25th July, NASA announced that the rock exhibits chemical signatures and structures that could possibly have been formed by life billions of years ago when the area contained running water. This is not yet a definitive conclusion – other explanations are being pursued – but it is a strong pointer to life.

The rock sample was collected on July 21, as the rover explored the northern edge of Neretva Vallis, a 400 metre-wide ancient river valley carved by water flowing into Jezero Crater.

Multiple scans of Cheyava Falls by the rover's onboard instruments indicate it contains organic compounds. While such carbon-based molecules are the building blocks of life, they can be formed by non-biological processes (such as heating of rocks by volcanic activity).

In its search for signs of ancient microbial life, the Perseverance mission has focused on rocks that may have been created or modified long ago by the presence of water. That’s why the team homed in on Cheyava Falls.

NASA report that running the length of the rock are large white calcium sulphate veins. Between those veins are bands of material whose reddish color suggests the presence of hematite (iron oxide), one of the minerals that gives Mars its rusty hue.

When Perseverance took a closer look at these red regions, dozens of irregularly shaped, millimeter-size off-white splotches were observed, each ringed with black material, likened to leopard spots. These black halos contain both iron and phosphate.

These spots were a big surprise to the NASA team. On Earth, these phenomena in rocks are often associated with the fossilised record of microbes living in the subsurface. Spotting of this type on sedimentary terrestrial rocks can occur when chemical reactions involving hematite turn the rock from red to white. Those reactions can also release iron and phosphate, possibly causing the black halos to form. Reactions of this type can be an energy source for microbes, explaining the association between such features and microbes in a terrestrial setting.

One scenario being considered by the Perseverance science team is that Cheyava Falls was initially deposited as mud with organic compounds mixed in that eventually cemented into rock. Later, a second episode of fluid flow penetrated fissures in the rock, enabling mineral deposits that created the large white calcium sulfate veins seen today and resulting in the spots.

While both the organic matter and the leopard spots are of great interest, they aren’t the only aspects of the Cheyava Falls rock confounding the science team. They were surprised to find that these veins are filled with millimeter-size crystals of olivine, a mineral that forms from magma. The olivine might be related to rocks that were formed farther up the rim of the river valley and that may have been produced by crystallization of magma.

If so, the team has another question to answer: Could the olivine and sulfate have been introduced to the rock at uninhabitably high temperatures, creating an abiotic chemical reaction that resulted in the leopard spots?

"We have zapped that rock with lasers and X-rays and imaged it literally day and night from just about every angle imaginable," said Farley. "Scientifically, Perseverance has nothing more to give. To fully understand what really happened in that Martian river valley at Jezero Crater billions of years ago, we'd want to bring the Cheyava Falls sample back to Earth, so it can be studied with the powerful instruments available in laboratories."

More Mission Information

A key objective of Perseverance's mission on Mars is astrobiology, including caching samples that may contain signs of ancient microbial life. The rover will characterize the planet's geology and past climate, to help pave the way for human exploration of the Red Planet and as the first mission to collect and cache Martian rock and regolith.

NASA's Mars Sample Return Program, in cooperation with ESA (European Space Agency), is designed to send spacecraft to Mars to collect these sealed samples from the surface and return them to Earth for in-depth analysis.

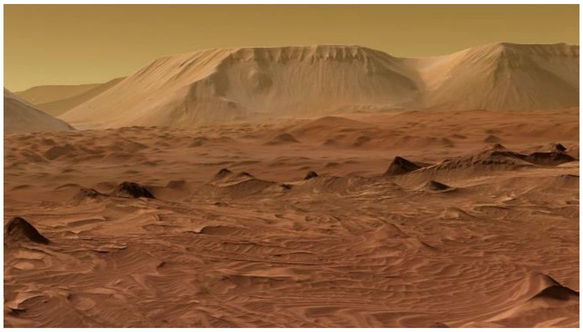
The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

NASA's Jet Propulsion Laboratory, which is managed for the agency by Caltech, built and manages operations of the Perseverance rover.

For more about Perseverance:

science.nasa.gov/mission/mars-2020-perseverance

PICK OF THE PICS



Credit:NASA

A brilliantly evocative image taken by the Curiosity Rover.

LET US KNOW WHAT YOUR FAVOURITE PIC IS AND WHY! WE ARE ALWAYS INTERESTED IN YOUR COMMENTS.

MARS TECHWATCH

Looking out for tech advances that will be useful on Mars…

Terraformation win?

It looks like an Antarctic moss might be a prime candidate for helping create a biosphere on Mars. The moss species *S. caninervis* found in the Antarctic can survive very dry and cold conditions. It now looks like it might actually survive in Mars-like conditions.

A series of "Red Planet" tests were run on the moss and it appears that it passed them with flying colours. Extreme dryness, radiation, cold and a Mars-like atmosphere (in terms of gas constituents) were no problem. However, we could find no reference to atmospheric pressurisation. Perhaps that would be a bridge too far. But the moss might still prove extremely useful to the terraformation project once pressure was in the range of 10-20% of Earth, assuming a high CO2 concentration.

So, it might well be a good pioneer plant for Mars as we begin to terraform the Red Planet.

The research paper can be found here:

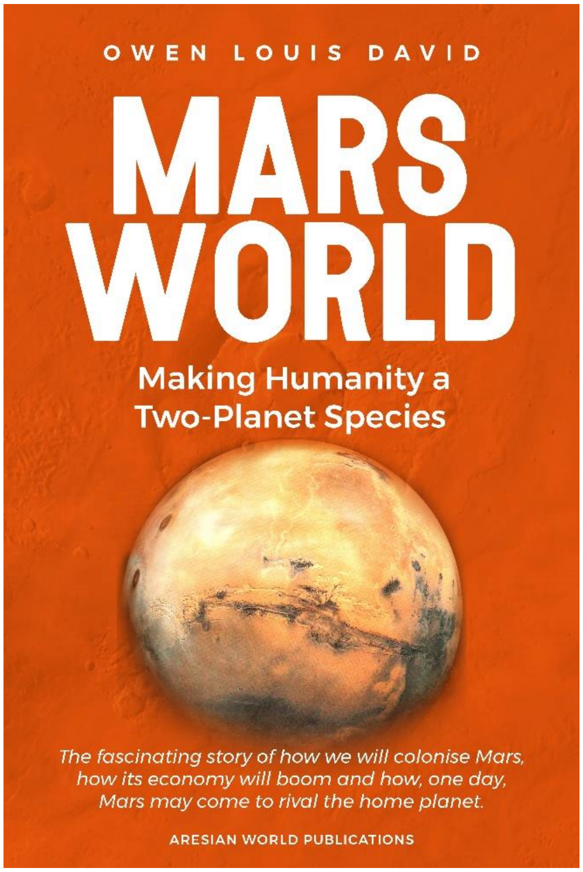
https://www.cell.com/the-innovation/fulltext/S2666-6758(24)00095-X

Heat is going to be needed in settlements on cold, cold Mars. We know we can get plenty of energy from solar panels during the day, but what about once the sun dips down to the horizon. Where will the colony's energy come from then? For district heating of the colony and for industrial processes requiring heat a sand battery might well be a good solution. The Polar Night Project in Finland has demonstrated that sand batteries can be used for heating in a domestic and industrial setting. The sand battery stores heat at between 500 and 600 degrees Celsius.

https://www.vatajankoski.fi/en/projects/sand-battery/

Exploration is going to be a huge and dominating theme of Mars colonisation from Sol One onwards. NASA and its collaborators have come up with a novel way of exploring the planet quickly and methodically. Think swarms of bees launched from a mobile command rover. These "Marsbees" will use insect-like wings to take flight and record the landscape below. A swarm of such "bees" would be able to map large areas in a short amount of time. Much more efficient that current rovers but still, in our view, way behind what humans could achieve on the planet.

https://www.nasa.gov/general/marsbee-swarm-of-flapping-wing-flyers-for-enhanced-mars-exploration/



COMING SOON –

MARSWORLD

By Owen Louis David