Every challenge astronauts will face on a flight to Mars

February 5 2021, by Matt Williams

Artist's impression of the Mars Base Camp in orbit around Mars. When missions to Mars begin, one of the greatest risks will be that posed by space radiation. Credit: Lockheed Martin

In 1972, the space race officially ended as NASA sent one last crew of astronauts to the surface of the moon (Apollo 17). This was the brass ring that both the US and the Soviets were reaching for, the "moonshot" that would determine who had supremacy in space. In the current age of renewed space exploration, the next great leap will clearly involve sending astronauts to Mars.

This will present many challenges that will need to be addressed in advance, many of which have to do with simply getting the astronauts there in one piece! These challenges were the subject of a presentation made by two Indian researchers at the SciTech Forum 2020, an annual event hosted by the International Academy of Astronautics (IAA), RUDN University, and the American Astronomical Society (AAS).

The study that describes their research findings recently appeared online and has been accepted for publication by Advances in Aeronautical Sciences (publication date pending). Both it and the presentation made at the SciTech Forum 2020 were conducted by Malaya Kumar Biswal and Ramesh Naidu Annavarapua—a graduate researcher and Associate Professor of Physics from Pondicherry University, India (respectively).

Their research was also the subject of a presentation made during the seventh session of the Space Biology Virtual Workshop hosted by the Lunar Planetary Institute (LPI) – which took place between Jan. 20th and 21st. As Biswal and Annavarapua indicated in their study and presentations, Mars occupies a special place in the hearts and minds of scientists and astrobiological researchers.

Next to Earth, Mars is the most habitable location in the solar system (by terrestrial standards). Multiple lines of evidence accumulated over the course of decades have also shown that it may have supported life at one time. Unfortunately, sending astronauts to Mars will inevitably entail a number of distinct challenges, which arise from logistics and technology to human factors and the distances involved.

Addressing these issues in advance is paramount if NASA and other space agencies hope to conduct the first crewed missions to Mars in the next decade and after. Based on their analysis, Biswal and Annavarapu identified 14 distinct challenges, which include (but are not limited to):

- The flight trajectory for Mars and corrective maneuvers
- Spacecraft and fuel management
- Radiation, microgravity, and astronaut health
- Isolation and psychological issues
- Communications (in transit and on Mars)
- The Mars approach and orbital insertion

All of these challenges experience some degree of overlap with one or more of the others listed. For instance, an obvious issue when it comes to planning missions to Mars is the sheer distance involved. Because of this, launch windows between Earth and Mars only occur every two years when our planets are at the closest in their orbits to each other (i.e., when Mars is in "opposition" relative to the sun).

During these windows, a spacecraft can make the journey from Earth to Mars in 150 to 300 days (about five to ten months). This makes resupply missions impractical since astronauts cannot wait that long to receive much-needed shipments of fuel, food, and other supplied. As Biswal told Universe Today via email, the distances involved also creates problems where astronaut safety and are power-generation are concerned:

"In case of any emergency situation, we cannot bring back astronauts from Mars [as we could] in the case of LEO or Lunar Missions… Similarly, distance reduces the solar flux from Earth orbit to Mars orbit resulting in the deficit power production which is very significant to power vehicle and maintain thermal stability (As again the far distance may lead to low environment temperature causing hypothermia and frost formation (especially in mouth)."

In other words, simply getting to Mars presents multiple specific challenges that Biswal and Annavarapu included in their analysis. When talking about astronaut healthy and safety, there are several specific challenges that come into play here as well. For instance, the fact that astronauts will be spending an several months in deep-space creates all kinds of risks for their physical and mental health.

For starters, there's the psychological toll of being confined to a spacecraft cabin with other astronauts. There's also the physical toll of long-term exposure to a microgravity environment. As research aboard the International Space Station (ISS) has shown—particularly, NASA's Twin Study—spending up to a year in space takes a considerable toll on the human body.

Beyond muscle and bone density loss, astronauts who's spent long periods aboard the ISS also experienced a loss in eyesight, genetic changes, and long-term issues with their cardiovascular and circulation systems. There have also been instances of psychological effects, where astronauts experienced high levels of anxiety, insomnia, and depression.

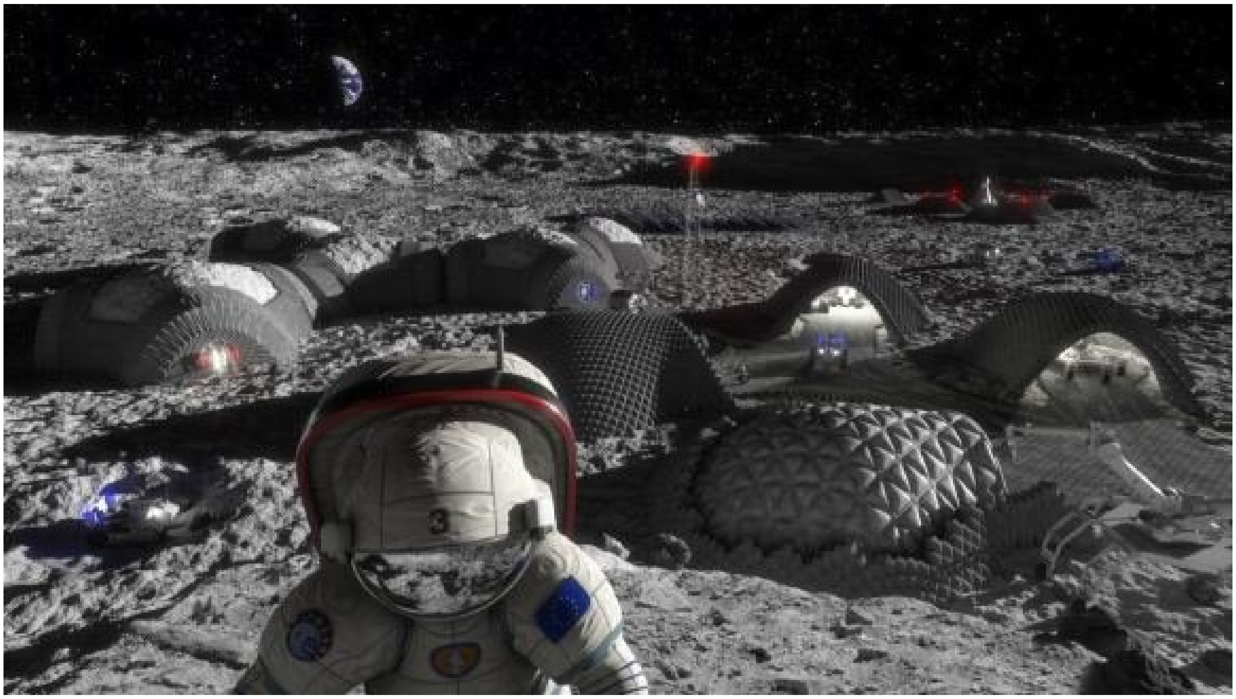
But as Biswal indicated, the single-greatest and most obvious challenge is all the radiation (solar and cosmic) that the astronauts will be exposed to over the course of the entire mission:

"[The] greatest dangers include the risk of prolonged cancer and its effects due to exposure to both interplanetary radiation (during Mars transit) and surface radiation (during extended surface stay). Then, the effect of radiation cause improper brain coordination function and other brain-related diseases; then the psychological effect of the crew during complete isolation. Since the crewed mission relies on the performance of astronaut, the astronaut experience more health-related issues."

In developed nations, people on Earth are exposed to an average of about 620 millirem (62 mSv) annually, or 1.7 millirems (0.17 mSv) a day. Meanwhile, NASA has conducted studies that have shown how a mission to Mars would result in a total exposure of about 1,000 mSv over a two and a half year period. This would consist of 600 mSv during a year-long round-trip, plus 400 mSv during an 18-month stay (while the planets realigned).

What that means is that astronauts will be exposed to 1.64 mSv a day while in transit and 0.73 mSv for every day that they are staying on Mars—that's over 9.5 and 4.3 times the daily average, respectively. The health risks that this entails could mean that astronauts would be suffering from radiation-related health problems before they even arrive on Mars, to say nothing of the surface operations or return trip.

Luckily, there are mitigation strategies for the transit and surface parts of the mission, some of which Biswal and Annavarapua recommend. "We are currently developing a Mars subsurface habitat that could address all the health-related issues on the extended mission or permanent settlement on Mars," said Biswal. "[T]he crewed mission should include faster production of crew necessities from in-situ resource [utilization] (ISRU)."



An illustration of a moon base that could be built using 3-D printing and ISRU, in-situ resource utilization. Credit: RegoLight, visualisation: Liquifer Systems Group, 2018

This proposal is in keeping with the many mission profiles that NASA and other space agencies are developing for future lunar and Martian exploration. There are already many existing strategies to keep crews protected from radiation while in space, but in extraterrestrial environments, all concepts incorporate the use of local resources (such as regolith or ice) to create natural shielding.

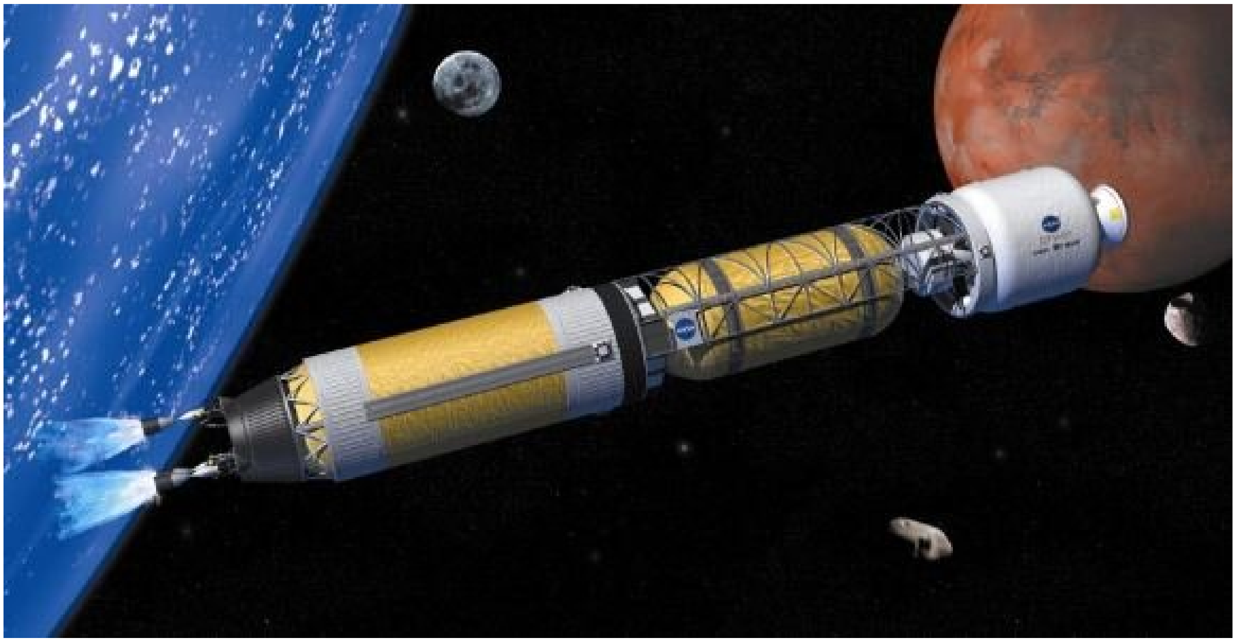
The local availability of ice is also seen as a must for the sake of ensuring a steady water supply for human consumption and irrigation (since astronauts on long-duration missions will need to grow much of their own food). Aside from all that, Biswal and Annavarapu emphasized how maintaining a fast flight and return trajectory will help reduce travel time.

There is also the possibility of leveraging advanced technologies like nuclear-thermal and nuclear-electric propulsion (NTP/NEP). NASA and other space agencies are actively researching nuclear rockets since a spacecraft equipped with NTP or NEP could make the journey to Mars in just 100 days. But as Bisawl and Annavarapu indicated, this raises the challenge of dealing with nuclear systems and more exposure to radiation.

Alas, all of these challenges can be addressed with the right combination of innovation and preparation. And when you consider the payoffs of sending crewed missions to Mars, the challenges seem a lot less daunting. As Biswal offered, these include proximity, the opportunities to study Martian soil samples in an Earth laboratory, the expanding of our horizons, and the ability to answer fundamental questions about life:

"We have always been fascinated to know where we have come from and if there is any life like us in other astronomical bodies? [W]e cannot execute a crewed mission to any other interplanetary destination due to mission risk and management.

"Mars is the only neighboring planet in our solar system we can explore, it [has] a good geologic record to answer all [of] our unsolved questions, and [we can] bring samples [back] to analyze in our terrestrial lab?" And finally, it would be interesting to execute a human mission to Mars in order to demonstrate the extent of current technology and aerospace progression."



Artist’s concept of a bimodal nuclear rocket making the journey to the moon, Mars, and other destinations in the solar system. Credit: NASA

Since the early 1960s, space agencies have been sending robotic missions to Mars. Since the 1970s, some of those missions have been landers that set down on the surface. With the over forty years of data and expertise that's resulted, NASA and other space agencies are now looking to apply what they've learned so they can send the first astronauts to Mars.

The first attempts may still be over a decade (or more) away, but only if significant preparations take place beforehand. Not only do a lot of mission-related components and infrastructure still need to be developed, but a lot of research still needs to be done. Thankfully, these efforts benefit from the kinds of thorough assessments we see here, where all potential risks and hazards are investigated (and counter-measures proposed).

All of this will hopefully lead to the creation of a sustainable program for Martian exploration. It might even enable the long-term human occupation of Mars and the creation of a permanent colony. Thanks to the efforts of many researchers and scientists, the day may finally come when there is such a thing as "Martians."

More information: Interplanetary Challenges Encountered by the Crew During their Interplanetary Transit from Earth to Mars. arxiv.org/abs/2101.04723

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