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25 July 2022

Study explores waste-stream impact on human missions to Mars and beyond

With the National Aeronautics and Space Administration (NASA) planning to send humans further into the solar system by the 2030s, research from the University of Cape Town's (UCT) SpaceLab suggests that new strategies must be developed to address the challenges of waste management during long-duration human spaceflight missions, most especially on the surface of Mars.

Conducted by doctoral graduate, Dr Samuel Anih, the research explored the possible impact of waste management on the exploration of Mars when humans eventually set foot on the planet, potentially bringing the various waste to an erstwhile pristine celestial body.

"In the nearest future, it is expected that humans will move beyond the Earth system to regions deeper into the solar system. However, throughout human space exploration, waste management has never had to be solved holistically because missions have never been long enough or far enough away from Earth that waste management has become a mission-critical issue," said Anih.

The research findings revealed that almost all crewed space missions had adopted a similar approach to waste management, consisting of a one-time use of supplies. The resultant waste is manually compacted, consolidated, stabilized, and stowed for final disposal. "This is not sustainable in the long run for long-duration crewed space missions, especially those with destinations far away from Earth," explained Anih.

From the research decomposition measurements, Anih observed a larger mass loss of waste simulants with an increase in decomposition time when exposed to high enthalpy inductively-heated plasma in various operating conditions. The pyrolytic sample remnants had a higher mass than the combustion sample remains after the experiment.

"Optical emission spectroscopy conducted following the steady-state conditions of the boundary layer consistently showed the abundance of diatomic species associated with organic materials. The presence of organic lines and bands in the various spectra obtained during the oxygen and nitrogen test conditions indicate the possible abundance of gases potentially suitable for the production of thermal and propulsive energy with possible applications during long-duration crewed space missions," he said.

Currently, on the International Space Station (ISS), waste is stowed for months and later loaded onto an outbound cargo vehicle for incineration in the Earth's atmosphere. ISS astronauts gather waste and then keep it on the space station for several months until the cargo vehicle collects it.

Recoverable waste may be returned for further analysis or use, while non-recoverable waste is not required to be returned for any purpose, said Anih.

He noted that untreated wet waste is potentially hazardous for the crew and could pose a health hazard if not handled appropriately. "Considerable effort has to go into handling and storage since safely managing human waste and related processing systems in constrained scenarios would require extensive treatment and handling," he said.

"As humans move further away from low Earth orbit, to the Moon and beyond in the future, the resupply of consumables and the management of waste will become increasingly difficult due to the increasing distance from Earth and various constraints on crewed spacecraft."

Anih said during the transit to Mars, the atmospheric incineration option used for missions to ISS would not be applicable due to the absence of an atmosphere between the Earth and Mars during the transit period.

"On Mars surface, stringent measures would be taken to avoid contamination materials and microbes from Earth. Waste could potentially serve as a host for microbes to hitchhike and disperse on the planet as Mars presents peculiar pathways for possible dispersal due to the active ambient condition on the surface," he said.

According to Anih, crew safety is of great importance when astronauts are on board a spacecraft. "It is important to evaluate the possible impact of waste handling holistically and disposal activity on the astronauts' time, safety, and health since possible contamination by hazardous waste could spell disaster for the mission," he said.

There is a transformation in the space sector with the entrant of private space entities also developing plans for carrying out crewed space missions to the Moon and Mars. Private space companies such as Bigelow Aerospace, SpaceX and Blue Origin, already have blueprints to participate in charting the course of future crewed space programmes, be it as partners with the government or solely as private entities embarking on such missions.

Said Anih: "It is expected that these private sector concepts will have more people involved in exploration activities, with the number of crew members increasing substantially as we move from public to private space entities in various mission scenarios.

"Given the projected significant increase in the number of spaceflight participants, mostly nonprofessional astronauts, and spacecraft size, one can immediately see that in a transfer trajectory of six to seven months to Mars, there is a direct effect on the required habitable volume of spacecraft as well as the scale of activities required to execute these missions.

The crew increase will not only result in tremendous growth in waste-streams generated during such missions but also in the increased need for a sustainable waste management system, taking into account factors such as waste generation from a source, mission segment, and the waste disposal options for non-traditional flight participants, especially with the emergence of active commercial space actors."

The experimental work of this research was performed at the Institute of Space Systems of the University of Stuttgart as part of the collaboration with UCT's SpaceLab.

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