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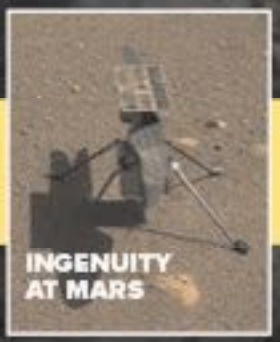
2021 Year in review

247 kilometers on one charge

and dozens of other breakthroughs



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SHAPING THE FUTURE OF AEROSPACE

DECEMBER 2021 | A publication of the American Institute of Aeronautics and Astronautics | aerospaceamerica.aiaa.org

Focusing on nuclear propulsion and power for Mars missions

BY BRYAN PALASZEWSKI

The **Nuclear and Future Flight Propulsion Technical Committee** works to advance the implementation and design of combinations of chemical and high-energy megawatt-class nuclear propulsion systems using electric thruster systems.

Nuclear power and propulsion will allow faster and more effective human missions to Mars, Aerojet Rocketdyne engineers reported at the AIAA virtual Propulsion and Energy Forum in August. Nuclear electric propulsion, or NEP, uses the fission reactor power to ionize and accelerate xenon propellants to very high exhaust velocities. Nuclear thermal propulsion passes hydrogen through a nuclear reactor core; the hydrogen becomes very hot and provides rocket thrust.

Also at the AIAA event, NASA and a group of research partners reported that **low enriched uranium, or LEU, reactors for human Mars space vehicles are affordable and feasible.** Research showed that nuclear propulsion — either electric power from a fission reactor or a nuclear thermal rocket using hot hydrogen — would be effective in carrying large chemically propelled landers and humans to Mars. The research focused on LEU cores. NASA's partners were DARPA, the U.S. Department of Energy, Aerojet Rocketdyne, the Aerospace Corp., BWX Technologies and Ultra Safe Nuclear Corp.

The Aerojet Rocketdyne team assessed near-term missions for the 2030s and **long-term human Mars bases for the 2040s**. It designed two NEP space vehicles for separate human transport and cargo transport. The simulated cargo transport carried several chemically propelled Mars landers. The human transport used both NEP and chemical propulsion; this propulsion combination created significant trajectory benefits, including faster missions, exposing the human crew to less of the deep space radiation.

The research also showed that **human Mars bases can be resupplied with the fast NEP transports**. The human transport used a 1.9-megawatt electric NEP stage with 20 100-kilowatt electric Hall-effect thrusters (18 active thrusters, with 2 spares), four Xenon Drop Tanks attached to a drop tank truss, a deep space habitat where a crew would live during the in-space portion of the mission, and a liquid oxygen/liquid methane chemical stage with two 25,000-pound thrust pump-fed engines. Ejecting empty drop tanks after their propellant is consumed would allow improved Mars payload performance. The research showed that the **chemical propulsion system would make the Earth departure and entry into Mars orbit faster than using NEP alone**. The transport design is flexible and would accommodate many human Mars exploration campaigns. Aerojet Rocketdyne assessed many Mars flights, improving our knowledge of the technology gaps that must be filled for mission success.

Nuclear propulsion is also critically important for outer planet exploration and exploitation. In August, NASA's Glenn Research Center in Ohio reported new results for the **mining requirements for outer planet moons**. Given the large fraction of water ice that's available on the moons of Uranus and Neptune, that ice is crucial to refueling mining vehicles. The mass of the mined water would be only a small fraction of the total mined matter. The water ice would be used to make oxygen and hydrogen for both chemical rocket engines and refuel nuclear electric propulsion orbit transfer vehicles to carry helium 3 and deuterium from additional nuclear mining vehicles working in Uranus' and Neptune's atmospheres.

In August, the Limitless Space Institute reported on dynamic vacuum research. **Extracting energy from the vacuum of space** is not yet practical on a large scale. However, the institute's research focused on potential applications to propulsion, communications, sensors and optics. Researchers visualized potential space-warp fields and theorized new insights into a negative vacuum energy density. They discovered warping space-time requires enormous energy, usually far beyond present human and world scales.★