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Key Challenges for Human Missions to Mars and Some 2033 Readiness Implications

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Radiation

Issues

- Episodic solar storm high proton flux
- Continuous high energy Galactic Cosmic Radiation (GCR) flux
- Human health risks from cumulative exposure
  - Mutagenic effects
  - Unquantified, adverse cognitive effects

Mitigation Challenges

- *Option 1*: Shorter interplanetary transit times for humans
  - Requires nuclear propulsion
    - The technology is not mature
- *Option 2*: Onboard protection
  - Mass burden for solar proton “storm shelter”
  - Big power burden for high magnetic field GCR shield
    - The technology is not mature

In-Space Mission Vehicle Assembly & Fueling

Issues

- Interplanetary transit vehicles for humans require in-space assembly
  - Components to be carried on multiple heavy-lift boosters
- Assembly may be in cislunar space
  - Limits solar-relative plane change delta-v (to move from assembly orbit plane to interplanetary trajectory plane)
- Cryogenic propellant storage and transfer capability needed
  - LH2 needed even for nuclear thermal propulsion

Mitigation Challenges

- Assembly platforms still need to be developed
  - Gateway could be a starting point, but needing added scale and capability
- In-space cryogenic propellant transfer not yet demonstrated
  - Need means for pre-transfer thermal conditioning and boil-off prevention
  - Must also be addressed for Artemis

Implications for a 2033 Human Mars Mission

Some Risk Assessment/Mitigation Studies are Urgently Needed

- In-space investigation of cumulative GCR effects
  - Could utilize Gateway for multiple human missions with progressively longer durations (up to a year or more)
    - Such missions would be more frequent and longer than now planned
  - Gateway would need more capability to enable this research
    - Accommodation of extended human stays
    - Greater consumables resupply than now planned
- Development and in-space demonstration of near-zero loss systems for LOX and LH2 transfer and depot storage
- Accelerated development of GCR mitigation technology
  - Includes development of supporting high-power generation capabilities
    - Must work within applicable mass allocation limits
  - Probably already too late to enable availability for 2033 use