

Chemical Propulsion for Crewed Mission to Mars

Humans to Mars Summit 2022

Washington DC

Hoppy Price

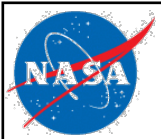
Jet Propulsion Laboratory
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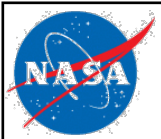
Chemical Propulsion Options (leading options)

- LOX/hydrogen
 - $I_{SP} \sim 450$ s
 - Low density, high volume, very cold cryo
 - Suited for Lunar and Mars water ice based ISRU
- LOX/methane
 - $I_{SP} \sim 360$ s
 - Suited for Mars ISRU (water ice and CO_2 atmosphere)
- NTO/hydrazine (pump fed)
 - $I_{SP} \sim 340$ s
 - Non-cryo, high density, low inert mass fraction, high TRL, low complexity
 - No ISRU potential
- LOX/hydrazine
 - $I_{SP} \sim 365$ s
 - Could be a potential ISRU upgrade to an NTO/hydrazine system
- LOX/kerosene (RP-1)
 - $I_{SP} \sim 350$ s
 - High TRL, low toxicity



Comparison to Other Propulsion Options

- **Nuclear Thermal Propulsion (NTP)**
 - $I_{SP} \sim 850$ s
 - Liquid hydrogen storage issues
 - Low TRL; would require high power, high temperature systems
- **EP**
 - Very high I_{SP} – up to 4,000 s
 - High inert mass fraction
 - Low thrust could make chemical propulsion hybrid the optimal implementation
 - Would require very high power for crewed systems (500 – 1,000 kWe)
 - **Nuclear Electric Propulsion (NEP)**
 - Low TRL
 - Radiation shielding issues
 - Deployment issues for very large radiators
 - **Solar Electric Propulsion (SEP)**
 - High TRL at 35 kWe, but lower TRL at the needed power levels
 - Deployment and control issues for very large solar arrays



Take Aways

- Chemical propulsion could provide a near-term capability for crewed missions to Mars
 - Implementation would not need to be dependent on advanced technology propulsion. Chemical propulsion would be capable for beginning a human exploration program.
 - The cost impact of larger propellant mass could be mitigated by the lower costs of reusable commercial launch vehicles and the lower development and production costs of chemical propulsion
- Nuclear propulsion could provide enhanced capability for the future
 - As described in NAS report, there are many challenges to achieving nuclear propulsion and qualifying it as human rated
 - The performance advantages make it compelling to continue development of this technology
 - Nuclear propulsion could be on-ramped to a crewed Mars exploration program when it is available