Mission Architecture Observations on Cryogenic Technology Impacts

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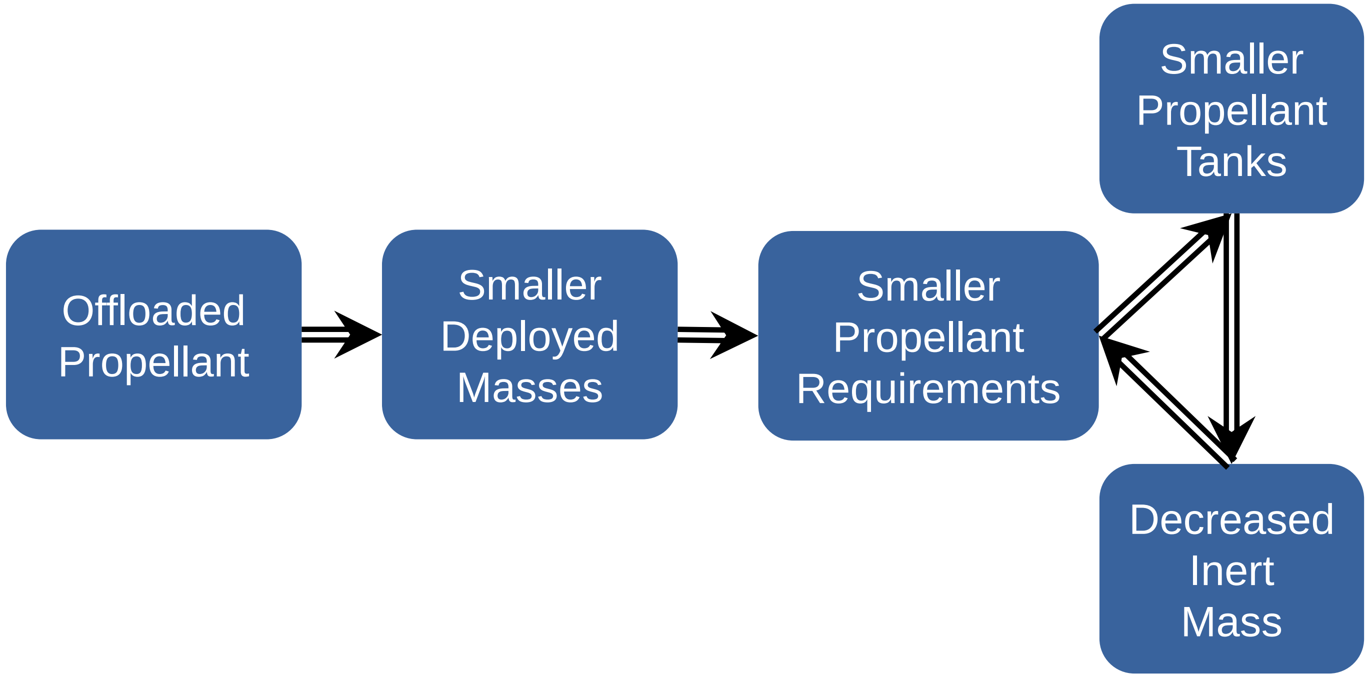
Balancing the Benefits and Challenges of Cryos

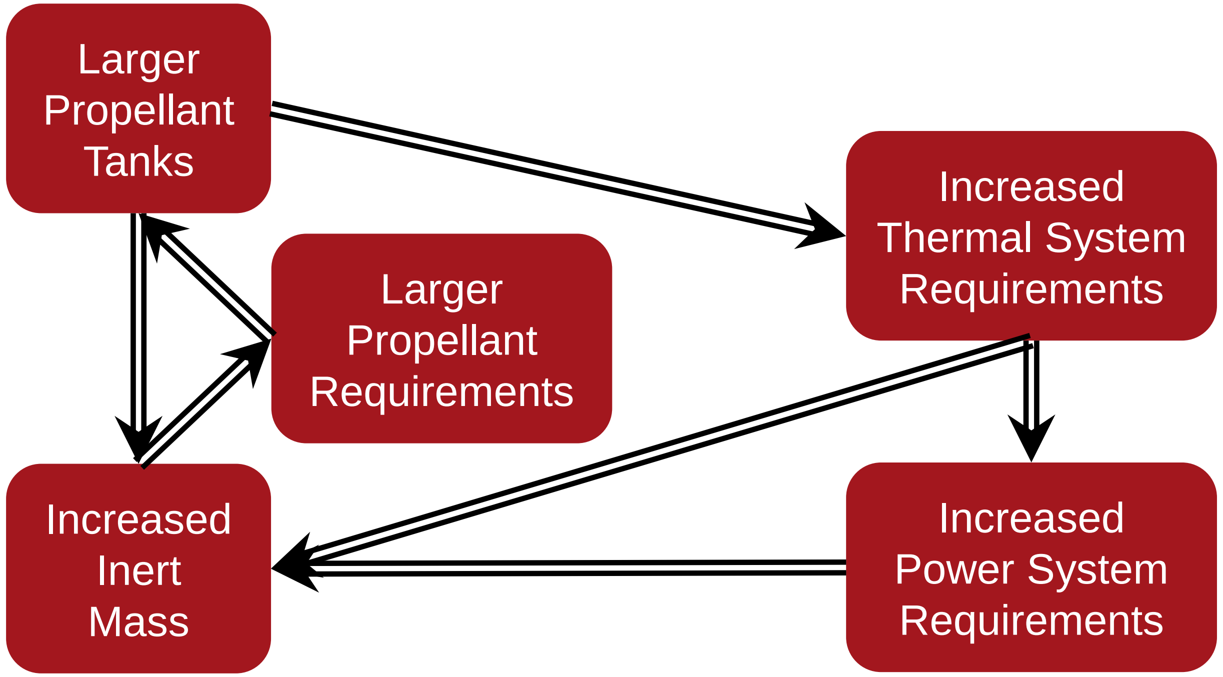
Major benefits of cryogenic propellants

- Higher propulsive efficiency
- Feasibility of in-situ propellant production



Major challenges of cryogenic propellants

- Lower density (except for LOX)
- Thermal requirements



In order for cryos to serve as enablers to Moon and Mars architectures, their benefits must outweigh the cost of technological solutions to their associated challenges

Example Cryo Technology Impacts

Mars Ascent Vehicle (MAV) and Mars Descent Module (MDM) Sizing

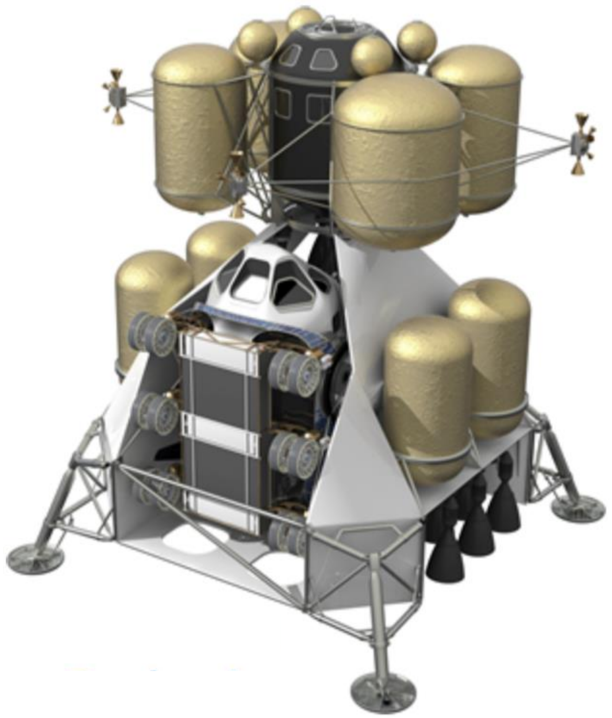
With In-Situ LO2 Production

	LO2/LCH4	*LO2/LH2*	*N2O4/MMH*
Surface Mission Payloads, HIAD, & Crew	34,813	34,813	34,813
ISRU Plant	1,217	1,217	0
MAV	14,598	20,026	29,627
Total Descent Payload	50,628	56,056	64,440
MDM Gross Mass	34,065	69,375	33,598
Initial Gross Mass in Mars Orbit	***84,693***	***125,431***	***98,038***

Without In-Situ LO2 Production

	LO2/LCH4	*LO2/LH2*	*N2O4/MMH*
Surface Mission Payloads, HIAD, & Crew	34,813	34,813	34,813
ISRU Plant	0	0	0
MAV	34,168	45,324	29,627
Total Descent Payload	68,981	80,137	64,440
MDM Gross Mass	~ 39,839	~ 76,373	33,598
Initial Gross Mass in Mars Orbit	***~ 108,820***	***~ 156,510***	***98,038***

- Cryo elements employ Active CFM
- MDM thermal system sized to support long-term MAV propellant storage on Mars surface
- With ISRU, Cryo MAVs are landed partially-fueled (LOX tanks empty)
- Storable MAV does not benefit from ISRU, is landed fully-fueled
- Some limitations:
  - MDM thermal system not re-sized to accommodate additional requirements of long-term storage for both fuel and oxidizer
  - Descent trajectory not re-closed for smaller/larger gross masses → same descent ΔV sized in all cases
  - Surface power system not re-sized for removing ISRU power demands



General Architecture Observations for Cryos

	Moon	Mars
Cryogenic Fluid Management	Highly efficient Passive CFM systems often trade better than Active CFM systems	Mission durations require Active CFM, Passive only close for corner cases
	Active CFM trades better for: • Elements with larger propellant loads • Elements with higher Isp (within the same cryo family)	
In-Situ Propellant Production	Enables more conops, but not strictly required to make architectures close	A game-changer, enabling otherwise infeasible architectures
Propellant Transfer	Required for any architecture leveraging reusability	