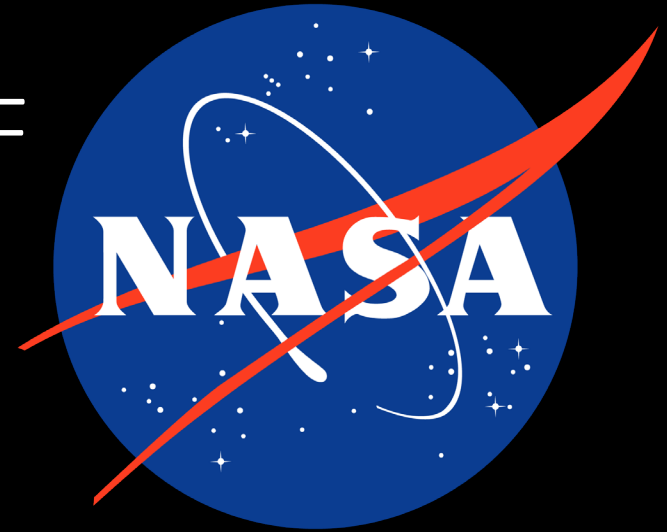


ARCHITECTURAL IMPACTS OF IN-SITU RESOURCE UTILIZATION PRODUCTION OF OXYGEN FOR USE AS PROPELLANT IN A MARS ASCENT VEHICLE



Angela Krenn (NASA KSC), Doug Trent (NASA MSFC), Jerry Sanders (NASA JSC), Steve Hoffman (Aerospace Corp. JSC), Patrick Chai (NASA LaRC), Eric Hinterman (MIT)

Cryogenic Engineering Conference
Virtual - Wednesday July 21st, 2021
C3Or1B-01

INTRODUCTION

- NASA is analyzing various approaches to accomplish human missions to, and returning from, Mars
- Entry, Descent, and Landing capabilities impose landed mass limitations that drive architectural concepts
- A Mars Ascent Vehicle (MAV) will likely require on-surface propellant servicing prior to launch
- Mass/power/operations comparisons analyzed for 3 MAV propellant servicing concepts
 - Landed hypergolic propellant
 - Landed cryogenic propellant
 - ISRU cryogenic propellant



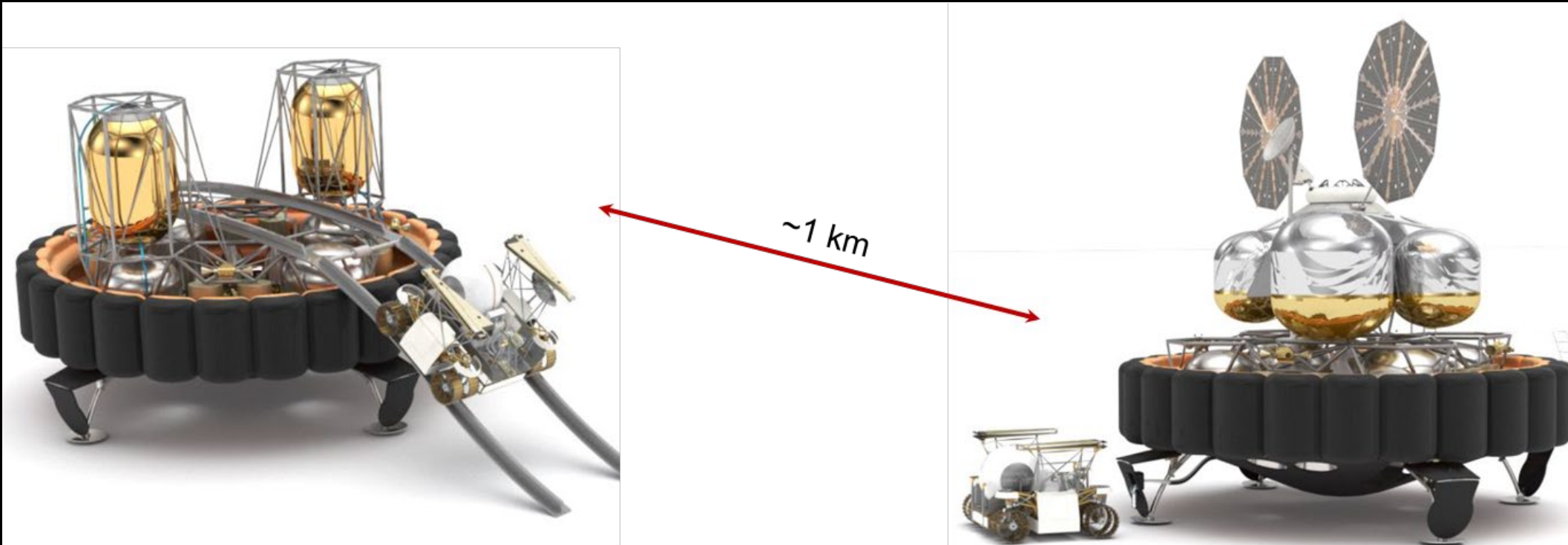
COMMON ASSUMPTIONS

	Launch from Earth	Arrive in Mars Orbit	Land on Mars Surface
Lander 1	April 2033	November 2033	November 2033
Lander 2	June 2035	January 2036	January 2036
Lander 3	August 2037	July 2038	February 2040
Crew Transit Vehicle	June 2039	February 2040	NA

-
- Landed mass limit is 25 metric tons
 - Landing site at +45 deg latitude & -4 km elevation as measured on the Mars Orbiter Laser Altimeter
 - Ambient Temp 150 – 300 K
 - MAV filled for launch prior to crew touchdown on Mars
 - 1 Nuclear fission generated power unit providing 10 kW to end items
 - MAV required to lift 2 Crew

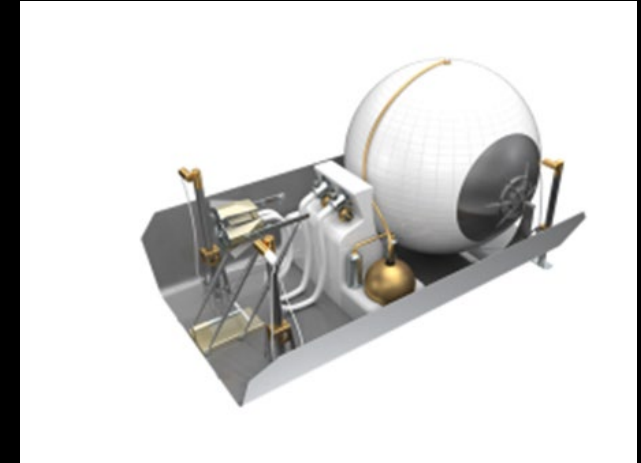
PROPELLANT PRE-POSITION CONCEPTS

- Propellant transfer package transfers NTO/LO₂ between Lander 1 and MAV
- Transfer is accomplished using the unpressurized rover for mobility
- Nominal power draw < 2.0 kW with potential peaks < 5.6 kW



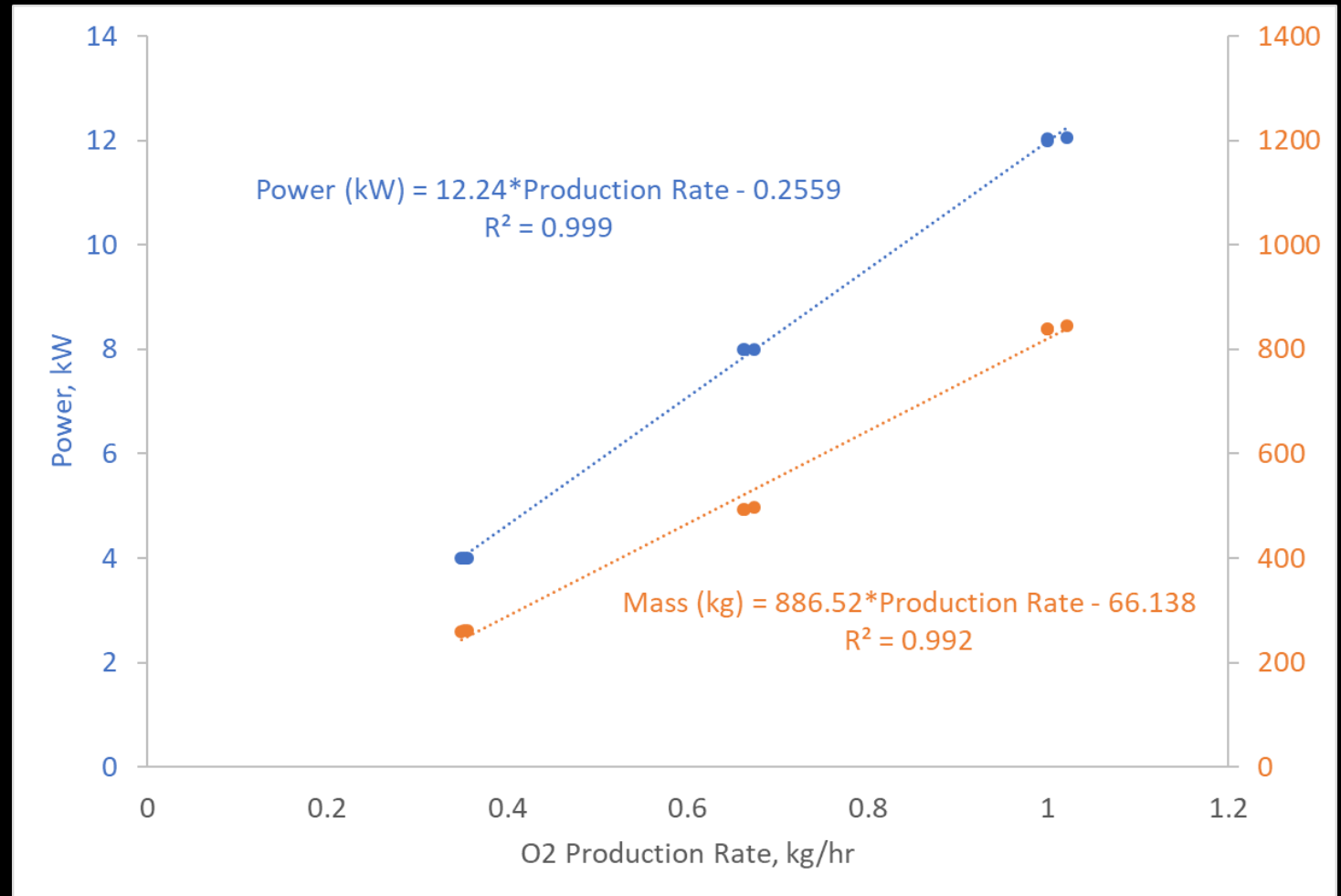
PROPELLANT PRE-POSITION CONCEPTS

- Lander 1: ~25 tons (hypergolic baseline concept), ~30 tons (cryogenic reference concept)
 - Stored nitrogen tetroxide (NTO) or liquid oxygen (LO₂) for transfer into the MAV
 - Propellant transfer package
 - Unpressurized rover
 - 1 Power supply and distribution
 - Cargo offloading equipment
- Lander 2: ~25 tons (hypergolic and cryogenic propelled MAV concepts)
 - MAV (filled with Monomethylhydrazine (MMH) or liquid methane)
 - Miscellaneous equipment for crew access
- Lander 3: ~22 tons (same mass for both pre-positioned propellant concepts)
 - Crew
 - Science equipment
 - 1 Back-up power supply
 - Pressurized rover
 - Miscellaneous equipment



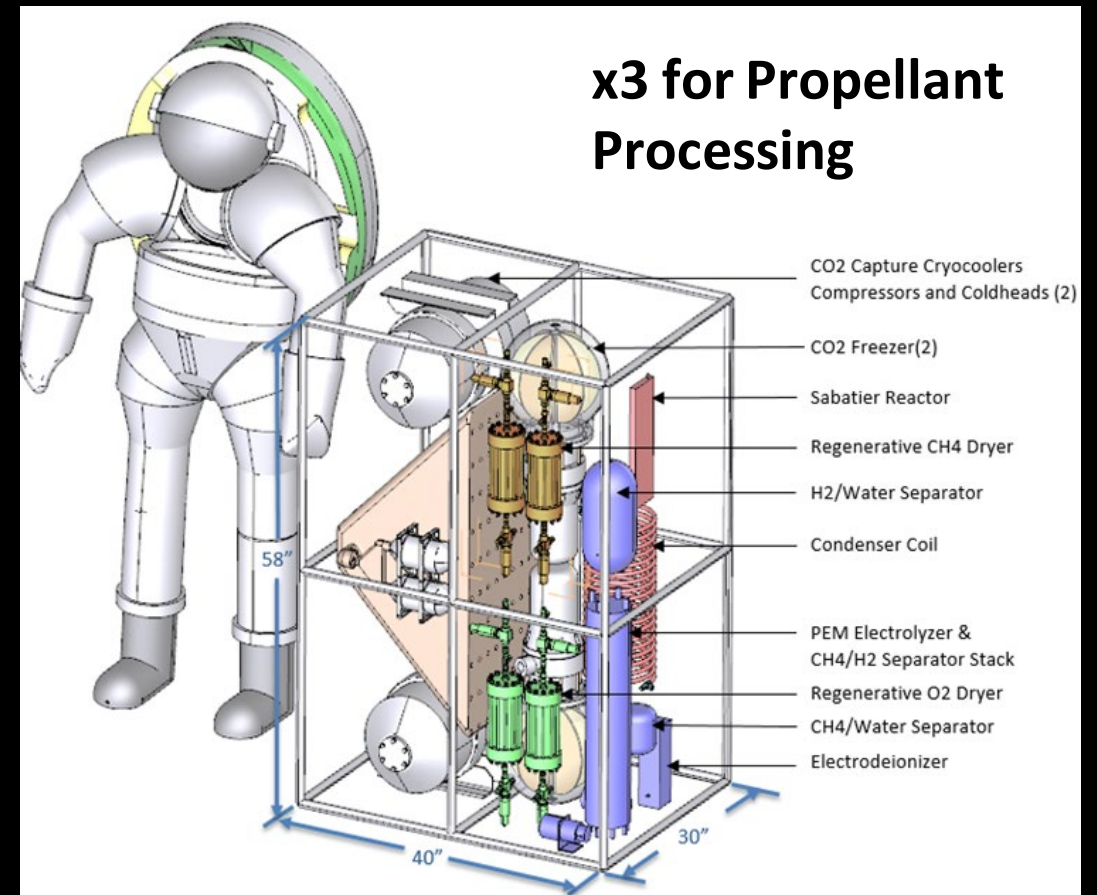
ISRU PROPELLANT PRODUCTION CONCEPT

- Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)-like Oxygen Production (scroll pump/compressor and solid oxide electrolysis)
- Approximately 1,400 days available for O₂ production
- Second 10 kW power unit required to achieve sufficient production rates



ISRU PROPELLANT PRODUCTION CONCEPT

- Lander 1: ~14 tons
 - Unpressurized rover
 - 2 Power supplies and distribution
 - Cargo offloading equipment
- Lander 2: ~21 tons
 - MAV (filled with liquid methane)
 - ISRU Production plant
 - Miscellaneous equipment for crew access
- Lander 3: ~17 tons
 - Crew
 - Science equipment
 - Pressurized rover
 - Miscellaneous equipment



OTHER CONSIDERATIONS



- Number of physical/data/power interfaces
- Reliance on mobility system capability
- Sensitivity to landing site/local atmospheric conditions
- Complexity of automated operations
- Sensitivity to uncrewed surface timeline
- Technology maturation required



CONCLUSIONS

- Significant mass reductions can be realized throughout the architecture if ISRU processes are used for propellant production
- 3 landers are still required to achieve mission objectives
 - A reduction to 2 landers would require an increase in landed mass capability to >32 tons
 - Hardware volume constraints may also drive the need for 3 landers – 8.4-meter payload fairing limits
- Power requirements nearly double for a cryogenic ISRU architecture (total delivered power units remains the same, but the baselined back-up power unit is delivered early and becomes a second primary supply)
- Other integrated, operational, and reliability considerations are substantial and require further study

QUESTIONS?

