



Top 10 Technologies for Reusable Cislunar Transportation

October 30, 2010

Space Manufacturing 14
October 30-31, 2010

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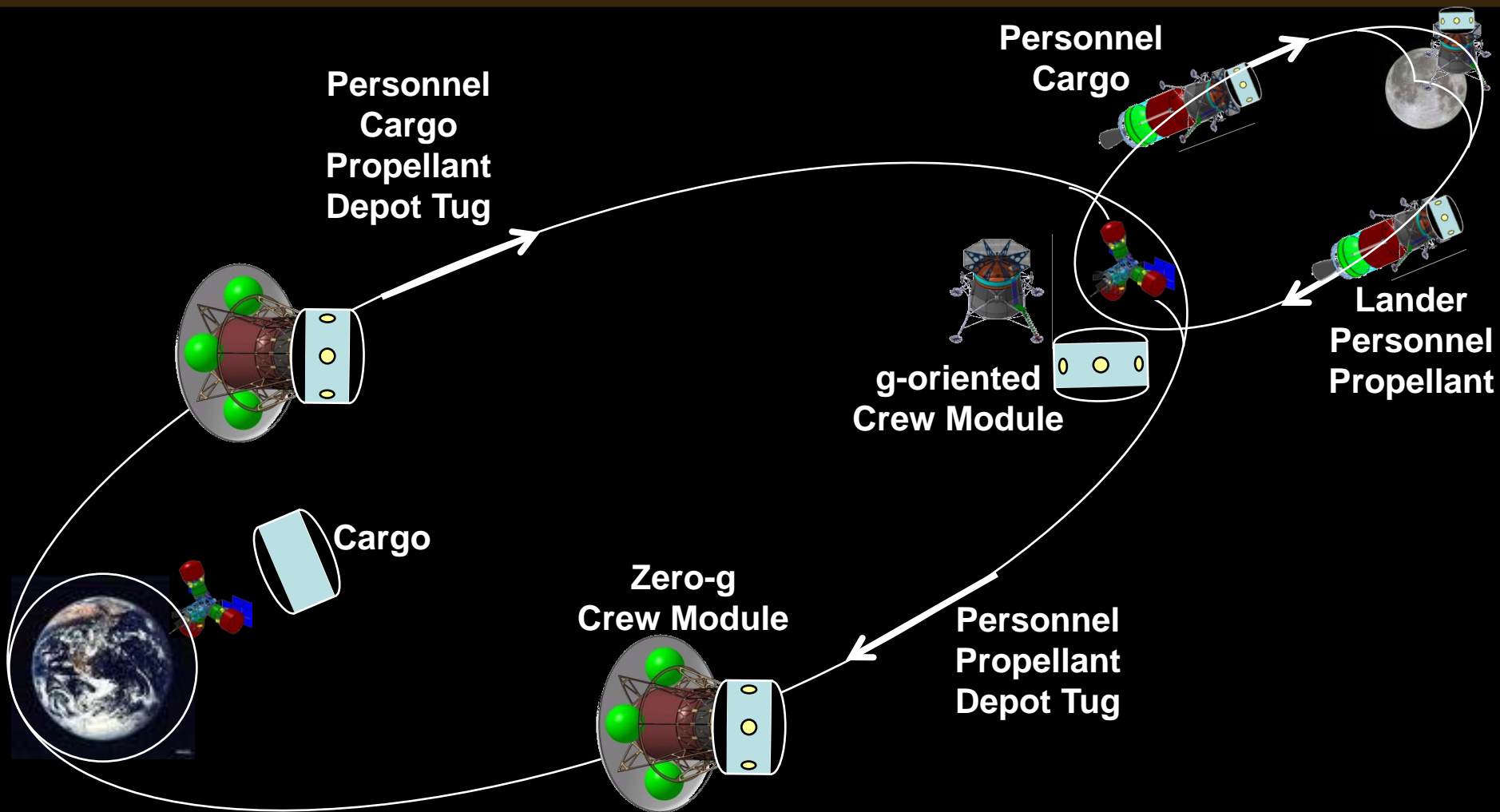
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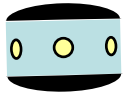
Top 10 Technologies for Reusable Cislunar Transportation

- **A Reusable Cislunar Transportation Architecture**
- **Top 10 Technologies**
- **Technology and Cislunar Transportation Timeline**
- **NASA Budget Funding**
- **Technology Impact**

A Depot-Enabled Reusable Cislunar Architecture



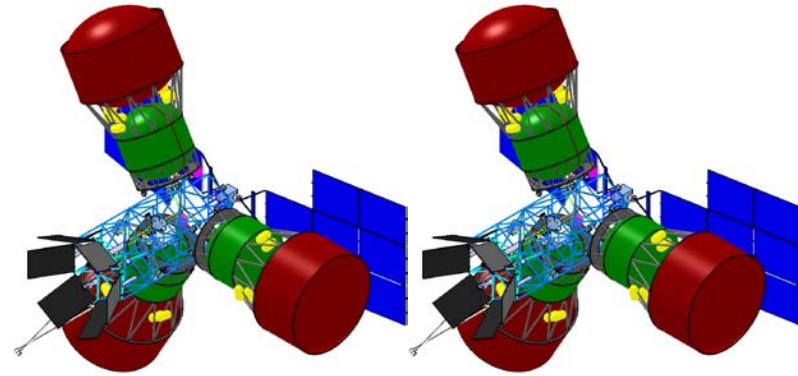
Systems Comprising a Depot-Enabled Reusable Cislunar Architecture



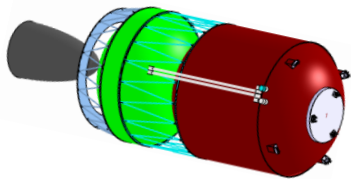
Personnel Modules
0-g and g oriented



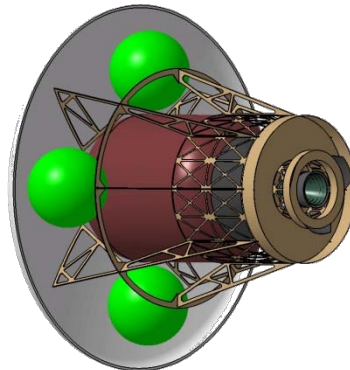
Propellant Carrier



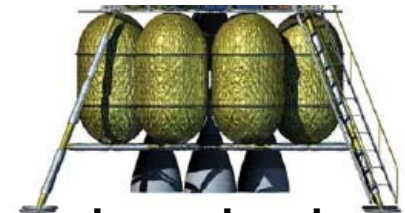
2 Modular Propellant Depots



Space Reusable Transfer Vehicle
EML1 to Perilune delivery
 O_2/H_2



Aerobraked Reusable Transfer Vehicle
GTO and/or GEO delivery
 O_2/H_2

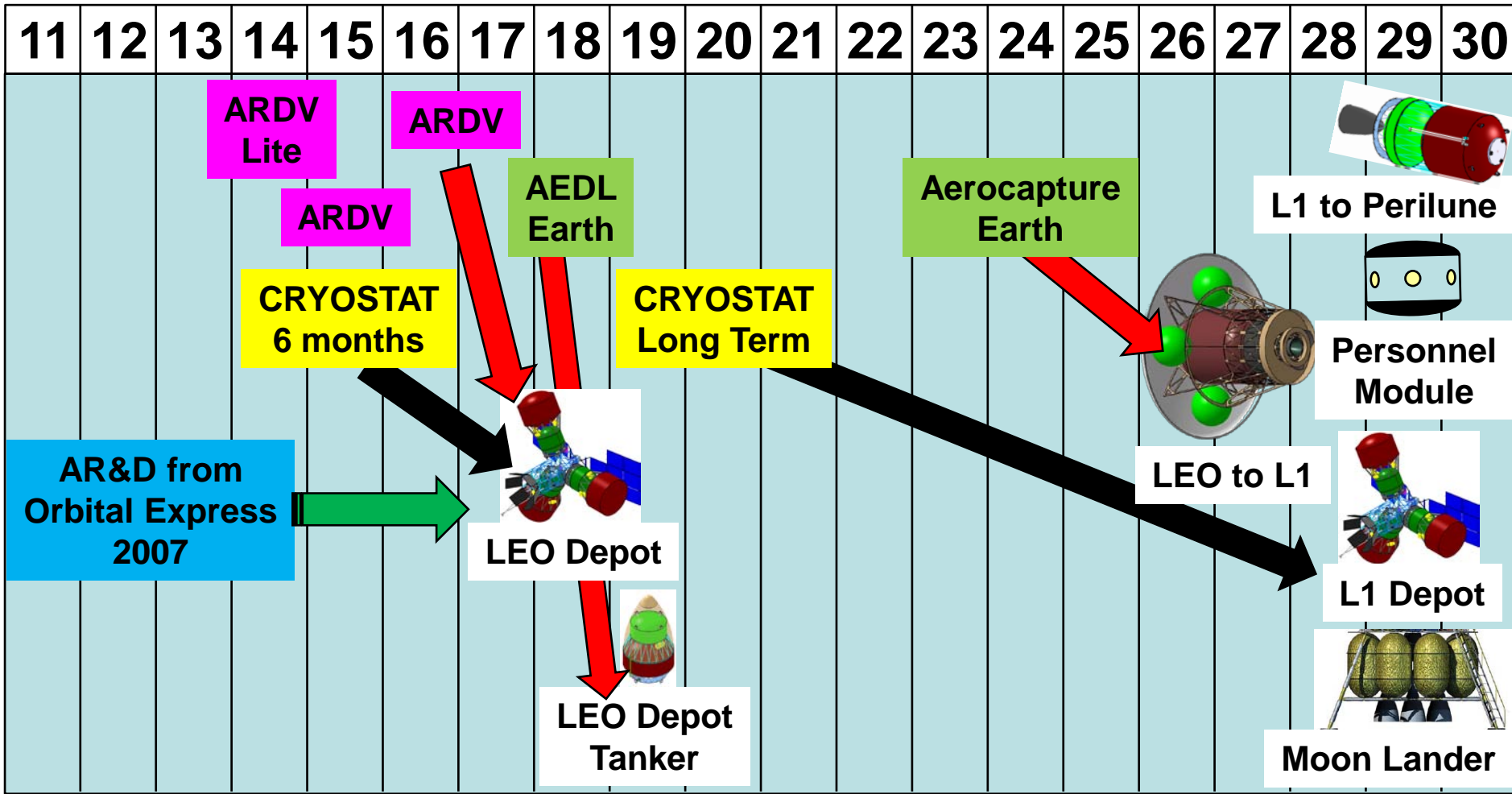


Lunar Lander
Perilune to Surface
 O_2/H_2

Top 10 Technologies for Reusable Cislunar Transportation

1. Zero-g cryogenic fluid management (CFM).
2. Zero-g cryogenic fluid transfer (CFT).
3. Long-term zero-g cryogenic storage.
4. Aero-assisted entry, descent, and landing (AEDL).
5. Long-life reusable O₂/H₂ Space rocket engine.
6. Aerocapture.
7. Deep Space autonomous rendezvous and docking (AR&D).
8. Low-g water electrolysis.
9. Low-g and zero-g O₂/H₂ liquefaction.
10. Variable mixture ratio O₂/H₂ Space rocket engine.

NASA FTDs Support Some Reusable Cislunar Architecture Needs But Schedule Too Long



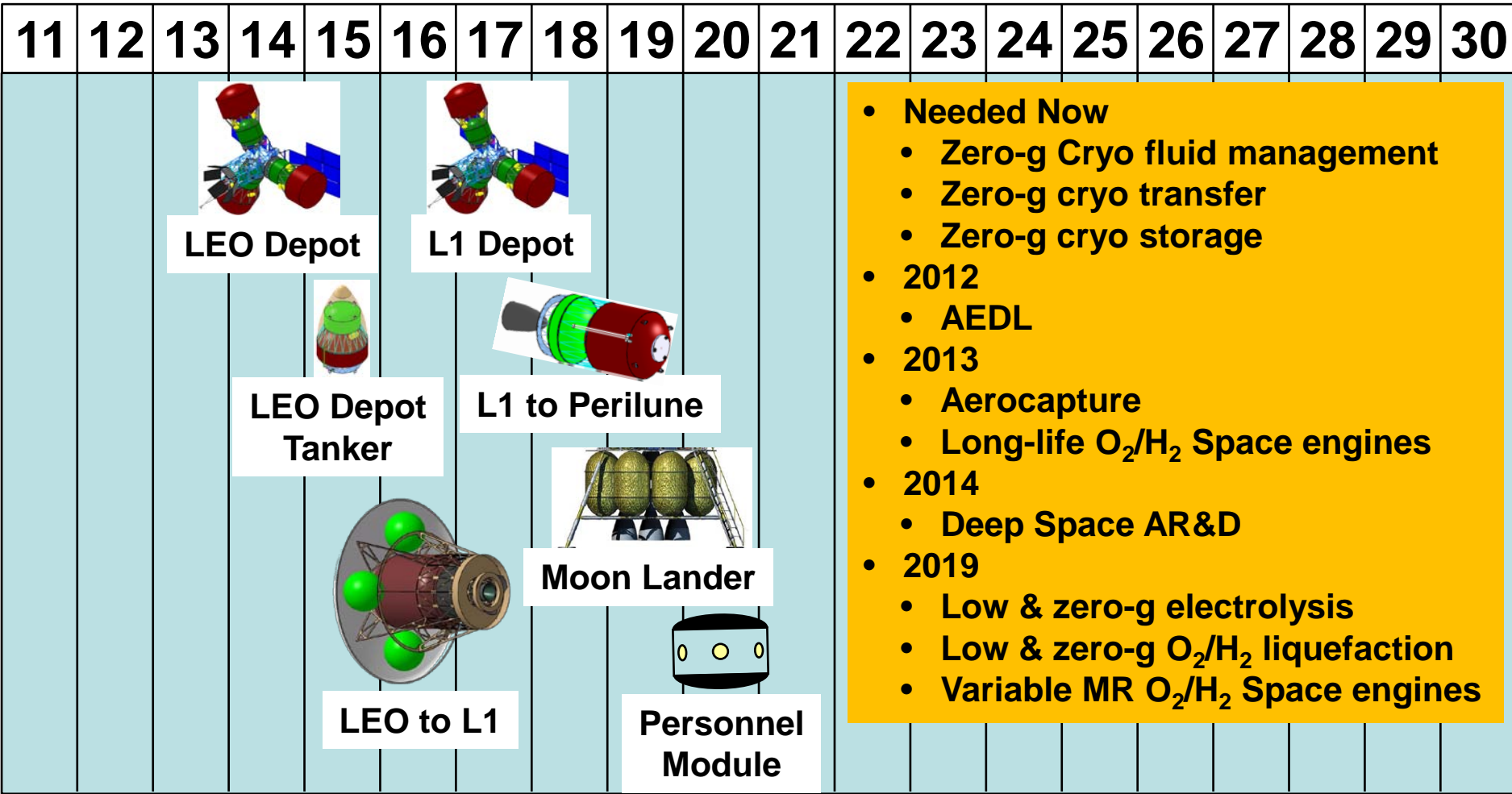
Top 10 Technologies Not Covered by NASA FTDs

5. Long-life reusable O₂/H₂ Space rocket engine.
7. Deep Space autonomous rendezvous and docking (AR&D).
8. Low-g water electrolysis.
9. Low-g and zero-g O₂/H₂ liquefaction.
10. Variable mixture ratio O₂/H₂ Space rocket engine.

Needed Technologies Defined

- **Long-life reusable O₂/H₂ Space rocket engine**
 - Unlimited starts
 - Multi-year operations
- **Deep Space autonomous rendezvous and docking (AR&D)**
 - Locate and rendezvous without GPS
- **Low-g water electrolysis**
 - Water dissociation into O₂ and H₂ in 1/6 and 1/3 g fields
- **Low-g and zero-g O₂/H₂ liquefaction**
 - Liquefy gasses in 1/6 and 1/3 g fields
- **Variable mixture ratio O₂/H₂ Space rocket engine**
 - Operate at mixture ratios between 5 and 11

Technology Needs Driven by Timely Cislunar Transportation



NASA Budget for Technology Maturation

● S.3729 NASA Authorization Act of 2010

• Title I – Authorization of Appropriations

- Sec 101 FY 2011 (1) (C) \$250,000,000 for Exploration Technology Development
- Sec 102 FY 2012 (1) (C) \$437,300,000 for Exploration Technology Development
- Sec 103 FY 2013 (1) (C) \$449,000,000 for Exploration Technology Development

• Title III – Expansion of Human Space Flight Beyond the ISS and LEO

- Sec. 308 – Development of Technologies and robotic elements for human space flight and exploration
 - (a) (2) In-space capabilities...refueling and storage...orbital transfer stages...
 - (b) (1) In-space technologies...propellant depots, in situ resource utilization...
 - (b) (2) In-space transfer vehicle...
 - (b) (4) in technologies and capabilities relating to...propulsion...
 - (b) (6) in technologies and capabilities relating to...in situ resource utilization...
 - (c) Utilization of ISS as Testbed

Top 10 Technologies Impact on Space Development

1 – 3 Zero-g cryo fluid management, storage, & transfer

- 2 – 3 times current HEO and Deep Space mission capability
- Enables reusable Space transportation systems
- Enables cryogenic propellant depots

4 AEDL

- Enhances reusable ETO propellant tankers

5 Long-life O₂/H₂ Space rocket engines

- Enables operationally efficient reusable Space transfer vehicles

6 Aerocapture

- ~7 t less propellant for 25 t cargo on LEO-EML1-LEO leg
- ~21 t less propellant for 5 t crew module on LEO-EML1-LEO leg
- ~1 t ARTV stage inert mass increase

Top 10 Technologies Impact on Space Development

7 Deep Space AR&D

- Enables EML1 depot assembly and operations
- Enables lander and transfer stage mating

8 & 9 Low-g and zero-g water electrolysis & liquefaction

- Enables lunar propellant use for lander departure
- Enables water transport from Moon to EML1 and LEO depots
- ~16 t less propellant for 25 t cargo to Moon
- ~25 t less propellant for 5 t crew module to/from Moon

10 Variable mixture ratio O₂/H₂ Space rocket engine

- Enables full use of water-derived O₂/H₂ propellants

Top 10 Technologies for Reusable Cislunar Transportation...

- **Provide 2-3x capability mission capability with full current systems in LEO**
- **Enable reusable Space transportation systems**
- **Enhance reusable Space systems operational efficiency**
 - Aerobrake saves up to 21 t propellant for return to Earth orbit
 - Moon propellant saves up to 25 t propellant for lander & SRTV
- **Enable O₂/H₂ propellant production from Moon water**