Space Exploration

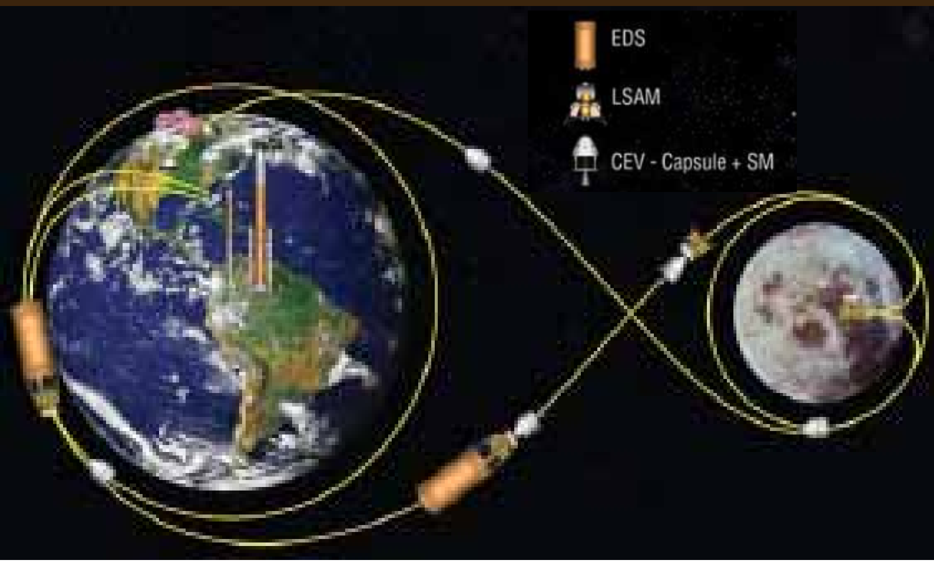
LEO Propellant Depot:

A Commercial Opportunity?

LEAG
Private Sector Involvement
October 1 - 5, 2007
Houston, Texas

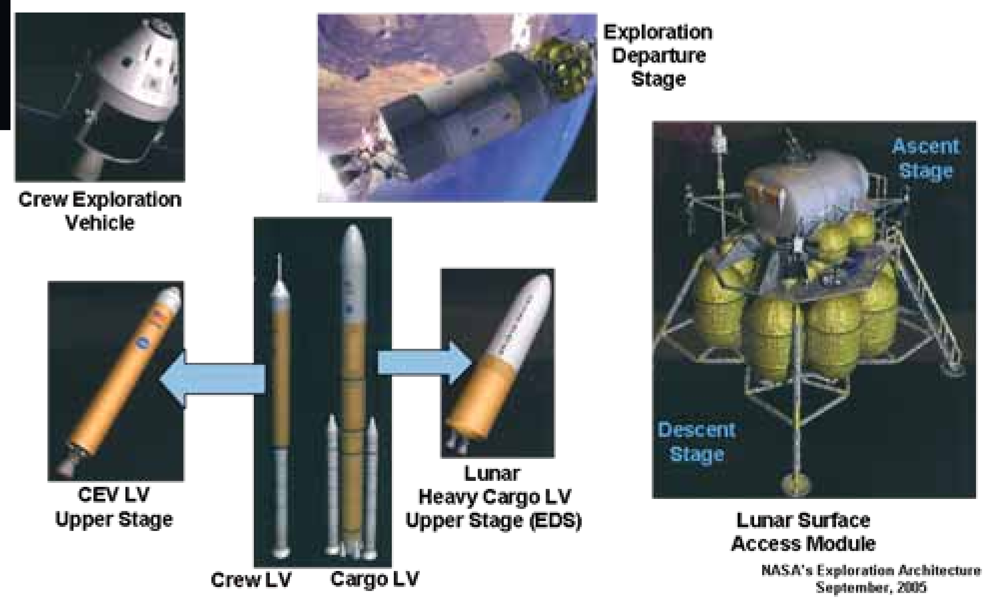
Dallas Bienhoff
The Boeing Company
703-414-6139

The ESAS Recommended Architecture



- 1.5 Launch architecture: Ares I & V
- Earth orbit rendezvous: CEV to LSAM/EDS
- EDS performs Earth orbit insertion & circularization and TLI burns

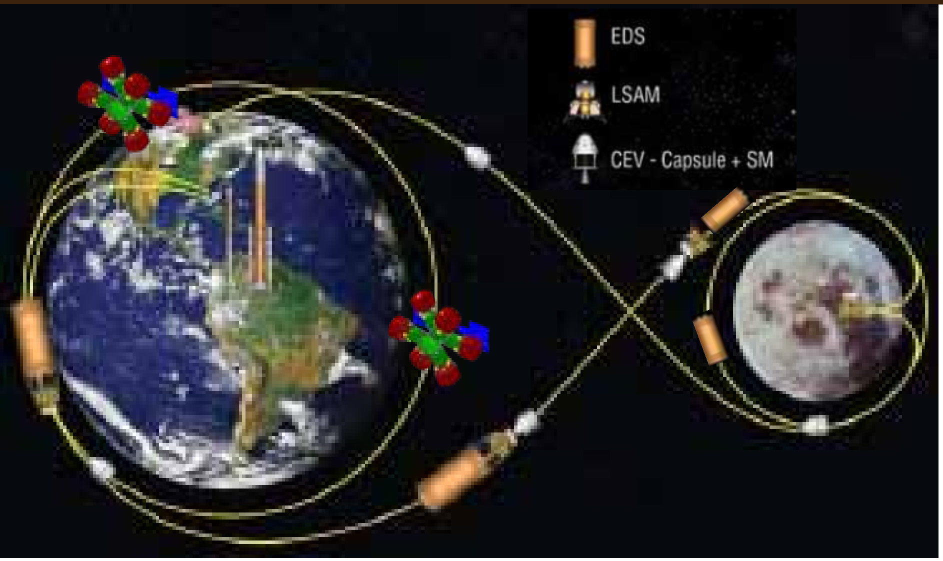
- LSAM DS performs LOI with CEV and lunar descent and landing
- Lunar orbit rendezvous: LSAM AS to CEV
- LOx/LH in EDS and LSAM DS
- Lox/Methane in LSAM AS and CEV



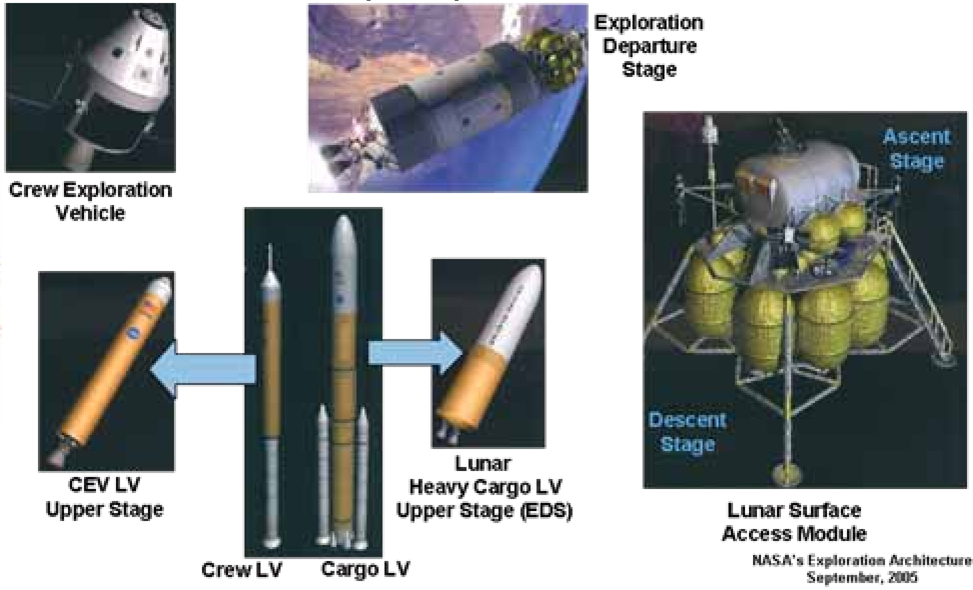
Followed by Dr. Griffin's Comments at 52nd AAS Annual Meeting in Houston, 11/05

- "But if there were a fuel depot available on orbit, one capable of being replenished at any time, the Earth departure stage could after refueling carry significantly more payload to the Moon…"
- "The architecture which we have advanced places about 150 metric tons in LEO, 25 MT on the Crew Launch Vehicle and 125 MT on the heavy-lifter. "
- During ascent, the Ares V Earth Departure Stage uses approximately 125 t of propellant to deliver 125 t to LEO
- "…at a conservatively low government price of $10,000/kg in LEO, 250 MT of fuel for two missions per year is worth $2.5 B, at government rates."

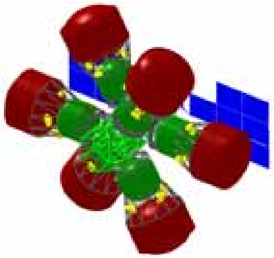
Two LEO Propellant Depots
Add Capability, Options and Resiliency



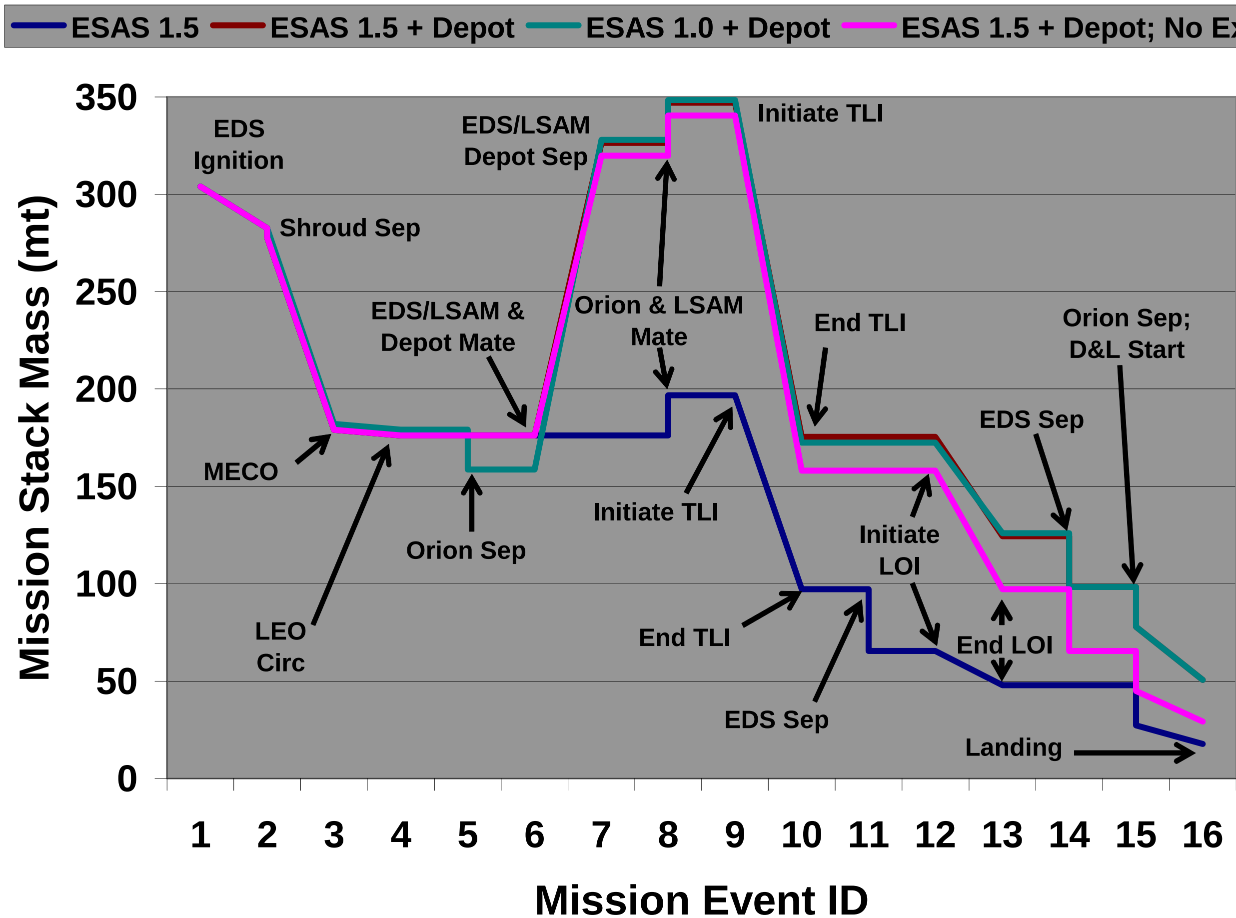
- 1.5 Launch or Single Launch architecture: Ares I & V or Ares V
- EDS & LSAM receive propellant in LEO
- Eliminates EDS & LSAM boil-off concerns
- Earth orbit rendezvous: EDS/LSAM to Depot; CEV to LSAM/EDS
- EDS performs Earth orbit insertion & circularization, TLI, and LOI burns



- LSAM DS performs only lunar descent and landing
- Lunar orbit rendezvous: LSAM AS to CEV
- LOx/LH in EDS and LSAM DS
- Lox/Methane in LSAM AS and CEV



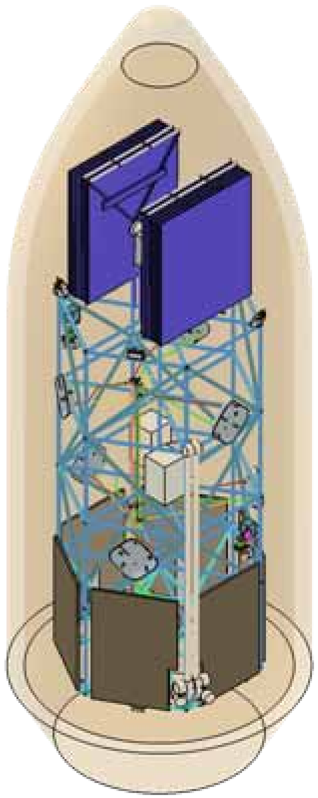
Lunar Missions Using Ares I and V or Ares V; with 51 t Landed with Depot vs. 18 t Without; or Two Sorties per Launch with Depot



- EDS mods for propellant receipt and routing to Lander
- ARPO added to EDS
- Lander struts strengthened
- 6 t increase in Lander primary structure capability at launch
- ~25 t propellant offloaded from EDS for Ares V only
- No extra payload for two-sortie missions
- Lander has propellant for two-sortie missions

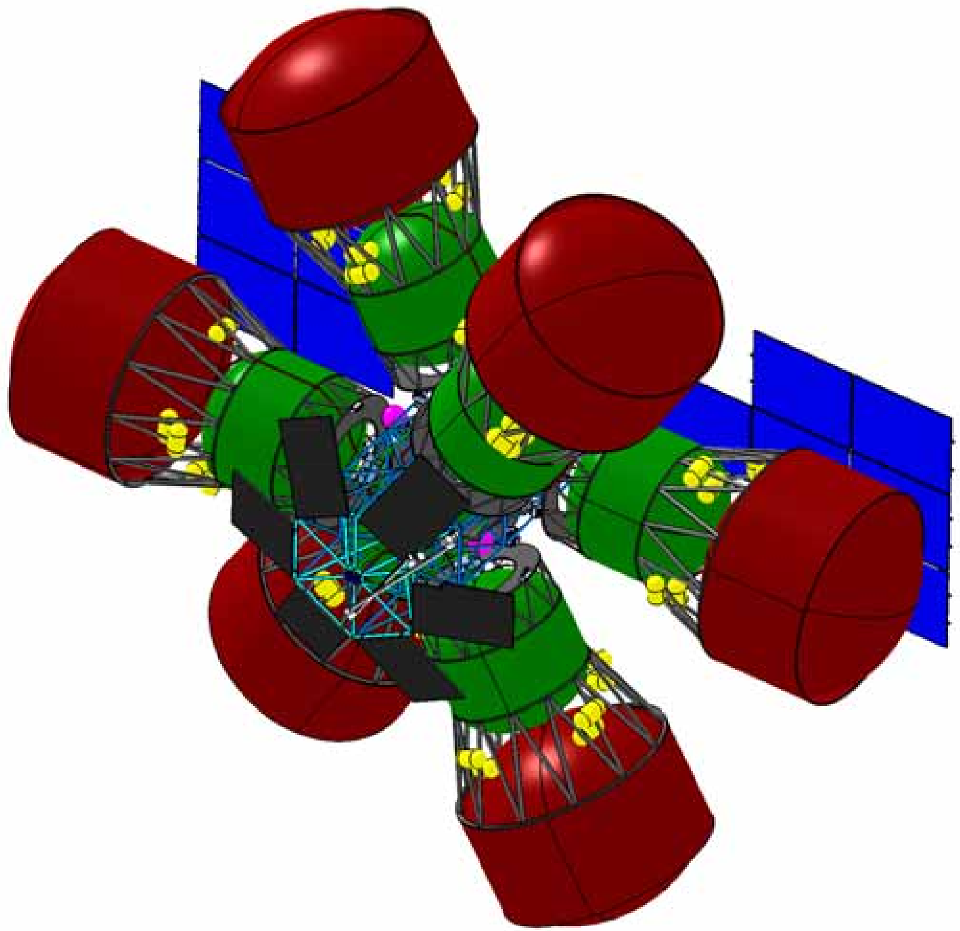
150 - 175 mt Lox/LH transferred from depot to EDS and LSAM DS

A Propellant Depot System

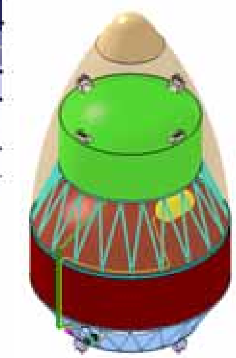


Truss in Launch Configuration

Tank Set in Launch Configuration

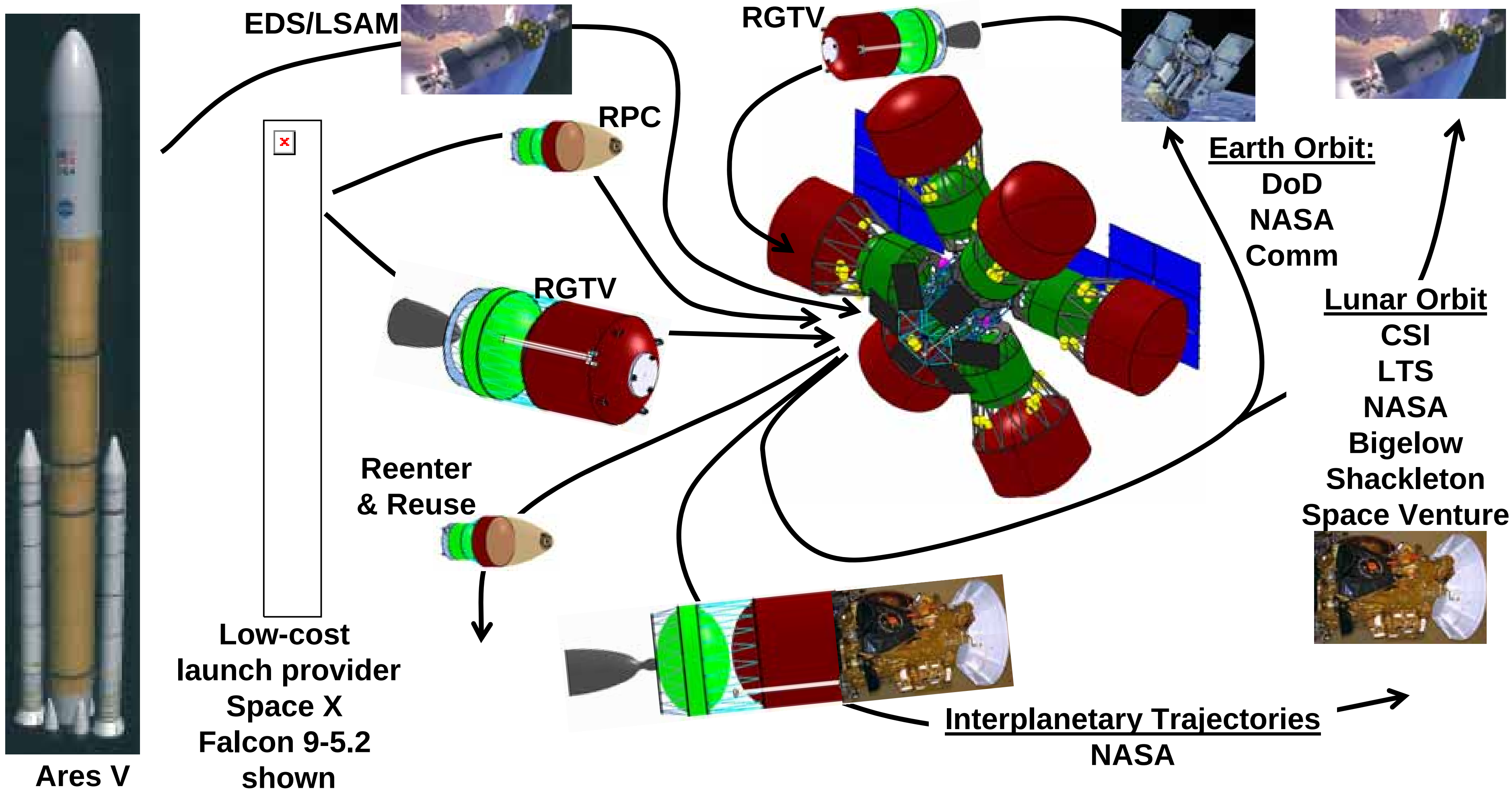


Assembled Propellant Depot in Orbit



Reusable Propellant Carrier

A LEO Propellant Depot Operational Concept: A Hub for Exploration and HEO Missions



Examples of Propellant Depot Impact on Mission Performance

	Current	With Depot
Lunar Missions		
• Landed mass	18 t	51 t
• Lunar surface payload:	2 t	35 t
• Sorties (with ESAS landed mass)	1	2
GTO mission (167 km x 35,788 km x 27°):		
• Delta IV H:	13 t	35 t
• Atlas V 551:	9 t	23 t
GSO mission		
• Delta IV H:	6 t	18 t
• Atlas V 551:	4 t	10 t
Interplanetary injection (C3 = 0)		
• Delta IV H:	10 t	20 t
• Atlas V 551:	7 t	15 t

2 – 3 times

Refueling the EDS/Lander Vehicle from Depot

- LPD RMS berths EDS & LPD
- Single mating interface
- Transfer prior to Orion mate
- Lox and LH to EDS & Lander
- ~25 t transferred to Lander
- ~125 t transferred to EDS
- 2 depots for redundancy
- 12-month depot refill cycle

Commercial Propellant Depot Risks

- Cryo fluid management technology not matured
- SpaceX fails to successfully deploy Falcon 9
- Other customers fail to materialize
- Unable to sign long-term purchase agreement
- Lunar missions cancelled, delayed or reduced rate
- Maximum LEO price less than required for minimum ROI
- NASA opts to use Ares V as tanker; accepts less capability per mission and forgoes two-sortie mission

Steps to LEO Propellant Depot

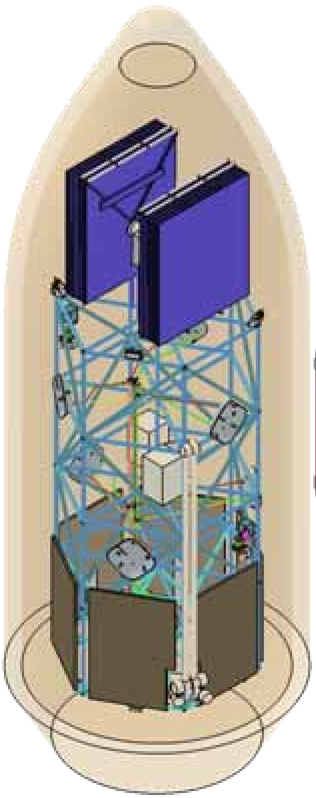
- **Mature cryo fluid management capability**
- **Successful Space Ex Falcon 9 development**
- **Mature business plan**
- **Long term propellant purchase agreements**
- **Continuation of lunar exploration/development plans**
  - NASA
  - Bigelow Aerospace
  - Shackleton Energy Company
- **Successful depot system DDT&E**

Business Case Constraints

- **$10,000/kg propellant value to NASA in LEO (Griffin, 11/05)**

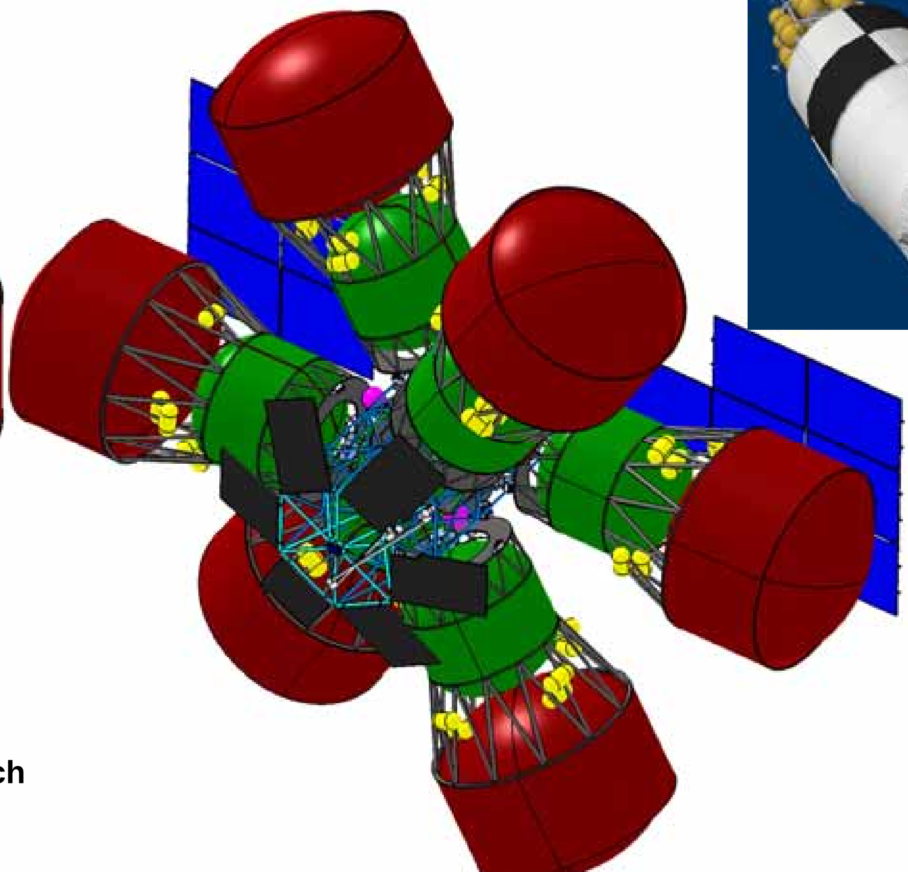
- **$3,300 – 3,600/kg to 185 km x 28.5**
  - Space X Falcon 9 and Falcon 9 Heavy with 5.2 m shroud
  - Unit launch price based on gross mass to LEO
  - www.spacex.com (July 3, 2007)

Questions?

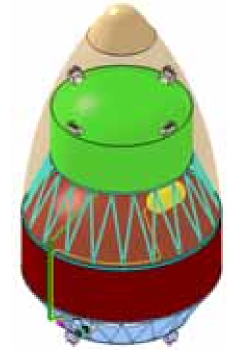


Truss in Launch Configuration

Tank Set in Launch Configuration



Assembled Propellant Depot in Orbit



Reusable Propellant Carrier