



Space Exploration

LEO Propellant Depot: A Commercial Opportunity?

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

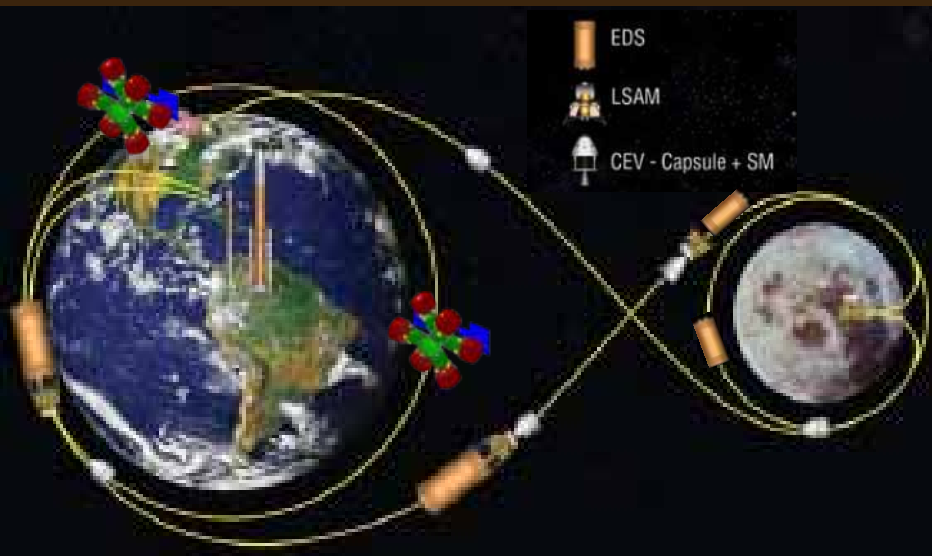
*Dallas Bienhoff
The Boeing Company
703-414-6139*

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.”**

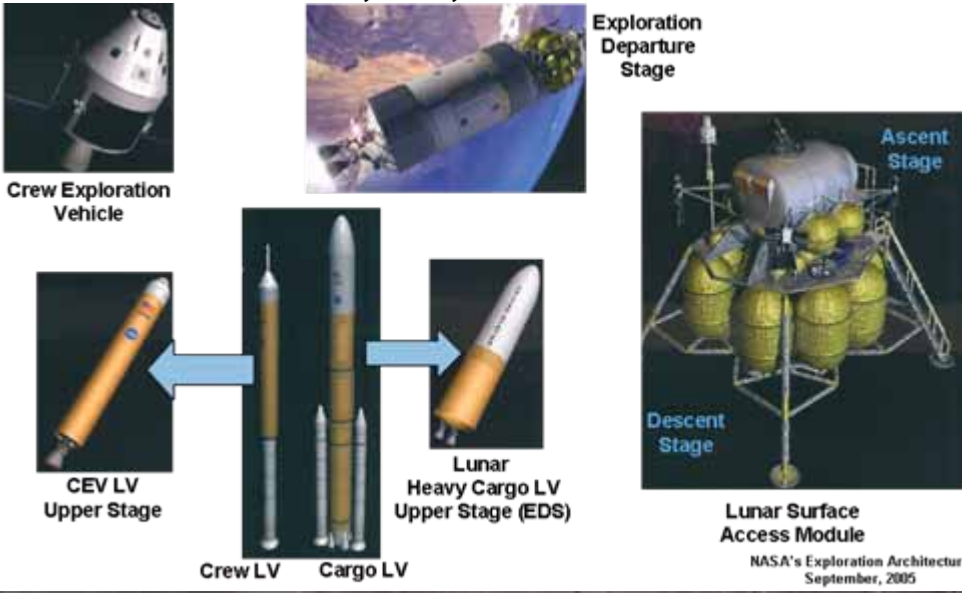
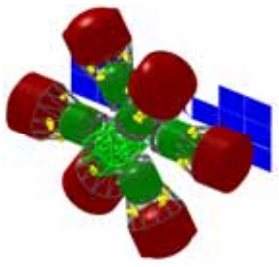
Two LEO Propellant Depots

Add Capability, Options and Resiliency



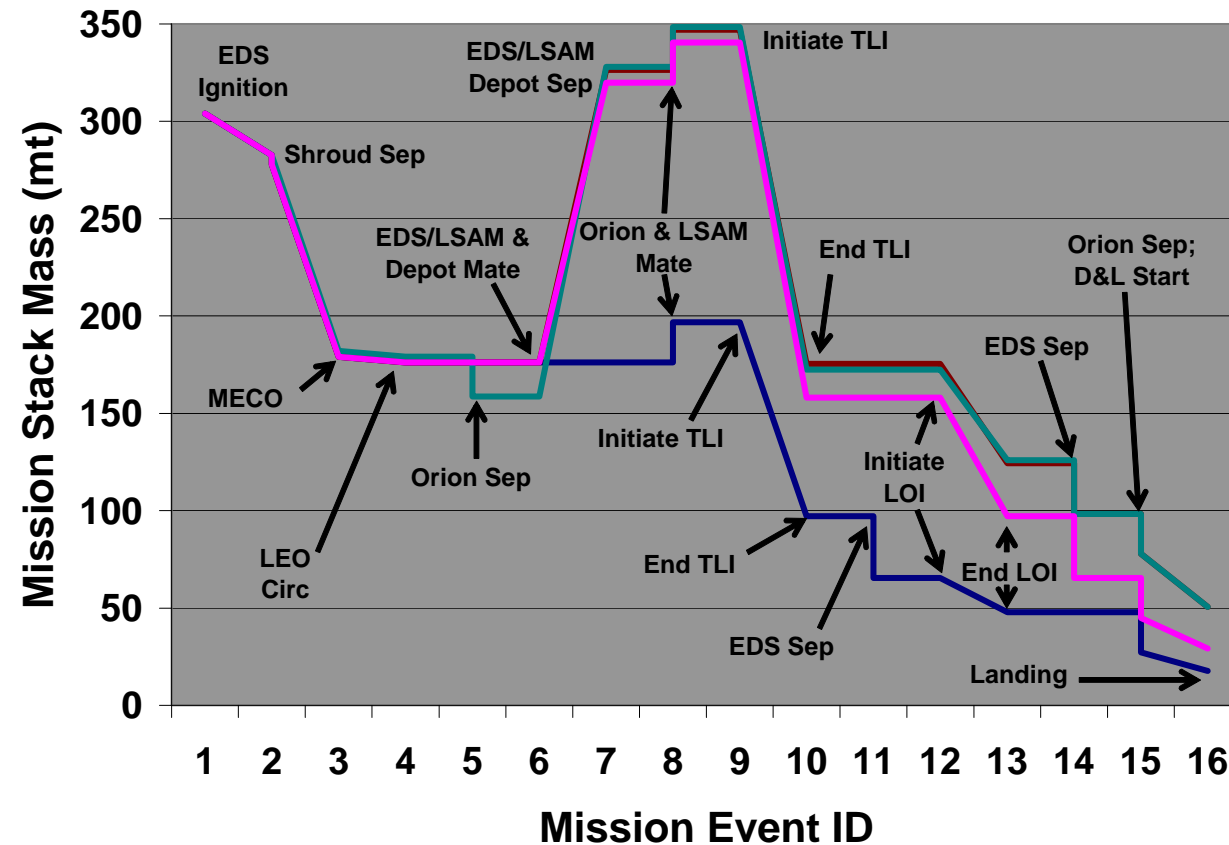
- 1.5 Launch or Single Launch architecture: Ares I & V or Ares V
- EDS & LSAM receive propellant in LEO
- Eliminates EDS & LSAM boil-off concerns
- Earth orbit rendezvous: EDS/LSAM to Depot; CEV to LSAM/EDS
- EDS performs Earth orbit insertion & circularization, TLI, and LOI burns

- 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

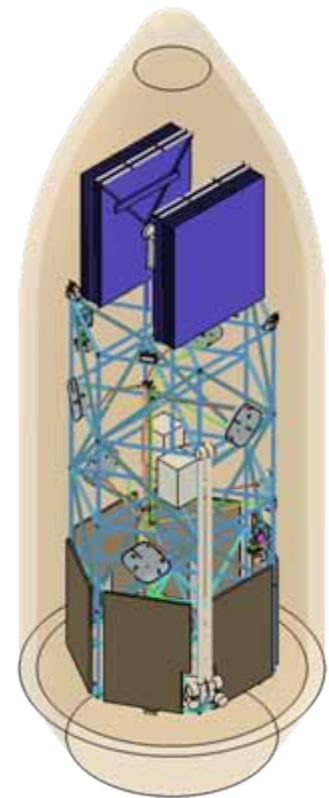
— ESAS 1.5 — ESAS 1.5 + Depot — ESAS 1.0 + Depot — ESAS 1.5 + Depot; No Extra Pyld



- 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

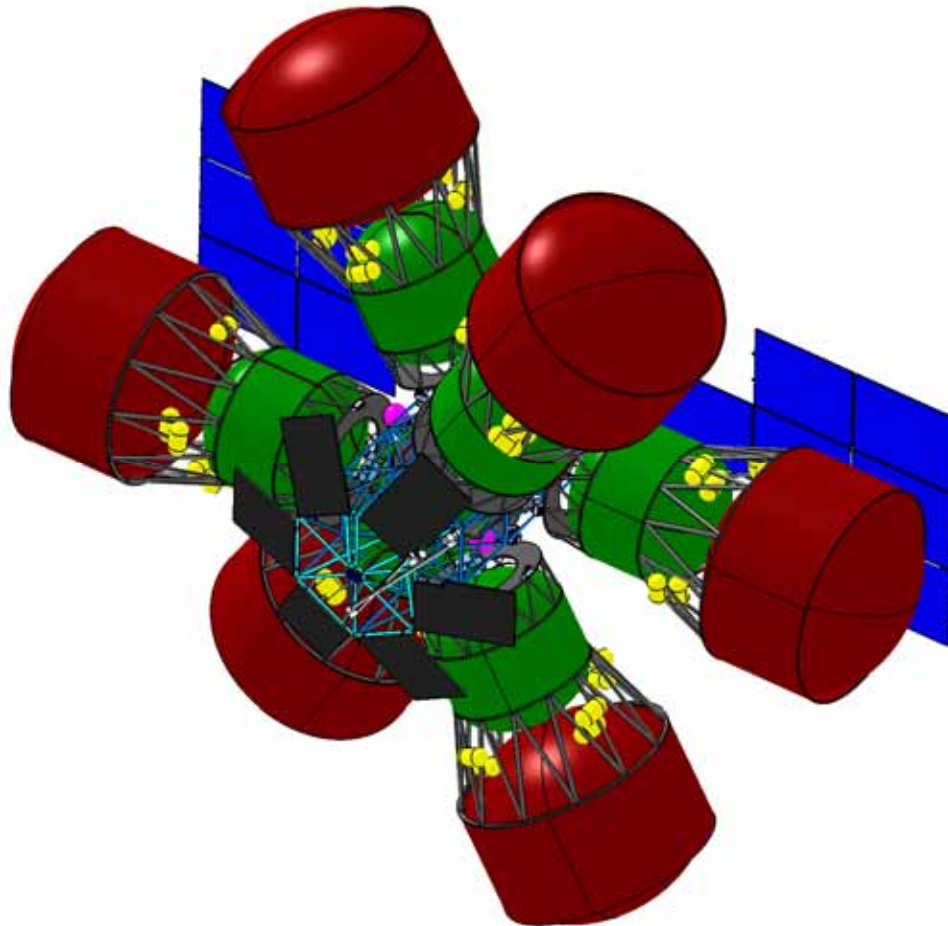
A Propellant Depot System



Truss in Launch Configuration



Tank Set in Launch Configuration

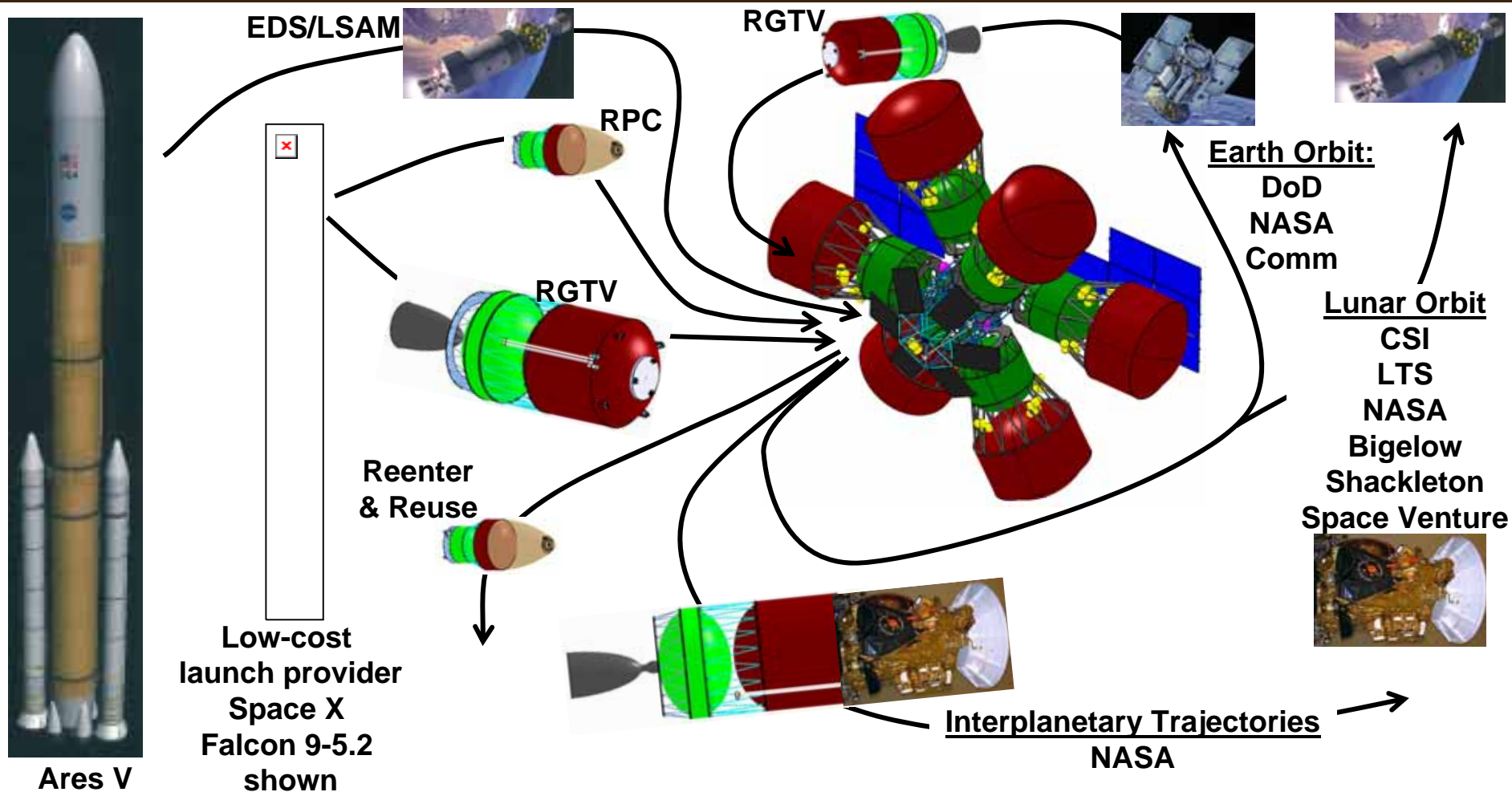


Assembled Propellant Depot in Orbit




Reusable Propellant Carrier

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



Examples of Propellant Depot Impact on Mission Performance

	<u>Current</u>		<u>With Depot</u>
● Lunar Missions			
• Landed mass	18 t		51 t
• Lunar surface payload:	2 t	2	35 t
• Sorties (with ESAS landed mass)	1	-	2
● GTO mission (167 km x 35,788 km x 27°):		3	
• Delta IV H:	13 t		35 t
• Atlas V 551:	9 t		23 t
● GSO mission		4	
• Delta IV H:	6 t	3	18 t
• Atlas V 551:	4 t	0	10 t
● Interplanetary injection (C3 = 0)			
• Delta IV H:	10 t		20 t
• Atlas V 551:	7 t		15 t

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)

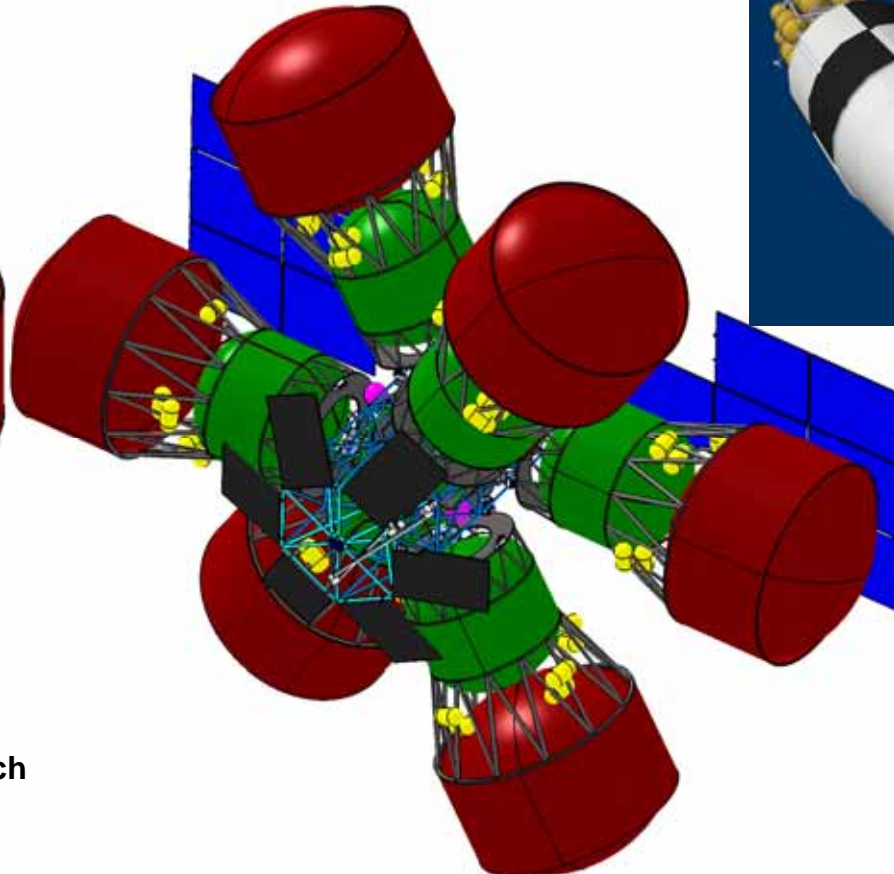
Questions?



Truss in Launch Configuration



Tank Set in Launch Configuration



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Reusable Propellant Carrier