A LEO Propellant Depot System Concept for Outgoing Exploration

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First, There was the Vision...

A Bold Vision for Space Exploration

- Complete the International Space Station
- Safely fly the Space Shuttle until 2010
- Develop and fly the Crew Exploration Vehicle no later than 2014 (goal of 2012)
- Return to the Moon no later than 2020
- Extend human presence across the solar system and beyond
- Implement a sustained and affordable human and robotic program
- Develop supporting innovative technologies, knowledge, and infrastructures
- Promote international and commercial participation in exploration

"It is time for America to take the next steps.

Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress – one mission, one voyage, one landing at a time."

President George W. Bush – January 14, 2004
Then, the ESAS Final Report.

- 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

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

ESAS Recommended Architecture (ESAS Final Report Chapter 6): Comparative Baseline

541 klbm at launch
270 klbm in LEO
Margin Payload = 19.5 klbm

• ESAS Reference provided total LSAM departure mass (44.9 t)
• LSAM stage and propellant mass calculated
• Descent Stage mass includes surface payload (~2.2 t)
• Ascent Stage mass includes crew and provisions

LSAM landed mass = 18 t
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, maximizing the utility of the inherently expensive SDHLV for carrying high-value cargo.”

“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. Of the total, about half will be propellant in the form of liquid oxygen and hydrogen, required for the translunar injection to the Moon.”

“If the Earth departure stage could be refueled on-orbit, the crew and all high-value hardware could be launched using a single SDHLV, and all of this could be sent to the Moon.”
The Exploration Architecture with a LEO Propellant Depot

- **1.5 Launch or Single Launch architecture:** Ares I & V or Ares V
- **EDS & LSAM receive propellant in LEO**
- **Earth orbit rendezvous:** 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**

**Diagram details:**
- EDS
- LSAM
- CEV + Capsule + SM

**Launch Configurations:**
- **EDS & LSAM receive propellant in LEO**
- **Earth orbit rendezvous:** CEV to LSAM/EDS
- **EDS performs Earth orbit insertion & circularization, TLI, and LOI burns**

**Diagram icons:**
- Crew Exploration Vehicle
- Exploration Departure Stage
- Ascent Stage
- Descent Stage
- Lunar Surface Access Module
- Lunar Heavy Cargo LV Upper Stage (EDS)
- CEV LV Upper Stage
A LEO Propellant Depot Concept

- 150 – 175 t capacity
- 28.5 x 400 km orbital location
- Structural spine with subsystems and interfaces
- Multiple tanks to minimize failure impact
- Micrometeorite and orbital debris protection
- Thermal and fluid management

A Modular LEO Propellant Depot
ESAS Recommended Architecture Capability with LEO Propellant Depot

ESAS Recommended Architecture (ESAS Final Report Chapter 6): Comparative Baseline

541 klbm at launch
270 klbm in LEO
Margin Payload = 19.5 klbm

- ESAS Reference Systems
- Descent Stage launched dry
- 33 t surface payload replaces 27 t propellant at launch
- EDS margin payload reduced 6 t to offset propellant and payload mass difference
- Descent Stage struts and primary structure strengthened
- Mating and propellant transfer capability added to EDS

LSAM landed mass = 50.8 t

42.6
8.2
77.8 t
69.6 t
20.6 t
541 klbm
270 klbm
19.5 klbm

[Diagram showing mass breakdown and payload distribution]
A LEO Propellant Depot System Concept with Reusable Propellant Carrier

Reversible Propellant Carrier
9400 kg total mass
LOx/LH

Reusable Transfer Stage
GTO and/or GEO delivery
LOx/LH

2 Modular Propellant Depots
150-175 t capacity
LOx/LH

Low-cost launch provider
Space X Falcon 9-3.6 shown
A LEO Propellant Depot System Concept with Depot Tug and Expendable Propellant Carrier

Depot Tug with Expendable Propellant Carrier
9400 kg EPC mass
LOx/LH

2 Modular Propellant Depots
150-175 t capacity
LOx/LH

Reusable Transfer Stage
GTO and/or GEO delivery
LOx/LH

Low-cost launch provider
Space X Falcon 9-3.6 shown
A LEO Propellant Depot Assembly Sequence – 1a

Low-cost launch
Space X
Falcon 9-5.2

Initial Launch
As Released
A LEO Propellant Depot Assembly Sequence – 2

Low-cost launch
Space X
Falcon 9-5.2

2nd Launch
A LEO Propellant Depot Assembly Sequence - 3

Low-cost launch
Space X Falcon 9-5.2

3rd Launch
A LEO Propellant Depot Assembly Sequence - 4

Low-cost launch
Space X
Falcon 9-5.2

4th Launch
A LEO Propellant Depot Assembly Sequence - 5

Low-cost launch
Space X
Falcon 9-5.2

5th Launch
A LEO Propellant Depot Assembly Sequence – 6

Low-cost launch
Space X
Falcon 9-5.2

6th Launch
A LEO Propellant Depot Assembly Sequence - 7

Low-cost launch
Space X
Falcon 9-5.2

7th Launch
A LEO Propellant Depot Assembly Sequence

Low-cost launch
Space X
Falcon 9-5.2

As Released
Deployed

Initial Launch
2nd Launch
3rd Launch

4th Launch
5th Launch
6th Launch
7th Launch
A LEO Propellant Depot Operational Concept:
A hub for Exploration and HEO Missions

Low-cost launch provider
Space X
Falcon 9-3.6 shown

Reenter & Reuse

EDS/LSAM

RGTV

RPC

Earth Orbit

Lunar Orbit

Interplanetary Trajectories
## Examples of Propellant Depot Impact on Mission Performance

### Lunar Missions
- **Landed mass**: Current - 18 t, With Depot - 51 t
- **Lunar surface payload**: Current - 2 t, With Depot - 35 t
- **Sorties (with ESAS landed mass)**: Current - 1, With Depot - 2

### GTO mission (167 km x 35,788 km x 27°):
- **Delta IV H**: Current - 13 t, With Depot - 35 t
- **Atlas V 551**: Current - 9 t, With Depot - 23 t

### GSO mission
- **Delta IV H**: Current - 6 t, With Depot - 18 t
- **Atlas V 551**: Current - 4 t, With Depot - 10 t

### Interplanetary injection (C3 = 0)
- **Delta IV H**: Current - 10 t, With Depot - 20 t
- **Atlas V 551**: Current - 7 t, With Depot - 15 t
EML1 Depot Could be Added with Lunar Propellant Production and Reusable Lander

- Enables reusable all-propulsive EDS and reusable lander
- EML1 depot supplied from any Earth space port or lunar outpost
- Reusable lander can be based at depot or lunar surface
- Earth launch reduced to Orion and mission payload
Outbound Exploration and LEO Operations Significantly Enhanced by Propellant Depots

- Lunar Exploration mission capability significantly increased
  - Triples landed mass capability of ESAS Architecture
    OR
  - Enables two lunar sorties per launch

- Provides >300 t annual propellant launch market
- 2.5 – 3.0x GTO and GSO capability for Atlas 551 and DIVH
- 2x interplanetary missions at C3 = 0
- An EML1 depot enables EDS and LSAM reusability
- An EML1 depot provides natural international staging point
References


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