Reusable Lunar Lander
Agenda

• Introduction
• Mass Allocations and Equipment List
• Lander Schematics
• Flight One and Two Sequence
• Lunar Outpost Assembly Sequence and Crew Rotation
• Conclusion
Introduction:
Reusable Lander Concept
Concept

• Instead of abandoning the Lunar Lander after ascent each flight reuse for crew change out.
• Requires several development components.
  – Propellant Transfer Module
    • Provides Delta V to CEV for LOI since LSAM is no longer part of TLI stack
    • Provides Delta V to resupply Lander for descent and ascent
    • Provides Consumables to CEV and Lander
  – Lunar outpost modules that can be stowed in Lander
• Based off Single Stage, Dual Hab design
  – concept #2 Lunar Surface Access Module Study, RFT0020.05JSC
Phased In approach

• First flight consists of CEV and Lander
  – Lander performs LOI
  – Lander deploys first Outpost Module via attached Flat Bed Transport

• Second and subsequent flights consist of CEV, PTM and Outpost Modules/Resupplies
  – CEV performs LOI with prop from PTM
Lander

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Mass Allocations: Equipment List
Mass Allocations

- **Lander**: 99,000 lb
  - Includes 10,000 outpost module capacity
- **CEV**: 50,000 lb
- **PTM**: 89,000 lb
  - Prop for CEV to perform LOI
  - Prop for Lander Descent and Ascent Resupply
  - Consumables for Lander
    - N2/O2 for cabin represses, Suit cooling H2O
- **Outpost Module #X**: 10,000 lb max
# Propellant Mass Estimates (FWD)

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**Total Propellant Weight**: 41812.9 lb
**Total Tank Weight**: 1615.4 lb
**Total Prop plus Tank Weight**: 43428.3 lb

**Total LO2 Weight**: 1313.4 lb
**Total Tank Weight**: 1643.0 lb
**Total LO2 plus Tank WI**: 2956.7 lb

**Total H2, Prop, & Tank Weight**: 46384.8 lb

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**Total Propellant Weight**: 24339.7 lb
**Total Tank Weight**: 912.2 lb
**Total Prop plus Tank Weight**: 25251.9 lb

**Total LO2 Weight**: 764.8 lb
**Total Tank Weight**: 1152.8 lb
**Total LO2 plus Tank WI**: 1916.6 lb

**Total H2, Prop, & Tank Weight**: 21168.4 lb

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**Total Propellant Weight**: 9047.5 lb
**Total Tank Weight**: 361.1 lb
**Total Prop plus Tank Weight**: 9408.6 lb

**Total LO2 Weight**: 284.2 lb
**Total Tank Weight**: 603.6 lb
**Total LO2 plus Tank WI**: 887.8 lb

**Total H2, Prop, & Tank Weight**: 10296.3 lb

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*If estimates are correct only 5150 lb for all Lander systems except prop wet mass*
### Propellant Mass Estimates (Back)

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Lander Performs LOI Burn
Trans Lunar Stack 176,910
Post LOI Burn 128,954
TLI Constraint 149,000
Lander Allocation 99,000
Margin -27,910

Includes 50,000 for CEV
Lander Systems

• Propulsion
  – 4 +Z Direction 10Klb engines
    • Lunar Descent and Ascent
  – 4 +X Direction 10lkb engines
    • For LOI and Deorbit Burn
    • Allows for g loads eyeballs in for LOI
  – 4 RCS Quads located on Engine Pods
    • 870 lb engines for attitude control and translation
  – 4 RCS Tris located on Engine Pods
    • 870 lb engines for attitude control and translation
  – Tanks not optimized for size and shape
    • 3 He tanks
    • 7 Lox tanks
    • 7 CH4 tanks
Lander Systems

• GNC
  – 3 IMUs
  – 2 Star Camera for IMU alignments
  – RNDZ Sensors
    • IROC
    • SROC
    • LROC
    • Lidar
    • Aux Computers for image processing
    • Transponders for comm with CEV or outpost
    • Sensor redundancy is covered by the CEV that can rescue Lander for failed rndz
  – Descent Sensors
    • Ground Proximity sensors
    • Ground Radar

• Power
  – Solar Arrays
    • It may be possible to oversize solar arrays such that post landing crew can remove arrays for use in outpost solar array farm
  – Battery backup for night pass and supplement arrays during peak loading
  – Three redundant buses
Lander Systems

• DPS
  – 3 Computers
  – BIUS
  – AUX computers for rndz sensor navigation
  – 1553 Data Bus

• ECLSS
  – Consumables to support two cabin depress/repress cycles
    • Nominally should only require one depress post descent and then repress for ascent
  – Suit Cooling and Recharge capabilities
  – Resupply consumables from PTM

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Lander Schematics
Lander

- Descent/Ascent Cockpit with LIDS
- Lunar Orbit Insertion/Deorbit Engines (10klb): QTY 4, 2 per AFT Pod
- Lunar Descent/Ascent Engine (10klb): QTY 4, 1 per Pod
- RCS Quad Engines (870 lb)
- RCS TRI Engines
- RMS
- Propellant tanks
- Propellant pressurization tanks
- Solar array panels
- Propellant tanks
- Lunar Outpost Module on flatbed
- Descent/Ascent consumables tanks
- Landing gear: 4 struts per pod
AFT Engine Pods

Two Gimbaled 10 klb Engines

RCS Quad
870 lb

RCS Tri
870 lb

Gimbaled 10 klb Engine

+X
+Y
+Z

www.nasawatch.com
FWD Engine Pods

RCS Quad
870 lb

RCS Tri
870 lb

Gimbaled 10lkb Engine
FWD Engine Pods Internal

- LROC Sensor (port pod)
- LIDAR (starboard pod)
- IROC Sensor (port pod)
- SROC Sensor (starboard pod)
- RNDZ Sensor Electronics
- Ground Proximity Sensor
- Battery
- BIU
- RNDZ Aux Computer
- RCS Driver Electronics
- Gimbal Electronics
- www.nasawatch.com
Cockpit Internal Side View

- Lids
- Cockpit Displays
- Star Tracker
- Computer
- Crew member in Eva Suit for Landing
- Propellant Transfer Lines
- O2 Tank
- IMU
- Ground Radar
- Porch and Ladder in Stowed Position
Flat bed Transport

- Outpost Solar Array Panel stowed in Flatbed
- Flat Bed Attach Point
- RMS
- Hatch to non-pressurized cockpit
- Computer
- Solar Array Panel
- Battery
- Electric Drive
- Plow attachment for regolith movement
- Suit H2O Supply tank for extended rover ops
- Suit O2 Supply tank for extended rover ops
- Transport can be used without flat bed for rover ops

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Flight Sequence:
Flights Ones and Two
Flight One

Lander performs Lunar Orbit Insertion with 4 AFT Engines
Flight One

Lander Releases Outpost Module and flat bed

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Flight One

flat bed deploys Outpost Module with RMS

Lunar Regolith for Shielding

www.nasawatch.com
Flight Two

Outpost Module #2

PTM with DeltaV for LOI and Lander resupply

CEV2 with Crew Rotation

CEV2 Performs Lunar orbit Insertion

www.nasawatch.com
Flight Two

CEV2 with Crew Rotation

PTM with DeltaV for LOI and Lander resupply

Outpost Module #2

CEV2 Station keeps with CEV1 awaiting Lander

CEV1
Flight One Termination

Crew egresses outpost and takes off in Lander

Solar Array Farm

Lunar Regolith for Shielding

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CEV2 Station keeps with CEV1
Lander docks to outpost module #2
Crew Rotation

CEV2 with Crew Rotation

CEV2 Station keeps with CEV1
Lander grapples outpost module #2
Crew Rotation

CEV2 with Crew Rotation

CEV2 Station keeps with CEV1
Lander with outpost module #2 grappled undocks at PTM separation plane
Crew Rotation

CEV2 with Crew Rotation

CEV2 Station keeps with CEV1
Lander stows outpost module #2
CEV2 with Crew Rotation

CEV2 Station keeps with CEV1 Lander
PTM redocks with PTM
PTM resupplies Lander with propellant and consumables
CEV2 crew modes CEV2 to loiter and ingresses PTM
CEV1
**Crew Rotation**

CEV2 Station keeps with CEV1

Lander undocks with CEV2 at CEV separation plane

CEV2 crew flies Lander while CEV1 crew loiters in PTM
Crew Rotation

CEV2 Station keeps with CEV1
Lander docks with CEV1 with PTM attached
CEV1 crew powers up CEV1
Crew Rotation

CEV2 Station keeps with CEV1
Lander undocks with CEV1 at PTM separation plane
CEV1 crew preps CEV1 for TEI
CEV2 crew performs Lunar Descent in Lander
Flight Two Lunar Surface

Crew egresses Lander and ingresses flat Bed

Solar Array Farm

Lunar Regolith for Shielding

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Flight Two Lunar Surface

Flat bed extracts Outpost Module #2 from Lander

Lunar Regolith for Shielding

www.nasawatch.com
Flight Two Lunar Surface

Flat bed installs Outpost Module #2

Lunar Regolith for Shielding

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Lunar Outpost: Assembly Sequence and Crew Rotation
Lunar Outpost

Solar Array Farm

Airlock

Regolith Berm for radiation shielding

Node

Mini Supply Module

Future Add-on Point

Two Landers allows 8 person Outpost crew rotating 4 crew members every 3 months
# Assembly Sequence and Crew Rotations

**[Jan 2016-April 2017]**

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Assembly Sequence and Crew Rotations
[Jan 2017-April 2018]

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<td>Node 2 &amp; MSM</td>
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</tr>
<tr>
<td>Outpost Module #4</td>
<td>Outpost Module #4</td>
<td>Outpost Module #5</td>
<td>Outpost Module #5</td>
<td></td>
</tr>
<tr>
<td>PTM #2</td>
<td>PTM #3</td>
<td>PTM #4</td>
<td>PTM #4</td>
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</tr>
</tbody>
</table>

**NOTE:**
It may be possible to send a third Lander with Node 2 & MSM which could be used for surface flying. Would also need surface refueling capability which could be Crew 8’s payload.
Conclusion
Total Mass Rollup

- Prop Dry: 10,000 lb excluding valves/manifolds
- GNC: 100 lb
- DPS: 200 lb excluding wiring
- Power: 2,000 lb
- LIDS: 1,000 lb
- Crew: 1,280 lb (4 crew, suits and accommodations)
- RMS: 1000 lb
- ECLSS: ?
- Structure: ?
- ATCS: ?
- Total: CBE 20,000 (15,580 + ?) not including 10,000 for OM (outpost module)
- Lander total:
  - CBE+ OM+PROP (fwd) = 107500 (8,500 Negative Margin)
    - Prop wet mass for Lander: ~77500
  - CBE+ OM+PROP (Back) = 126,910 (28,000 Negative Margin)
    - Prop wet mass for Lander: ~96,910
Conclusion

• Reusable Lander is Not closed Design
  – Significant Negative Margin (8,500-28,000)

• Limits of current design
  – Based on limited tools from Smart Buyer Effort
    • Prop Sizing Generic 6.xls for prop budget
    • CEV SBT Master Workbook for equipment mass
  – Based on limited engineering development
    • MOD notional concept based on Smart Buyer experience

• Is concept viable?
  – Necessitates further study