Enhanced Feasibility Assessment of Payload Adapters for NASA’s Space Launch System

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• **Challenge**
  - Development of 8.4m diameter Space Launch System (SLS) requires new family of 8.4m Payload Adapters (PLA)
  - SLS PLAs need to accommodate unique requirements (relative to existing launch vehicles) including payload types, sizes, mass, and trajectories

• **Solution**
  - Iterative PLA design approach to optimize performance, reduce mass, increase potential model reusability

• **Approach**
  - Apply a Model Based System Engineering (MBSE) approach to managing data flow through PLA design-analyze-build process
AGENDA

• **Part 1**
  – Understand the unique payload accommodation requirements of SLS PLA
  – Establishes trade study constraints

• **Part 2**
  – Discuss results of NASA Engineering and Safety Center (NESC) - sponsored PLA MBSE pathfinder
  – Conclusions
  – Future Work
SLS BLOCK CONFIGURATIONS

SLS Block 1
>26t to TLI
(No Earlier than 2020)

SLS Block 1B
34 - 40t to TLI
(No Earlier than 2024)

SLS Block 2
>45t to TLI
(No Earlier than 2029)

OSA - Orion Stage Adapter
ICPS - Interim Cryogenic Propulsion Stage
PLF - Payload Fairing
EUS - Exploration Upper Stage
USA - Universal Stage Adapter
PPL - Primary Payload
CPL - Co-manifested Payload
SPL - Secondary Payload
SLS PAYLOAD MISSION CAPTURE

- **Lunar**
- **Mars**
- **Jupiter/Europa**
- **Saturn via JGA**
- **Saturn/Uranus/Neptune Direct**

**Existing Expendable Launch Vehicles**

*Based on publically available data

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www.nasa.gov/sls
• **Shorter Transit Times to Destination**

• **Europa Clipper**
  – Desired launch date of June 2022
  – Jovian system transit time reduced by 65% over existing launch vehicles
  – Reduced mission operations cost over time

<table>
<thead>
<tr>
<th>Earliest Launch</th>
<th>Cruise:</th>
<th>Jupiter Orbit Insertion</th>
<th>Jovian System Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Period</em>: 6/4/22 - 6/24/22 (SLS)</td>
<td>2.5 Years (SLS)</td>
<td>12/24/24 or 5/1/25 (SLS)</td>
<td>Prime Europa Flyby Campaign: 36 months</td>
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</tbody>
</table>

Current LVs SLS

C3=15 km²/s²

2 Earth Flybys

C3=82 km²/s²

0 Earth Flybys

Earliest Launch

Cruise:

Jupiter Orbit Insertion

Jovian System Operations

SLS
• **Up to 5 times greater mass to orbit capability than current launch systems**
  – Increases payload mass margins
  – Offers range of injection propulsion options

• **New Horizons**
  – SLS would have doubled delivered payload mass to Pluto

• **Europa Lander**
  – 16 mT delivery to outer planets (with margin)
• **Up to 6 times greater volume available**

• **Multiple payload combinations**
  – Dual manifesting within fairing
  – Payload constellations
  – More powerful injection stages

• **Telescopes**
  – Larger payloads translate into simpler orbital operations (fewer deployments)
RANGE OF PAYLOAD ENCLOSURE

Conceptual

<table>
<thead>
<tr>
<th>Enclosure</th>
<th>5.1m PLF</th>
<th>5.1m PLF</th>
<th>OSA</th>
<th>8.4m USA</th>
<th>8.4m USA PLF</th>
<th>8.4m PLF, Short</th>
<th>10m PLF, Short</th>
<th>8.4m PLF, Long</th>
<th>10m PLF Long</th>
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<tbody>
<tr>
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<td>5m PPL</td>
<td>5m SPL</td>
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<td>8.4m PPL</td>
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<td>10m PPL</td>
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COTS: Commercial Off-the-Shelf  CPL: Co-manned Payload  OSA: Orion Stage Adapter  PPL: Primary Payload
SPL: Secondary Payload  PLF: Payload Fairing
SLS 8.4m PLA CONCEPT

Payload Adapter (PLA)

PAF Outer Surface

27U Secondary Payload & Deployment System

Secondary Payloads Support Structure (Bolted to Inserts in PAF)

Camera

Cable Harnesses

Vent Valves

Utilities Feed Through plate

12U Secondary Payload & Deployment System

Secondary Payloads Support Structure (Bolted to Inserts in PAF)

Camera

USA/PLF I/F

EUS I/F

Secondary Payload Deployment Sequencer/Battery
• Gather stakeholder requirements from existing documents and COTS specifications

• Develop User Interface (UI) to capture PLA accommodation attributes, such as payload destination, mass, width, height, potential loads, etc.

• Requirements and user data represented as a CAD model
  – Needed updates to PLA design will be by parameter modifications
  – Loads/stress analyses made within CAD modeling function
  – Results are exported along with any parameter updates into a SysML MagicDraw model

• Model verification will indicate that requirements were successfully verified and which were not
Pathfinder Findings

- Benefits:
  - Outward facing GUI for capture of SLS payloads
  - Automated concept design of PL integrated to SLS
  - Demonstrated MBSE to MBE for design and mfg.
  - Minimizes error from manual steps in integration
  - Matures design to higher fidelity quickly

- Next Step: Develop front-end SLS user interface within existing SLS Mission Planners Guide

Technical Challenge

SLS engineering resources insufficient to evaluate 10’s-100’s of optimized PL adapter options for SLS users over life of program

MBSE Challenge

Develop User Interface to feed MagicDraw parameters into CAD/analytical model and verify requirements were met by PL adapter concept
• NASA is moving toward more digitally integrated solutions that span life-cycle from concept to manufacturing

• Unique scale of SLS and associated payload accommodation options benefits from a MBSE PLA approach
  – Partial “automation” of analysis cycle provides analysts with a 75% fidelity answer at the beginning of their detailed analysis
  – Allows potential users to “self analyze” accommodation feasibility on SLS sooner
  – Provides SLS with enough fidelity to determine feasibility of optimizing payload complement sooner
    • Insight into whether existing PLA design is sufficient or use of new design is worth performance enhancement investment
    • Ability to accommodate single payload or fly multiples on one mission
    • Opportunity to trade performance to destination for different payloads
FUTURE WORK

• Compare MBSE finding to the full range of NASA missions ranging from Super Heavy to Sounding Rocket launch vehicles as well as Habitat to Nanosat spacecraft.

• Understand where MBSE provides the biggest return soonest
  – Determine where models and data can flow most easily and efficiently
  – Application should include internally to a launch vehicle or spacecraft as well as externally across a range of launch vehicle and spacecraft delivery providers.

• Ultimate goal is more detailed design/analysis improvements earlier resulting in less re-work across not only physical interfaces, but the entire federated infrastructure.