Heavy Lift Capability with a New Hydrocarbon Engine (NHE)

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Agenda

• MSFC ACO Overview
• Study Objective/Approach
• Heavy Lift Concept Configurations
• Configurations Derived from the LRB
• Effect of Engine Out on 100 MT Configuration
• Summary
We Are An Office Specializing In Pre-Phase A & Phase A Concept Definition

- Human Exploration Systems
- In-Space Transportation and Science Systems
- Launch Vehicle Systems
Launch Vehicle Design Process

Note: Cost and Reliability Analyses were not performed for this study
Determine the thrust requirement for a new LOX Rich Stage Combustion Kerosene (RP) Engine that can lift 100 MT to LEO in a 2 Stage series configuration… and by adding strap-on LRBs with the same engine lift 140 MT using common stages to minimize design and development costs. Evaluate other potential concepts derived from the engine/stages.
Launch Vehicle Architecture and Element Commonality Approach Using NHE

Thrust Trades (1.0 Mlbf Vac – 1.3 Mlbf Vac Class)

NASA Heavy Lift 1
100 MT

Design for Common 2\textsuperscript{nd} Stage with J-2X-285

NASA Heavy Lift 2
140 MT

Design for Common 1\textsuperscript{st} Stage Add LRBs for increased Payload Requirements

Single Engine LRB Could become 1\textsuperscript{st} Stage In New Launch Vehicle

Potential Use in New Reusable First Stage for Air Force

Not Analyzed in this Study

Potential DoD / Commercial Application

Potential Use in New

NHE
General Top Level Ground Rules and Assumptions

- Vehicle Stages up to 33 ft diameter
- Vehicle not higher than 390 ft
- Thrust / Weight at liftoff not less than 1.2
- NHE engine thrust to not exceed 1.3 Mlbf vacuum
- Ascent axial acceleration to not exceed 5.0 g
- NHE has continuous throttling capability
- Second Stage is LOX/LH2 using J2X-285

**NHE Engine Assumptions**

- Vac Isp: 332 s
- T/W = 70
- Mixture Ratio: 2.7
- Engine Length: 180 in.
- Engine Nozzle Diam: 120 in.

* Engine Assumptions Provided by ER21 Propulsion Team at MSFC
Payload to LEO as a Function of First Stage Thrust at Liftoff

For 100 MT Capability with Six First Stage Engines, NHE Thrust Requirement is 1.08 Mlbf @ SL / 1.25 Mlbf @ Vac per Engine

\[ y = 1.817817E-05x - 1.297062E+01 \]
\[ R^2 = 9.970072E-01 \]
## Heavy Lift Vehicle Results

### Vehicle Data

<table>
<thead>
<tr>
<th>140 MT</th>
<th>100 MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.22 Mlb</td>
<td>5.42 Mlb</td>
</tr>
<tr>
<td>GLOW</td>
<td></td>
</tr>
<tr>
<td>33.2 Klb</td>
<td>33.2 Klb</td>
</tr>
<tr>
<td>Shroud</td>
<td></td>
</tr>
<tr>
<td>112 Klb</td>
<td>112 Klb</td>
</tr>
<tr>
<td>2nd Stage Dry Wt.</td>
<td>2nd Stage Dry Wt.</td>
</tr>
<tr>
<td>4.07 Mlb</td>
<td>3.69 Mlb</td>
</tr>
<tr>
<td>1st Stage Prop.</td>
<td>1st Stage Prop.</td>
</tr>
<tr>
<td>91.8 Klb</td>
<td>91.8 Klb</td>
</tr>
<tr>
<td>LRB Dry Wt.</td>
<td></td>
</tr>
<tr>
<td>501 Klb</td>
<td>501 Klb</td>
</tr>
<tr>
<td>LRB Prop.</td>
<td>LRB Prop.</td>
</tr>
<tr>
<td>143.7 MT</td>
<td>104.2 MT</td>
</tr>
<tr>
<td>Payload</td>
<td></td>
</tr>
</tbody>
</table>

(Emphasizing Commonality)

- **1st Stage LOX/RP**: 6 – NHE
- **2nd Stage LOX/LH2**: 4 – J-2X-285
- **LRB LOX/RP**: 1 – NHE
Launch Vehicles from the NHE LRB

New Launch Medium Class Launch Capability Could Be Derived from the LRB Used as a first stage in a series burn concept.

- **1st Stage**
  - LOX/RP
  - 1 – NHE

- **2nd Stage**
  - LOX/LH2
  - 1 – J-2X-285

Payload:
- 11.5 MT LEO
- 4-7 MT GTO depending on structural design

Propellant:
- 1st Stage Propellant – 719 Klb
- 2nd Stage Propellant – 902 Klb

- **GLOW**
  - 901 Klb
  - 12.9 MT LEO

- **1st Stage Propellant – 501 Klb**

Modify LRB by Increasing Propellant Load

Use LRB as is Remove Nosecone
## Engine Out Capabilities of the 100 MT Vehicle

<table>
<thead>
<tr>
<th></th>
<th>Nominal</th>
<th>2nd Stage EO</th>
<th>1st Stage EO</th>
<th>EO Both Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLOW</td>
<td>5.42 Mlb</td>
<td>5.42 Mlb</td>
<td>4.51 Mlb</td>
<td>4.51 Mlb</td>
</tr>
<tr>
<td>2nd Stg Dry Mass</td>
<td>112 Klb</td>
<td>112 Klb</td>
<td>112 Klb</td>
<td>112 Klb</td>
</tr>
<tr>
<td>2nd Stage Prop</td>
<td>955 Klb</td>
<td>655 Klb</td>
<td>963 Klb</td>
<td>656 Klb</td>
</tr>
<tr>
<td>2nd Stg % Offload</td>
<td>12.1% Offload</td>
<td>40.0% Offload</td>
<td>11.4% Offload</td>
<td>39.6% Offload</td>
</tr>
<tr>
<td>1st Stg Dry Mass</td>
<td>337 Klb</td>
<td>337 Klb</td>
<td>337 Klb</td>
<td>337 Klb</td>
</tr>
<tr>
<td>1st Stg prop</td>
<td>3.69 Mlb</td>
<td>4.02 Mlb</td>
<td>2.83 Mlb</td>
<td>3.17 Mlb</td>
</tr>
<tr>
<td>1st Stg % Offload</td>
<td>9.5% Offload</td>
<td>1.3% Offload</td>
<td>30.5% Offload</td>
<td>22.2% Offload</td>
</tr>
<tr>
<td>Payload LEO</td>
<td>104.2 MT</td>
<td>89.0 MT</td>
<td>77.9 MT</td>
<td>65.1 MT</td>
</tr>
</tbody>
</table>
Summary

• A Family of Launch Vehicle Concepts can be Derived from a New Hydrocarbon Stage Combustion Engine (NHE) to Meet Future Civil, Military, and Commercial Space
  – NHE Thrust Requirement Determined at 1.25 Mlbf @ Vacuum
  – Heavy Lift Capability in the 100 MT – 140 MT Class Defined
  – ELV Payload Class Capability with Single NHE

• Stage Commonality Can Be Utilized and Still Meet Performance Requirements
  – Reduced Development, Manufacturing, and Operations Costs

• Missions Can Be Flown with Engine Out For Crewed Flights or High Value Payloads For Increased Launch Reliability
  – Payload Capabilities of 65 MT to Nearly 90 MT can Still be Obtained with the 100 MT Vehicle Depending on the Amount of Engine Out is Desired