Next Generation
Solid Boosters

R. K. Lund
27 June 1990
Space Transportation Solid Rocket Motor Systems

Large Launch Booster

Small Launch Vehicle

Reusable Flyback Booster System

Space Propulsion Motor

Thiokol Corporation

Large Launch Solid Rocket Boosters

- Concept objectives:
  - Reduce booster costs to $5-6/lbm of booster weight (60% decrease)
  - Increase booster reliability and safety (demonstrate 0.999X reliability/booster)
  - Clean propellant exhaust (no HCl)

INFORMATION ON THESE PAGES WAS PREPARED TO SUPPORT AN ORAL PRESENTATION AND CANNOT BE CONSIDERED COMPLETE WITHOUT THE ORAL DISCUSSION
Shuttle-Derived Heavy Lift Launch Vehicles

<table>
<thead>
<tr>
<th>Booster</th>
<th>2 ASRBs</th>
<th>2 ASRBs</th>
<th>4 ASRBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Stage</td>
<td>Standard ET</td>
<td>Standard ET</td>
<td>32.9 ft dia</td>
</tr>
<tr>
<td>Core Propulsion</td>
<td>3 SSMEs</td>
<td>3 SSMEs</td>
<td>Recoverable P/A With 5 SSMEs</td>
</tr>
<tr>
<td>Payload Envelope</td>
<td>15.1 ft dia</td>
<td>24.9 ft dia</td>
<td>41 ft dia</td>
</tr>
<tr>
<td>92 ft length</td>
<td>89.9 ft length</td>
<td>96.4 ft length</td>
<td></td>
</tr>
</tbody>
</table>

Net Payload .................................. 71 t .......................... 61 t .............................. 140 t

Booster Thrust (klb) .................. 8460 .......................... 6600 .............................. 12600

Payload (klb) .................. 88 .......................... 117 .............................. 250

ALS-Derived Heavy Lift Launch Vehicles
### Enabling Technologies

<table>
<thead>
<tr>
<th>Design</th>
<th>Process/Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Reliability</td>
</tr>
<tr>
<td>Nose cone</td>
<td>Stiffened shell</td>
</tr>
<tr>
<td>Forward skirt extension</td>
<td>Stiffened shell</td>
</tr>
<tr>
<td>Forward attach structure</td>
<td>Pivot</td>
</tr>
<tr>
<td>Case/skirts</td>
<td>Monolithic</td>
</tr>
<tr>
<td></td>
<td>Integral aft dome</td>
</tr>
<tr>
<td></td>
<td>Symmetric aft opening</td>
</tr>
<tr>
<td>External insulation</td>
<td>Variable thickness</td>
</tr>
<tr>
<td>Internal insulation</td>
<td>Single material</td>
</tr>
<tr>
<td></td>
<td>Flapless</td>
</tr>
<tr>
<td>Propellant/grain</td>
<td>Slotted CP</td>
</tr>
<tr>
<td>Aft attach structure</td>
<td>Aft and thrust reaction</td>
</tr>
<tr>
<td></td>
<td>Truss structure</td>
</tr>
<tr>
<td>Aft skirt extension</td>
<td>Stiffened shell</td>
</tr>
<tr>
<td>Nozzle</td>
<td>Submerged centerline</td>
</tr>
<tr>
<td></td>
<td>Canted boss</td>
</tr>
<tr>
<td></td>
<td>Symmetric nozzle</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Ignition/ordnance</td>
<td>Pyrogen/laser-initiated</td>
</tr>
<tr>
<td></td>
<td>igniter</td>
</tr>
<tr>
<td></td>
<td>Forward dome</td>
</tr>
<tr>
<td></td>
<td>termination</td>
</tr>
</tbody>
</table>

### S.A.F.E.R<sup>sm</sup> Philosophy

Statistical Analysis for Engineering Reliability

- Link reliability and producibility to affect design
- Conduct design to meet allocated reliability
  - Estimate design reliability based on estimated performance and capability distributions
  - Base capability distribution on historical test data and established requirements
  - Develop approach to estimate performance distribution from standard engineering models
- Link process control variables and key design variables to critical failure modes
- Establish test program to demonstrate reliability (tailor test data to establish capability and performance distributions)
Independent Performance and Capability Distributions Combined Into One Failure Distribution: \( X = C - P \)

Small Launch Vehicle Concept Objectives

- Provide family of small launch vehicles to increase user flexibility in delivering a broad range of payloads (600 to 2,000 lb) into LEO
  - Remote sensing satellites
  - Communication and scientific research satellites
  - Recoverable capsules for industrial applications
- Retain high reliability of military systems
- Vehicle family based on basic motors (building blocks) derived from current strategic motor systems
- Minimize launch operations relating to vehicle
- Provide resiliency and responsiveness to launch on alert
Small Launch Vehicle Concept

650 lbm  800 lbm  1,200 lbm  1,400 lbm

Payload (250-nmi polar orbit)

Small Launch Vehicle Enabling Technologies

Integrated Technologies

Improved Manufacturing Processes
Optimized Designs for Low Cost
Efficient Program Management
Launch Operations Consideration

Standardized Materials and Specifications
Inherent High Reliability of "Solid" Motors Maintained
Building Block Vehicle Concept
Minimum Cost Per Pound of Payload into Orbit

Thiokol CORPORATION
Reusable Flyback Booster System

- Concept objectives:
  - Solid rocket or hybrid propulsion
  - Booster transportation system for manned shuttle II and unmanned cargo carriers
  - Vertical launch, horizontal landing
  - Short turnaround cycle time
  - No preflight assembly required (load fuel and launch)
  - Lower recurring cost

- Enabling technologies:
  - Composite cases, struts, and wings
  - Cartridge-loaded propellant (SRM) or fuel (hybrid) grains
  - Integral removable aft dome/nozzle/skirt for quick fuel loading
  - Quick-change moldable nozzle insert or completely reusable (3–5 flights) advanced ceramic, passively cooled nozzle

High-Performance Solid Motors for Space

- Concept objectives
  - High-performance space propulsion system for:
    - Mars and lunar ascent propulsion
    - Orbit transfer propulsion
    - Long space storage capability
    - High $I_{sp}$ performance
    - High mass fraction performance

- Enabling technologies
  - High-performance beryllium propellants
    - $I_{sp}$ (theoretical) = 360–400 lbf·sec/lbm at 100:1
    - High propellant density ($\sim 0.05–0.06$ lbm/in$^3$)
  - Braided carbon–carbon exit cone
  - 4D carbon–carbon throat
  - Consumable igniter
  - Laser-diode safe-and-arm device
  - Graphite composite case
Measured Comparison of Be and Al Propellants

<table>
<thead>
<tr>
<th>Propellant</th>
<th>TP-H-3062</th>
<th>TP-H-1092</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal fuel</td>
<td>Al</td>
<td>Be</td>
</tr>
<tr>
<td>Solids/metal (%)</td>
<td>86/16</td>
<td>86/12</td>
</tr>
</tbody>
</table>

**Ballistics (BATES)**
- Burn rate, 500 psi (In/sec) ........... 0.246 .... 0.260
- Pressure exponent (n) ............... 0.26 .... 0.33
- Theoretical $I_{sp}$, vac, $\varepsilon = 50$ (lbf-sec/lbm) .......... 315.50 .... 342.20
- Measured $I_{sp}$, $\varepsilon = 50$ (lbf-sec/lbm) .......... 293.00 .... 312.50
- Efficiency, $\eta$ (%) ................ 92.80 .... 91.30

**Conclusions**

- **Solids have multiple uses**
  - Boosters
  - Small launch vehicles
  - Flybacks
  - Space transfer motors

- **Keys to use**
  - "Designed in" reliability
  - Low cost
  - Simplicity
ADVANCED LAUNCH SYSTEM