Launch Propulsion Systems
TA-01

Orbital Perspective

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ORB
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Launch Vehicle Propulsion Industry Status

- US Industrial Space Policy has Hampered Emerging Technology, Specifically the Availability of Affordable Liquid Propulsion Solutions
  - Lack of focus and consistent direction has effectively curtailed engine development
    - "No significant investment or broad-based planning by NASA in Launch Propulsion technologies over the last 7 years"
  - Lack of production and future definable business plan is leading to erosion of the U.S. propulsion industrial base
    - Technology, development, and production cycle has been broken

- Engine Technology Development is the Key to New Launch Vehicle Development
  - Successful development in one initial area leading to sustainable production rates will facilitate advances in further areas

- In These Times of Fiscal Constraint, Strategic Investments in Technology Should Made Which Meet Immediate Needs, Have Broad Application and Benefit Multiple Users

Propulsion Technology Leads Vehicle Development

- Launch Vehicle Industry Follows Model of Other Vehicle Evolutions where Advances in Propulsion Technology Advance the State of the Art and Make Vehicles Economically Viable

Aircraft

Commercial Propeller-Driven Aircraft of the 1950s
• Introduction of the turboprop engine

Commercial Jet Aircraft of the 1950s
•Low-bypass ratio turbojet engines

Large Commercial Jet Aircraft of the 1960s
• Four Engine Configurations

Large Commercial Jet Aircraft of the 1970s
•High-bypass turbofan engines

Commercial Jet Aircraft of the 2000s
•Improved Engines

Rail

Steam Engines of the 1800s

Electric Engines of the early 1900s

Diesel Engines of the 1940s

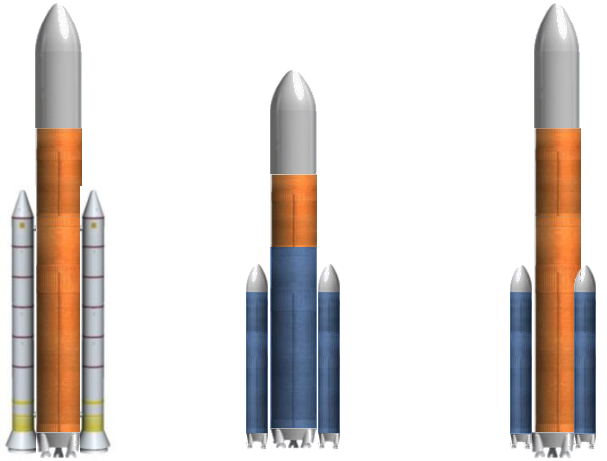
Diesel - Electric Engines of the 1960s

High Speed Electric of the 1970's

Magnetic Levitation 1990s-2000's

Immediate Need is a New U.S. Heavy Lift Launch System

- NASA and Industry Teams Currently Studying Optimal Configurations
- Three Most Likely Competing Configurations



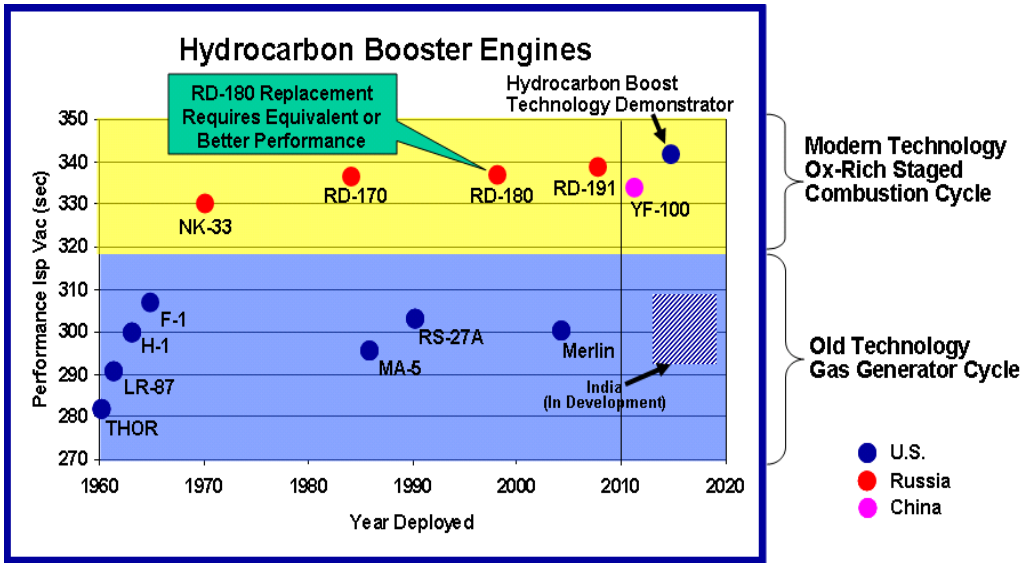
Core	**LOx/H2**	**LOx/RP**	**LOx/H2**
Upper Stage	**LOx/H2**	**LOx/H2**	**LOx/H2**
Boosters	**SRB x 2**	**LOx/RP x 2**	**LOx/RP x 2**

Optimal Configuration Must Be Affordable, Sustainable and Realistic

- Boost Phase Propulsion Technology Development and / or Cost Reduction is Required for Each Configuration

Engine Technology Gap Assessment

- No Currently Available Main Engine Propulsion System is Ideal for Heavy Lift Systems
  - All Cost, Performance and / or Availability "Challenged"
- Near Term HLV Funding and Schedule Constrained
  - Insufficient to support "Start from Scratch" propulsion system development program with IOC of 2016
- Economies of Scale Can Positively Influence Recurring Costs
  - LOx/RP more readily adaptable to other applications and vehicles
- LOx/RP Engine Development Should Focus on State of the Art, High Performance / High Efficiency Solutions
  - Oxygen Rich Staged Combustion



Path to High Performance U.S. LOx / RP Engine

- New ORSC LOx/RP Engine Could be Developed Using Existing Engines as Test-beds
- Could Facilitate Rapid Development of U.S. ORSC LOx/RP Technology
- Would Have Broad Application to U.S. Launch Vehicle Fleet

AJ26

- Or -

RD-180

New U.S. High Thrust Lox/RP Engine (~500K - 1M Lbf)

Atlas V

Taurus II

HLLV

Other

Consolidated Development Activity Required

- Advances in U.S. Technology have been made in isolated areas:
  - Brazed Nozzles
  - High Performance Injectors
  - Lower cost / high pressure thrust chambers
  - Common Booster Pumps
  - Extendable Nozzles (upper stage)

- Significant performance gains can be achieved through development of other key technologies:
  - High-performance, high-pressure turbopumps
  - High strength materials
  - High-pressure flexible feed lines
  - Lox rich pre-burners

- A properly funded, coordinated program could capitalize on advances in these areas and facilitate development and production of high performance, reliable, and cost-effective liquid propulsion engines

Summary

- US Industrial Space Policy has Hampered Emerging Technology, Specifically the Availability of Affordable Liquid Propulsion Solutions

- Strategic, Focused Investments in Technology Should be Made Which Meet Immediate Needs, Have Broad Application and Benefit Multiple Users

- Multiple NASA, Commercial, and Other USG Launch Vehicles Could Significantly Benefit From a Consolidated, Incremental Liquid Propulsion Development Program