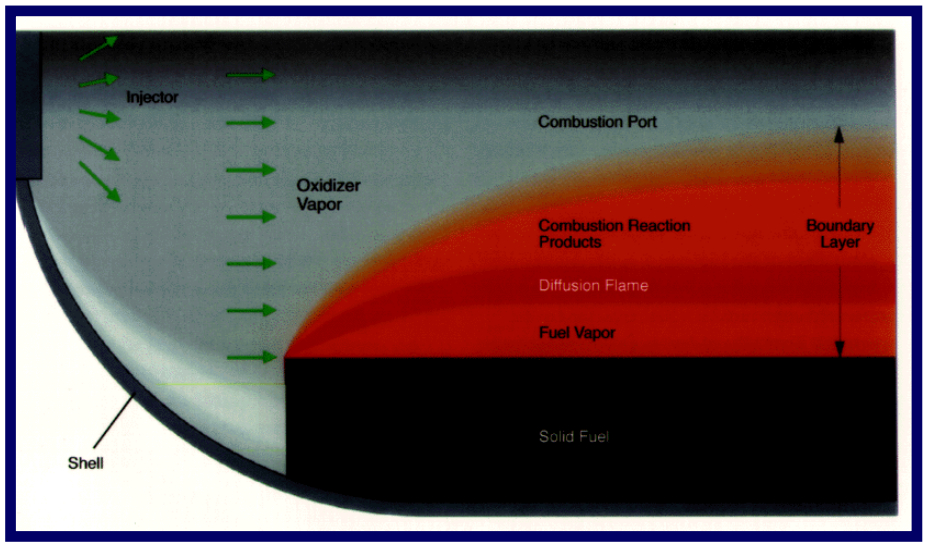
Hybrid Motor Ignition and Operation

1) **Fuel grain (HTPB) is ignited electrically using a small flow of gaseous oxidizer**
   - Non-pyrophoric
   - Non-pyrotechnic

2) **The main oxidizer valve opens and the oxidizer is injected into motor**

3) **Fuel vaporized from solid HTPB mixes with oxidizer to sustain combustion**

From Oxidizer Tank



To Nozzle

4) **Thrust can be tailored by adjusting oxidizer flow rate**

5) **Termination of oxidizer flow rate will shut off motor**

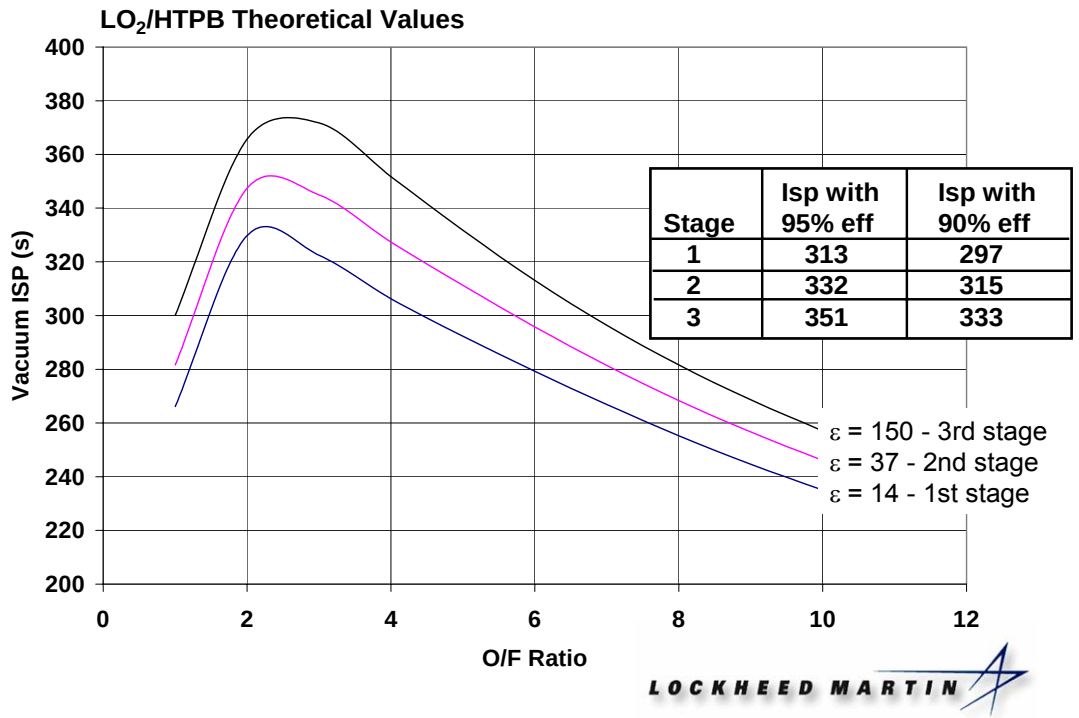
6) **The fuel grain can be re-ignited if necessary**

Non-Explosive Propulsion Technology

LOCKHEED MARTIN

Hybrid Propulsion Attributes

- **Benefits of Hybrid Propulsion**
  - Safety (inert fuel, liquid oxidizer)
  - Low cost (commercial components/rapid demonstration)
  - High Isp (equivalent to liquids)
  - Ability to throttle
  - Minimum debris thrust termination
  - Environmentally benign (fuel is landfillable, exhaust constituents: CO, CO_2, H_2O)
  - Ability to stop and start (regulate oxidizer flow)
  - Safe operations/handling
  - Non-explosive



Stage	Isp with 95% eff	Isp with 90% eff
1	313	297
2	332	315
3	351	333

LOCKHEED MARTIN

Michoud Operations Hybrid Propulsion Background

Lockheed Martin Has 17 Continuous Years of Hybrid Motor Development and Testing

89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05

HPIAG

DM-01

HyTOP

HPDP

HYSR

NSRP

FALCON







Significant Experience Base

- Over 640 motor tests
- Numerous Fuels and Oxidizers Tested
- Hybrid based Subsystem Developments
- Five Flights from WFF








Hybrid IR&D Testing

Hybrid Based Patents:	1. Steam Generator	2. Heated Helium	3. Staged Combustion	4. Hybrid/LH2 Vehicle	5. Combined Heated Helium/SC Cycle	6. HITVC	7. Hybrid Based GO2 Gas Generator
**2 additional concepts With secrecy orders	US# 5,572,864	US# 5,722,232	US# 5,794,435	US# 5,765,361	US# 6,073,437	US# 6,470,669	Patent Pending

Michoud Operations has been actively involved with Hybrid Propulsion Technology since 1989

LOCKHEED MARTIN

SLV Responsiveness Features

- System design driven by responsive operations requirements instead of typical performance driven requirements

Driving Responsiveness Features

- Surge and all weather capability (cat 2)
- Robust vehicle with performance margin
- Horizontal stage integration
- Vehicle self test and checkout
- Stage integration & launch in <24 hours
- Preloaded inert fuel
- Fault-tolerant avionics
- Simple field operations:
  - - Factory mated T- 0 disconnects
  - - "OneClick" Vehicle/Payload field joint
  - - Only 2 fluids loaded at the launch area
  - - No pyrotechnics/no hydraulics

- Responsiveness

Hybrid Propulsion & Basing Flexibility are Key Elements For Responsive Space

Anytime, Anywhere, Affordable Launch

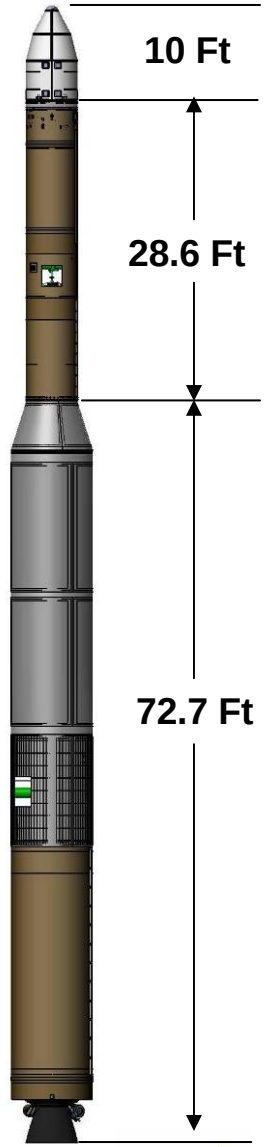
LOCKHEED MARTIN

Video of LM Falcon/SLV Concept

Falcon SLV Performance

- SLV-DS meets all mission performance requirements
- Single vehicle design accomplishes two different mission profiles
  - Small satellite delivery to orbit (100 nm x 100 nm from KSC):
    - 1,000 lb minimum
    - 1,855 lb maximum
  - Hypersonic test vehicle profile
    - 2,000 lb minimum
    - 3,055 lb maximum

Over the Road Transportation Enables CONUS Operation



SLV-DS Achieves All Performance Requirements with a Single Vehicle

LOCKHEED MARTIN

RR101 Motor Firing – January 2005

- First Test 4 Months after ATP
- 60 Second Burn Time
- 500 psi

OBJECTIVES:

- Acquire the critical data necessary to validate the analytical baseline for LMF900 multi-row, multi-port hybrid technology
  - Combustion stability
  - Regression rate
  - Thrust
  - Chamber pressures
  - Port to port pressures
  - Low frequency vibration
  - High frequency G levels
  - Demonstrate increased performance of LMF900
  - Baseline residuals

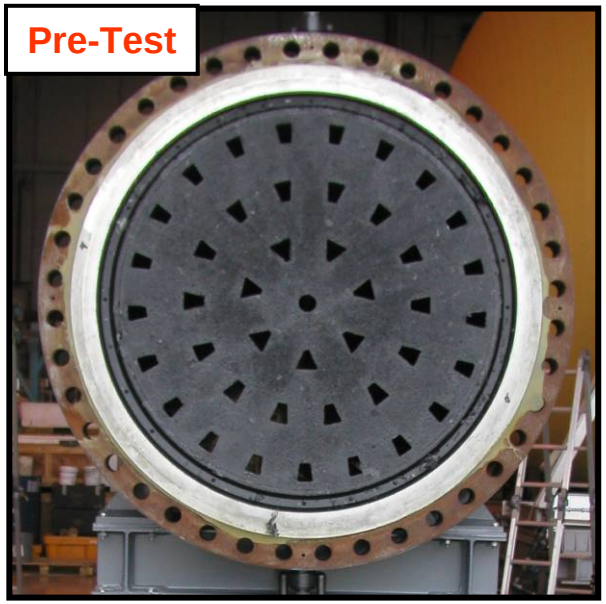
Successful Firing Increased Technology Readiness Level and Grounded Falcon SLV Sizing Parameters

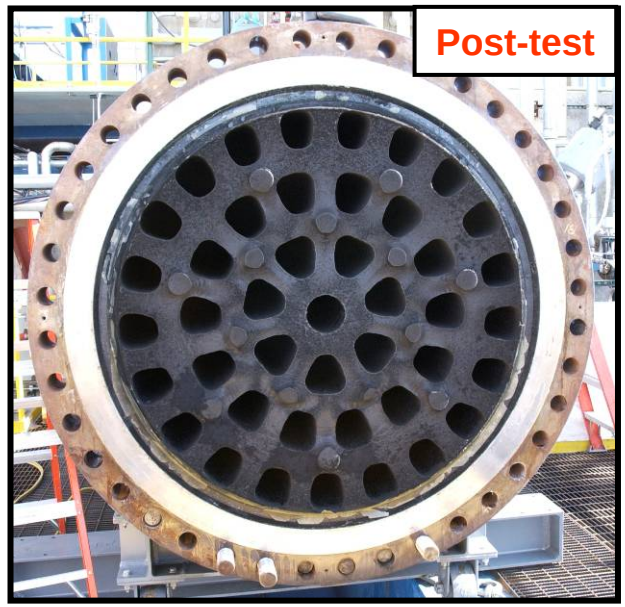
LOCKHEED MARTIN

LOCKHEED MARTIN

Multi-row Multi-port Fuel Grain Performed As Predicted

- **RR101 Acquired critical data to validate the analytical baseline for multi-row, multi-port hybrid technology**
  - Stable Combustion
  - Favorable Regression
  - Thrust within Predictions
  - Isp within Predictions



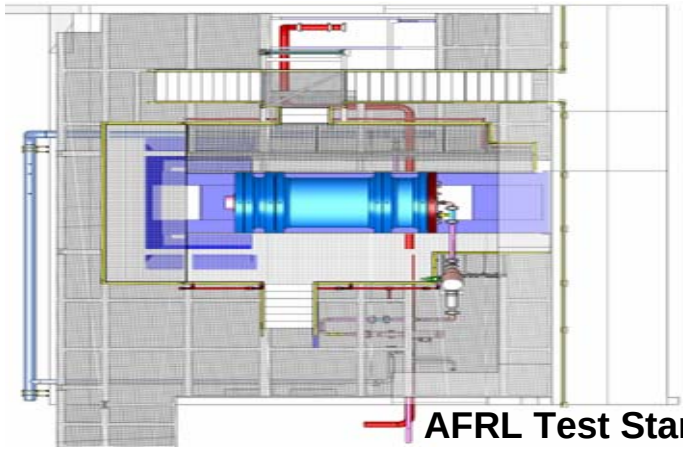


RR101 Results Incorporated Into Vehicle Design & Next Test Article

LOCKHEED MARTIN

RR102 Motor Firing – May 2005

- Second Test Planned 4 Months after RR101
- 120 Second Burn Time
- 900 psi



AFRL Test Stand

OBJECTIVES:

- Acquire the critical data necessary to refine the analytical baseline for LMF900 multi-row, multi-port hybrid technology
  - Combustion stability
  - Regression rate consistency
  - Thrust
  - Chamber pressures
  - Port to port pressures
  - Low frequency vibration
  - High frequency G levels
  - Residuals Consistency
  - Fuel Integrity
    - 75% Flight Duration

RR102 Completes Falcon Phase IIa Testing

LOCKHEED MARTIN

Falcon SLV Summary

- **SLV system design driven by responsive operations requirements**
- **FALCON SLV is a significant spiral in the development of operationally responsive space**
  - Designed for operational speed and flexibility
  - Costs approaching $5M including operations & range costs
- **PDR in June 2005**

Innovative Hybrid SLV On-Track For Flight Demonstration

LOCKHEED MARTIN