Hybrid Rocket Propulsion for Sounding Rocket Applications

NASA OSSA
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HYBRID ROCKET TECHNOLOGY

• Why Hybrid Rocket Technology?
• HyFlyer Sounding Rocket
Why Hybrid Rocket Technology?

- Hybrid Rocket Fundamentals
- Hybrid Characteristics
- Hybrid Advantages

Hybrid Rocket Fundamentals

- Solid Hydrocarbon Fuel (e.g., PBD) and Liquid Oxidizer (e.g., LOx)
- Combustion Process
  - Driven by Flow of Oxidizer over Fuel Surface
- Fuel/Oxidizer Separation
  - Safe
  - Throttleable

H-225K Hybrid Motor
Hybrid Characteristics

- Safe - Cannot Explode
  - No Intimate Mixing of Fuel and Oxidizer
  - Combustion Process is Diffusion Limited
- Throttleable
  - Thrust Proportional to Oxidizer Flowrate
- Scaleable
  - Thrust Scales with Internal Surface Area and Oxidizer Mass Flux
- Environmentally Clean
  - Fuel Selection and High Flame Temperature Result in Clean Exhaust Products

Hybrid Advantages

- High Performance
- Low Cost Due to Fundamental Safety
- Low Cost Due to the Nature of Hybrids
- Low Risk
- Flexible
American Rocket Company - HyFlyer Sounding Rocket Program

Hybrid Advantages

**High Performance**

- $I_{sp}$ is Equivalent to LOX/Hydrocarbon Engines (e.g. Saturn V F-1 1st Stage Engine)--10-15% Higher than Solid Motors
- Throttleability Increases Payload to Orbit

![Graph showing specific impulse for hybrid, solid, and liquid rocket motors.](image)

**Low Cost Due to Fundamental Safety**

- Safe Technology Reduces Costs in All Phases of Development, Production and Operations
- No Remote/Automated Production Facilities Required
- Anomalous Events Do NOT Destroy Test Facilities or Launch Pads
- No Restrictions on Personnel Activity In Any Phase of Development, Production or Operations
- No Special Handling or Transportation Requirements
- Lower Insurance Costs in All Phases
### Hybrid Advantages

**Low Cost Due to the Nature of Hybrids**

- Low Production Costs
  - Reduced Complexity
  - Few Critical Tolerances
  - Short Production Cycle (weeks)
  - Low Production Facilities Costs
- Low Materials Costs
  - No Strategic Materials
  - Multiple Commercial Sources
  - Many Material Options
- Low Operations Cost
  - Reduced Manpower Requirements
  - Reduced Inspection Requirements

### Low Risk

- Non-Explosive Therefore No Catastrophic Detonations
- Command Shutdown In the Event of Problems Affords Safe Abort
- Safe Engine Idle Allows Engine Verification Prior to Full Thrust
- Insensitive to Environmental Conditions
- Robust Combustion Cycle
  - Resistant to Manufacturing Defects
  - Self-Damping
- Safety = Less Complexity = High Reliability
- No Uninsurable Liability
- No Hazardous Materials and Clean Exhaust = No Environmental Risk
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**Hybrid Advantages**

- **Flexible**
  - Rapid Response to Customer Requirements
    - Simple Designs Allows Product Customization
    - Short Development Cycle (Months)
  - Facilitization
    - Commercial Production Facilities and Short Lead Time Parts
      Permits Buildup of Production Capability to Match Demand
  - Surge Capability
    - No Specialized Manufacturing Equipment
    - No Long Lead Time Items
    - No Strategic Materials

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**Why Haven't Hybrids Been Used Before?**

- Initial Difficulty in Maintaining Stable Hybrid Combustion
- Early Focus on "Performance At Any Cost"
  - Designs Optimized for Maximum $I_{sp}$
  - Military ICBM Requirements Drove All Initial Designs
- Initial Emphasis on Solids Based on System Readiness
  - ICBM Requirement
- Liquids Developed Intensively For Apollo Program
- Larger Database on Solids and Liquids Made Hybrids
  Higher Risk Option for Later Programs
- Large Investment in Facilities to Produce and Test Solids
  and Liquids Supported Predisposition to Those Technologies
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The HyFlyer Suborbital Vehicle

- Provides 11 Minutes of Microgravity Time for a Joust-class Payload
- Based on AMROC H-1500 Liquid Oxygen/Polybutadiene Hybrid Rocket Motor
- In Development to Validate H-1500 Motor for Use in Aquila Orbital Vehicle

HyFlyer Mission Profile
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**HyFlyer Performance**

- Micro-G Time (min)
- Altitude (nm)

![Graph showing HyFlyer performance](image)

**HyFlyer Comparitive Performance**

**APOGEE PERFORMANCE COMPARISON**

![Comparison graph of HyFlyer and other rockets](image)
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**Sounding Rocket Fleet**

<table>
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<th>Name</th>
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<th>Payload Capacity (kg)</th>
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**HyFlyer Summary**

- AMROC's HyFlyer is the Mac Truck of Sounding Rockets
- Unique Heavy Lift Capability - 8 Tons!
- 72" Diameter Booster - Large Payload Volume Available
- Developed to Validate Hybrid Propulsion For AMROC's Orbital Vehicle - Aquila
- Available Late 1993
- Estimated Launch Cost = $3.5M