American Rocket Company - HyFlyer Sounding Rocket Program

Hybrid Rocket Propulsion for Sounding Rocket Applications

NASA OSSA
November 12, 1991

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
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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
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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

![Ideal Vacuum Specific Impulse for a Hybrid, Solid, and Liquid Rocket Motor](image)

Hybrid Advantages

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
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<tr>
<th>Hybrid Advantages</th>
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- 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

\[
\text{Standard Light Industrial Facilities Are Adequate}
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- 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

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<sub>sp</sub>
  - 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

- Apogee: t = 424 sec, h = 987 km, v = 9150 fps, range = 336 nm, Payload wt. = 1.420 lbm
- Burnout/Payload Separation: t = 949 sec, h = 9277 ft, v = 9336 fps, second = 4.53 g, y = 84.6 deg
- Max Q: t = 34 sec, h = 4.4 km, v = 1.623 fps, Q = 1.330 lbft/s2
- Liftoff: t = 0
- Range = 104 nm
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HyFlyer Performance

![Graph showing HyFlyer performance with Micro-G Time (min) and Altitude (nm) against Payload (lbf)].

HyFlyer Comparative Performance

![Graph comparing Apogee performance for different payloads].
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Sounding Rocket Fleet

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