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American Rocket Company - HyFlyer Sounding Rocket Program

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Hybrid Rocket Propulsion for Sounding Rocket Applications

NASA OSSA

November 12, 1991

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HYBRID ROCKET TECHNOLOGY

- Why Hybrid Rocket Technology ?
- HyFlyer Sounding Rocket

805-987-8970
CAMARILLO, CA

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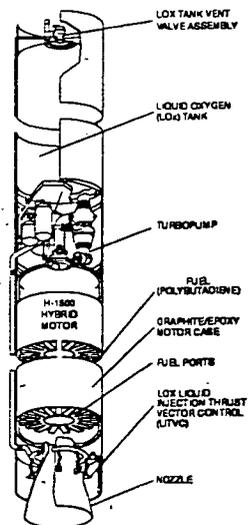
Why Hybrid Rocket Technology ?

- Hybrid Rocket Fundamentals
- Hybrid Characteristics
- Hybrid Advantages

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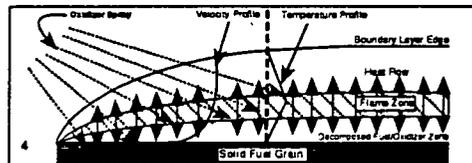
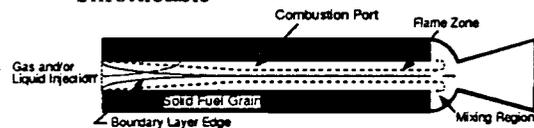
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Hybrid Rocket Fundamentals



H-225K Hybrid Motor

- 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



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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

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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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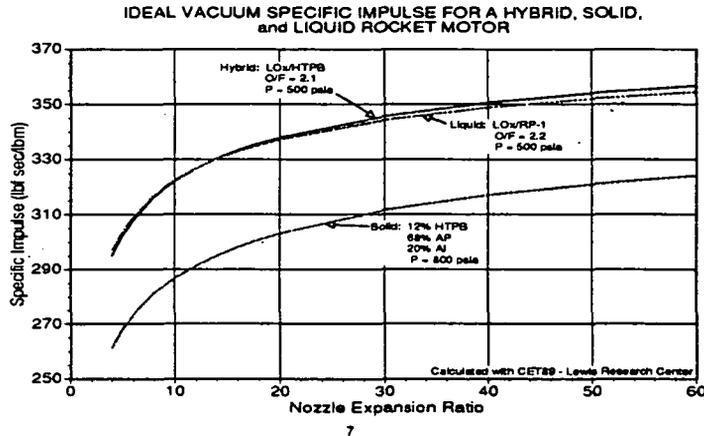
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Hybrid Advantages

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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



Hybrid Advantages

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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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Hybrid Advantages

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Low Cost Due to the Nature of Hybrids

- **Low Production Costs**

- Reduced Complexity
- Few Critical Tolerances
- Short Production Cycle (weeks)
- Low Production Facilities Costs



*Standard Light
Industrial Facilities
Are Adequate*

- **Low Materials Costs**

- No Strategic Materials
- Multiple Commercial Sources
- Many Material Options

- **Low Operations Cost**

- Reduced Manpower Requirements
- Reduced Inspection Requirements

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Hybrid Advantages

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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

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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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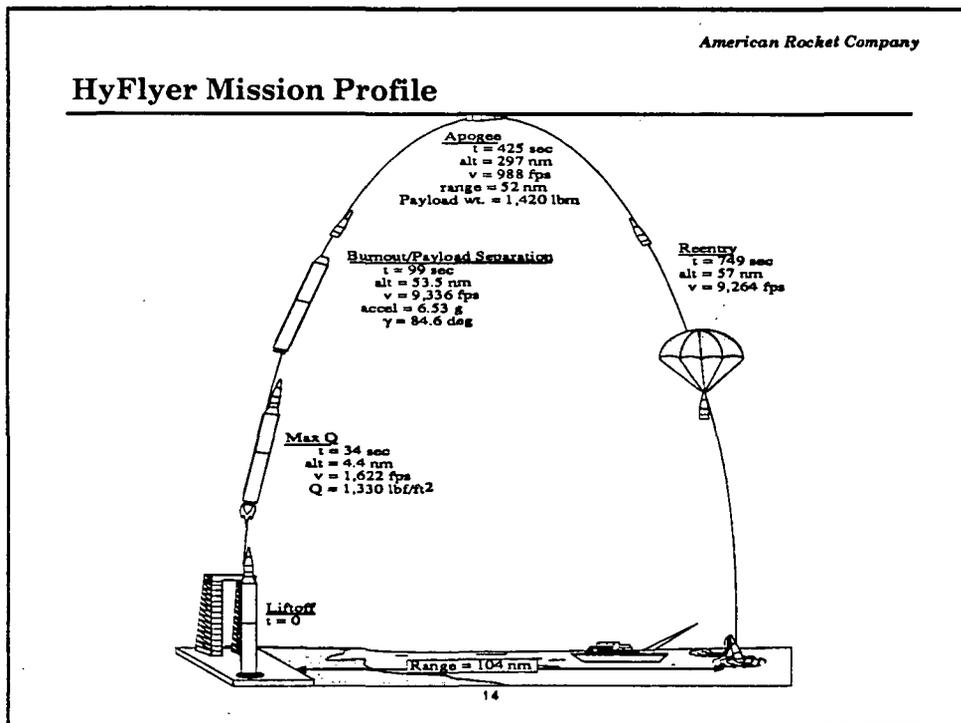
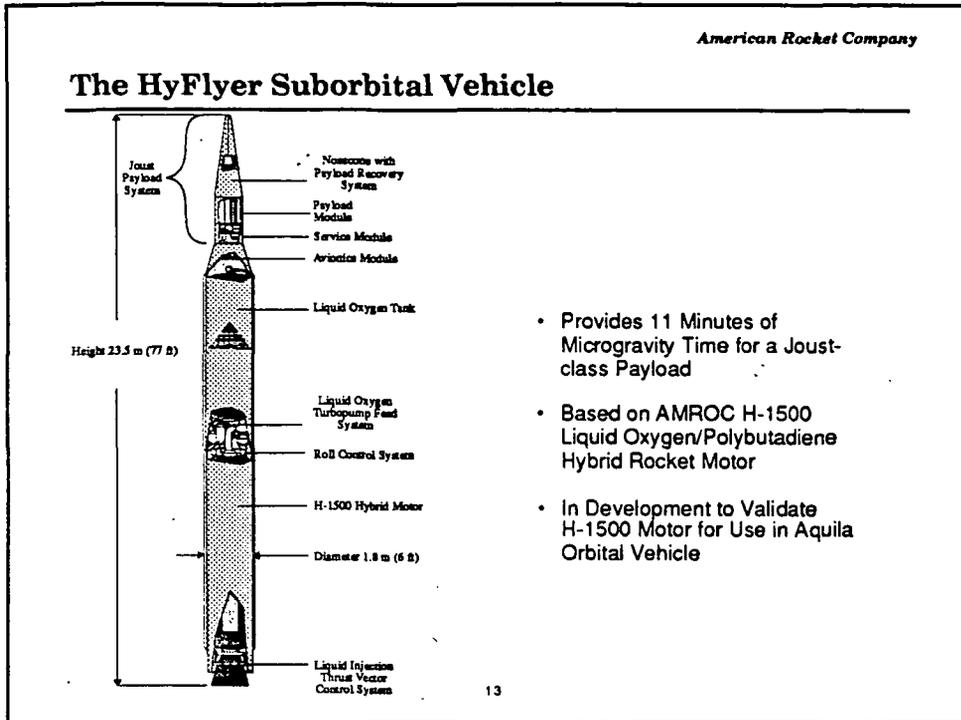
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Why Haven't Hybrids Been Used Before ?

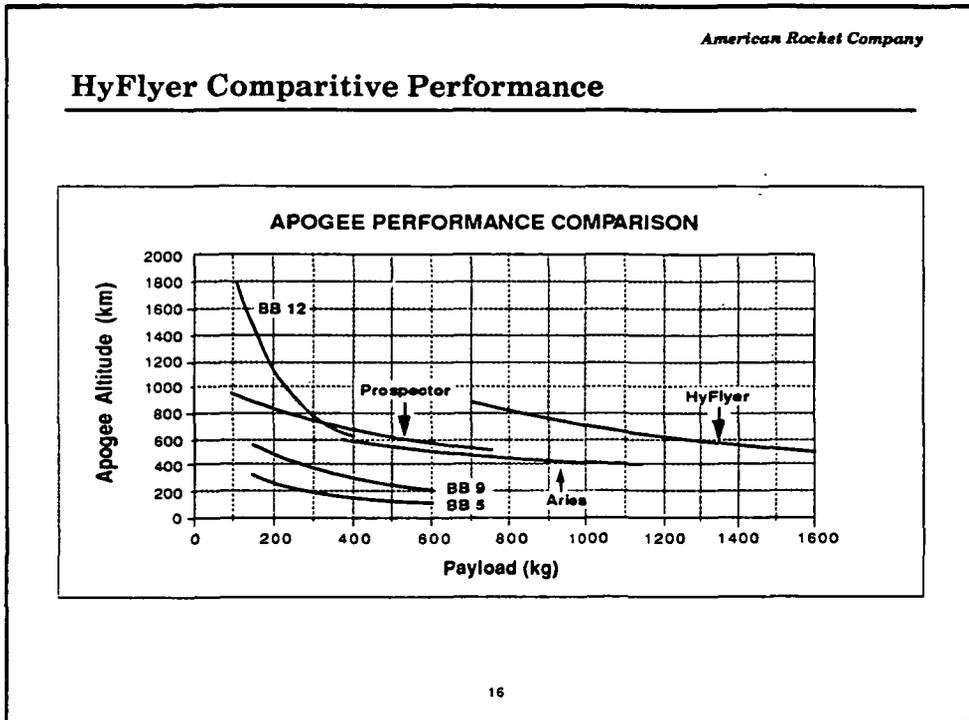
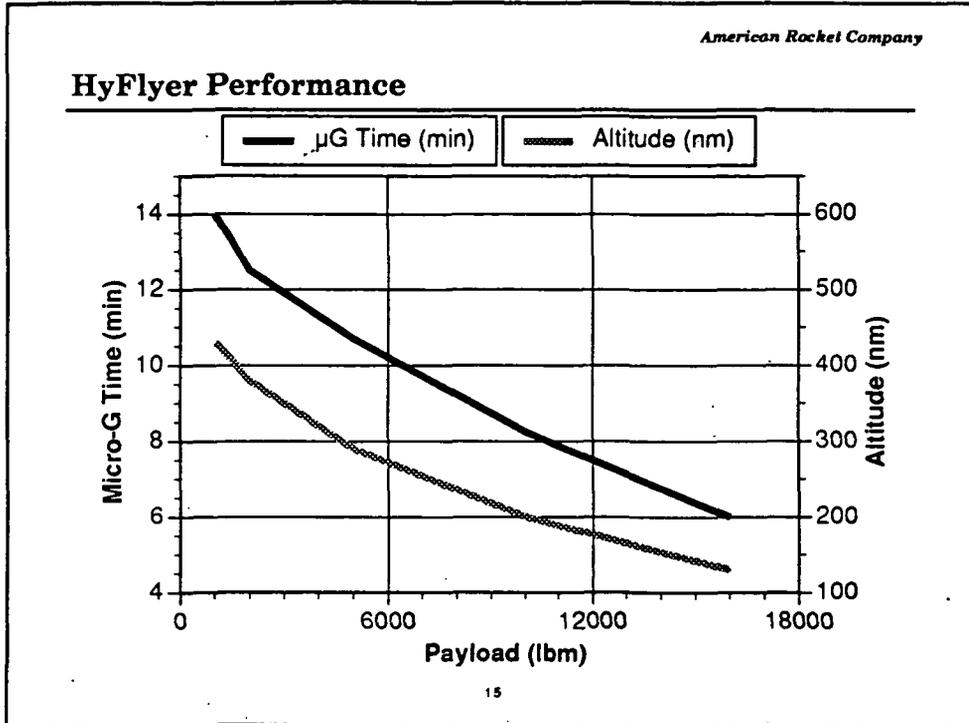
- **Initial Difficulty in Maintaining Stable Hybrid Combustion**
- **Early Focus on "Performance At Any Cost"**
 - Designs Optimized for Maximum I_{sp}
 - Military ICBM Requirements Drove All Initial Designs
- **Initial Emphasis on Solids Based on System Readiness**
 - ICBM Requirement
- **Liquids Developed 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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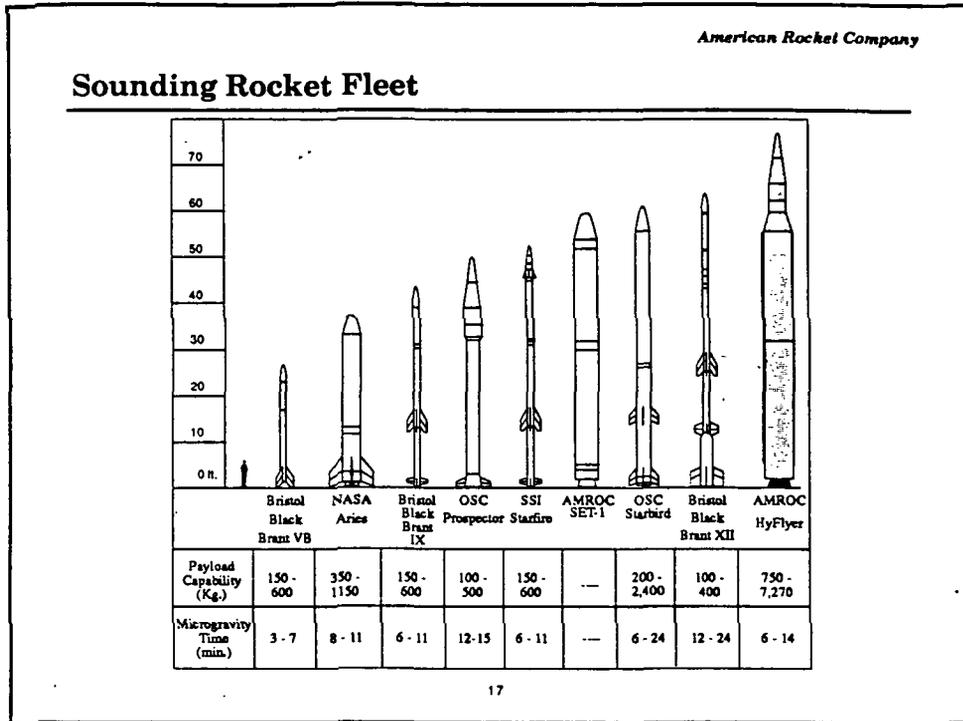
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HyFlyer Summary

- **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**

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