Manfred Lochs Conference on Regulation of Emerging Modes of Transportation
XP Program Briefing
May 24, 2013
The Suborbital Markets

Source: FAA/AST – SpaceFlorida Suborbital Market Study by Tauri Group, July 2012
The Rocketplane Flight Profile

Rocketplane XP Suborbital Flight Trajectory

The “Astronaut Line” 328K’/100 KM Altitude

Ground Track (Statute Miles)

Altitude (ft)

Rocket Motor Cut Off (MECO)

3-4 min Sensation of Weightlessness

Jet Powered Climb to Rocket Ignition

180° Turn

Takeoff & Landing

Decelerate to Subsonic & Spiral Decent

Energy Management

Rocket Ascent

3g Pull-Up

Rocket Ignition
The View From 100 km

The Blackness of Space
The Curvature of the Earth
Weightlessness
Full-Surround SPACE VISION

Interior Designed by Frank Nuovo
• Chief of Design for Nokia
• Design Director for BMW/Designworks
<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cockpit Crew</td>
<td>1</td>
</tr>
<tr>
<td>Seating Capacity</td>
<td>6 (5 passengers + pilot)</td>
</tr>
<tr>
<td>Seat Pitch</td>
<td>36 in (0.91 m)</td>
</tr>
<tr>
<td>Takeoff Field Length</td>
<td>9200 ft (2800 m)</td>
</tr>
<tr>
<td>Landing Field Length</td>
<td>4300 ft (1300 m)</td>
</tr>
<tr>
<td>Max. Altitude</td>
<td>340,000 ft (104 km)</td>
</tr>
<tr>
<td>Mission Time ($\mu$G Time)</td>
<td>45 min (3+ min)</td>
</tr>
<tr>
<td>Jet Engine Type</td>
<td>GE J-85 w/ AB</td>
</tr>
<tr>
<td>Rocket Engine Type</td>
<td>Polaris AR-36</td>
</tr>
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Systems Overview

- Kerosene Tank
- Liquid Oxygen Tank
- Rocket Propulsion System
- Afterburning Turbo Jets
- Electromechanical Actuators
- Reaction Control System
- Conventional Landing Gear
- Conventional Aluminum Airframe
- Environmental Control System
- Redundant Fly-by-Wire Flight Control System
- 6 Person Crew Cabin
- Electrical Power System
• **Combined Jet-Rocket Architecture Allows More Abort Options**
  – RP is a Fuel Used By Both XP Rocket and Jet Engines

• **Abort Scenarios:**
  – During Jet-Powered Profile
    • Jettison LOX
    • Transfer RP as Required
    • Fly Conventional Aircraft Mode to Landing

  – During Rocket Assent
    • Jettison LOX
    • Transfer RP as Required
    • Fly Conventional Aircraft Mode to Landing

  – During Ballistic Trajectory
    • Continue Unpowered Profile
    • Fly Normal Glide-Assist Aircraft Mode to Landing
Proven Rocket Technology

Atlas Sustainer Engine
(1959) Rocketdyne
Over 550 Successful Flights
Only 3 failures all non-catastrophic

Navajo (1956)
North American Aviation

Thor / LR-79
(1958) Rocketdyne

Atlas booster
(1959) Rocketdyne

Delta (1960)
Boeing

Saturn H-1 (1959)
Rocketdyne

Polaris AR-36 (2008)

<table>
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<tr>
<th>Propellants</th>
<th>LOX / RP</th>
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<tr>
<td>Isp (vac)</td>
<td>309 sec</td>
</tr>
<tr>
<td>Thrust (vac)</td>
<td>36,000 lbf</td>
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<tr>
<td>Thrust to Weight</td>
<td>80</td>
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</table>
Jet Propulsion System

- **XP Uses Two J85-15 Turbojet engines**
  - Millions of Operating Hours - Military and Commercial
  - Each provide 4300 lbf of thrust, 11 engines purchased from Canadian Air Force

- **Orenda Turbines Selected Supplier**
  - Subsidiary of Magellan Aerospace Corp
  - Repair, Modification and Testing

- **Modifications:**
  - Replace QEC Kit With Air Start Inlet Check Valve For Ground Start Capability
  - Replace the AC-Powered Ignition Exciter With 28VDC Powered Exciter
  - Blank Off the Customer Bleed Ports
Flight Control Actuators

• Use: Atmospheric Attitude Control and Maneuverability

• Design:
  – Off-The-Shelf, Proven Design
  – Used on Boeing 787
  – Developed by Moog
  – Quality Supplier With Decades of Aerospace Experience Electromechanical Actuators
  – Drive Flaperons, Horizontal Stabilizer, Rudder
  – System is Redundant and Fully Electric (270V)

• Status
  – Firm Fixed Price From Moog
  – Conceptual Design Complete
Reaction Control System

- **Use:** Space Attitude Control and Maneuverability

- **Design:**
  - Off-The Shelf Components, Proven Design
  - Used For Maneuvering During Space Flight
  - Based on X-15 Flight Control System
  - Hot Gas System Utilizing 90% H2O2
  - Pitch and Yaw Thrusters: 75 lbf
  - Roll Thrusters: 15 lbf
  - Eight Thrusters In Nose
  - Two On Each Wing
  - Redundant For Safety

- **Status:**
  - Conceptual Design Established
  - Notional Routing Layout Complete
Landing Gear System: Simple Design With Off-The-Shelf Components

• Design
  – Based on Gear From the F-5 Fighter Jet
  – Features Nose Wheel Steering
  – Features Brakes/Antiskid Functions
  – Self-Contained Electro-Hydraulic Retract/Deploy System

• Status
  – Conceptual Design Complete
ECLSS Preliminary Design Is Mature

ECLSS Test Chamber

• Complete and Checked Out
• Used For Development & Qualification Testing
• Interim Technical Review completed May 06
• ECLSS design at PDR level
• Components identified
• Schematic complete
• FMECA Completed
Camera System

• XP Camera Uses
  • Flight Test (Visual and IR (Heat) Capable)
  • Hi-Res Science and Reconnaissance Missions
  • Passenger “SPACE VISION”

• XP Has 8-Camera System
  – Part of Data Acquisition System (DAS)
  – 5+ Lenses Available for Tailored Views, Even “Fish-eye”
  – Full Resolution Video Compressed and Stored on Board
  – Variable Frame Rate & Resolution Transmitted to Ground
  – Full Resolution Streamed to Passenger Monitors—“SPACE VISION”

• Flight Proven Hardware Flown on Shuttle, Multiple NASA and DoD Missions
Contractor Team
NASA KSC FastRack Program

- **GOAL** – bring suborbital microgravity research activity to KSC
- **Modular System**
  - 1 FastRack = 1 passenger seat
- **Prototype Completed**
- **Flight Testing August 2009**
- **Space Life Sciences Lab payload integration support facilities available**
- **XP provide on-board Payload Specialist work station for customers**
Small Satellite Launch Missions

- **With Upper Stage:**
  - Micro/NanoSat ~50kg to 100km LEO

- **Reconnaissance/Tech Demo**
  - XP can carry >2000lb payload in lieu of passengers without major modification
  - At apogee horizon approximately 700 miles
  - Payload mount on seat rails, modified window viewport
  - Tech Demo: Telescopes, Star Trackers, Air Data Systems, IVHMS & other avionics

- **Operational Demonstration:** Rapid Turn Around, Rapid Time-To-Launch, etc.

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<tr>
<th>XP ORS</th>
<th>Upper Stage</th>
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<tbody>
<tr>
<td>Small Sat</td>
<td>~25-50kg 100km</td>
</tr>
</tbody>
</table>
Several Upper Stage Options

Star 20B Stack – MATRA alternative?

New Liquid Fuel Upper Stages

CAMUI Hybrid Rocket

Velocity increment vs. Payload mass (Isp = 317 s)
A Global Spaceport Network

• Spaceport Oklahoma (1st)
  – Licensed Spaceport
  – Flight Test and Manufacturing
  – Continued 1-2 ship operations

• Secondary Spaceports
  – Cecil Spaceport FL
  – Kennedy Space Center
  – Spaceport Hawaii
  – Spaceport Barcelona
  – EU Spaceport Lelystad
  – Singapore Spaceport

• Future Potentials
  – Hokkaido Spaceport
  – Puerto Rico Spaceport
  – Swedish Spaceport
  – Virginia Spaceport
2,700 acres of inland property, 168 square-mile Spaceport Territory.

13,500 foot runway.

On-site medical facility with pharmacy and a crash and rescue unit.

300 VFR flying days per year.
Florida P2P Testbed Corridor

This Document contains Proprietary Information of Rocketplane Global, Inc.
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• A Rocketplane XP Suborbital flight operations base with related space-themed tourist attraction developments
• Prototype business model for global spaceport projects at major tourist destinations around the world
• Use of existing airport infrastructure & 5 Star resort lodging
Barcelona Spaceport
EU Spaceport Lelystad/NL

- Dual use GA airport + Spaceport
- Becomes a major regional tourist attraction
- Leverages billions in existing tourism & culture investments
- Co-located with NL National Aerospace Museum
- Use of North Sea military restricted areas for spaceflight
Rocketplane Growth Path

- Commercial Path unlikely to allow rapid advances in propulsive capability
- DoD Support Could accelerate development at small scale generating residual capabilities and big dividends for future capability.
First EU Suborbital International Passenger and Cargo Hub

Netherlands to Spain Spaceflight Corridor

Netherlands to Doha Spaceflight Corridor

Netherlands to Singapore Spaceflight Corridor
The Future Vision Is Point-To-Point

- Develop A New Commercial Aerospace Industry
- Develop A World-Wide Network of Spaceports
- World-Wide P2P Service in <2hrs
- Global Same Day Logistics Service as Lead Market

<table>
<thead>
<tr>
<th>Flight</th>
<th>Distance</th>
<th>Airliner</th>
<th>P2P Rocketplane</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York – Los Angeles</td>
<td>2,500 miles</td>
<td>5 hrs</td>
<td>1.0 hr</td>
</tr>
<tr>
<td>Memphis – Paris</td>
<td>4,600 miles</td>
<td>9.25 hrs</td>
<td>1.25 hrs</td>
</tr>
<tr>
<td>Los Angeles – Tokyo</td>
<td>5,500 miles</td>
<td>12 hrs</td>
<td>1.5 hrs</td>
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Diagram:
- Horizontal Glide/Airbreathing, Landing
- Subsonic Approach to Populated Area
- Hypersonic Glide
- Sub-Orbital Trajectory
- Reentry & Energy Management
- Non-Airbreathing Rocket Boost
- Accelerate to Supersonic and Climb
- Subsonic Cruise Away from Populated Area
- Horizontal Airbreathing Takeoff & Climb
Licensing vs. Certification

- FAA/AST adopted “Fly at your own risk” regulatory model WITH informed consent and signed waivers of liability
- Launch licensing protects public safety but NOT space flight participants
- Legislation designed to allow new industry to grow and learn BEFORE moving to higher regulatory standards
- Flexible Guidelines promote safety without undue regulatory burden
Certification Cost Example

- **Embraer Phenom 300 vs. Learjet 25**

  - **Cruise Speed:** 834 km/h Mach 0.78
  - **Range:** 3,650 km
  - **Passengers:** 9 (+1 crew)
  - **Ceiling:** 13,715 m
  - **Climb Rate:** 20.2 m/sec
  - **Year Certified:** 2009
  - **Price:** ~ $8,000,000

  - **Cruise Speed:** 859 km/h Mach 0.81
  - **Range:** 2,853 km
  - **Passengers:** 8 (+2 crew)
  - **Ceiling:** 13,715 m
  - **Climb Rate:** 30.7 m/sec
  - **Year Certified:** 1967
  - **Price:** ~ $500,000
Phenom 300 Certification Costs

• Quote from Embraer Press Release
  – “The overall certification campaign involved five aircraft that performed more than 1,200 flight test hours, certifying the aircraft for RVSM (Reduced Vertical Separation Minimum), day and night IFR (Instrument Flight Rules) operations, and flying into known and forecasted icing conditions. In addition, there were full-scale static and fatigue tests, and rigs were used for environmental, avionics, and electrical systems.”

• 400 engineers working for 3 years +
• Total investment ~ $1 billion