Industry Perspective
Orbital Sciences Corporation

NIRPS Workshop
2012 JANNAF Conference

December 2012

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Significant Changes in Launch Industry

- The Traditional Model of US Launch Is Being Challenged
  - US Launch Vehicles Evolved from the Disaggregated, Specialized Industrial Base Models of the 1960's
    - Specialized, Niche Components Suppliers (Propulsion, Avionics, Manufacturing, etc.) Emerged from Large Aerospace Industrial Base Created During WWII & Sustained During the Cold War
    - Large Integrators (McDonnell Douglas, General Dynamics, Lockheed, Martin Marietta)
  - Atlas V, Delta IV Initiated a Shift to More Vertical Integration In an Effort to Maximize Efficiencies and Minimize Cost
    - Dedicated, Integrated Factories
    - Unrealized Assumptions Due to Market Shifts Limited Effectiveness
  - New Entrants Developing New Vehicles Using In-House Technology or Streamlined Integration
    - Dedicated, Vertically Integrated Companies
    - Proprietary Propulsion Technology
    - Just in Time Assembly

The Nature and Composition of The Traditional Propulsion Industrial Base is Changing As Well

Titan 1 Factory, 1960

Boeing / ULA Factory, 1996 -

Orbital Antares HIF - 2012

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Liquid and Solid Propulsion Industry Status

- US Industrial Space Policy Became Unfocused and Lacked Specific Direction
  - Lack of Sustained Investment has Effectively Curtailed Large New Propulsion Development
  - Hampered Emerging Technology, Specifically the Availability of Affordable Liquid Propulsion Solutions
  - Limited Tangible Technology Development in the Last Decade

- New Entrants Leveraging Existing Technology to Develop Proprietary Systems or Sourcing Abroad
  - Domestic - Small Scale, ~150K lbf or less (Boost Phase)
  - Only Affordable Sources of Large (>500k lbf) Liquid Engines is Russia

- Global Launch Vehicle Industry Relies on non-U.S. Sources for Affordable Liquid Propulsion Technology
  - Many Indigenously Developed with Russian Support

- Engine Technology Development is the Key to New Launch Vehicle Development
  - Significant Advances in Capability or Affordability Will Not Be Possible If We are Forced to Continue to Use Only What is Currently Available Domestically
  - Successful Development in One Initial Area Leading to Sustainable Production Rates will Facilitate Advances in Other Areas

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Propulsion Technology Leads Vehicle Development

- Launch Vehicle Industry Follows Model of Other Vehicle Evolutions
- Advances in Propulsion Technology Advance the State of the Art and Make Vehicles Economically Viable

Rail

Steam Engines of the 1800s

Electric Engines of the early 1900s

Diesel Engines of the 1940s

Diesel - Electric Engines of the 1960s

High Speed Electric of the 1970's

Magnetic Levitation 1990s-2000's

Aircraft

Commercial Propeller-Driven Aircraft of the 1950s
• Introduction of the turboprop engine

Large Commercial Jet Aircraft of the 1960s
• Four Engine Configurations

Large Commercial Jet Aircraft of the 1970s
•High-bypass turbofan engines

Commercial Jet Aircraft of the 2000s
•Improved Engines

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Foreign Government Investment in Propulsion Technology Continues

- Russian Space Agency
  - Continued RD Engine Development (RD-190 series)
  - Dual Fuel Engine Technology (RP and Hydrogen)
- European Space Agency
  - High-Thrust / Staged Combustion Demonstrator Engine
  - Ariane 5 Vinci expander cycle upper stage development
  - Slush propellant manufacturing
- Japanese Space Agency (JAXA)
  - Continued LE-5A / B Production and Improvement
  - IHI Solid Motor Production
- China National Space Administration
  - YF-77 Cryogenic Upper Stage Engine development
- Indian Space Research Organization
  - L110 / Vikas Engine - re-startable liquid stage
  - C25 cryogenic upper stage engine

Other Countries Continue To Make Investments To Advance Propulsion Technology

"Nationalized" Programs Justify Similar U.S. Investment

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USG Investment Continues to be Unfocused

- NASA and DoD (USAF) Have Intersecting Interests in the Development of Advanced US Booster Technology

- NASA Currently Invests in **17 Launch Propulsion Projects** including SLS Advanced Booster Engineering Demonstration and Risk Reduction ($200M)
  - Both low and Medium TRLs
  - Liquid and Solid Rocket Propulsion Systems, as Well as Air-breathing and Ancillary Propulsion Systems
  - Potential Future Investments in Liquid Propulsion Technologies may Include new Liquid Engine Systems, Propulsion Materials Research, High-density Impulse Propellants, and new Subsystem Modeling and Design Tools

- **USAF Rocket Propulsion Technology Project (Applied Research) : FY12 Funding of $60.4M (FY13 Request: $55.29M -- $25.3M Identified for Advanced Liquid Propulsion Technology)**
  - Thrust 1 (FY13, $6.2M): Develop, characterize, and test advanced hydrocarbons, energetics, solid propellants, and monopropellants to increase space launch payload capability and refine new synthesis methods.
  - Thrust 2 (FY13, $7.8M): Develop advanced liquid engine combustion technology for improved performance, while preserving chamber lifetime and reliability needs for engine uses in heavy lift space vehicles.
  - Thrust 4 (FY13, $11.3M): Develop advanced liquid engine technologies for improved performance, while increasing life and reliability needs for engine uses in expendable and reusable launch vehicles.

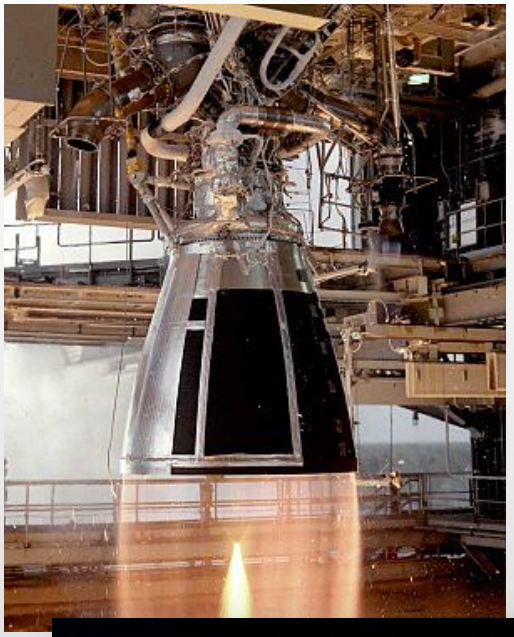
- **USAF Space & Missile Rocket Propulsion Project (Advanced Technology Development): FY12 Funding $22.5M (FY13 Request: $22.5M -- $19.7M Identified for Advanced Liquid Propulsion Technology)**
  - Thrust 1 (FY13, $19.7M): Develop liquid rocket propulsion technology for current and future space launch vehicles.

Source: DRAFT NASA Strategic Space Technology Investment Plan
Space News: "NASA, Air Force Haggling Over Cost Sharing on Engine Project
DoD FY13 PBR - Air Force RDT&E Justification Book Volume I

Need Tangible Products – Not More Studies!

- Efforts of NASA and USAF Should be Coordinated and Targeted to Hardware Development
- Priorities Should Be First Boost Phase and Then Upper Stage Propulsion
- Both Liquid and Solid Targeted Investments

More Of This



Less Of This

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Consolidated Development Activity Required

- Advances in U.S. Technology Have Been Made in Isolated Areas:
  - Brazed Nozzles
  - High Performance Injectors
  - Low cost / high pressure thrust chambers
  - Common Booster Pumps
  - Extendable Nozzles (upper stage)
  - Sintered Metals

- Significant Performance Gains can be Achieved Through Development of Other Key Technologies:
  - High-performance, high-pressure turbopumps
  - High-pressure flexible feed lines
  - Lox rich pre-burners
  - Engine start capabilities

- A Properly Funded, Coordinated Program Could Capitalize on Advances in These Areas and Facilitate Development and Production of Modular, Reliable, Cost-effective Liquid Propulsion Engines

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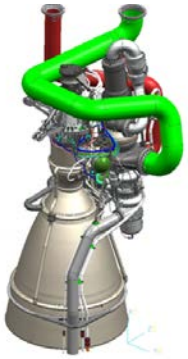
Path to Domestic High Performing LOX/RP Engine

- New ORSC LOX/RP Engine Could be Developed using Existing Engines as Test-beds
- Could Facilitate Rapid Development of U.S. ORSC LOX/RP Technology
- Would have Broad Application to U.S. Launch Vehicle Fleet

AJ-26

- OR -

RD-180



New U.S. High Thrust LOX/RP Engine (~500K-880K)

Atlas V

Antares

SLS Block 1 Boosters

Other

Optional, Subsequent Higher thrust Engine development

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Orbital Overview

- Leading Developer and Manufacturer of Small- and Medium-Class Space Systems
  - 30-Year Record of Reliable, Rapid and Affordable Development and Production
  - Serving Customers in Commercial, National Security and Civil Government Markets

- Over 1,000 Satellites and Launch Vehicles Built or Under Contract for Customers
  - 205 Satellites and Space Systems
  - 165 Space and Strategic Launch Vehicles
  - 635 Target Vehicles and Sounding Rockets

- 3,900 Employees and 1.7 Million Square Feet of State-of-the-Art Facilities

- Revenues of About $1.45 Billion Expected in 2012

- Contract Backlog Totals $5.15 Billion for Delivery Through 2018

- Conservative Balance Sheet With Strong Liquidity

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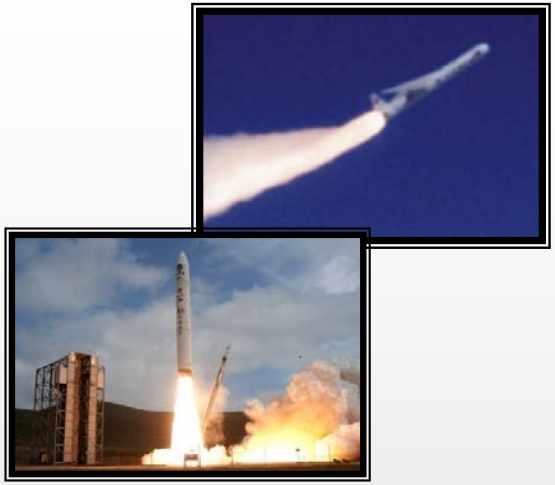
Orbital Launch Systems Group



Space Launch Vehicles

- Small Payloads (Up to 2 Tons)
- Medium Payloads (3 to 7 Tons)
- Special Purpose Vehicles

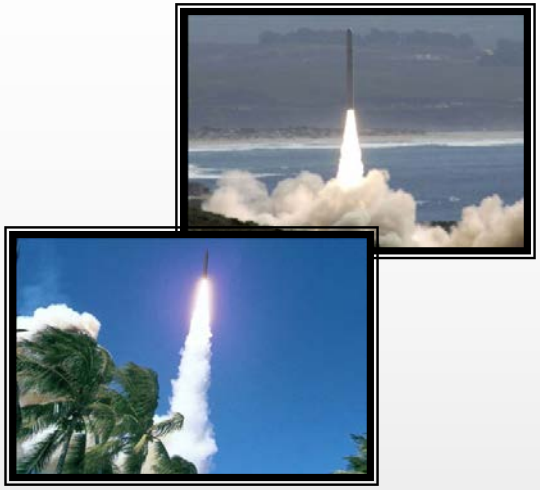
Mission Record

- 71 Launches Since 1982

Production Backlog

- 3 Units Delivered
- 13 Units in Backlog

Solids & Liquids



Strategic Launch Vehicles

- Interceptor Vehicles
- Global Strike Vehicles
- ICBM/IRBM-Class Targets

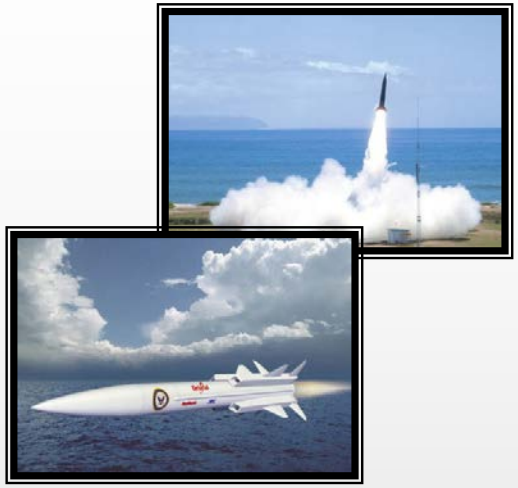
Mission Record

- 22 Launches Since 1982

Production Backlog

- 38 Units Delivered
- 16 Units in Backlog

Solids



Target Vehicles

- Short-Range Targets
- Medium/Intermediate Targets
- Special Purpose Vehicles

Mission Record

- 166 Launches Since 1982

Production Backlog

- 49 Units Delivered
- 42 Units in Backlog

Solids

104 Launches With 97% Success in Last 10 Years

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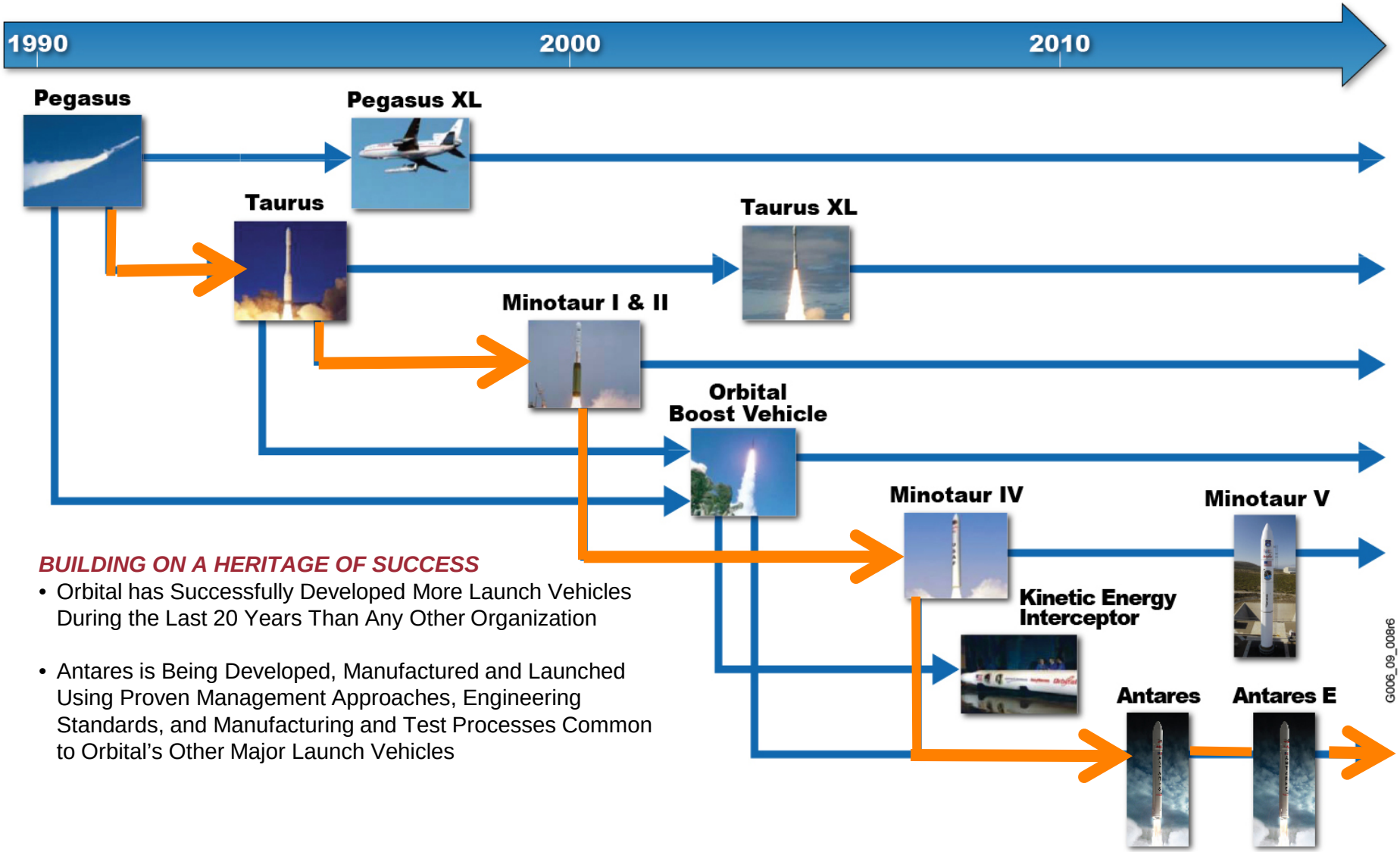
Two Decades…12 Space and Strategic Launch Vehicles



BUILDING ON A HERITAGE OF SUCCESS

- Orbital has Successfully Developed More Launch Vehicles During the Last 20 Years Than Any Other Organization
- Antares is Being Developed, Manufactured and Launched Using Proven Management Approaches, Engineering Standards, and Manufacturing and Test Processes Common to Orbital's Other Major Launch Vehicles

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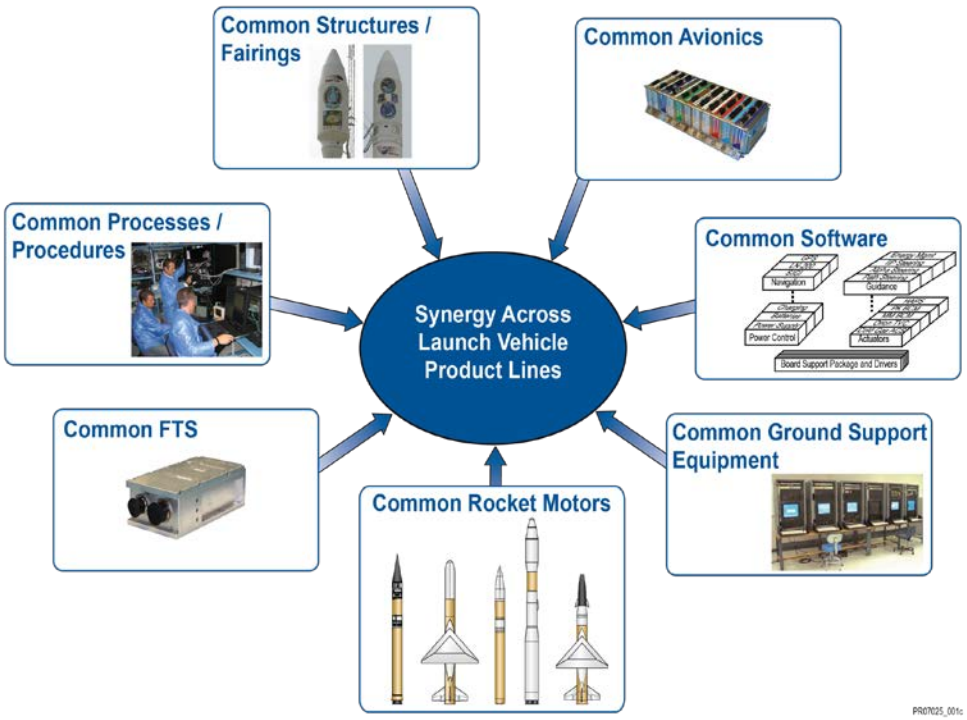
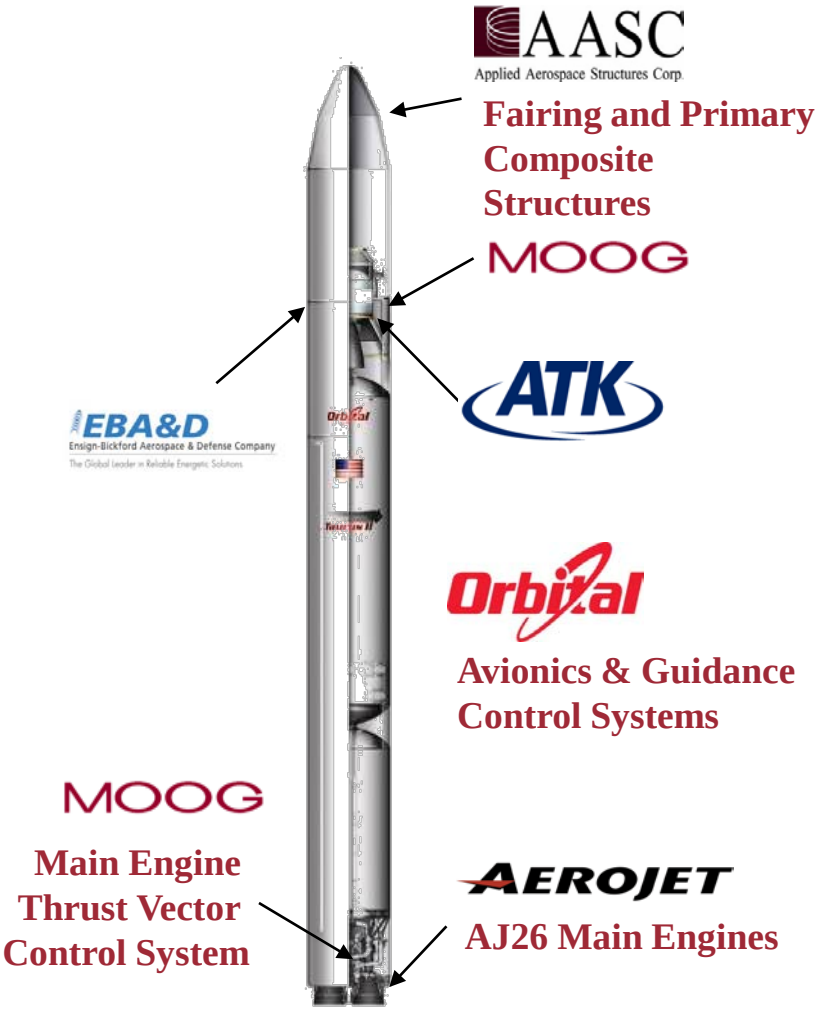
Orbital Leverages Commonality To Reduce Cost and Technical Risk

Orbital Innovation You Can Count On®

Orbital's Flight Proven Common Systems



Common Suppliers Support U.S. Industrial Base



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Antares

Designed to Provide Versatile, Cost-effective Access to Space for Medium-Class Payloads

Currently Under Contract to Support 10 NASA International Space Station (ISS) Re-supply Missions

On-Ramped to NASA NLS-II Contract

On-Ramp to USAF OSP-3 Contract

EELV New Entrant Statement of Intent Accepted by USAF

PAYLOAD FAIRING
- 3.9 meter diameter by 9.9 meter envelope
- Composite Construction
- Non-contaminating Separation Systems

STAGE 2
- ATK CASTOR® 30/30B/30XL Solid Motor with Active Thrust Vectoring
- Orbital MACH avionics module
- Cold-gas 3-axis Attitude Control System

STAGE 1
- Liquid Oxygen/RP-1 fueled
- Two AJ26 engines with independent thrust vectoring
- 3.9 meter booster derived from heritage Zenit design

VEHICLE PARAMETERS
- Gross Liftoff Mass: 290,000 kg
- Vehicle Length: 40 m
- Vehicle Diameter: 3.9 m
- Mass to ISS Orbit: 5000 kg Baseline
  6265 kg Enhanced

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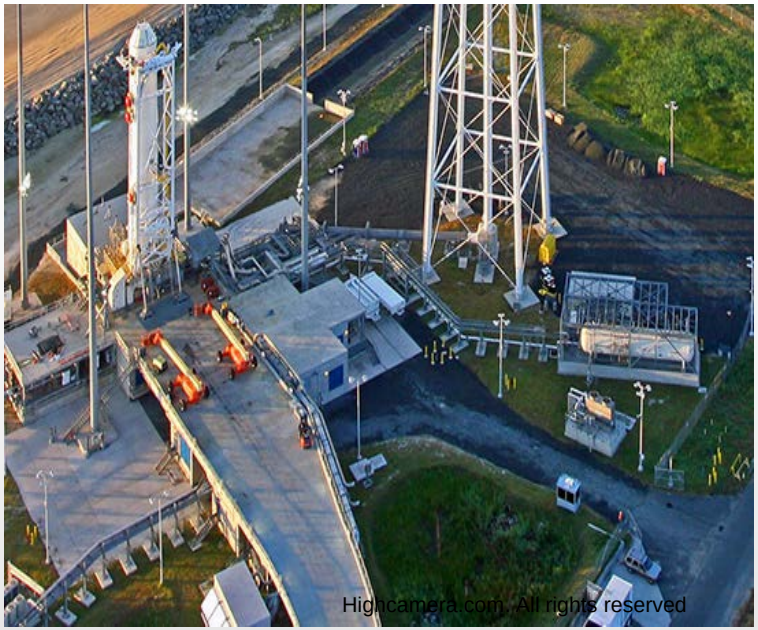
Antares Status

- Hardware Ready at WFF Launch Site for Hot-Fire Test and Test Flight
- Additional Boosters at WFF for COTS Demo and First CRS Missions
- Launch Site Construction Complete



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Orbital Perspective Summary

- 30 Years of Successful Space Launch System Development and Launch
- Leading Provider in US for Small/Medium Launch
- Orbital has Developed a Broad Range of Launch Vehicle Solutions Using Both Solid and Liquid Propulsion
- Advocates Targeted Investment in Tangible Propulsion Solutions Benefiting Multiple Customers

Orbital's Objective Is To Be The Best Value Provider In the Small and Medium Class

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AFFORDABLE END-TO-END SPACE SYSTEMS

There is a Better Way

Orbital

Innovation You Can Count On®