Reliable and Versatile Launch Vehicle Family

- 8 of 8 First Flight Successes
- 78 Consecutive Successful Atlas Centaur Flights
- 100% Mission Success Atlas II, IIA, IIAS, III & V Families
- 487 Total Launch Successes Since Atlas Program Inception

Mission Success—One Launch at a Time
AV-010 Launch

- January 19, 2006
- NASA Pluto New Horizons Spacecraft
- First 551 configuration
- First Block 2 Fault Tolerant Avionics
- First Block B SRB
- Nuclear certified
- Nominal flight profile
- Injection conditions well within 1 sigma
  - C3, RLA, DLA

Fastest Spacecraft Ever Launched
Atlas Evolution History

**Atlas I/II Family**
- Atlas I
- Atlas II
- Atlas IIAS
- Single Engine Centaur
- RD-180 Engine
- SRBs
- First Flight: 7/90

**Atlas III Family**
- Atlas IIIA (SEC)
- Common Centaur
- LO2 Tank Stretch
- First Flight: 5/00

**Atlas V Family**
- Atlas V (400 Series) (0–3 SRBs)
- Atlas V (500 Series) (0–5 SRBs)
- First Flight: 8/02

**Demonstrated Low-Risk Evolutionary Development**

Atlas for Human Spaceflight 15 Feb 2006
Atlas V HLV – Highlights

- 30 month order to launch
- All Common Element Design Criteria Envelope HLV Requirements
- Liquid Rocket Booster “Strap-Ons” Same as Flight Proven Common Core Booster
- RD-180 Engine HLV Certification Testing Complete
- RL10 Fully HLV Qualified, Including 3-Burn, Long-Coast Missions
- Most Common Hardware Already Qualified to HLV levels
- Minimal New HLV Hardware for Airborne and Ground Systems
- Block 2 Avionics Upgrade, Providing HLV Fault-Tolerance
- Software update < 25% Change to Current FSW
- Existing Facilities Accommodate HLV

95% of HLV System Flight Proven
Atlas Program Evolution Approach

• Atlas evolution elements become fleet baseline

• Atlas evolution benefits existing customer base
  – Maintain/improve Atlas 401 cost/launch
    • Phase 1 Centaur (SEC) cost ≤ Centaur III cost
    • Phase 2 Booster cost ≤ Atlas V booster cost
  – Improve cost at 5XY and HLV performance levels
  – Accommodate NASA Space Exploration and NRO growth requirements
    • Both super heavy lift and CEV requirements

• Maximize DoD/NASA/ Commercial synergy
  – Common element architecture
  – Enable NASA/ DoD sharing of investment

• Credible, sustainable program
  – Time phased to meet NASA affordability
  – Minimize use of new or risky technology, minimize complexity
    • No new engines required for baseline evolution
    • No cross feed, limit clusters to five-body

• Existing LC-41 infrastructure through Phase 2 development

• Current and evolved mission reliability and safety supports human rating
  – Inherent design reliability, demonstrated reliability through commonality
Continued Atlas Evolution

Baseline
HLV
(9-28 mT LEO)

Phase 1
(Wide Body Centaur)
(9-36 mT LEO)

Phase 2
(Wide Body Booster)
(9-68 mT LEO)

Phase 3A
(5 Body)
(107 mT LEO)

Phase 3B
(Super HLV)
(54-140 mT LEO)

Existing Pad and Infrastructure

Existing Pad and Infrastructure

Existing Pad and Infrastructure: New MLP

New Launch Site

New Launch Site

Centaur Engine Out

Centaur and Booster Engine Out

Increasing Reliability

Atlas Evolution Meets Space Exploration & Nation’s Needs

Atlas for Human Spaceflight 15 Feb 2006
Atlas As A Human Rated LV

- LM has a rich heritage in human spaceflight
  - First American in Space Flew Atlas / Mercury
  - Race to moon relied on flights of Atlas and Titan
  - Today’s Atlas V is most reliable Atlas ever

- Human Spaceflight Opportunities extend beyond CEV
  - Commercial opportunities emerging

Photos Courtesy NASA
# Human Launch Options

## Proven

<table>
<thead>
<tr>
<th>Some options</th>
<th>Maturity</th>
<th>Destination</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS</td>
<td>Proven</td>
<td>LEO, ISS</td>
<td>NASA Owned</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Phasing Out 2010</td>
</tr>
<tr>
<td>Russian Soyuz</td>
<td>Proven</td>
<td>ISS</td>
<td>$20M per Seat</td>
</tr>
<tr>
<td><strong>Atlas V</strong></td>
<td><strong>Proven</strong></td>
<td><strong>LEO, ISS, GEO, GSO Lunar Transfer, etc. Most Recently Pluto!</strong></td>
<td><strong>NASA Certified Human Spaceflight Heritage</strong></td>
</tr>
</tbody>
</table>

## Development

<table>
<thead>
<tr>
<th>Virgin Galactic</th>
<th>Infancy</th>
<th>Suborbital</th>
<th>Spaceship One technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clipper/Soyuz</td>
<td>In Design</td>
<td>ISS</td>
<td>Russian</td>
</tr>
<tr>
<td>Crew Launch Vehicle, CEV</td>
<td>In Design</td>
<td>ISS</td>
<td>NASA Owned (Currently 5 segment / J2)</td>
</tr>
<tr>
<td>“Low Cost” LV</td>
<td>Infancy</td>
<td>LEO, ISS</td>
<td>First Flight with payload only</td>
</tr>
</tbody>
</table>
Commercial Opportunities

• Commercial Orbital Transportation Services Demo
  – Capability D: Crew transportation

• Space Tourism

• Other

• Flight Proven Atlas V
  – Performance up to 28mT to LEO
  – Fault Tolerant Design
  – Potential for Mission Peculiar Kit additions for crew / cargo
Atlas Design Philosophy
Overview

• Common elements
  – Commonality driven down to part level

• Flexibility, wide range of missions & capabilities

• Simplicity, fault elimination
  – Reduced part counts
  – Fewer stages, fewer engines, fewer sep. events

• Fault tolerance, high reliability
  – Eliminate single point failures

• Rigorous margins & testing
  – Comprehensive, test like you fly
  – Analysis anchored to test & flight data

Detailed System Understanding Key to Mission Success
# Atlas V Human Rating Configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Atlas 401</th>
<th>Atlas HLV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8.2mT</td>
<td>28mT</td>
</tr>
<tr>
<td>Performance</td>
<td>Performance (220nmi. X 51.6)*</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Black Zone Closure</td>
<td>Yes</td>
</tr>
<tr>
<td>( &gt; 99% )</td>
<td>Reliability</td>
<td>( &gt; 98% )</td>
</tr>
<tr>
<td>All Liquid Rocket</td>
<td></td>
<td>All Liquid Rocket</td>
</tr>
<tr>
<td>Single RD-180</td>
<td></td>
<td>Single RD-180/Booster</td>
</tr>
<tr>
<td>Single RL-10</td>
<td></td>
<td>Dual RL-10’s</td>
</tr>
<tr>
<td>Low Cat Fraction</td>
<td></td>
<td>Low Cat Fraction</td>
</tr>
<tr>
<td>Fault Tolerant</td>
<td></td>
<td>Fault Tolerant Avionics</td>
</tr>
<tr>
<td>Avionics</td>
<td></td>
<td>High Margins</td>
</tr>
<tr>
<td>High Margins</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Performance includes PLF, Margin and Optimized Trajectory

**Reliable Human Spaceflight Vehicles**
Atlas Reliability Improvement

Atlas II
Demonstrated (63 of 63)

Atlas V Design Reduced POF
by Factor of 2.65
• Engines, Staging Events, Parts Eliminated
• Increased Redundancy
• AIII/V Demonstrated 10 of 10

Mission Reliability Requirement (0.99325)

R=0.9947 @ 65%
R=0.9965 @ 50%

9 mT
Atlas V 401

Atlas Reliability Meets NASA Standards

0.87 Allowable Abort System Reliability required to meet NASA Ascent Crew survival probability
System-Level Human Rating

Reliability
- Fault-Tolerant Systems
- Centaur and Booster Engine-Out Capability
- Demonstrated Reliability through high launch rate
- Vehicle Characterization
- Rigorous, closed-loop processes
- Experienced People

Health Monitoring
- Situational Awareness
- Monitor Critical Systems Using Independent Fault Tolerant Failure Sensing System
- Fly Monitoring System on All Missions
- Engine Out Detection and Abort Commands

Intact Abort Capability
- Catastrophic LV failures minimized
- Abort to Orbit under most engine failures

System Level Approach Meets Human Rating Requirements
### Human Spaceflight Requirements

<table>
<thead>
<tr>
<th>Human Rating Requirement</th>
<th>Atlas Approach</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FAA - Crew and Public Safety</strong></td>
<td>Maximize Safety and Reliability</td>
<td>Atlas V FAA Licensed and range Certified - Human Passenger requirements readily addressable</td>
</tr>
<tr>
<td>Reliability</td>
<td>Design POF reduced by factors relative to 100% successful Atlas II family</td>
<td>Atlas V: 62% reduction in POF High flight rate provides experience, cost reduction and alleviates “Infant mortality” failures</td>
</tr>
<tr>
<td>Demonstrated Reliability,</td>
<td>Common fleet provides flight tests &amp; high flight rate. Atlas II/III/V 100% success.</td>
<td>Proven Mission Success Atlas: 78 Flights 100% Success including 8 new configurations, 3 new launch pads and 7 Atlas V Flights</td>
</tr>
<tr>
<td>Dual Fault Tolerance</td>
<td>Single fault tolerance (SFT)</td>
<td>Abort provides second fault protection</td>
</tr>
<tr>
<td>Robustness, Factors of Safety</td>
<td>Common elements designed to envelope of fleet requirements</td>
<td>Human rated configurations have robust margins relative to design</td>
</tr>
<tr>
<td>Common Cause Software Failures</td>
<td>Rigorous SW development &amp; test processes provide necessary SW reliability</td>
<td>Backup flight control SW approach maximizes commonality</td>
</tr>
</tbody>
</table>
Atlas V Abort Black Zone Closure

Loads vs Duration in the +Gx Direction ("Eyeballs In")

- Red: Human G Limit for Aborts
- Cyan: G Exposure During Worst Atlas V HLV Abort
- Blue: G Exposure During Worst Atlas V 401 Abort

Uncontrolled Abort Reentry

Duration (sec)
Crew Access Alternatives

via MLP Fixed Crew Access Tower

Crew Access Alternatives
- Fixed Crew Tower at CX-41
- Mobile Launch Platform existing lift

Crew access keyed to requirements
Summary

• Flight Proven, Credible
  – 8 of 8 first flight successes over 12 years
  – 78 consecutive successful flights

• Available
  – Atlas V with Mission Peculiar kit can be available for 2008 demo flight
  – Flight proven common Booster and Centaur provides path to HLV
  – Atlas HLV ready within 30 month order to launch timeline

• Affordable
  – Cost minimized using current Atlas to eliminate dedicated test flights
  – Fleet baseline approach minimizes recurring cost

• Sustainable
  – Substantial synergy with DoD
  – Infrastructure supported by total launch market

• Safe and Reliable
  – Human Rating requirements evaluated, analyzed and assessed
  – Atlas has the best demonstrated reliability of worlds launch vehicle
  – All liquid vehicles have low Cat Fraction

Atlas V - Ready to Support Human Spaceflight!
Backup
Atlas Program Approach

- Minimize cost, risk & schedule
  - Introduce improvements one step at a time
  - Ensure improved flying product at each step
  - Grow capability as needs mature – incremental cost

- Maintain common vehicle configurations
  - Atlas Common Element Approach
    - Common Booster
    - Common Centaur
    - Launch complex
  - Flight Proven Hardware
    - Eliminates risk prior to crewed flights
    - Evolving fleet baseline supports certification
    - High demonstrated reliability
  - Affordability
    - High production rates reduces cost
    - Shared infrastructure cost between users

- Additional Enhancements to increase Reliability benefits all users
  - Critical one of a kind national missions
  - Enable human rating
401 Vehicle Configuration

Fault Tolerant Architecture
Minimum Staging Events

Reliably Simple Vehicle Configuration
Atlas V Heavy Lift Vehicle

*Design complete, Qual remaining

Staging Thrusters & Separation* Ordnance (In Development)

Launch Site Additions: Launch Heads, HPSS & Decouplers Install Mechanical GSE Fluid Lines Pathfinder

ATS Attach Fittings & Back-Up Structure*

Composite 5.4 Meter Dia., 87-ft Long Payload Fairing

Composite 5.4 Meter Dia., 87-ft Long Payload Fairing

ATS Attach Fittings & Back-Up Structure*

Composite Boattail ISA & Aft Bolt-Ons Centaur Interstage Adapter (C-ISA) - 12.5-ft Dia. & Aft Bolt-Ons

Build 7 Flight Software

Centaur Forward Load Reactor (CFLR) Deck & Fwd. Bolt-Ons

Additional Performance with Flight Proven Reliable Common Elements