Low Cost Spacelift to LEO, GTO, and Beyond Using the OSP-2 Minotaur IV Space Launch Vehicle

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Launch Systems Group
Chandler, AZ
Agenda

• Program Overview

• Baseline Vehicle Description, Heritage, and Manifest

• GTO Configurations and Performance

• Summary
OSP-2 Organizational Structure

US Govm't Customer / Sponsored Payload

USAF
SMC Det 12/RP

Det 12 Technical & Ops Support

OSP-2 Contractor

Minuteman-based Launch Vehicles

Peacekeeper-based Launch Vehicles

Commonality

- Avionics
- Subsystems
- GSE
- Processes
## Minotaur Launch Vehicle Family

<table>
<thead>
<tr>
<th></th>
<th>Minotaur I</th>
<th>Minotaur II</th>
<th>Minotaur III*</th>
<th>Minotaur IV</th>
<th>Minotaur V*</th>
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</thead>
<tbody>
<tr>
<td>S1</td>
<td>M55 (GFE)</td>
<td>M55 (GFE)</td>
<td>M55 (GFE)</td>
<td>PK S1 (GFE)</td>
<td>PK S1 (GFE)</td>
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<tr>
<td>S2</td>
<td>SR 19 (GFE)</td>
<td>SR 19 (GFE)</td>
<td>Orion 50XL</td>
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<td>Orion 50XL</td>
<td>Orion 50XL</td>
<td>PK S3 (GFE)</td>
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<tr>
<td>S4</td>
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<td>Orion 38</td>
<td>Orion 38</td>
<td>Star 48V</td>
<td>Star 37GV</td>
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<td>S5</td>
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<td>HAPS (Optional)</td>
<td>HAPS (Optional)</td>
<td>HAPS (Optional)</td>
<td>HAPS (Optional)</td>
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<tr>
<td>Fairing</td>
<td>50 Inch (Pegasus)</td>
<td>61 Inch</td>
<td>61 Inch</td>
<td>92 Inch (Taurus)</td>
<td>92 Inch (Taurus)</td>
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### Performance:

<table>
<thead>
<tr>
<th></th>
<th>Minotaur I</th>
<th>Minotaur II</th>
<th>Minotaur III*</th>
<th>Minotaur IV</th>
<th>Minotaur V*</th>
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</thead>
<tbody>
<tr>
<td>100 nmi, 28.5°</td>
<td>1280 lbm</td>
<td>1260 lbm</td>
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<td>3800 lbm</td>
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<td>2200 lbm</td>
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<td>GTO</td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>1355 lbm</td>
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</table>

* Conceptual - not part of current OSP contract
Minotaur IV is a combination of flight proven subsystems.

- Peacekeeper ICBM Boosters
  - 50 launches (49 successful)
  - 14 instrumented development launches
  - Robust weaponized subsystems
  - Unmodified GFE

- OBV
  - 3 launches (3 successful)
  - Demo in 13 months from ATP

- Pegasus
  - 35 launches (32 successful)

- Taurus
  - 6 launches (5 successful)
  - 2 launches (2 successful)

- Minotaur
  - 2 launches (2 successful)

- TLV
  - 5 launches (5 successful)

Orbital Flight-Proven Components and Processes
- 51 heritage launches
- 92% total success rate
- 100% successful first missions

Minotaur IV SLV
- Components and processes highly common with 100% successful OSP launch vehicles
- Orion 38 stage 4, 47 launches, 100% success
- Flight-proven Orbital standard avionics components
  - Flight computer
  - SIGI INS
  - MACH Avionics
  - Taurus 92 in. payload fairing

PK Motors
Guidance Control Assembly (GCA)
Payload Adapter Module (PAM)
## OSP Flight History Prior to First Minotaur IV

### Successfully Launched

<p>| | | | | | | | |</p>
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<td>TLV-Demo</td>
<td>IFT-7/TLV-1</td>
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<td>IFT-10TLV-4</td>
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</table>
Minotaur IV Uses Largely Flight Proven Components

Avionics Structure
- Honeycomb Composite
- Annular Structure
- Integrated Avionics Assembly
  - Flight Computer
  - INS
  - MACH Avionics
  - Batteries
  - Attitude Control System
  - PK Booster Control Module
  - AC Firing Unit
  - FTS Converter Module

Payload Fairing
- 92” Taurus Design
- Frangible Separation Rails

Payload Adapter Cone
- Fixed 62” Interface
- Payload Separation System/Adapter Cone Interface

Fairing Adapter Ring
- Frangible Separation Ring

Motor Adapter Cone
- Composite Structure

Stage 4 Motor
- Orion 38 (Baseline)
- Optional STAR 48

GCA Structure
- Composite Structure

Frangible Ring
- Separates S3

3/4 Interstage
- Composite Structure

Stage 3 Assembly
- Unmodified GFE

Stage 2 Assembly
- Unmodified GFE

Stage 1 Assembly
- Unmodified GFE

GFE/Flight Proven
Existing/Flight Proven
Adapter from Existing Flight Proven Design
New Design
All But Three Components Have Direct Flight Heritage

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<tr>
<th>Component</th>
<th>Qty</th>
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<td>Guidance and Control Module</td>
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<tr>
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<td>92&quot; Shroud</td>
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<tr>
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<td>Transient NiCd 1.8 Ah Battery</td>
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<td>Safe/Arm Switch</td>
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<td>Arm/Disarm Switch</td>
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<td>C-Band Coupler</td>
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<td>Safe/Arm Switch</td>
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<td>S-Band Coupler</td>
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<tr>
<td>S-Band Antennas</td>
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<td>Qualified (Q)</td>
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</table>

**GCA Module**
- graphite epoxy and aluminum honeycomb
- similar to taurus design

**92" Shroud**
- Flight proven 92" fairing
- Graphite epoxy and aluminum honeycomb
- Frangible joint separation system

**RCS Thrusters**
- 2 triads of thruster valves provide independent pitch, yaw, roll control, 5800 psi regulated system

**Flight Computer**
- Orbital Flight Computer
- Remote load and verification of software and mission data loads
- Ethernet and RS-422 connectivity

**Space Integrated GPS/INS (SIGI)**
- Tightly coupled IMU/GPS/Nav Unit
- Low noise, "zero lock" Ring Laser Gyros
- RS422 interface capability

**Avionics/Booster MACH**
- Modular Avionics Control Hardware (MACH) allows customization as requirements are refined
- Ethernet and RS422 communications interfaces
- Separate and isolated power switches, each rated at 4.5 Amps
- Avionics and TLM batteries are 28V, 5 AHR NiCd cells
- 10 Mbytes of memory for telemetry archive and retransmission
- Current limited ordnance drivers up to 10 Amps 40 mSec
- Ordinance batteries are 28V, 1.2 AHR rechargeable NiCd cells

**Command Receiver, UHF Antennas and GPS Beacon**
- Receiver Decoders 180 degrees apart for redundancy
- Fully 127-1 compliant
- UHF Patch Antenna from Ball
- 12 Channel GPS Receiver -10 Hz Position Velocity Time (PVT) Output

**PCM Encoder**
- Orbital MACH-based Modular encoder allows system expansion/modification
- Shock and Vibe environment monitor inputs

**Telemetry Transmitter, S-Band antennas**
- Wide band transmitter (user selectable frequency over S-band), IRIG 106-00 compliant
- 10 Watt minimum power output
- S-band slot antennas provide -18 dBi 95% coverage

**Note:**
- MS = Mission Specific
- Q = Qualified
- PQ = Pending Qual
- NQ = New Qual
Minotaur IV Processing Flow Based on Taurus Experience

- Launch Site Processing Derived from Minotaur and Taurus Operations
- Payload Integration Independent of Booster

**Crane Lift Emplacement Of Boosters and GCA/Stage 4**

**Payload Integration & Encapsulation**

**Transport to Launch Pad**

**Crane Lift Emplacement Of Payload/Fairing Assembly**

**Final Pre-Launch Verification Tests**
Minotaur IV Performance

NOTE:
1. Payload Mass includes Adapter Cone, Separation System and Other Mission-Specific Hardware.

1735 kg to 185 km (3826 lbm to 100 nm)
OSP Provides Consistent, Realistic Low Cost Performance

• Minotaur Cost Has Increased Only at About 5% Per Year

• Demonstrated 1st Mission Schedule and Technical Performance
  – Minotaur I: 27 Months from ATP to First Launch
  – OSP TLV: 21 Months from ATP to First Launch

• OSP-2 LV Costs ‘Locked-in’ through 2013 for Minotaur I, Minotaur II, and Minotaur IV
### OSP-2 Mission Development Process

#### Notional Eighteen Month Schedule

<table>
<thead>
<tr>
<th>Event</th>
<th>Year 1</th>
<th>Year 2</th>
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<tbody>
<tr>
<td>ATP</td>
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<tr>
<td>Requirements Development</td>
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<tr>
<td>System Design</td>
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<td>Qtr 3</td>
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<tr>
<td>Mission Design Review</td>
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<td>Factory Integration &amp; Test</td>
<td>Qtr 2</td>
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<tr>
<td>Ship to Launch Site</td>
<td>Qtr 3</td>
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<tr>
<td>Launch Site Operations</td>
<td>Qtr 4</td>
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<td>Mission Readiness Review</td>
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<td>Qtr 1</td>
</tr>
<tr>
<td>Launch Window (w/grace period)</td>
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<td>Qtr 2</td>
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- 1st PK-based LV (SLV or TLV) mission: 24 month Schedule
- Subsequent Minotaur missions 18 months
- Mission Initiation via SMC Det 12/RP Program Office
High Energy “Minotaur V” Configuration Options

### Minotaur IV Concept

- S4: Orion 38
- S5: Orion 38

### Minotaur V Concepts

#### GTO Option 1
- S4: Orion 50XL
- S5: Orion 38

#### GTO Option 2
- S4: Star 48
- S5: Orion 38

#### GTO Option 3
- S4: Star 48
- S5: Star 37

### Performance

<table>
<thead>
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<th>Baseline</th>
<th>GTO Option 1</th>
<th>GTO Option 2</th>
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<tr>
<td>100 nmi, 28.5°</td>
<td>3800 lbm</td>
<td>1095 lbm</td>
<td>1219 lbm</td>
<td>1355 lbm</td>
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<td>400 nmi, SunSynch:</td>
<td>2200 lbm</td>
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PR04002_028
Minotaur V Front End Configuration (Option 1)

Avionics Structure
- Honeycomb Composite Annular Structure
- Integrated Avionics Assembly
  - Flight Computer
  - INS
  - MACH Avionics
  - Batteries
  - Attitude Control System
  - PK Booster Control Module
  - AC Firing Unit
  - FTS Converter Module

Payload Fairing
- 92" Taurus Design
- Frangible Separation Rails

Stage 5 Assembly
- Motor Adapter Cone
- Frangible Ring

Stage 5 Motor Orion 38

Stage 5 Motor Structure
- Fringing Adapter Ring
  - Frangible Separation Ring

Motor Adapter Cone
- Frangible Separation Ring

GCA Structure
- Frangible Ring
  - Separates S3

Stage 4 Motor
- Orion 50XL

GCA Structure
- Composite Structure

Stage 5 Assembly
- Standard Pegasus Separation System
  - Nutation Control System

Legend:
- GFE/Flight Proven
- Existing/Flight Proven
- Adapter from Existing Flight Proven Design
- New Design
Minotaur V Also Provides Translunar Performance

- Potential Lunar Missions
  - Lunar flyby, orbit, impact/lander, free-return, other?
- Minotaur V (Option 3) Capabilities
  - Option 3 Configuration (PK1/PK2/PK3/Star48V/Star37FM)
  - Direct Ascent Trajectory

<table>
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<tr>
<th>Lunar Inclination, Relative to the Equator</th>
<th>Payload Capability</th>
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<tbody>
<tr>
<td>28 deg</td>
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<tr>
<td>23 deg</td>
<td>1013</td>
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<tr>
<td>18 deg</td>
<td>901</td>
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Summary

• Minotaur IV is a “New” Launch Vehicle With an Extensive Flight Heritage
• Minotaur IV Prices and Performance Are Well Understood and Solid Based on the Long Experience With the Constituent Subsystems and Organizations (RSLP, Northrup Grumman, and Orbital)
• Minotaur IV Mission Prices Include All ‘Fly-Away’ Costs
• Concepts Have Been Developed for a Minotaur V Vehicle Capable of Supporting High Energy GTO and Translunar Small Spacecraft Missions
Minotaur IV Based on Robust Heritage Systems

- **Peacekeeper Boosters Built to ICBM Weapon System Rigor**
  - Front-Line Strategic Deterrent for the USA
  - Safety and Reliability for Nuclear Weapon Systems
  - Regular Aging And Surveillance Testing and Inspections
  - 50 Total Launches and At Least 18 Static Fire Tests

- **Orbital Flight Proven Avionics and Subsystems**
  - Avionics with Flight Heritage of 2 to 25 Launches
    - Uses StandardizeOSP Avionics Configuration Which Has Seven Total Launches (100% Successful)
  - Orion-38 Stage 4 Booster with 46 Total Launches
  - OSP-Standard ‘Object Oriented’ Software With Seven Total Launches
    - Also Used as Common Core Code for GMD Orbital Boost Vehicle With Three Total Flights

- **Integration and Test Processes and Procedures from OSP, Taurus, and PK Directly Apply**
  - Existing, Demonstrated Processes with Quality Assurance Approval Mitigate Risk
All Minotaur IV Motors Have Extensive Flight Histories

- Peacekeeper Motors Pedigree
  - Static Fire Tests
    - 20 – Stage 1
    - 18 – Stages 2
    - 18 – Stage 3
  - 50 PK Launches
  - 3 PK Taurus Launches (Stage 1)
  - No Motor Related Failures

- Orion 38 Motor Pedigree
  - One Static Fire Test
  - 46 Launches
    - 35 Pegasus
    - 6 Taurus
    - 2 Minotaur
    - 3 OBV
  - No Motor Related Failures
Minotaur IV Fairing and Envelope

Proven Orbital 92" Taurus Fairing
- Vertical Integration
- Aft Shield Isolates Payload Envelope
- S/C Encapsulated Independent of LV
Minotaur IV Can Launch from All US Space Launch Facilities

Flat Pad Stool Launch

Portable Control Consoles

KODIAK LAUNCH COMPLEX
Kodiak Island, AK

VIRGINIA SPACE FLIGHT CENTER
Wallops Island, VA
- Commercial Launch Sites at NASA’s Wallops Flight Facilities

WESTERN RANGE
Vandenberg AFB, CA
- Government Launch Sites
- California Spaceport SSI CLF

EASTERN RANGE
Patrick AFB, FL
- Government Launch Sites
- Spaceport Florida

Minimal Infrastructure and Portable GSE Allows Operations from Multiple Ranges
Minotaur V GTO Nominal Mission Timeline (Option 3)

Payload Mass: 1355 lbm
Orbit Altitude: 35600 km x 188 nm
Inclination: 28.5°
Argument of Perigee: 180°

<table>
<thead>
<tr>
<th>No.</th>
<th>Event</th>
<th>Time (s)</th>
<th>Altitude (km)</th>
<th>Range (km)</th>
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<td>33619.81</td>
</tr>
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<td>20411.78</td>
<td>35600.8</td>
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