XSM-1:
A Standardized Military Spacecraft

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Forging the Shape of Military Space for the 21st Century
Outline

XSM-1 Concept:
  – Standardized Spacecraft
  – Minotaur 4 Space Launch Vehicle
  – Responsive On-Orbit Operations
XSM-1 Concept

• Operationally and Tactically Responsive Spacecraft
  – Support Time-Over-Target (TOT) Operations
  – Overfly Specific Latitude/Longitude at the Desired Time
Standardized Spacecraft

• Spacecraft Requirements
  – Carry 150 kg of Payload Weight
    • Up to 5 Payloads
    • Based on Analysis of DOD Space Experiments Market
  – Carry 30% of Total Weight in Fuel
  – 500 KRad Radiation Tolerance
Candidate Payloads

• Research-Oriented Payloads
  – Mixed Reviews for Suitability of Orbit
  – Radiation Environment a Concern for Optics
  – Financial Incentive for Low Budget Experiments

• Promising Military Applications
  – RF Payloads
    • Communications
    • Signals Collection
  – Space Surveillance
Minotaur Space Launch Vehicle

• Performance Capability
  – 500 Kg to Intended Orbit

• Characteristics
  – 92” Bi-Conic Fairing
  – 1st Three Stages from Peacekeeper Missiles
  – 4th Stage is Orion 38 Motor

• Well Defined Interface to Launch Site and Spacecraft
Responsive On-Orbit Operations

• Chose Orbit to Overfly Theater Twice-a-Day
  – Orbit Period is Odd Divisor of 24 hours
  – One Ascending Pass Over Theater
  – One Descending Pass 12 hours Later

• Perform Conjunction Operations
  – Fly in Highly Elliptical Obit (HEO)
    • Maneuver to Control Time and Location of Overflight
    • Maneuver Nearly Continuously
  – Use non-Critically Inclined Orbit
    • Exploit Natural Orbit Precession
Orbit Characteristics

• Orbit Features
  – Apogee: 6042 km
  – Perigee: 674 km
  – Precession Rates
    • Nodal Regression: 0.23°/day
      – Offset with Orbit Period
    • Perigee Rotation: -1.28°/day
      – Temporal Precession: 4.8 min/day
      – Longitude Range: 14°
      – Repeats every 281 Days

Baseline Orbit Parameters:

<table>
<thead>
<tr>
<th>Orbit Parameter</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-Major Axis</td>
<td>a</td>
<td>9736 km</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>e</td>
<td>0.2757</td>
</tr>
<tr>
<td>Inclination</td>
<td>i</td>
<td>85 deg</td>
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</tbody>
</table>
Orbit Interactions

- Selected Orbit Allows for Interaction with Low Earth Orbit (LEO) Objects
  - Possibility of Collision Each Time the Surface of the Orbit Planes Intersect
  - Robust Mission Planning and Common Operational Perspective Needed for Safety of Flight/Collision Avoidance

![Diagram of orbit planes intersecting]
Candidate Maneuvers

- Timing Maneuvers
  - Control Time-of-Flight Over Desired Latitude
- Longitudinal Maneuvers
  - Control Longitude of Pass
- Combined Maneuvers
  - Optimize for Latitude, Longitude and Time
- Argument of Perigee Rotation
  - Control Altitude of Overflight
  - Zero-Momentum Burn to Yaw Orbit Plane
Maneuver Execution

• Allow 3 Days Notice to Reach Desired Position in Space
  – Based on 3-day Air Tasking Order (ATO) Planning Cycle
    • Initiate Maneuvers Based on Target Nomination
  – Fuel Calculations Assume Single Thrust 27 Revs Before Overflying Desired Support Point
  – Altitude of Overflight is Unconstrained
Maneuver Mechanics

• Burn Thrusters during Apogee Pass
  – Increase Velocity
    • Increase Orbit Period
    • Raise Perigee
    • Delay Arrival to Support Point
    • Walk Longitude to the West
  – Decrease Velocity
    • Reduce Orbit Period
    • Lower Perigee
    • Accelerate Arrival to Support Point
    • Walk Longitude to the East

Velocity Decreases are Limited by Earth-Impacting Orbits
# Timing Maneuvers

<table>
<thead>
<tr>
<th>Delta Time</th>
<th>Delta-v</th>
<th>Semi-major axis</th>
<th>Orbit period</th>
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<tbody>
<tr>
<td>3 hrs earlier</td>
<td>94.1 m/s</td>
<td>9,512 km</td>
<td>2.56 hr</td>
</tr>
<tr>
<td>1 hr earlier</td>
<td>11.6 m/s</td>
<td>9,694 km</td>
<td>2.64 hr</td>
</tr>
<tr>
<td>same time</td>
<td>27.6 m/s</td>
<td>9,785 km</td>
<td>2.68 hr</td>
</tr>
<tr>
<td>1 hr later</td>
<td>65.8 m/s</td>
<td>9,874 km</td>
<td>2.71 hr</td>
</tr>
<tr>
<td>3 hrs later</td>
<td>139 m/s</td>
<td>10,054 km</td>
<td>2.79 hr</td>
</tr>
<tr>
<td>6 hrs later</td>
<td>241 m/s</td>
<td>10,319 km</td>
<td>2.90 hr</td>
</tr>
<tr>
<td>9 hrs later</td>
<td>335 m/s</td>
<td>10,581 km</td>
<td>3.01 hr</td>
</tr>
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</table>

Based on Maneuver Occurring 27 revs Prior to Overflight
Thruster Considerations

• High Isp Thrusters Needed (>1,000 sec)
  – Increase Delta-V Budget
  – Necessitates Low Thrust System
    • Chemical-Electric
    • Hall Effect
    • Ion Propulsion

• Low Thrust Thrusters Increases Duration and Number of Burns Required
  – Thrust Nearly Every Orbit to Get 3-4 m/sec
Fuel Budget

• Typical Maneuvers
  – Peacetime, Routine Support
    • Typically Expend 20-30 m/sec per Mission
    • Conduct 2-3 Missions per Month
  – Crisis, Urgent Support
    • Typically Expend 100 m/sec per Mission
    • Conduct Missions Weekly

• Project Two-Year Life Span
  – Life Span Driven by Fuel Consumption
  – Expect Fuel Budget to be >3,000 m/sec
Radiation Analysis

• Space Environment
  – Solar Winds and Flares
  – Galactic Cosmic Rays
  – Van Allen Belt Radiation

• Radiation Effects
  – Surface Heating
  – Degrade Surfaces and Electronics

• Spacecraft Needs to be Radiation Tolerant
  – Performed Analysis with CREME96 Model
  – Estimated 100 KRad Over Two Years
Issues

• Challenges
  – Mission Planning Tools
  – Common Operational Perspective of Space
  – Safety of Flight During Transit of Populated Orbit Regimes
  – Crew Concept and Crew Stations

• Limitations
  – Maneuvers Limited by Earth-Impacting Orbits
  – Not Practical to Control Altitude of Overflight
Conclusion

• Concept Continues to be Evaluated by Air Force Space Command
• May Find a Home with the Joint Warfighting Space (JWS) Initiative