Small Body Mission Concepts

Presentation to the Small Bodies Assessment Group
January 13th, 2009

Dr. Luke Sollitt
Keith Kroening
Civil Space Business Development
SBAG Presentation Outline

- **EELV Secondary Payload Concepts**
  - LCROSS System Description
  - Candidate secondary payload missions to 4015 Wilson-Harrington
  - LCROSS Derivative Capabilities
    - Power
    - Propulsion
    - Communications

- **Primary Spacecraft Concepts**
  - Trajectories to 4015 Wilson-Harrington
  - Elst-Pizarro
Secondary Payload Concepts
Secondary Payload Definition

- Independent missions built into the launch vehicle adapter for a primary payload
  - Current primary payloads often defined by the Delta II lower launch mass

- Utilize excess capacity in EELV
  - Some primary missions can add strap-on solid motors for increased throw weight capability
  - Some primary missions are flying with upper stages not fully fueled

- Drastically reduced launch costs

- Must ‘not impact’ primary mission
  - Time of launch, trajectory etc restrictions

- Can be impacted by requirements of primary mission
  - Launch dates
  - Trajectory available – though the destination can be different from the primary payload
  - Launch slips or other issues

- Current Example: LCROSS
Why a Secondary Payload?

• Lower launch costs (much lower), with large throw masses
  – If the option is allowed by the AO

• With existing technology, it is possible to get to a small body with reasonable payload, propulsion, power, and comm to do first rank science

• Overall quality of the spacecraft/mission would be no different from a regular Discovery or other mission

• The only difference is a lower launch cost, for which the trade is a particular configuration and perhaps the need for higher onboard delta-V
### Atlas V Secondary Manifest Capability

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
<td>2nd</td>
<td>1st</td>
<td>2nd</td>
</tr>
<tr>
<td><strong>CCAFS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LC-41</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>19 Jan</strong></td>
<td><strong>Pluto</strong></td>
<td><strong>AV010/551</strong></td>
<td><strong>14 Feb</strong></td>
<td><strong>STP-1</strong></td>
<td><strong>AV-013 / 401</strong></td>
</tr>
<tr>
<td></td>
<td><strong>20 Apr</strong></td>
<td><strong>ASTRA 1KR</strong></td>
<td><strong>AV008/411</strong></td>
<td><strong>GPS IIF-4</strong></td>
<td><strong>401</strong></td>
<td><strong>GPS IIF-3</strong></td>
</tr>
<tr>
<td><strong>VAFB</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SLC-3E</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>3 Apr</strong></td>
<td><strong>NROL-28</strong></td>
<td><strong>AV006/411</strong></td>
<td><strong>16 Apr</strong></td>
<td><strong>DMSP-18</strong></td>
<td><strong>501</strong></td>
</tr>
<tr>
<td></td>
<td><strong>16 Apr</strong></td>
<td><strong>STP-1</strong></td>
<td><strong>AV-013 / 421</strong></td>
<td><strong>GPS IIF-4</strong></td>
<td><strong>401</strong></td>
<td><strong>GPS IIF-7</strong></td>
</tr>
</tbody>
</table>

**Legend:**
- Atlas V 400
- Atlas V 500

---

**Secondary Opportunity**
LCROSS Spacecraft
LCROSS Mission

- LCROSS – low-cost quick turnaround system
  - Search for H₂O in dark craters
  - Quick ‘low cost’ mission development cycle
  - Low-Cost secondary launch
  - ESPA-Ring structure
  - LRO derived avionics
  - Robust propulsion capability
LCROSS Mission Design

- Class-D Mission, Cost = $80M;
- 26-month Program: from authorization to proceed (ATP) to spacecraft delivery
- Mass: total = 895 kg
  - Spacecraft (dry) = 610 kg
- Power:
  - Solar Array = GaAs
  - Batteries = Li-ion
- LRO based avionics
  - C&DH, Power, Sensors, Transponder
- Thruster based pointing control:
- Communications: S-band
Candidate Secondary Payload Missions to 4015 Wilson-Harrington
Secondary payload mission concept to 4015 Wilson-Harrington

• Based on the LCROSS architecture
  - Assumed improved thrusters ($I_{sp}$ of 315)

• Looked at primary launches to:
  - Geostationary transfer orbit (launch with a commercial or military payload)
  - Trans-lunar trajectory (launch with a NASA payload)

• Two trajectory segments
  - GTO/TLI to Escape
  - Interplanetary

• Segments patched together
  - Segments boundaries do not match
  - $\Delta V$ may be higher due to mismatch
  - Additional lunar gravity assists may be necessary to match the required escape asymptotic right ascension
Candidate Primary Mission Types and Secondary Asteroid Trajectories

- GEO - Uses onboard propulsion to escape via lunar gravity assist
- Lunar - Uses lunar gravity assist to escape via lunar gravity assist
- L1/L2 - Uses onboard propulsion and gravity assist to escape
- Planetary - Uses onboard propulsion to make slight changes to trajectory to reach nearby asteroids
Secondary Mission: GTO to Wilson-Harrington in 6.6 years (Interplanetary Segment)

- Departure from Earth: 29 August 2012
- Earth Gravity Assist: 4 Oct 2014
- Lower Aphelion / Target Earth: 5 September 2013
- Arrival at Wilson-Harrington: 5 Nov 2018
- Mars
- Ceres
- 1:1 Resonance
Secondary payload mission concept to 4015 Wilson-Harrington

<table>
<thead>
<tr>
<th>Type of Launch</th>
<th>Delta-V (km/sec)</th>
<th>Wet Mass (kg)</th>
<th>Dry Mass (kg)</th>
<th>Cruise Duration (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTO</td>
<td>4.0</td>
<td>3365</td>
<td>778</td>
<td>6.6</td>
</tr>
<tr>
<td>Trans-Lunar</td>
<td>3.6</td>
<td>2788</td>
<td>778</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Necessary changes to the LCROSS architecture

- **Propulsion**
  - Equivalent of ~ 4 TDRS tanks
  - Pressurant tank and pressure regulator
    - May be traded for blow down system
  - Biprop, higher thrust engine

- **Comm**
  - Larger antenna/higher power might be needed due to larger distance (up to ~5 AU)

- **Power**
  - Additional solar panels due to larger aphelion (up to 4.2 AU)

- **Structure**
  - Adequate for loads. May need additional mounting surface for tanks
  - May affect CG of launch stack
  - Might be large enough to affect primary payload

- **Thermal**
  - Thermal environment different from LCROSS

- **Longer lifetime**
  - Higher redundancy
LCROSS Derivative
Power Capability
Derivative Solar Array Configurations

- LCROSS solar array used in all configurations
- LCROSS Cell: EMCORE InGap/GaAs/Ge 26% cells are upgraded to 29% cells by screening
- Primary objective is to maintain LCROSS power level

- When not at maximum distance from the Sun additional solar array output can be used by the 1.8kw EP thruster
Scaling of LCROSS Panels Required By Distance from Sun Trade Space

Load Power Range: 600W(LCROSS Baseline), 800W & 1000W

Sun Distance (AU)

Number of LCROSS Panels

1 AU 1.5 AU 2 AU 2.6 AU 3.5 AU 4 AU

1 1 1 2 2 2 3 4 4 5 6 6 8 8

600W 800W 1000W
ASRG Option Planned for Discovery

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ASRG – 650 C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>Stirling Convertor (650°C)</td>
</tr>
<tr>
<td>Power per Unit (BOL), [We]</td>
<td>143</td>
</tr>
<tr>
<td>Power Degradation Rate, [%/yr]</td>
<td>~ 0.8 (power decays roughly with fuel decay)</td>
</tr>
<tr>
<td>Mass per Unit, [kg]</td>
<td>~ 20.2*</td>
</tr>
<tr>
<td>Dimensions [mm]</td>
<td>Length: 762 mm ; Width: 394 mm ; Height: 457 mm</td>
</tr>
<tr>
<td>Radiation Tolerance (RDF=1)</td>
<td>126 krad**</td>
</tr>
<tr>
<td>Additional Shielding, [kg]</td>
<td>Mission Specific, required only for controller if left attached to generator housing in a high-radiation environment**</td>
</tr>
<tr>
<td>Number of GPHS Modules per Unit</td>
<td>2</td>
</tr>
<tr>
<td>Thermal Power (BOL), [Wt]</td>
<td>500</td>
</tr>
<tr>
<td>Unit Specific Power (BOL), [We/kg]</td>
<td>7.0</td>
</tr>
<tr>
<td>Conversion Efficiency</td>
<td>~ 28 %</td>
</tr>
<tr>
<td>Redundancy*</td>
<td>Single-fault tolerant, with N+1 redundant controller cards and the capability for the engines to operate independently of one another in the event of single engine failure. Initial reliability estimate ranges from 0.937 to 0.991 at 17 yrs, depending on conservatism of assumptions. (Further redundancy at the generator level should be left to mission analysts)***</td>
</tr>
<tr>
<td>Operating Environment</td>
<td>Vacuum and Atmosphere</td>
</tr>
<tr>
<td>Lifetime requirement, [years]</td>
<td>14 + 3 (storage)</td>
</tr>
<tr>
<td>Current Technology Readiness Level (TRL)</td>
<td>5****</td>
</tr>
</tbody>
</table>
LCROSS Derivative Propulsion Capability
Propulsion Schematic, Integration Diagram

- **Fill/Drain Module**
- **Propellant Distribution Module**

**8 x 4N ACS thrusters**

- 2 x 4N for shallow blowdown system Freeflyer; 2 x 20N for Impactor; with addition of 2 monopropellant Arcjets or METs for EP missions (Hydrazine not Xenon)

**EP** = electric propulsion
**MET** = microwave electrothermal thruster
• End-of-mission mass = 613 kg (LCROSS predict) + Prop ME + EPS ME + Com ME + DMS ME + Thermal ME + Structure ME + Payload + Dry Mass Margin

• EP options assume first 67% of delta V delivery via EP except for sample return (SR) at 33% EP, then 33% chem, then 33% EP

ME = mission enhancements needed to achieve particular mission
TacSat-2: 200 W Heterodyne Electric Thruster (HET) Propulsion System

- 200 Watt HET system and sensor suite
  - Flight hardware delivered May 05 for spacecraft I&T
  - 1600 + hours of life test prior to launch with no HET performance change
  - Minotaur 1 launch from Wallops Island
  - First flight of USA build Hall Effects thruster

- NGST was responsible for:
  - Propulsion system engineering, integration & test
  - Power Processing Unit (PPU) development (including Digital Control Interface Unit)

Innovation: low power (SOA ~2kW), pulsing (SOA steady state)
HET for SmallSats and Formation Flying Operation
TacSat-2: 200W HET Propulsion System

Technical Requirements

- Delta-V: 200 m/s minimum for 200 kg spacecraft
- Six month operational lifetime, with a 12 month goal (surpassed)
- Minimum Impulse Bit of 22 mN-s, with a goal of 5 mN-s
- Mass not to exceed 14 kg
  - HET, PPU, tank, propellant feedsystem, and ~1 kg of Xenon
LCROSS Derivative
Communication Capability
Comm Ground Rules & Assumptions

- Change LCROSS S-band baseline to X-band
  - Maintain Single-String Design
  - An additional Ka-band optional downlink to increase data rates would add weight, power, and cost

- Earth-to-Spacecraft distances: 0.5 – 4.5 AU (Deep Space)

- Baseline DSN 34m Stations for routine Communications; 70m Stations for critical events (flybys, impacts, emergencies, etc.)
## Downlink Data Rate Summary

<table>
<thead>
<tr>
<th>Comm Configuration</th>
<th>Earth Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 AU</td>
</tr>
<tr>
<td>X-Band 10 Watt, 0.6 m dish w/1.5 deg pointing</td>
<td>10/25 kbps</td>
</tr>
<tr>
<td>X-Band 25 Watt, 0.6 m dish w/1.5 deg pointing</td>
<td>40/100kbps</td>
</tr>
<tr>
<td>X-Band 100 Watt, 1 m dish w/1 deg pointing</td>
<td>100/400 kbps</td>
</tr>
<tr>
<td>X-Band 100 Watt 1.7 m dish w/0.5 deg pointing</td>
<td>1/4 Mbps</td>
</tr>
</tbody>
</table>

Data rates are given for 34m / 70m DSN Stations
Primary Mission Capability
Primary mission concepts: 4015 Wilson-Harrington

- Looked at two launch vehicles
  - Atlas V 401 (potentially better for Discovery-class missions)
  - Atlas V 551 (for New Frontiers-class missions)

- Two different launch scenarios
  - C3 of 69 km$^2$/sec$^2$: shorter duration, but smaller mass
  - C3 of 28 km$^2$/sec$^2$: longer duration, larger mass

- Orbiter/Lander mission trajectories are the same as sample return except for the burn back to Earth

<table>
<thead>
<tr>
<th>Mission Type</th>
<th>Launch C3 (km$^2$/s$^2$)</th>
<th>Atlas V</th>
<th>Duration (year)</th>
<th>ΔV (m/s)</th>
<th>Wet Mass (kg)</th>
<th>Dry Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbiter/Lander</td>
<td>69.1</td>
<td>401</td>
<td>4.09</td>
<td>1714</td>
<td>545</td>
<td>297</td>
</tr>
<tr>
<td>Orbiter/Lander</td>
<td>69.1</td>
<td>551</td>
<td>4.09</td>
<td>1714</td>
<td>1630</td>
<td>889</td>
</tr>
<tr>
<td>Sample Return</td>
<td>69.1</td>
<td>551</td>
<td>8.06</td>
<td>2356</td>
<td>1630</td>
<td>707</td>
</tr>
<tr>
<td>Orbiter/Lander</td>
<td>28.0</td>
<td>401</td>
<td>6.19</td>
<td>1772</td>
<td>1940</td>
<td>1039</td>
</tr>
<tr>
<td>Orbiter/Lander</td>
<td>28.0</td>
<td>551</td>
<td>6.19</td>
<td>1772</td>
<td>3820</td>
<td>2045</td>
</tr>
<tr>
<td>Sample Return</td>
<td>28.0</td>
<td>401</td>
<td>10.16</td>
<td>2414</td>
<td>1940</td>
<td>825</td>
</tr>
<tr>
<td>Sample Return</td>
<td>28.0</td>
<td>551</td>
<td>10.16</td>
<td>2414</td>
<td>3820</td>
<td>1625</td>
</tr>
</tbody>
</table>

Note: DAWN = 745 kg dry
4.1 Years to Wilson-Harrington ($C_3 = 69 \text{ km}^2/\text{s}^2$)

- Launch to a $C_3$ of 69 km$^2$/s$^2$ on 4 Oct 2014
- Target Wilson-Harrington on 18 July 2016
- Arrival at Wilson-Harrington on 5 Nov 2018
- Earth @ Arrival
10.2 Year Sample Return (C3 = 28 km^2/s^2)

- **Launch to C3 = 28 km^2/s^2**: 29 Aug 2012
- **Earth Gravity Assist**: 4 Oct 2014
- **Target Wilson-Harrington**: 18 July 2016
- **Depart Wilson-Harrington**: 28 May 2019
- **Arrival at Wilson-Harrington**: 5 Nov 2018
- **Reentry**: 26 Oct 2022
- **Earth @ Arrival**

Additional notes:

- | Event                        | Date       |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Wilson-Harrington</td>
<td>18 July 2016</td>
</tr>
<tr>
<td>Depart Wilson-Harrington</td>
<td>28 May 2019</td>
</tr>
<tr>
<td>Arrival at Wilson-Harrington</td>
<td>5 Nov 2018</td>
</tr>
<tr>
<td>Reentry</td>
<td>26 Oct 2022</td>
</tr>
<tr>
<td>Earth @ Arrival</td>
<td></td>
</tr>
</tbody>
</table>

**Diagram Details**:

- **Planets and Objects**:
  - Ceres
  - Wilson-Harrington
  - Earth
  - Mars
  - Mercury
  - Venus

**Other Information**:

- **Launch Site**
- **Mission Overview**
- **Mission Duration**
- **Technological Aspects**
- **Science Objectives**
Candidate Missions to Elst-Pizarro

- High $C_3 > 60 \text{ km}^2/\text{sec}^2$

<table>
<thead>
<tr>
<th></th>
<th>Atlas 401</th>
<th>Atlas 601</th>
<th>Atlas 621</th>
<th>Atlas 551</th>
<th>Delta IV Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Throw weight (kg)</strong></td>
<td>550</td>
<td>250</td>
<td>980</td>
<td>1650</td>
<td>~2000</td>
</tr>
<tr>
<td><strong>Fairing Diameter (m)</strong></td>
<td>3.75</td>
<td>4.572</td>
<td>4.572</td>
<td>4.572</td>
<td>4.572</td>
</tr>
<tr>
<td><strong>Fairing Length (m)</strong></td>
<td>10.367</td>
<td>10.184</td>
<td>10.184</td>
<td>10.184</td>
<td>10.974</td>
</tr>
</tbody>
</table>
Elst-Pizarro: \( C_3 = 68.28 \text{ km}^2/\text{sec}^2 \)
Mars Flyby

- Low $C_3 < 10 \text{ km}^2/\text{sec}^2$
- Requires Atlas 401 with 30% margin

<table>
<thead>
<tr>
<th></th>
<th>Atlas 401</th>
<th>Atlas 601</th>
<th>Atlas 621</th>
<th>Atlas 651</th>
<th>Delta IV Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throw weight (kg)</td>
<td>2000</td>
<td>2250</td>
<td>3800</td>
<td>5450</td>
<td>7950</td>
</tr>
<tr>
<td>Fairing Diameter (m)</td>
<td>3.75</td>
<td>4.572</td>
<td>4.572</td>
<td>4.572</td>
<td>4.572</td>
</tr>
<tr>
<td>Fairing Length (m)</td>
<td>9.397</td>
<td>10.184</td>
<td>10.184</td>
<td>10.184</td>
<td>10.971</td>
</tr>
</tbody>
</table>
Elst-Pizarro: $C_3 = 9.47 \text{ km}^2/\text{sec}^2$

(Mars fly by w/ 2$^{nd}$ stage solid motor)

$M_{s/c} = ~5000 \text{ kg}$

$C_3 = 9.47 \text{ km}^2/\text{sec}^2$
### Chemical Thrust Can Relieve Power Pressures of 280W Limit of ASRG

<table>
<thead>
<tr>
<th>Characteristic of Option</th>
<th>Chemical Propulsive Option</th>
<th>Electric Propulsive Option</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total ( \Delta V ) (m/s)</strong></td>
<td>2045</td>
<td>1543</td>
</tr>
<tr>
<td>TCMs</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>MOI + gravity loss</td>
<td>898</td>
<td>898</td>
</tr>
<tr>
<td>Orbit adjust</td>
<td>180 periapsis raising</td>
<td>50 walk-in/-out (estimated)</td>
</tr>
<tr>
<td></td>
<td>667 apoapsis lowering</td>
<td>300 periapsis raising (from previous chart)</td>
</tr>
<tr>
<td>Maintenance, Reserves, etc.</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td><strong>S/C Dry Mass (kg)</strong></td>
<td>1339</td>
<td>1339 (estimate as the same)</td>
</tr>
<tr>
<td><strong>Propellant Load (kg)</strong></td>
<td>1385 (294s effective average ( I_{sp} ))</td>
<td>949 (294s effective average ( I_{sp} ))</td>
</tr>
<tr>
<td><strong>Propulsion System</strong></td>
<td>Bi-prop, full-diameter tanks</td>
<td>Bi-prop, full-diameter tanks</td>
</tr>
<tr>
<td><strong>Launch Mass (kg)</strong></td>
<td>2721</td>
<td>2288</td>
</tr>
<tr>
<td><strong>Launch Vehicle</strong></td>
<td>Atlas V 411</td>
<td>Atlas V 401 - minimal cost savings over 411</td>
</tr>
<tr>
<td><strong>Spacecraft design</strong></td>
<td>• Propulsion system sized by MOI</td>
<td>• Propulsion system still sized by MOI</td>
</tr>
<tr>
<td></td>
<td>• Thermal, aero-interaction NRE</td>
<td></td>
</tr>
<tr>
<td><strong>Performance / Operations / Schedule</strong></td>
<td>• 1.5 months from MOI to operational orbit</td>
<td>• Up to 6 months from MOI to operational orbit</td>
</tr>
<tr>
<td></td>
<td>• Can support MSL EDL from an interim orbit, and rapidly support MSL surface ops</td>
<td>• May pause aerobraking operations to support MSL EDL, but adds ( \Delta V ) and time penalty</td>
</tr>
<tr>
<td></td>
<td>• Option to get to operational orbit in (-10 ) days, prior to MSL EDL</td>
<td></td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>• More expensive LV</td>
<td>• Cheaper LV</td>
</tr>
<tr>
<td></td>
<td>• Lower cost spacecraft</td>
<td>• Higher cost spacecraft</td>
</tr>
<tr>
<td><strong>Risk</strong></td>
<td>• Low: raise periapsis to 4450 km within 15 days of MOI, low-risk propulsion sys.</td>
<td>• Med-High: up to 6 months with periapsis ( \leq 250 ) km, significant atmospheric interaction</td>
</tr>
</tbody>
</table>
Conclusions

Secondary Payloads

• Secondary payloads might be a viable way to design a low-cost Discovery class mission
  – A variety of targets are accessible to secondary payloads
  – Much lower launch costs
  – The first version already exists (LCROSS)

• Adaptation of the LCROSS architecture to future missions is relatively straightforward

Primary Payloads

• We have looked a number of potentially intriguing options
  – 1000 kg of dry mass delivered to 4015 Wilson-Harrington with an Atlas V 401
  – Sample return with an Atlas V 401?

• For missions to the outer asteroid belt, chemical propulsion might allow for ASRG power

These are only examples of locations we could go. Where would SBAG like to go?
Backup Slides
6.2 Years to Wilson-Harrington ($C_3 = 28 \text{ km}^2/\text{s}^2$)

- Earth @ Arrival on 29 August 2012
- Departure from Earth on 29 August 2012
- Mars
- Lower Apoapsis / Target Earth on 5 September 2013
- Earth Gravity Assist on 4 October 2014
- 1:1 Resonance
- Ceres
- Target Wilson-Harrington on 18 July 2016
- Arrival at Wilson-Harrington on 5 November 2018
8.1 Year Sample Return (C3 = 69 km²/s²)

Launch to a C3 of 69 km²/s²
4 Oct 2014

Target Wilson-Harrington
18 July 2016

Depart Wilson-Harrington
28 May 2019

Arrival at Wilson-Harrington
5 Nov 2018

Reentry
27 Oct 2022

Earth @ Arrival

Mercury

Venus

Mars
Our MTO Design Incorporates Approaches and Technologies From NGST Programs

EOS Aqua & Aura
- High-capacity electrical power system
- Multi-unit cost savings

TDRSS 1-7
- Fixed trunk-line communications and pointing operations concept

GeoLITE
- Mass-efficient structure
- Precision thermal control
- Breakaway panel payload accommodation
- Large delta-V bi-prop propulsion
- Proven optical comm accommodation
- Electromagnetic Compatibility accommodation

SIM
- High-rate data management
- Fault management

NPOESS
- Ka-band rates of 20 Mbps from Jupiter
- telecom

JWST
- High-thrust propulsion

Chandra

Other

Existing product
Development product
Ka-band Power/Aperture & Antenna Trade

Amplifier RF Output (W) to Achieve Required EIRP

- 0.5 Degree Pointing Control
- 0.3 Degree
- 0.2 Degree
- 0.15 Degree
- 0.1 Degree
- 0.07 Degree
- 0.05 Degree
- 0.02 Degree

Deployed antenna required

TWTA power not credible

Additional margin above 3 dB
NGST Has Long History of Space-Based Communications Systems Development

TDRSS 1-7 Prime Contractor

Milstar Medium and Low Data Rate Payloads

Thuraya 12m Deployable HGA

FLTSATCOM Prime Contractor

DSCS-2 Prime Contractor
### NG AstroMesh Reflector – TRL-9

#### SPECIFICATIONS

<table>
<thead>
<tr>
<th>Performance</th>
<th>6-Meter</th>
<th>12-Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (Reflector only)</td>
<td>32.0 lb (14.5 kg)</td>
<td>125.7 lb (57.0 kg)</td>
</tr>
<tr>
<td><strong>Stowed Dimensions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>2.0 x 2.2 ft (0.60 x 0.66 m)</td>
<td>3.0 x 3.7 ft (0.91 x 1.14 m)</td>
</tr>
<tr>
<td>Length</td>
<td>5.05 ft (1.54 m)</td>
<td>12.50 ft (3.81 m)</td>
</tr>
<tr>
<td><strong>Deployed Configuration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aperture</td>
<td>18.05 ft (5.50 m)</td>
<td>40.19 ft (12.25 m)</td>
</tr>
<tr>
<td>Center Offset</td>
<td>12.3 ft (3.75 m)</td>
<td>27.2 ft (8.30 m)</td>
</tr>
<tr>
<td>Fid</td>
<td>0.64</td>
<td>0.45</td>
</tr>
<tr>
<td>First Mode (Fixed Boom)</td>
<td>2.00 Hz</td>
<td>0.80 Hz</td>
</tr>
<tr>
<td><strong>Surface Accuracy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (RSS)</strong></td>
<td>0.026 inch (0.62 mm)</td>
<td>0.055 inch (1.40 mm)</td>
</tr>
<tr>
<td>Faceling (Geometric) (RMS)</td>
<td>0.013 inch (0.33 mm)</td>
<td>0.043 inch (1.10 mm)</td>
</tr>
<tr>
<td>Manufacturing (RMS)</td>
<td>0.015 inch (0.38 mm)</td>
<td>0.020 inch (0.50 mm)</td>
</tr>
<tr>
<td>Thermal (RMS)</td>
<td>0.010 inch (0.25 mm)</td>
<td>0.020 inch (0.50 mm)</td>
</tr>
</tbody>
</table>
NORTHROP GRUMMAN
Defining the Future