Large Constellation Development
Using Small Satellites

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“CubeSat”

- Low mass, low volume, low power, low cost

- Low, but increasing science capabilities

- Enables missions not cost effective with larger spacecraft
Distributed Network of CubeSats

- Leverage simplicity of CubeSat design

- Unprecedented global science capability
HiDEF Mission Overview

• The High-latitude Dynamic E-Field (HiDEF)

• Observe high-latitude magnetosphere-ionosphere-thermosphere global electric field forcing, coupling dynamics, and evolution

• Unprecedented spatial and temporal coverage

• A substantial additional to the Heliophysics Great Observatory (HGO)
Mission Goals

Two phase science mission observes large and small scale electric field dynamics.
### Mission Parameters

90 satellites deployed from 5 distinct circular orbits

<table>
<thead>
<tr>
<th>Satellite Orbit Group</th>
<th>Release Altitude</th>
<th>Semi-Major Axis</th>
<th>Inclination</th>
<th>RAAN Precession Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km</td>
<td>km</td>
<td>degrees</td>
<td>degrees/day</td>
</tr>
<tr>
<td>1</td>
<td>515</td>
<td>6884 – 6902</td>
<td>77.0°</td>
<td>-1.70 to -1.72</td>
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<tr>
<td>2</td>
<td>555</td>
<td>6924 – 6942</td>
<td>77.7°</td>
<td>-1.58 to -1.59</td>
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<tr>
<td>3</td>
<td>595</td>
<td>6964 – 6982</td>
<td>78.4°</td>
<td>-1.46 to -1.47</td>
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<tr>
<td>4</td>
<td>635</td>
<td>7004 – 7022</td>
<td>79.1°</td>
<td>-1.35 to -1.36</td>
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<tr>
<td>5</td>
<td>675</td>
<td>7044 – 7063</td>
<td>79.8°</td>
<td>-1.24 to -1.25</td>
</tr>
</tbody>
</table>

Right Ascension of Ascending Node: 277.5°

True Anomaly: varies by satellite

Argument of Perigee: varies by satellite

Eccentricity: 0.0003 to 0.0013
“E-Sat”

- Cubesat becomes a highly integrated electric-field sensor

- Spin-stabilized inertially oriented
Launch Vehicle

Single Pegasus XL with HAPS 4th stage deploys entire constellation

Pegasus XL deployment from “Stargazer” aircraft

Hydrazine Auxiliary Propulsion System (HAPS)
Deployment Profile

- Air launch into 77° 515 km orbit from Vandenberg AFB, California
- Circularize orbit with HAPS
- Deploy 18 satellites at ascending node
- Raise apogee, perform plane change, and re-circularize with HAPS

- Deploy additional 18 satellites at ascending node
- Repeat for remaining satellites
Satellite Deployment System

System of up to 32 individual P-PODS

- Pegasus Payload Envelope
- Satellite Deployment System inside payload envelope
- HAPS Volume
- Layers Offset by 22.5°
- Modified Pusher Plate
- P-POD
Deployment Maximizes Precession

Precession Rate vs. Deployment Azimuth Angle

- $35^\circ$
- $102.5^\circ$
- $350^\circ$
- $170^\circ$
- $282.5^\circ$
- $215^\circ$
Unique Orbit Design

Orbit Design Supports Mission

• Orbit insertion designed so that satellites will disperse quickly into a string of pearls and the orbit planes will spread over time for global coverage.

• Orbit insertion is designed so that each satellite orbit is unique and does not cross other orbits (at the same altitude) to prevent the possibility of collisions within the constellation.
Relative Deployment Motion

Time = 0.018 s
Maximum Range = 0.001 km
Minimum Range = 0.00028285 km
1 Year Constellation Foldout
Mission Life

- Standardized compliance per NASA orbital debris standard
- Expected lifetime using extrapolated variable solar activity

<table>
<thead>
<tr>
<th>Satellite Orbit Group</th>
<th>Expected Lifetime</th>
<th>Standardized Compliance Lifetime</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2.4 - 4.0</td>
<td>1.1 to 1.5</td>
</tr>
<tr>
<td>2</td>
<td>6.1 - 6.9</td>
<td>2.1 to 2.9</td>
</tr>
<tr>
<td>3</td>
<td>7.8 - 8.7</td>
<td>4.1 to 5.6</td>
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<tr>
<td>4</td>
<td>10.8 - 17.1</td>
<td>7.9 to 10.5</td>
</tr>
<tr>
<td>5</td>
<td>19.6 - 27.7</td>
<td>14.3 to 18.7</td>
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</tbody>
</table>
Summary

• A global satellite constellation can be created using cubesats
• This constellation can be deployed from a single launch vehicle
• This global constellation can perform missions not possible even by very expensive spacecraft