ANDESITE: A Student-Built Swarm from Concept to Launch and Beyond

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AIAA/USU Small Satellite Conference
August 5th 2018
Hosted initial development of the first space-based “earth-observing” sensor

Corona project camera based on work at BUPRL*

HYAC-1 ca. 1957

BU Attempted to adapt the cube standard to a modular “plug-and-play” satellite design

One of the first student-built small satellites

TERRIERS during testing, Sandia National Laboratory 1999

BU was one of the first universities to have a student built satellite

*Boston University Physical Research Laboratory

CSP Founded!
Outline

- ANDESITE
  - Mission
  - Schedule
  - Flight Build Recap
- A New Opportunity for Science
- Conclusion
Doing More with Small Satellites

- Ideal problem to demonstrate small distributed space-based sensors

Fine-scale structure of near-earth electromagnetic environment not well understood due to lack of *in situ* measurements

\[ \nabla \times \left( \vec{B}_{\text{Earth}} + \delta \vec{B} \right) = \mu_0 \vec{J} \]

- Can directly measure auroral electromagnetics at previously unobservable scales
It’s increasingly apparent that energy transfer at small scale is important in magnetospheric–ionospheric (MI) coupling.

Length scales on the order of kilometers, time scales on the order of seconds.
Original Path to Orbit

- Selected to launch through NASA ELaNa
  - 85 degrees inclination, 500 km altitude
  - Mission Readiness Review (Launch Integrator) December 5th 2017
  - FCC License—Complications, but seems to be resolved
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Timeline to Launch V1

- On track to launch! Let’s make it happen
- IRR Expected by May/June
Timeline to Launch V2

### Milestones

**2016**
- Fall
  - Phase B
- Winter
  - Bus Integration and Testing

**2017**
- Spring
  - Phase C
  - Flight Structure and Boards
- Summer
  - Testing
- Fall
  - Phase D

**2018**
- Deliver to Launch Provider Mid-September
- ELaNa Launch November 1st

### UNP Reviews

- Jan 30th PIR
- Pre-Ship Review (PSR) AFRL
- Test Readiness Review (TRR)
- Mission Readiness Review (MRR) July 31st

### Discussions

- We can make the schedule
- What are our environment test options?
Timeline to Launch V3

- Our last rigid schedule was made before NASA MRR in December 2017
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Planet Constellation as a Space Weather Sensor

• Not as dense as the ANDESITE formation, but far exceeds any other deployed sensor network
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Conclusions

• **ANDESITE is built, becoming the first student-built, student-led cubesat from Boston University**

• **Schedule slip has kept the team under constant pressure**
  – Student graduation and turnover can be debilitating

• **Simplified radio licensing and clear “rules of the road” from the FCC would be greatly appreciated**

• **Commercial constellations offer a unique opportunity to do similar science**
  – Data density is a bottle neck in understanding of ionospheric dynamics

• **Controlled formations may offer an improved, longer lasting sensor like ANDESITE**
Backups
Natural Motion Orbits

- Without control there is a closed form solution to Hill’s equations

\[
\mathbf{x}(t) = \Phi(t, t_0) \mathbf{x}_0
\]

\[
\begin{bmatrix}
  x(t) \\
y(t) \\
z(t) \\
x(t) \\
y(t) \\
z(t)
\end{bmatrix} =
\begin{bmatrix}
  4 - 3 \cos nt & 0 & 0 & \frac{1}{n} \sin nt & \frac{2}{n} (1 - \cos nt) & 0 \\
6(\sin nt - nt) & 1 & 0 & -\frac{2}{n} (1 - \cos nt) & \frac{1}{n} (4 \sin nt - 3nt) & 0 \\
0 & 0 & \cos nt & 0 & 0 & \frac{1}{n} \sin nt \\
3n \sin nt & 0 & 0 & \cos nt & 2 \sin nt & 0 \\
-6n(1 - \cos nt) & 0 & 0 & -2 \sin nt & 4 \cos nt - 3 & 0 \\
0 & 0 & -n \sin nt & 0 & 0 & \cos nt
\end{bmatrix}
\begin{bmatrix}
x_0 \\
y_0 \\
z_0 \\
x_0 \\
y_0 \\
z_0
\end{bmatrix}
\]

- There is a unique set of initial conditions for what is called a “natural-motion orbit” (NMO)

\[
\mathbf{x}_{\text{circ}} = [r, 0, \pm 2r, 0, -2nr, 0]^T
\]

- This trajectory set provides stable circular orbits about the local origin, if we can get to these trajectories, we would have minimal control needed to stay there
Robust Sampling of the Aurora