Multi-Point Measurements of the Aurora with a CubeSat Swarm

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Abstract

Space weather awareness is data-starved and small satellites offer an opportunity to the community. Over the past few years, Boston University’s Center for Space Physics has been developing a 6U CubeSat that deploys a small swarm of magnetometers to measure the fine-scale structure of the Birkeland currents that create the aurora. By using direct three-axis measurements, spatially distributed, we hope to probe the plasma currents and fuse the data with other data products from ground-based optical and radio measurements. Boston University’s broad expertise in space physics and engineering systems offers a strong platform to foster a close relationship between those communities and to tailor the development of experiments while closely integrating students from several research fields. Through the efforts of such students, the ANDESITE program was selected to fly by the Air Force University Nanosat Program, and has been awarded a launch opportunity through NASA’s Educational Launch of Nanosatellites (ELaNa) initiative for the summer of 2017. Our university continues to foster a small satellite program and has used the momentum of its success in UNP-6 to lead development of new missions. Here in this paper, we will discuss the mission and concept of operations of ANDESITE, and how it integrates into current research at Boston University, along with a description of the strengthening satellite program at the school.

I. Auroral Science with Spacecraft

Some of the earliest in situ measurements of the aurora came from early satellite based magnetometer readings [1]. This led to many researchers postulating the cause of deflections in the magnetic field that was observed [2], which was ultimately attributed to the current system hypothesized by Birkeland [3].

AMPERE, a current scientific mission, uses precision magnetometer measurements from secondary payloads on the Iridium satellite constellation—more than 66 satellites in six distinct orbital planes. This network allows for a near real-time monitoring of the global current system, but is inherently limited in spatial resolution due to the orbital geometry chosen for the Iridium satellites [4].

High-resolution cameras reveal periodic fine-scale structure (order of 100 m) embedded within larger scale auroral arcs. The motions of these structures (seen below) suggest the presence of dispersive hydrodynamic waves (Alfven waves) [5,6]. When the ground based all-sky camera information is fused with the AMPERE magnetometer measurement data products, we can see that there is limited ability to spatially resolve many of the structures with a single satellite sensor. The spacecraft time-series data also indicates features that occur at frequencies can be associated with the local Alfven waves.

II. Doing More with Small Satellites

Problem:
The fine-scale structure of the near-earth electromagnetic environment is not well understood due to lack of in situ measurements.

Possible Solution:
- Ideal problem to demonstrate small distributed space-based sensors
- CubeSats offer a platform for development and deployment of cheaper spacecraft and are ideal for such scientific measurements

ANDESITE is a 6U (30x20x10 cm) CubeSat that deploys several smaller “pico-satellites” that each have their own self-contained scientific magnetometer, power system and radio communication system. The satellites collect data in a loosely held swarm, relaying the data back to the main spacecraft and down to the Earth through the GlobalStar sat-phone network.

The above figure shows an expanded view of the main 6U “mule” spacecraft and to the right is an expanded view of the pico-satellites that hold the scientific magnetometer payloads.

IV. Can We Do Better?

- ANDESITE isn’t the end, we are developing a follow-on mission concept
- First, design framework for developing satellite clusters that can robustly perform optimal sampling with minimal active control
- Then constrain satellite architecture development with intimate feedback between mission objectives and engineering realities
- What formation should you use and how well do you need to keep it?

V. Pathway to Launch

With the development and launch of ANDESITE in the summer of 2017, Boston University will have developed its first satellite since TERRIERs and increased the number of spacecraft it has on orbit by an order of magnitude—the mule and sensor nodes total nine satellite buses. The momentum gained has already led to an increase of expertise and interest at the university, spawning several new projects in the pipeline. The scientific mission of ANDESITE will also represent a new age of multi-point measurement capability for space science that will allow finer detailed investigations into the structure of the aurora with technology implications that affect many other areas of space plasma measurements. Effectively scaling down cost prohibitive experiment concepts, and opening up the opportunity for future multi-point measurements of the near-space plasma environment.

References:


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