Multi-Point Measurements of Small-Scale Aurora Phenomena with CubeSat Formations

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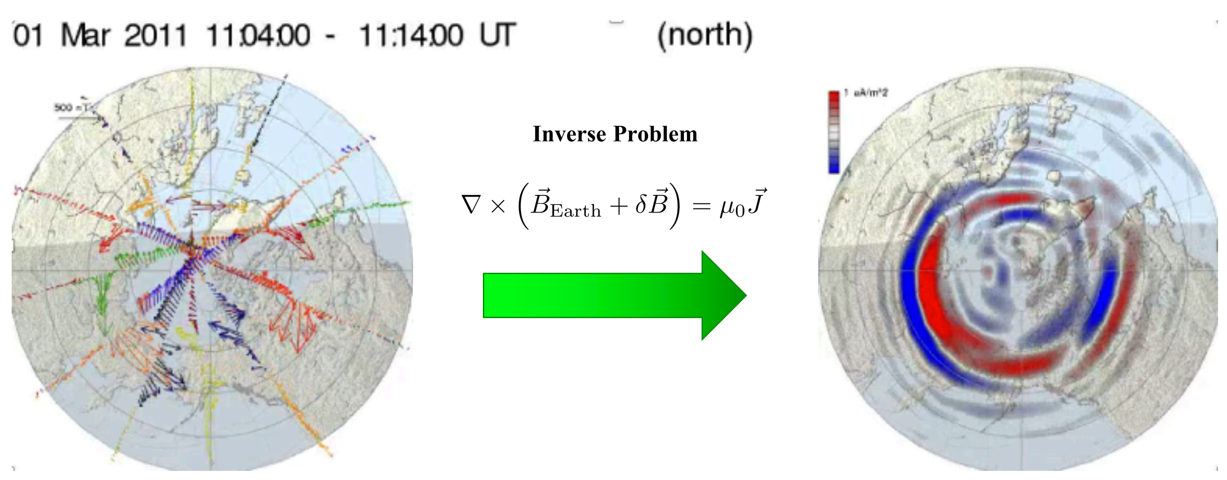
Abstract

Small-scale plasma phenomena, on the order of hundreds of meter, in the aurora are difficult to resolve with conventional satellite based measurements. Boston University will soon launch a satellite—ANDESITE—that allows for a spatial and temporal resolution at this scale by flying a formation of pico-satellites with on-board three-axis magnetometers. With local measurements spaced only a few hundred meters apart, we can differentiate current density distributions in auroral arcs with less constraints on the assumed geometries. These measurements then allow for a better view into the nature of current filaments and vortex structures as seen by high-resolution ground based optical cameras. Here we discuss the concept of operations of the satellite mission and possible data products that will result along with a timeline to launch. ANDESITE only represents one possible sensor arrangement, and we also propose follow up missions that consist of actively controlled formations for multi-point measurements at these scales in the ionosphere.

Auroral Science with Spacecraft

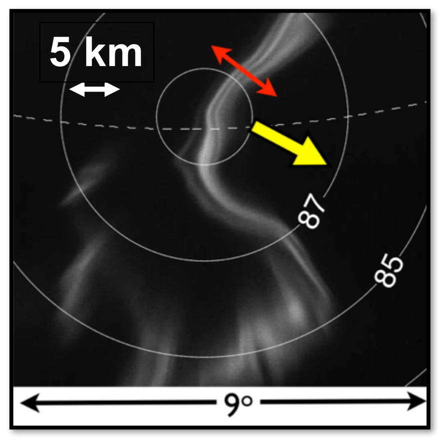
Some of the earliest in situ measurements of the aurora came from early satellite based magnetometer readings [1]. This led to many researchers postulating the cause of deflections in the magnetic field that was observed [2], which was ultimately attributed to the current system hypothesized by Birkeland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



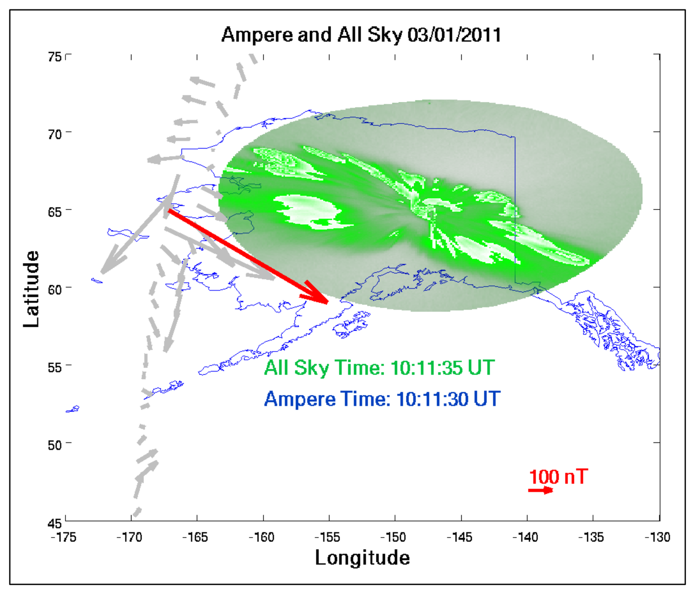
AMPERE constellation and data product

High-resolution cameras reveal periodic fine-scale structure (order of 100 m) embedded within larger scale auroral arcs. The motions of these structures (red and yellow arrows) suggest the presence of dispersive hydrodynamic waves (Alfven waves) [5,6]



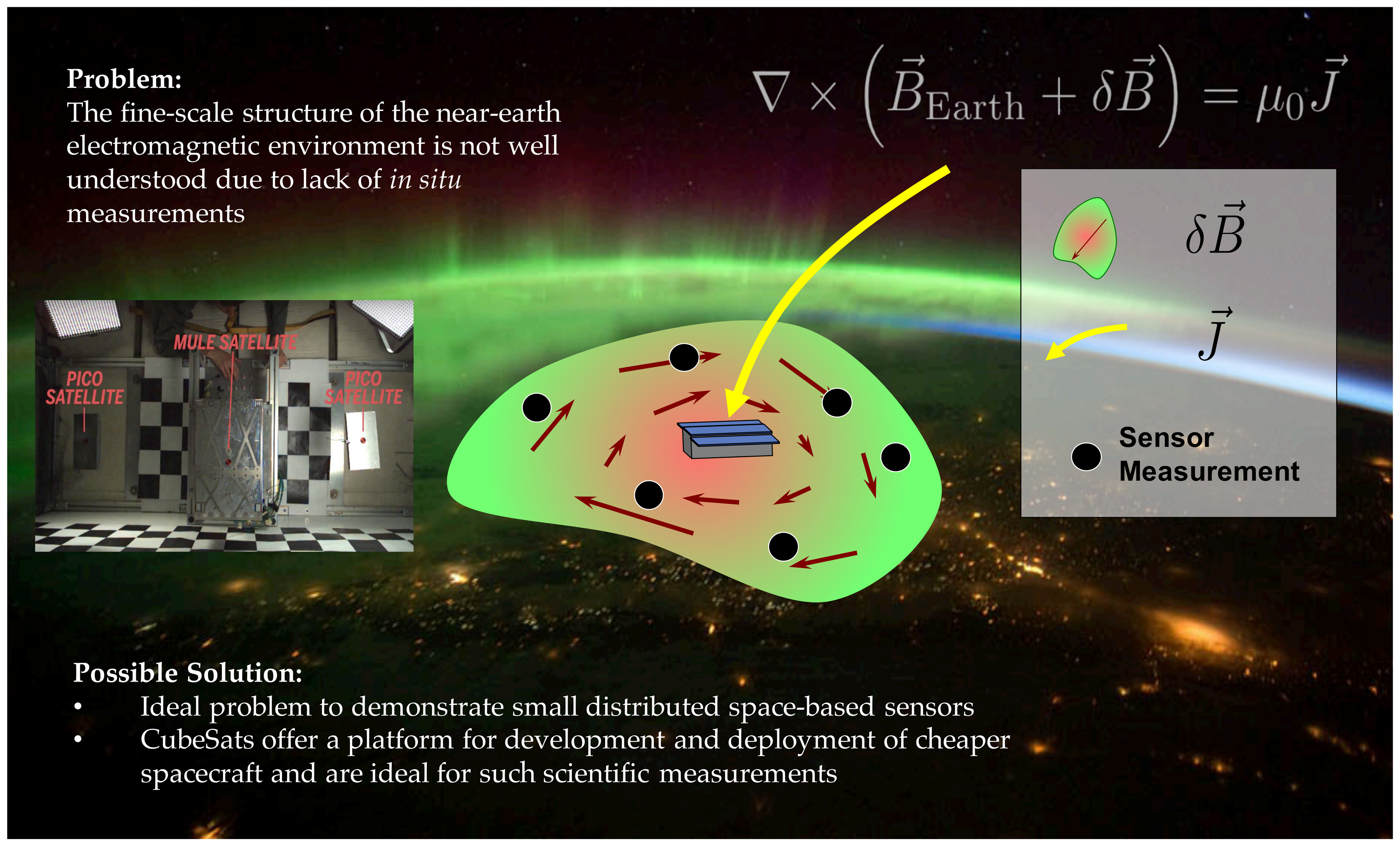
All-sky camera data

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



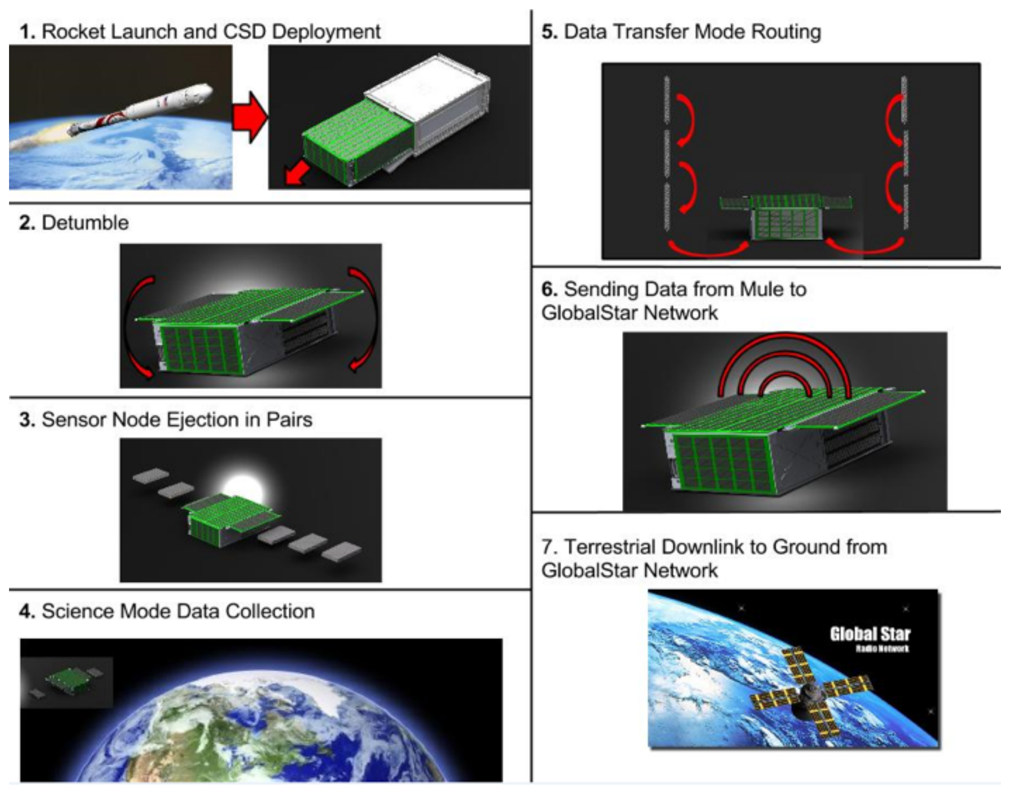
Data fusion Courtesy of John Swoboda (swoboj@bu.edu)

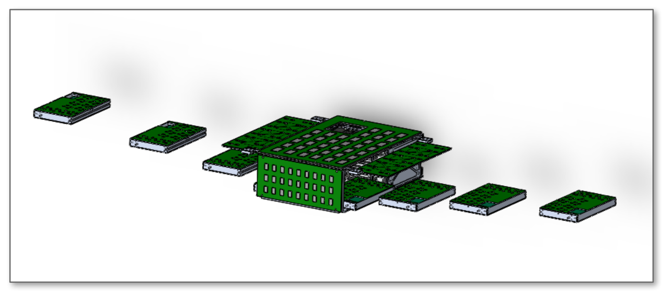
Doing More with Small Satellites



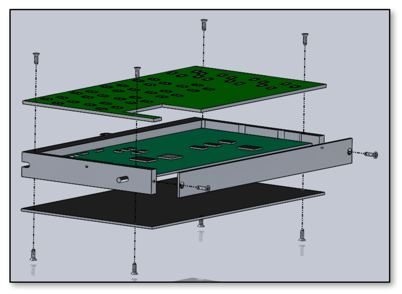
ANDESITE and Concept of Operations

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.

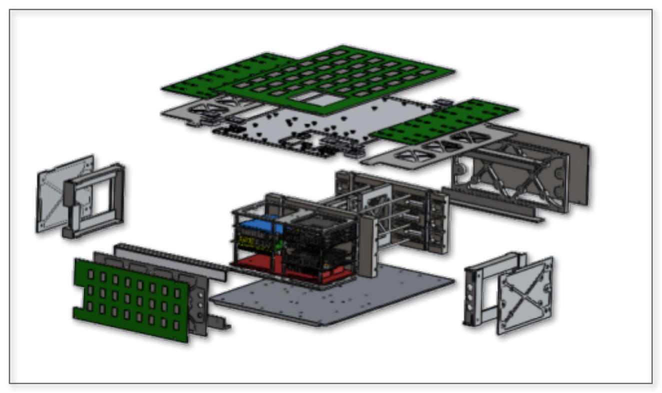




(a)



(c)



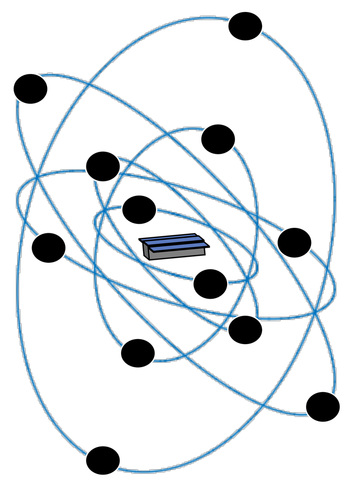
(b)

(d)

The above figures show (a) the entire aggregate system (b) an expanded view of the main 6U "mule" spacecraft (c) an expanded view of the pico-satellites that hold the scientific magnetometer payloads and (d) students testing the satellite deployment mechanisms on a recent micro-gravity flight

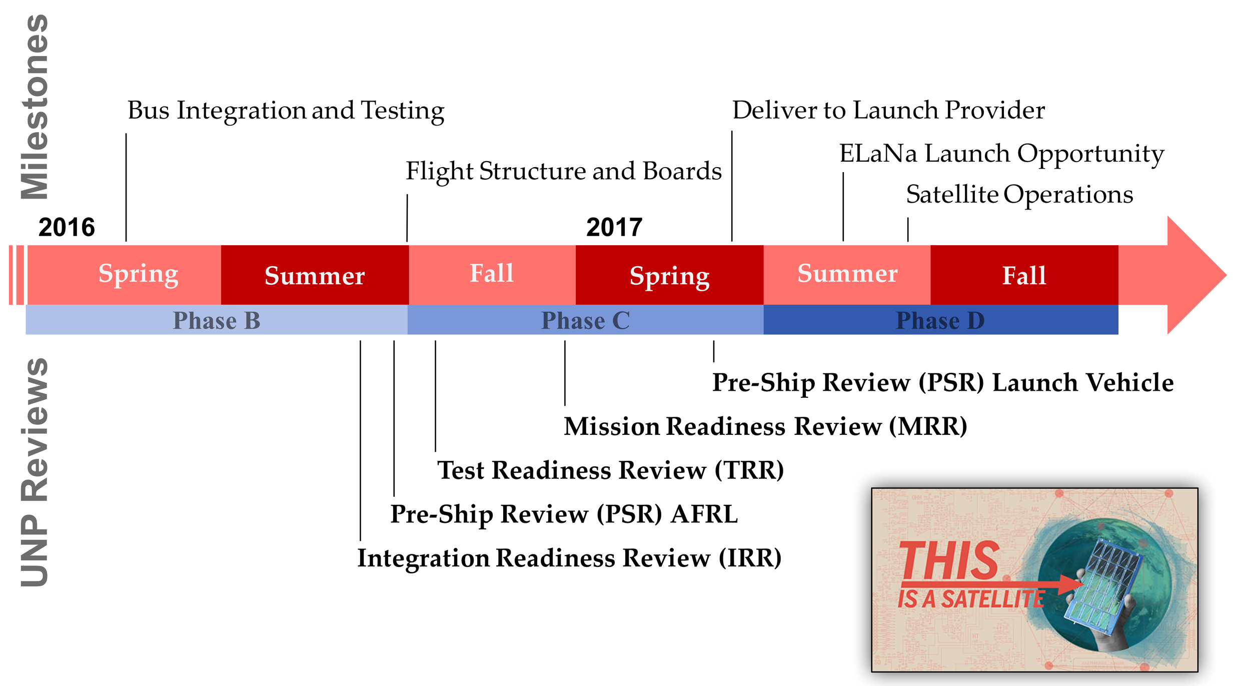
Can We Do Better?

- 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
  - Formation Flight in LEO is a hard problem due to atmospheric disturbances. How do you counteract the difficulties?
- 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?



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.



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