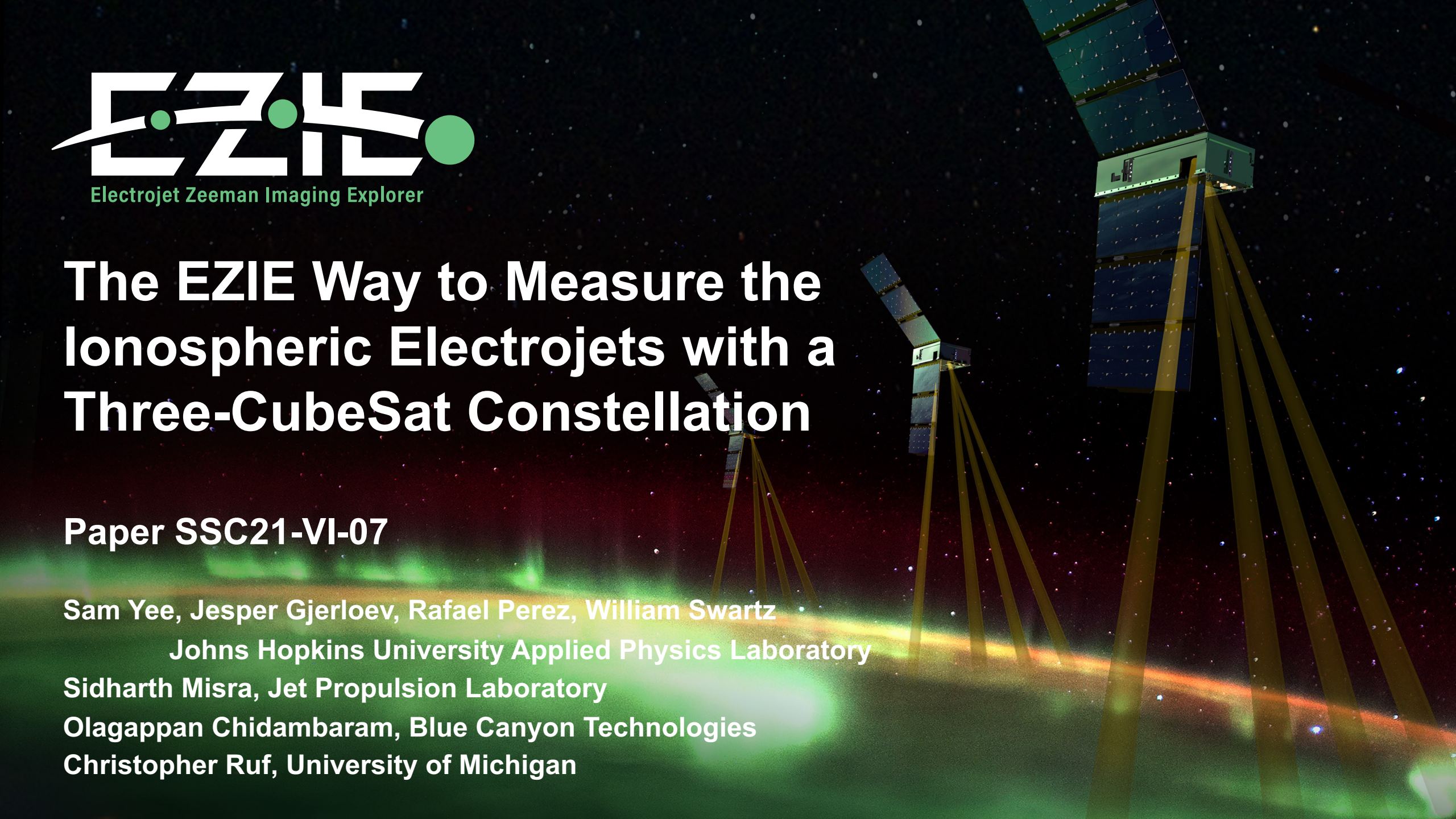
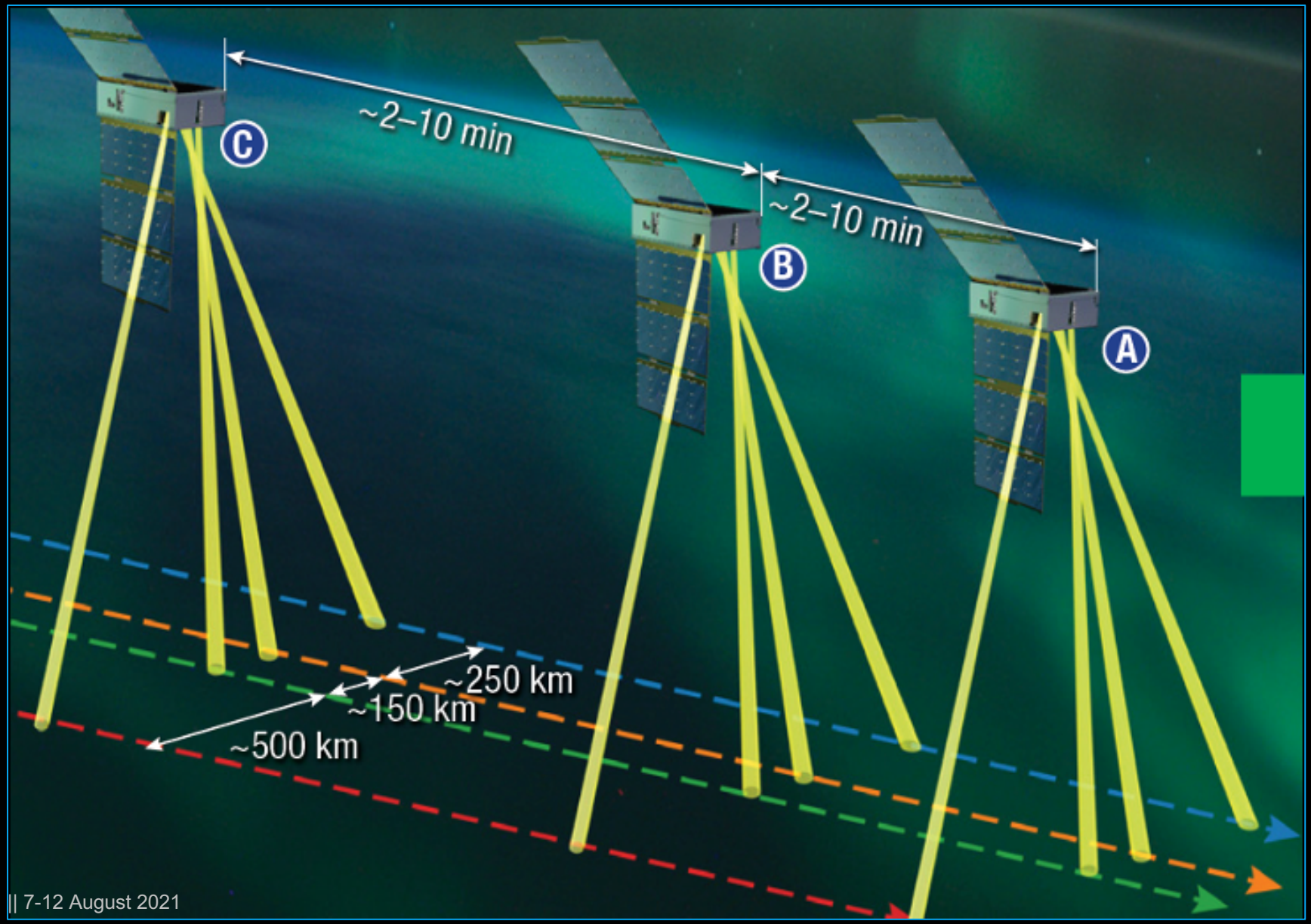


The EZIE Way to Measure the Ionospheric Electrojets with a Three-CubeSat Constellation

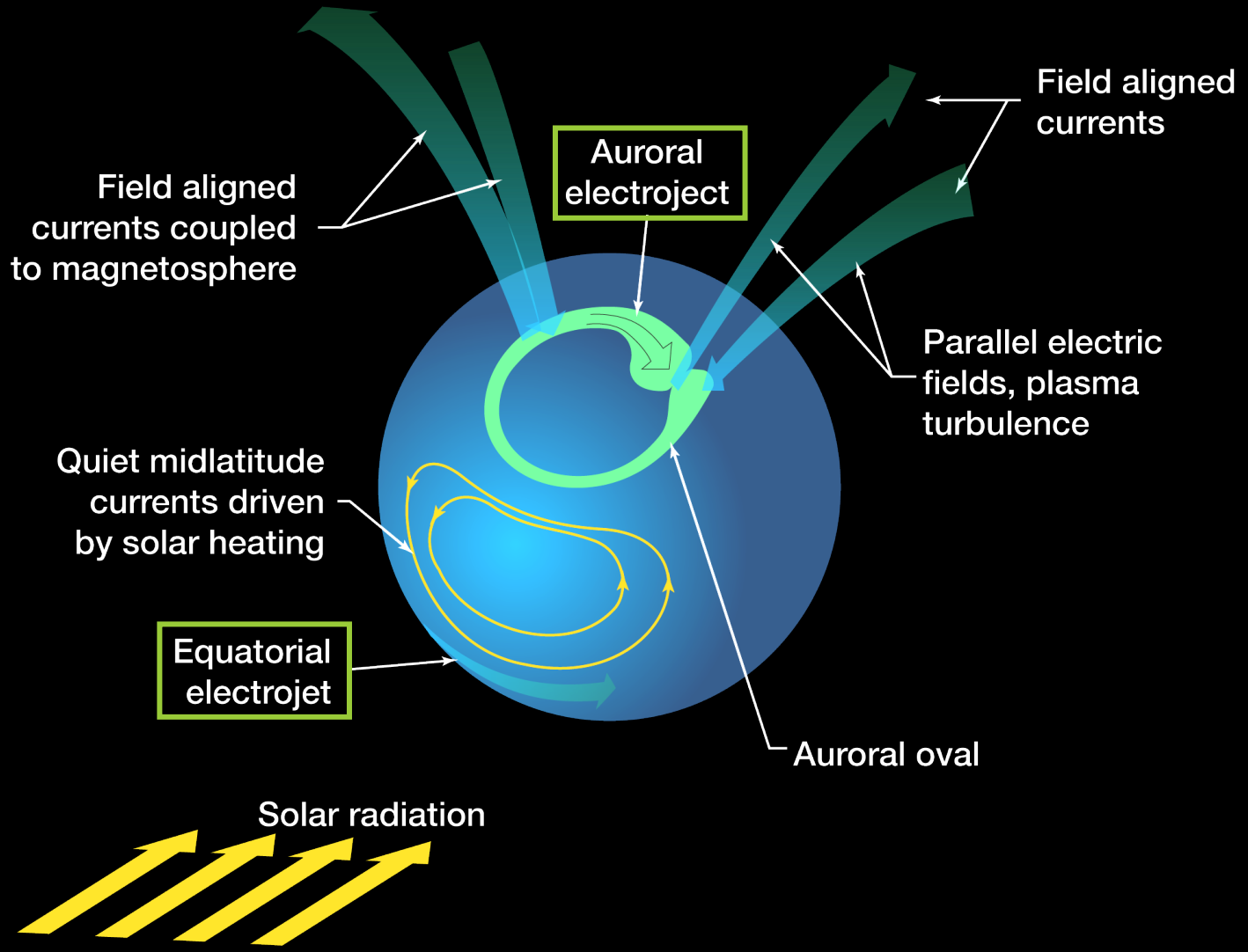
Paper SSC21-VI-07

Sam Yee, Jesper Gjerloev, Rafael Perez, William Swartz
Johns Hopkins University Applied Physics Laboratory
Sidharth Misra, Jet Propulsion Laboratory
Olagappan Chidambaram, Blue Canyon Technologies
Christopher Ruf, University of Michigan

EZIE: High-value Science within a MOO Budget

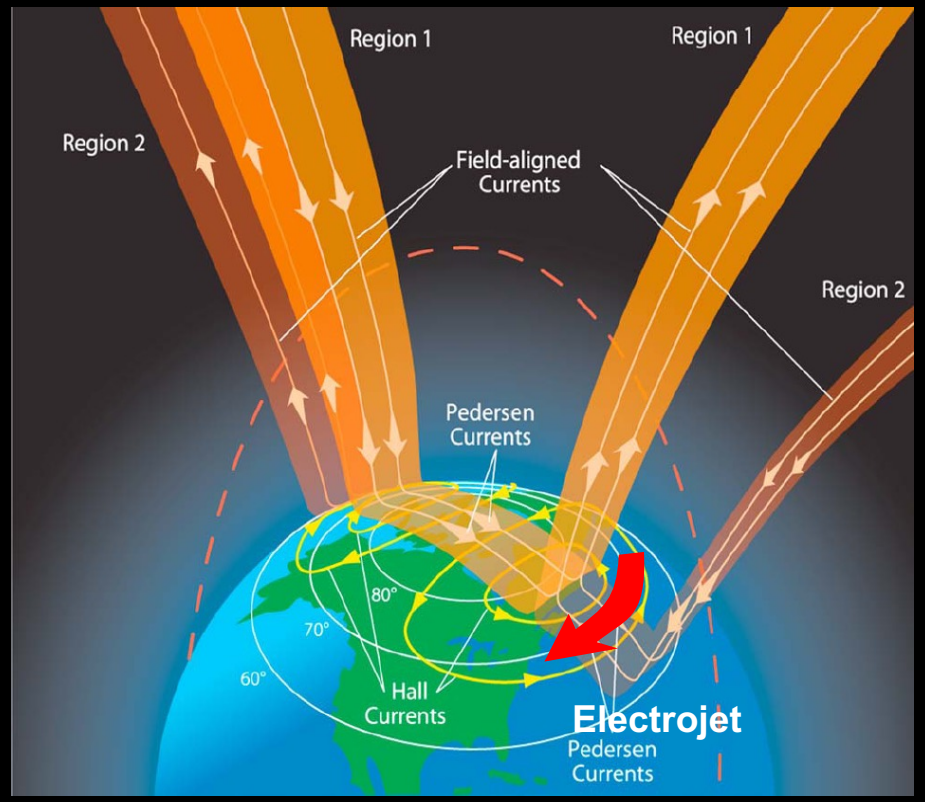


Electrical Currents in the Earth Ionosphere Are Fundamental to Energy and Momentum Transfer within the Sun-Earth System

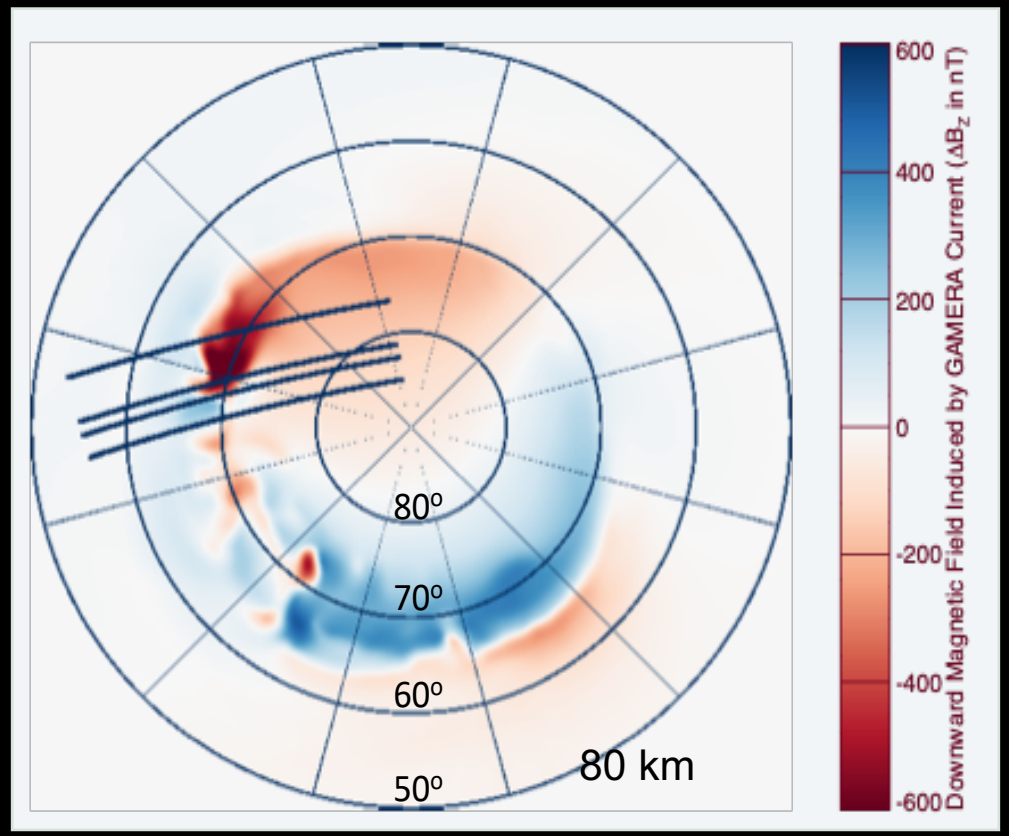


EZIE Overarching Science Measurement Goals

- The primary objective of the EZIE measurement goal is to reveal the mesoscale spatial structure and temporal evolution of the aurora electrojets during geomagnetic substorms to discern the physical mechanism of its generation.



Schematic of the high-latitude current system

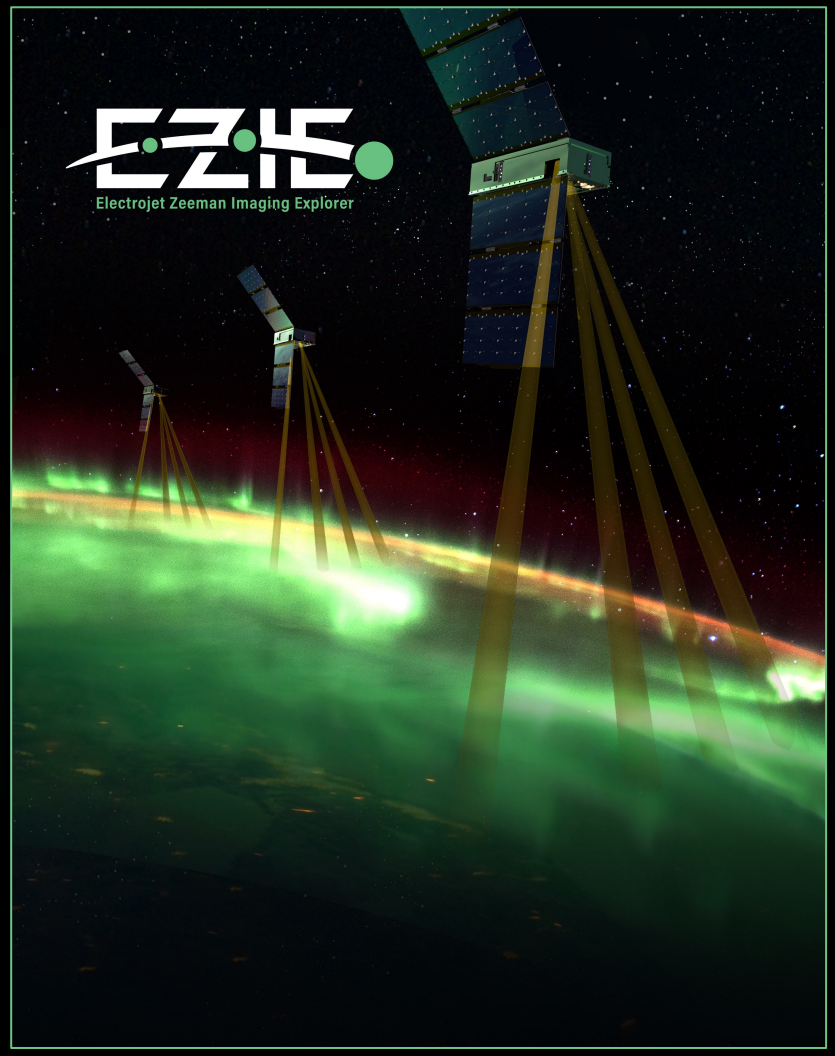


EZIE and Modeled ΔB_d induced by auroral electrojet

EZIE Achieves its Science Goal by Implementing the Mission with 4 Key Attributes to Meet Science Measurement and Cost Challenges

Innovative, Demonstrated Remote Sensing Technique

Heritage Low Size, Weight, and Power Instrument



Mature and Heritage CubeSat Technology

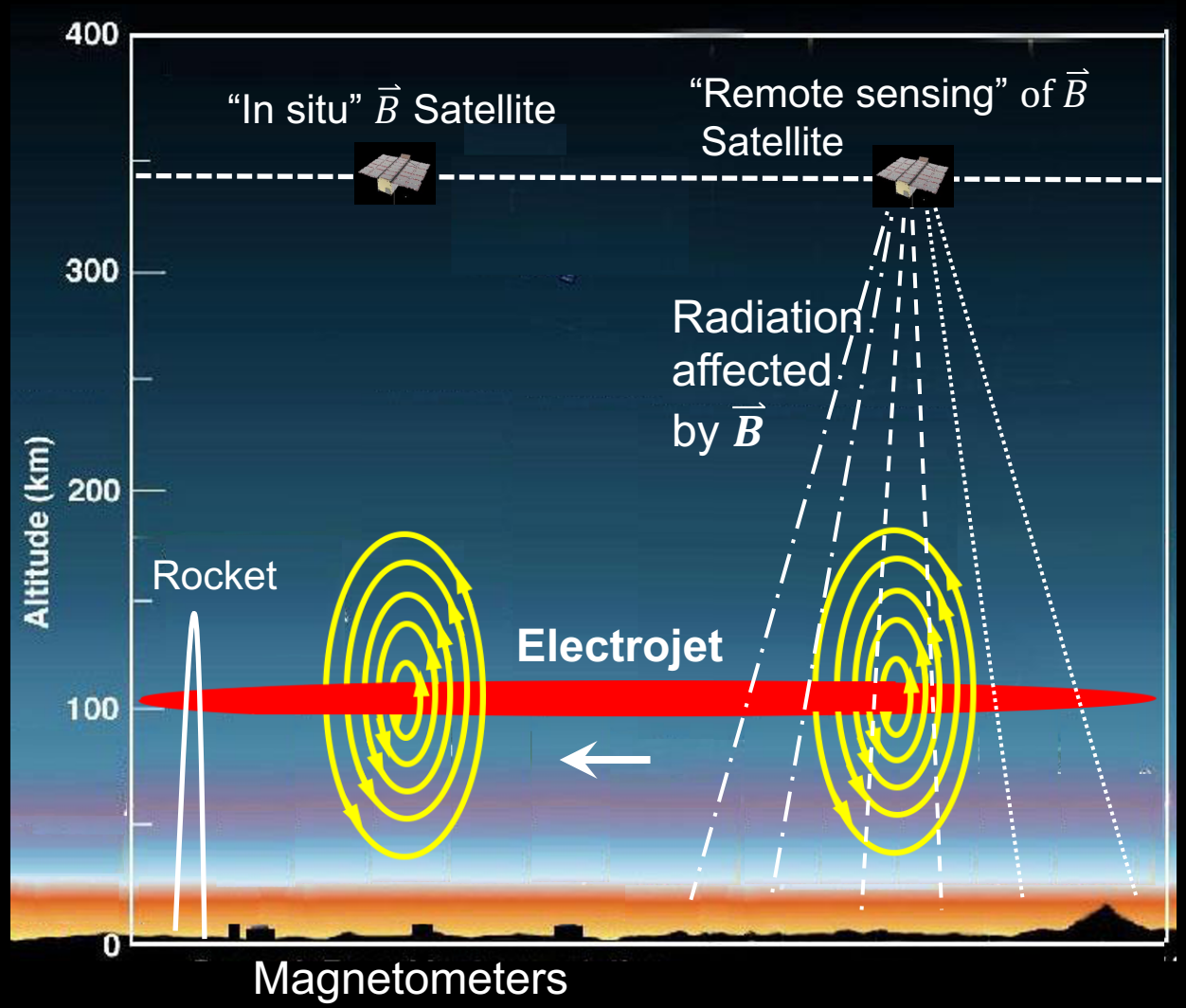
Demonstrated Orbit Management Approach

EZIE Visualizes Currents Remotely by Measuring Magnetic Field Perturbations Using an Old Technique Applied in a New Way

Currents are inferred from the measurements of the strength and direction of their induced magnetic fields.

Biot-Savart law:

$$d\vec{B} = \frac{\mu_0 I}{4\pi r^3} d\vec{L}\ x\ \vec{r}$$



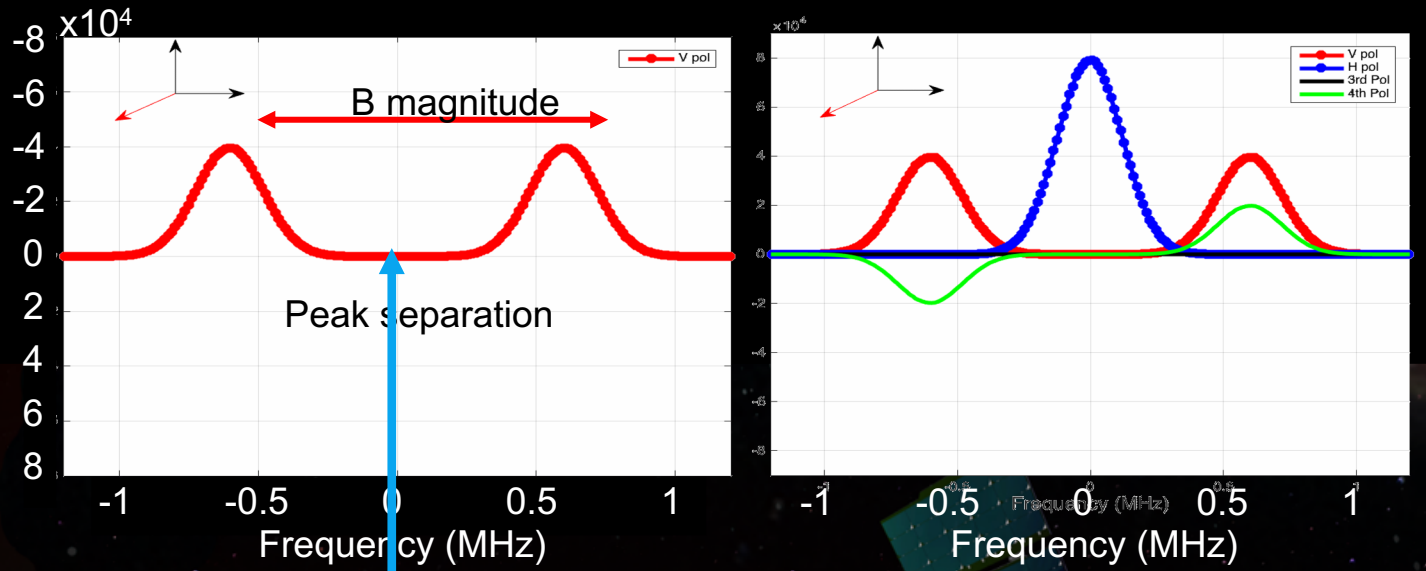
Conventional Means:

$\vec{B}$ sensing by "in situ" magnetometers

EZIE Means:

$\vec{B}$ sensing by "remote" spectrometers

EZIE Measures the Magnetic-field Induced Effects on the Spectral Radiances of the O_2 Emission line at 119 GHz



Unsplit Line Position (B=0)

Key EZIE O_2 118-GHz line measurement characteristics:

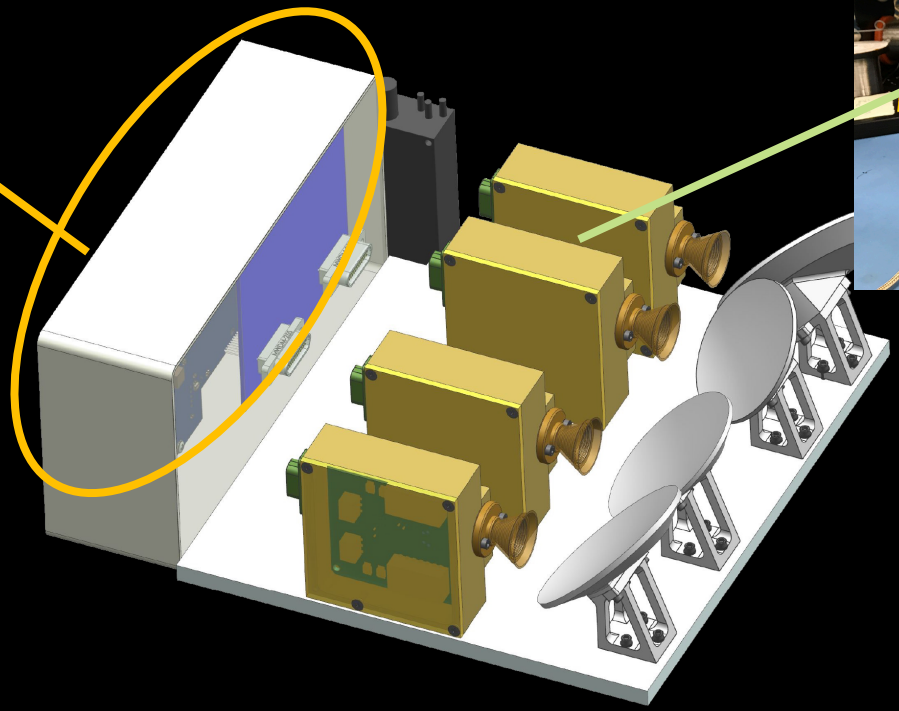
- Covers the entire Zeeman spectra and resolves the three split lines
  - Spectral splits → Total magnetic field
- Measures the full polarization state of the three lines
  - Polarization → Vector B-field
- Views nadir and off-nadir directions
  - Higher spatial resolution
  - Closer to the current source

EZIE utilizes four compact Microwave Electrojet Magnetogram (MEM) instruments flown and demonstrated on TEMPEST-D and CubeRRT

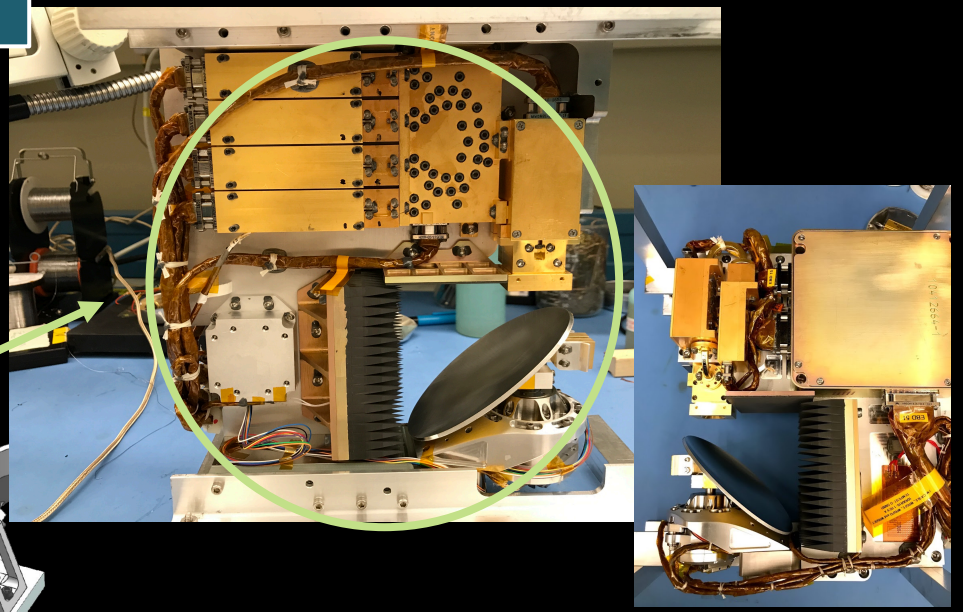
The MEM instrument is compact and proven

CubeRRT

EZIE MEM instrument layout



TEMPEST-D

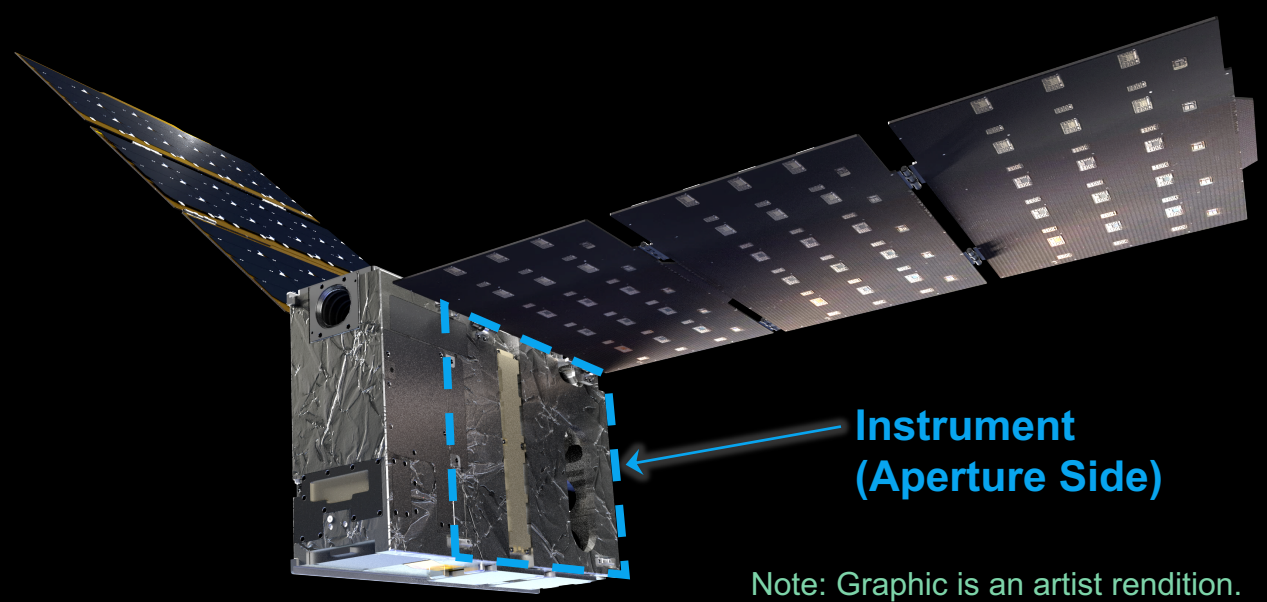


TEMPEST-D, CubeRRT launched in 2018 and are still operating

EZIE Provides a Low-Risk Approach to Achieve Science Objectives

- Significant heritage leveraged across all system elements and processes
- Multiple satellites ensure science success (two of three satellites required)
- BCT spacecraft accommodates MEM instrument with positive performance margins
- EZIE leverages high-availability commercial rideshare services via Spaceflight, Inc.

Deployed 6U CubeSat Configuration

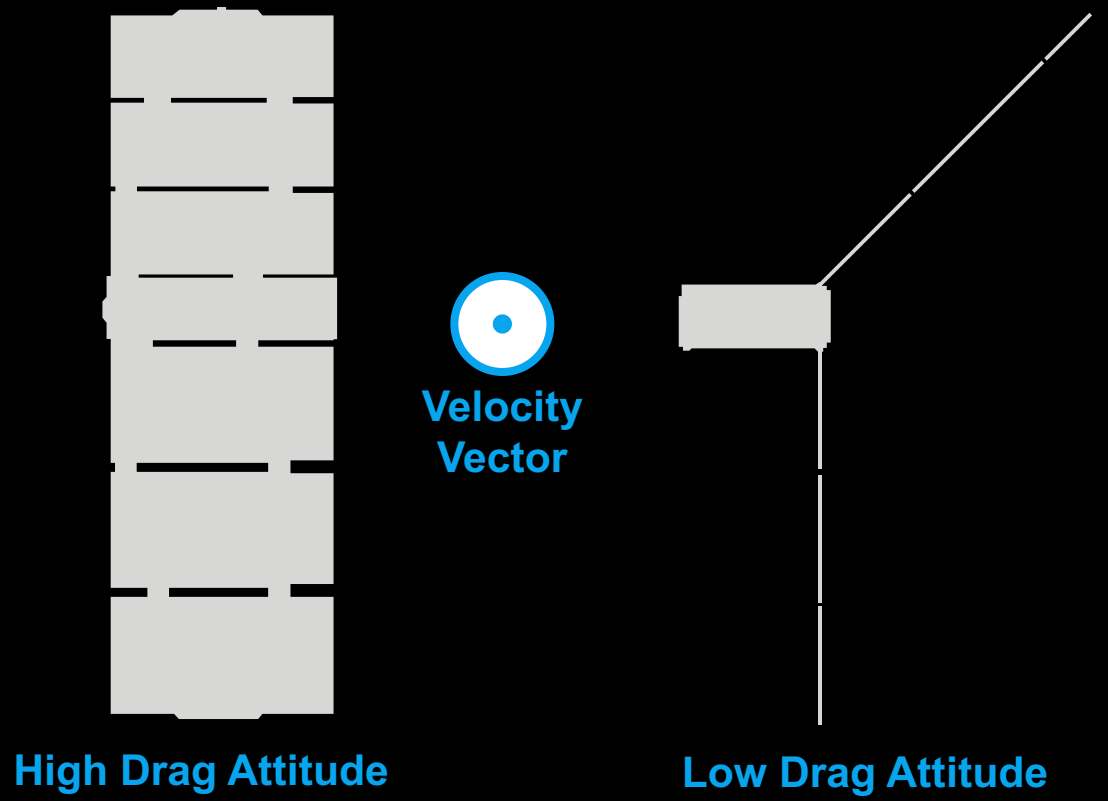


Note: Graphic is an artist rendition.

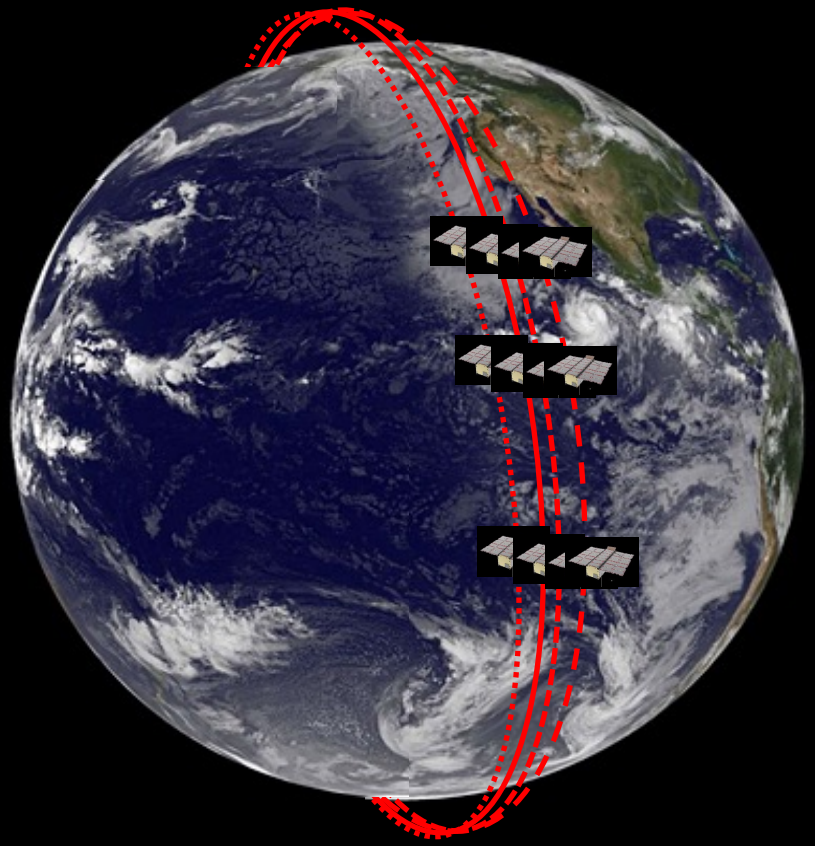
Size ≈ 14.3” × 9.4” × 4.2” (without solar arrays)
Mass Estimate ≈ 10 kg (Limit = 12 kg)

EZIE Performs Differential Drag Maneuvers To Provide Needed Spacecraft Spacings (in time) Without Propulsion

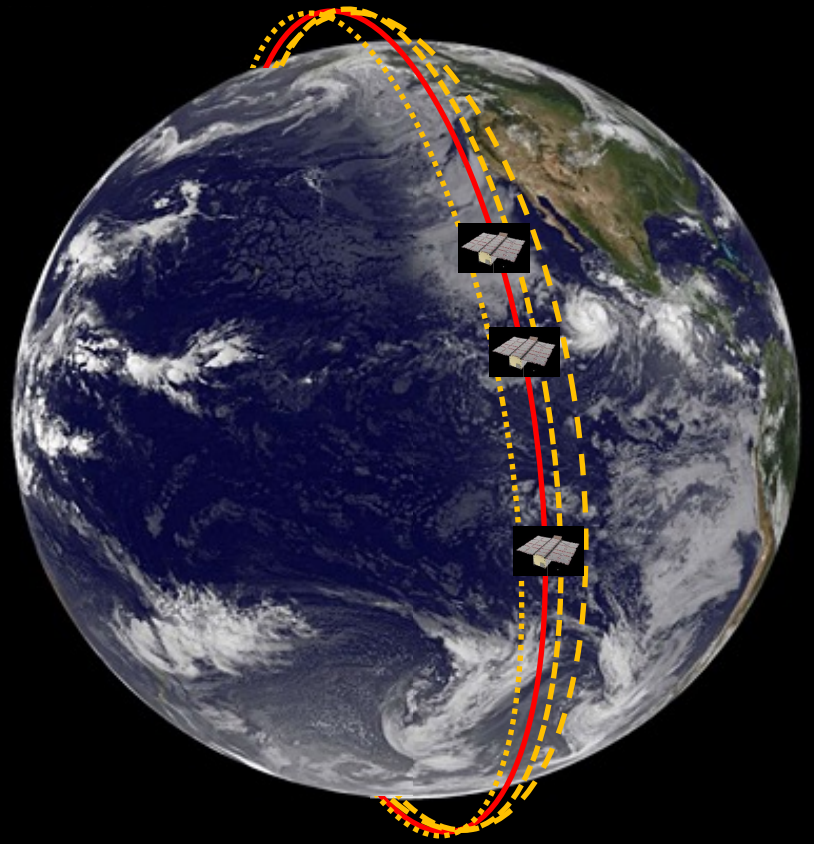
- No propulsion subsystem required, reducing overall system complexity
- Maneuvers achieved by changing attitude states using reaction wheels
- Strong heritage leveraged from two ongoing cubesat missions, CYGNSS and CAT
- EZIE implements a simpler configuration than CYGNSS and CAT



EZIE Zeeman Technique Not only Improves Current Imaging Resolution, but also Reduces Required Number of Spacecraft



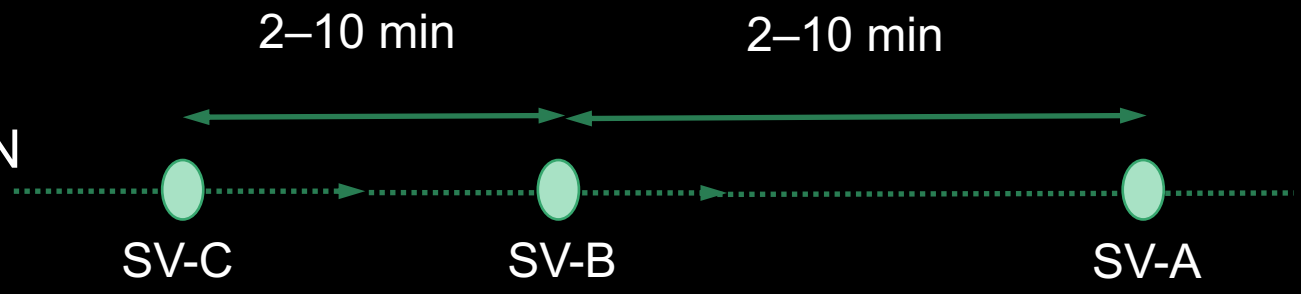
12 spacecraft with in-situ magnetometers



3 spacecraft with 4-beam Imaging MEM

EZIE Mission Summary

- A Heliophysics mission of opportunity designed to study the spatial structure and temporal evolution of the electrojets.
- It consists of three 6U CubeSat (provided by BCT) flying in a pearl-on-a-string formation with varying separation managed by differential drag.
- Each spacecraft carries four identical 118 GHz spectropolarimeters (provided by JPL) that remotely measure the electrojet induced magnetic fields
- Deployment orbit
  - Circular, 525- to 625-km altitude
  - Sun-synch, 09:00–11:00 or 22:30–00:30 LTAN
  - Can take advantage of any launch date



Thank You!