

# CubeSats to Classrooms

**Our Experience As Interns on NASA's Electrojet Zeeman  
Imaging Explorer (EZIE) Mission**

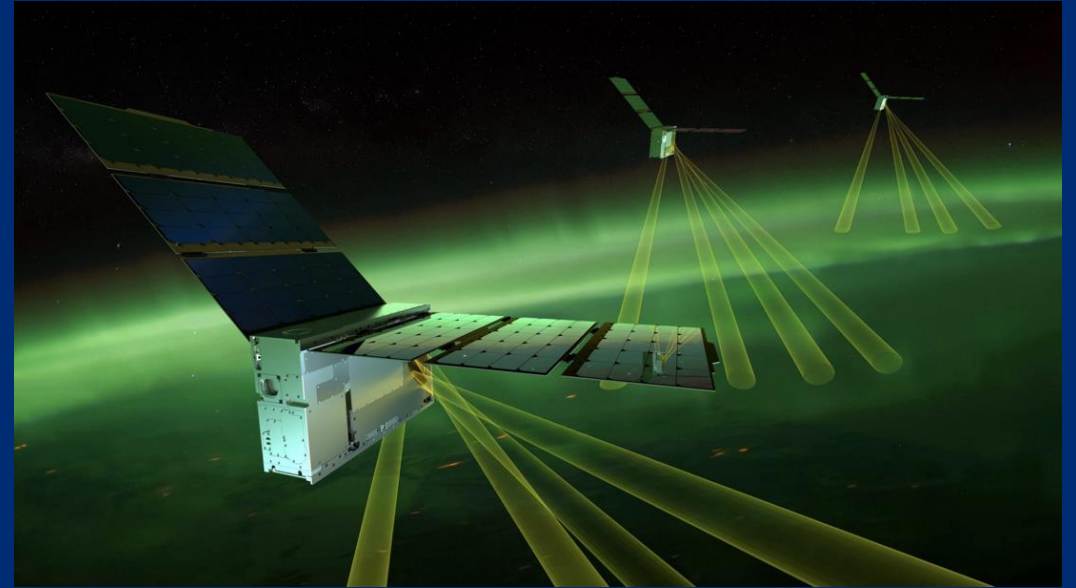
Harold Rathbun

Peter Seelman

Sienna Rader-Gowda

# EZIE Overview

- NASA's Electrojet Zeeman Imaging Explorer (EZIE) will determine the structure and evolution of Earth's electrojets.
  - *Electrojets*: 60-90 miles up in the ionosphere that are central to the electrical circuit that couples the planet's magnetosphere to its atmosphere.
- 3 CubeSats will measure the Zeeman effect, the splitting of the light spectrum of oxygen molecules in the presence of magnetic fields.
- These measurements will help determine magnetic field strength to calculate and map the electrojet.
- Why map the electrojet?
  - Greater insight into the physics of Earth's magnetosphere.
  - Better models for predicting the effects of space weather phenomena like geomagnetic storms and auroras.

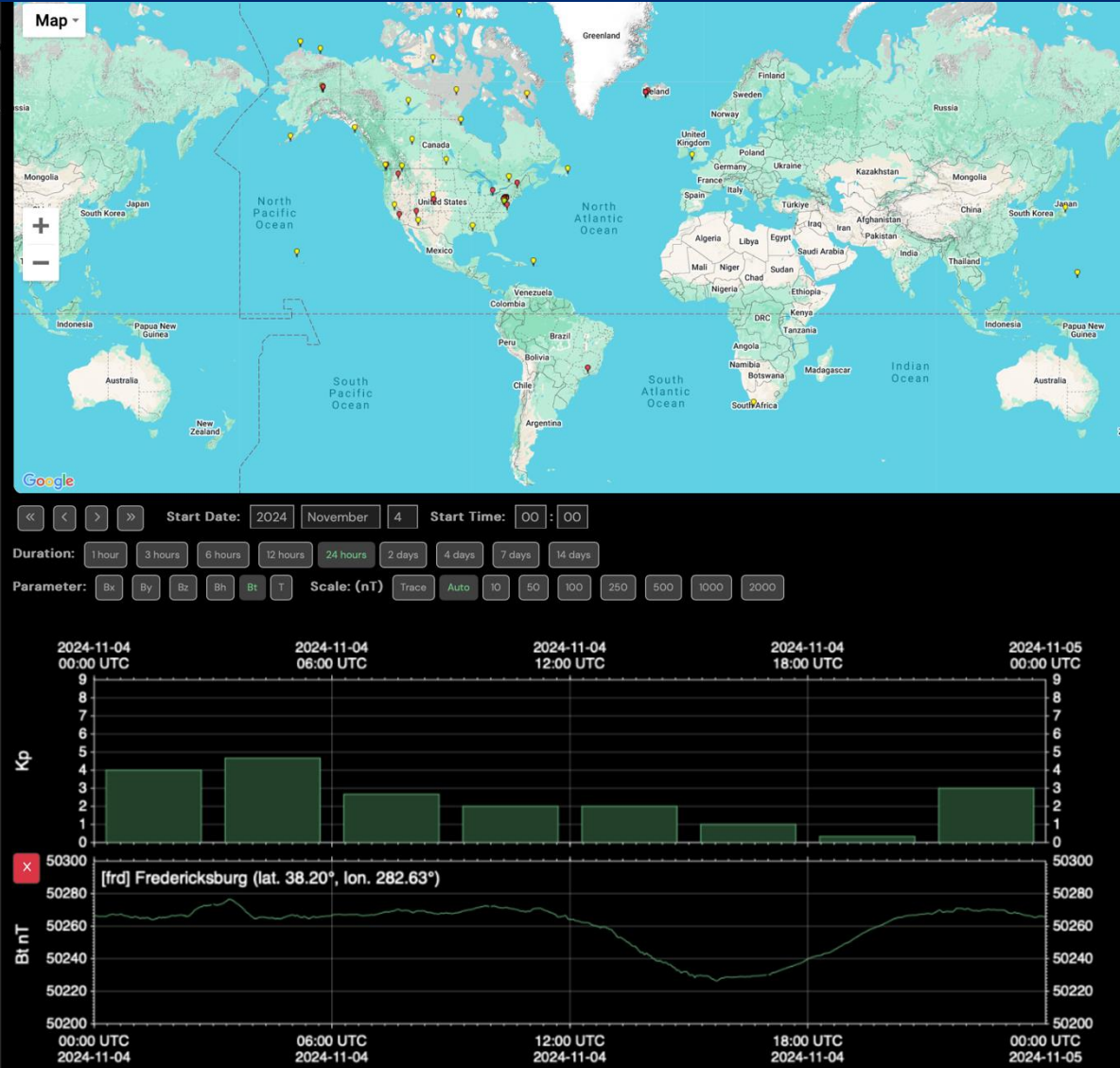


# Citizen Science!

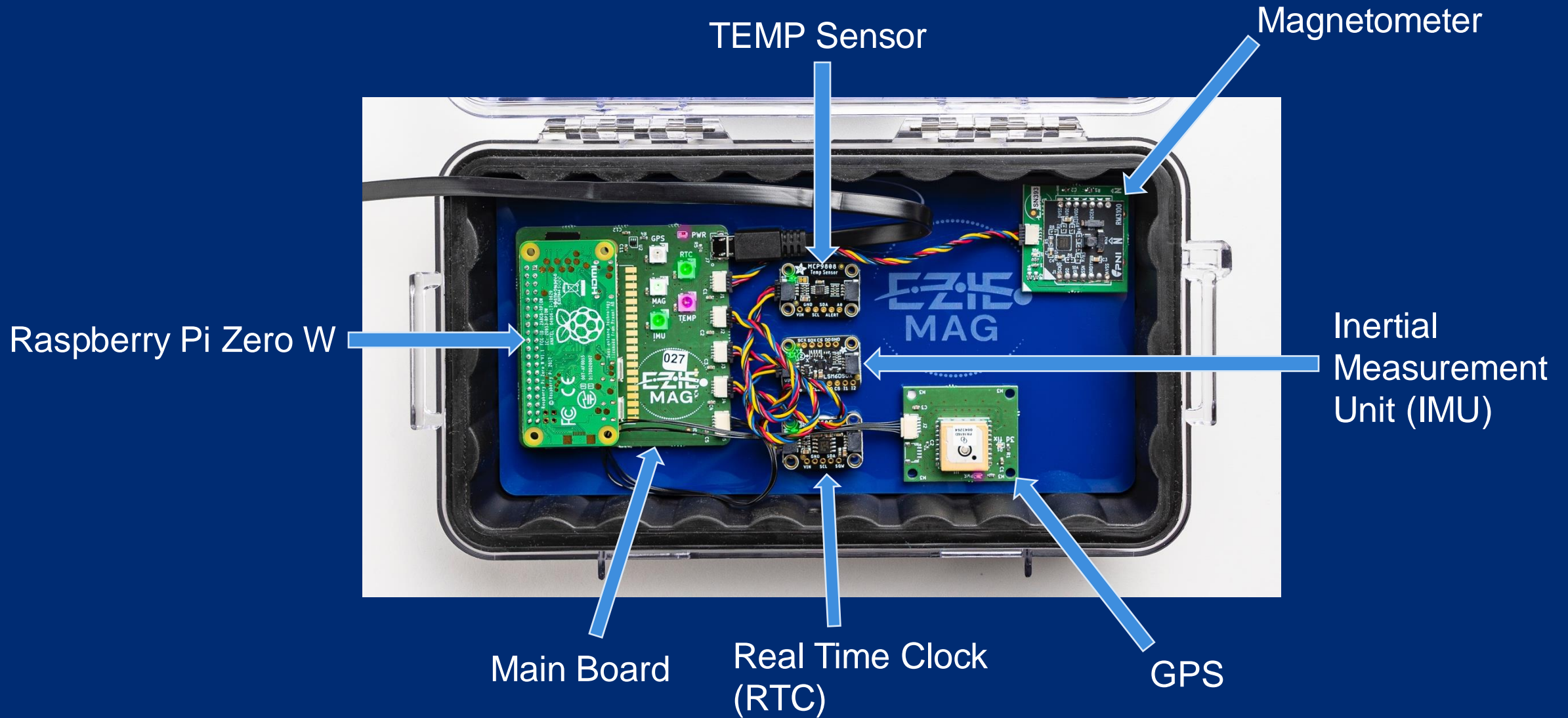
- EZIE-Mag is a public outreach program deploying ~700 science-grade magnetometer kits around the world, letting citizen scientists collect data, teach, and design their own experiments.
- Current science-quality magnetometer stations cost millions. EZIE-Mags cost ~\$250 and are distributed for free.



Stations	
Find Station by Name	
Clear All Select All	
eziemag:alw (Walla Walla, WA)	
eziemag:avl (Avalon Lake)	
usgs:bic (Baker Lake)	
usgs:bou (Boulder)	
usgs:brd (Brandon)	
usgs:brw (Barrow)	
usgs:bsl (Bay St Louis)	
usgs:cbb (Cambridge Bay)	
eziemag:cls (Colorado Springs, CO)	
usgs:cmo (College)	
usgs:dad (Deadhorse)	
eziemag:elc (Ellicott City)	
eziemag:eldbg (Eldersburg)	
eziemag:elk (Elkridge)	
eziemag:elk-bench (Elkridge Bench)	
usgs:eua (Eureka)	
eziemag:eziemag-JPL (EZIE Mag JPL)	
eziemag:eziemag_jpm (EZIE Mag Bristol, VA)	
eziemag:eziemaginpe01 (INPE Station I)	
eziemag:fbk (Fairbanks, AK)	
eziemag:fbk (EZIE Mag Fairbanks, AK)	
usgs:fcc (Fort Churchill)	
<b>usgs:frd (Fredericksburg)</b>	
usgs:frn (Fresno)	
eziemag:gdkA (Grindavik A, Iceland)	
eziemag:gdkB (Grindavik B, Iceland)	
usgs:gua (Guam)	
usgs:had (Hartland)	
eziemag:han (EZIE Mag Hanover, NH)	
usgs:her (Hermanus)	
usgs:hon (Honolulu)	
eziemag:iei-eziemag (IEI-EZIE-Mag Station San Juan Island, WA)	
usgs:iqa (Iqaluit)	
usgs:kak (Kakioka)	
eziemag:lsq (Little Singer School, AZ)	
eziemag:lyr-eziemag (EZIE-Mag Station Longyearbyen, Svalbard)	
eziemag:mfb (Mosfellsbaer)	
usgs:mea (Meanook)	
eziemag:msj (Mount Saint Joseph)	



# The EZIE-Mag: A Closer Look



# Preparing Kits for Shipment

- In a combined team effort, hand-prepared ~700 magnetometer kits for shipment in a week



# The EZIE-Mag Manual

- The EZIE intern team created the EZIE-Mag Manual, a LEGO inspired instruction set to make assembling the EZIE-Mag approachable for everyone
- These instructions cover software, hardware, and deployment.

Step 12 - Connect Mag to Power



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Step 25 - Deploy Your EZIE-Mag

Cover the mag with something to protect it from the elements which will not interfere with the measurements, such as a plastic cooler or flowerpot. Deploy the mag as level as possible, trying to avoid tilting. Keep the power cable away from the Mag Sensor.



Flower Pot

Plastic Cooler

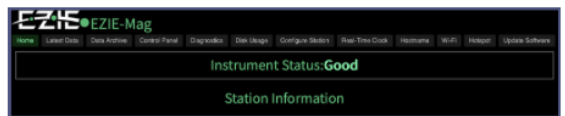
Cable across Mag Sensor

Cable away from Mag Sensor


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Step 14 - Check Status of Mag

The "Instrument Status" banner shows you the status of the magnetometer. It is green, "good," if the kit is functioning normally, or red, "bad," if there is a problem.



The next section of the page shows information about the location of your EZIE-Mag and some of its operating parameters.



Station Information

Identification:  
ID Code: ezmag  
Name: EZIE-Mag Station  
Operation: JHU/APL

Station Frequency: 333441.0000

Location:  
Latitude: 39.558°  
Longitude: -76.809°  
Altitude: 45-500 meters

IQRF Model Field:  
North/South component H: 2080787 nT Horizontal component H: 2188708 nT  
East/West component H: -4430646 nT Total Field H: 6075443 nT  
Vertical component H: -4657644 nT  
Declination D: -10.61°  
Inclination I: 85.20°

Hardware Configuration:  
Magnetometer: 800 Gauss (384.5T)  
Temperature Sensor Resolution: 3 (±0.0025° ± 250mK)  
MAG Accelerometer Full Scale: 200 (±0.02g)  
MAG Gyroscope Full Scale: 250 (±0.250°/s)

Latest Data

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# Navteca's EZIE Chatbot

- Goal: Increase EZIE's accessibility
- Parker Solar Probe website hosts similar AI
- Prepared and modified training data to improve:
  - Inflexibility
  - Irrelevant data retrieval
  - Overly technical responses
  - Inadequate knowledge base
- Enhanced the EZIE AI-based chatbot's safety, accuracy, and intelligibility in preparation for public release on the mission's website

The screenshot displays the 'Voice Atlas' interface. At the top, there are navigation tabs for 'Details', 'Analytics', and 'Integrations'. The main content area is titled 'Voice Atlas Team' with the email 'team@voiceatlas.com'. Below this is the 'EZIE Mission' section, which states: 'This Atlas has been created to provide information about APL and NASA's EZIE mission to image the magnetic fingerprint of the auroral electrojets. The JHU Applied Physics Lab will use this Atlas to support EZIE public outreach activities.' A small image of the EZIE mission is shown to the right. Below the mission text is a grid of document thumbnails, each with an 'OPEN' button and a refresh icon. The documents include 'EZIE\_Mag\_Assembly\_Instr...', 'Journal of Geophysical Re...', 'JGR Space Physics - 2014...', '49\_947.pdf', '1-s2.0-S00224073130036...', 'Journal of Geophysical Re...', 's11214-014-0124-9.pdf', 'Electric Currents in Geosp...', 'Journal of Geophysical Re...', 'Journal of Geophysical Re...', 'Geophysical Research Let...', and 'XXXII. On the influence of ...'. On the right side of the interface, there is a chat window with a date 'TUESDAY, AUGUST 6, 2024'. The chat contains a welcome message: 'Welcome to Atlas Playground. Ask questions to this Atlas, test the accuracy of answers, see the knowledge sources being utilized, and evaluate Atlas responses here.' Below this is a red input box with the question 'What should I include in my intern presentation?'. The chat response reads: 'I have not found relevant information to adequately answer this question. However, I suggest considering the following elements for your intern presentation: 1. **Introduction:** Briefly introduce yourself and your role as an intern. 2. **Project Overview:** Summarize the main project or tasks you worked on during your internship. 3. **Key Learnings:** Highlight the skills and knowledge you gained. 4. **Challenges Faced:** Discuss any obstacles you encountered and how you overcame them. 5. **Results and Impact:** Present any outcomes or contributions you made to the team or project. 6. **Future Goals:** Share how this experience will influence your future career or studies. You may also want to include visuals or data to support your points. For more guidance on creating effective presentations, you can explore resources such as [Toastmasters](#) or [Canva's presentation tips](#).' At the bottom of the chat window, there is a text input field with the placeholder 'Ask something...'. The top right corner of the interface has a toggle for 'Open-Domain Question Answering' and a user profile icon.

# EZIE-Mag Tutorial Videos and Science Gateway

- We worked with APL COMMs to produce tutorial videos for citizen scientists
- Helped design the EZIE-Mag science gateway
- Gateway will host the manual, tutorials, chatbot, and a plethora of other resources for citizen scientists

## Get Your Free EZIE-Mag

Apply to receive an EZIE-Mag kit!

By uploading your data, you are agreeing to provide the Johns Hopkins Applied Physics Laboratory and NASA the measurements from your magnetometer, which includes information about the registration of the magnetometer and geolocation where such measurements were taken.

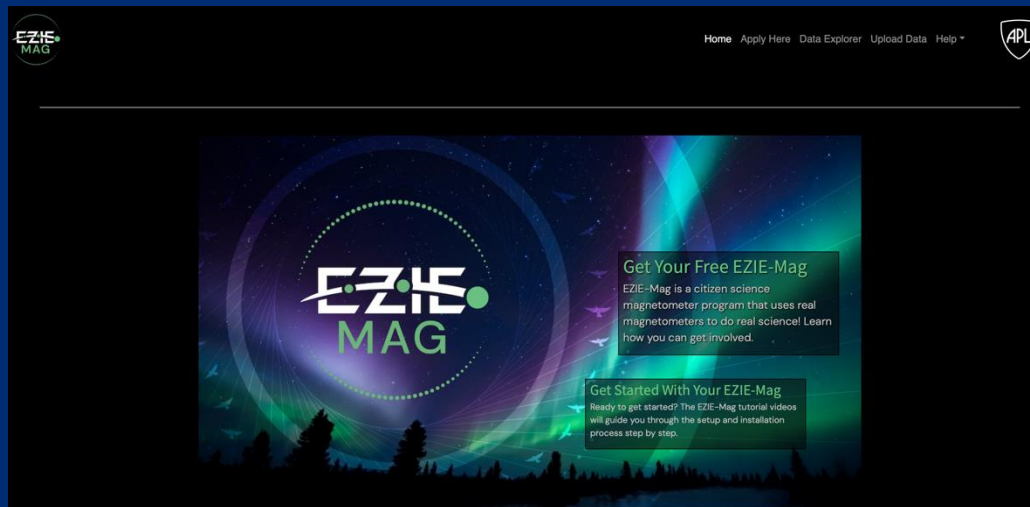
### What is EZIE-Mag?

Want to experience the aurora from your hometown? You can with EZIE-Mag.

EZIE-Mag is a citizen science magnetometer program that will enable learners to capture science data similar to that obtained by the EZIE mission.

The program will distribute kits around the time of EZIE's launch in Spring 2025 that will enable diverse communities to collect data about the connections between Earth and space.

But the program is much more than just a kit! EZIE-Mag is also a learning program that includes activities and challenges that focus on science, engineering, art, literacy and leadership, as well as social and emotional skill-building. There are many options to customize and enhance learners' experiences.

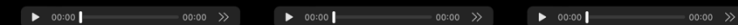
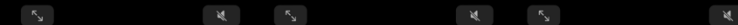


## EZIE-Mag Help: Getting Started

General Info Getting Started Live Data Local Dashboard Data Explorer Uploading Data

### EZIE-Mag Tutorial Videos

Watch All Three Tutorial Videos Before Visiting These Links!



Watch Tutorial Video One

Watch Tutorial Video Two

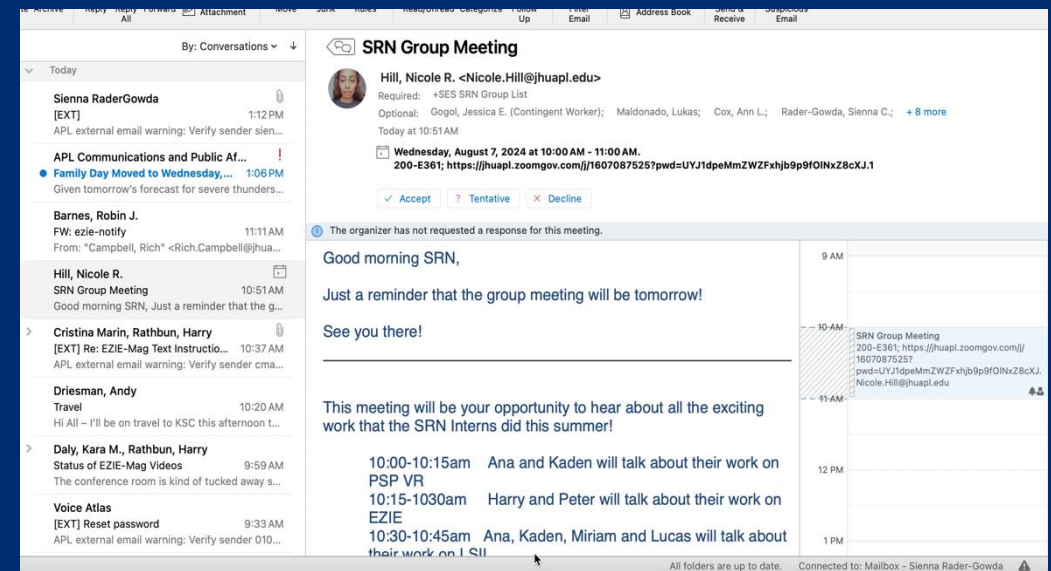
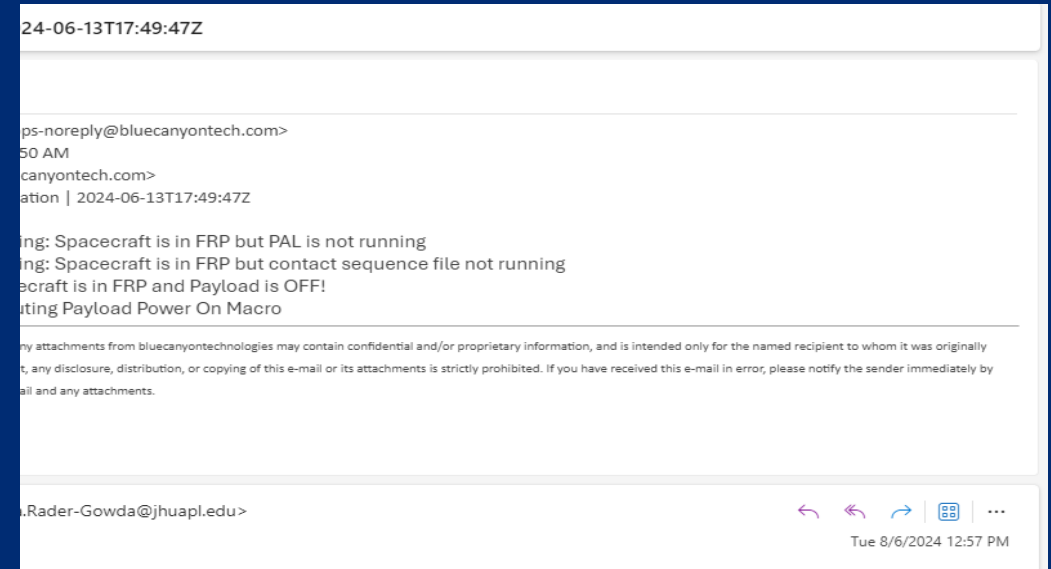
Watch Tutorial Video Three

# Automated Email Sorting

- During testing, the EZIE spacecraft send many automated emails, so the EZIE team needed something to alert team members of important messages.
- We wrote a Python script to read the emails and notify the team when an urgent message was received.
- APL security measures made it difficult to run the script perpetually on a compute cluster
- This led to alternate approaches:
  - Containerizing code and running on a VM
  - Running on Chrome through a cluster

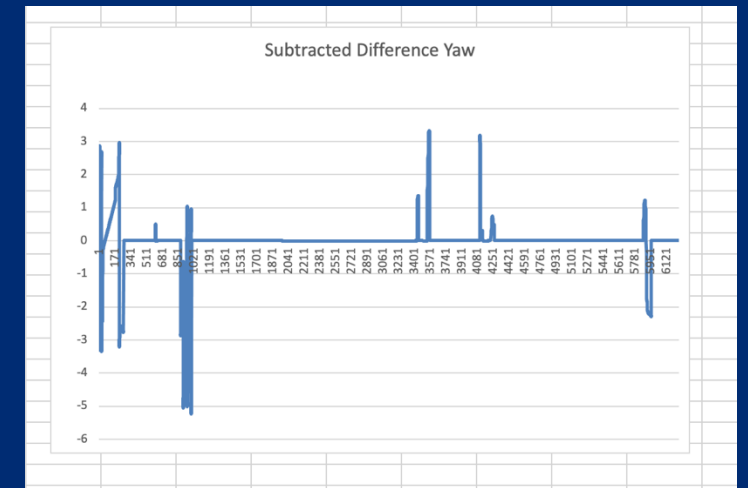
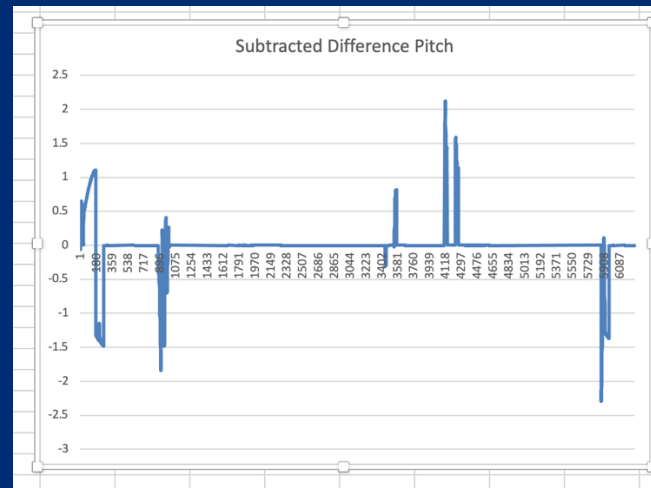
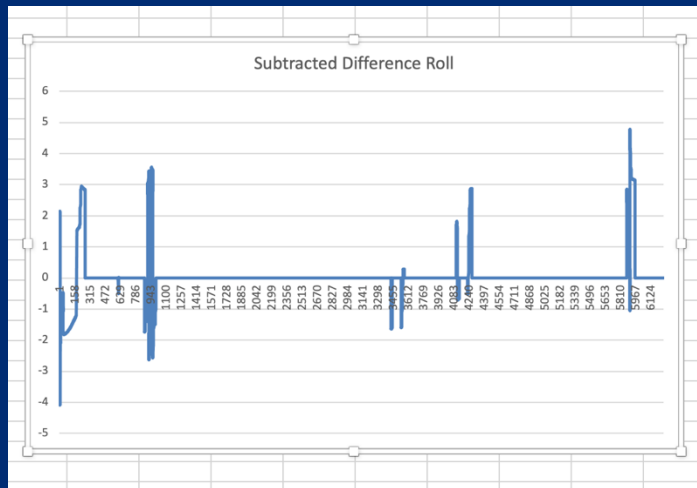
**From:** bct-mops no-reply <bct-mops-noreply@bluecanyontech.com>  
**Sent:** Wednesday, June 19, 2024 11:13 AM  
**To:** David Vickery <dvickery@bluecanyontech.com>  
**Subject:** EZIE-02 Customer Notification | 2024-06-19T17:12:49Z

2024-06-19T17:12:09Z: Bus Reset Detected! Reset occurred at 2024-06-19T16:57:24Z  
2024-06-19T17:12:16Z: Executing Macro 70



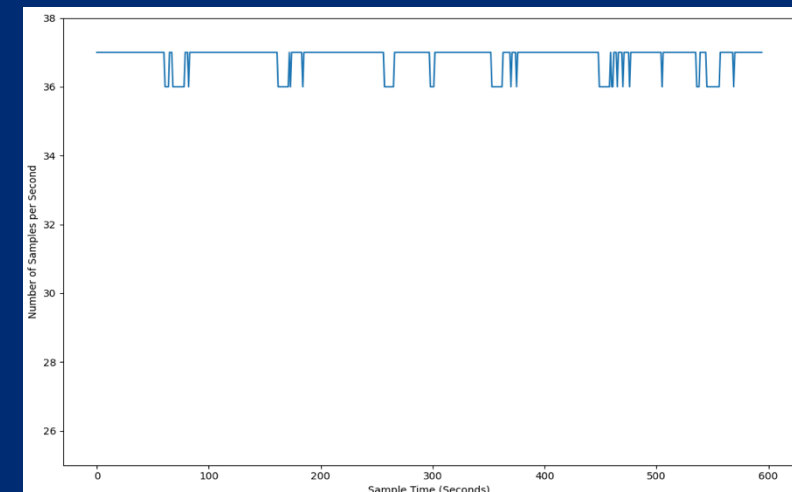
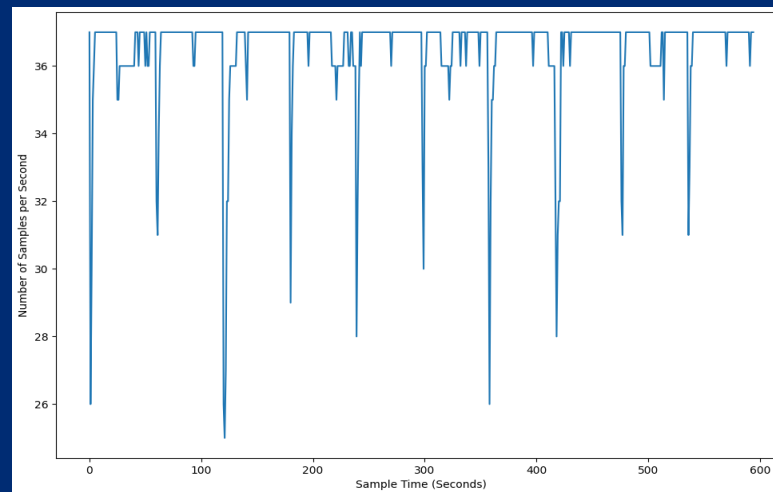
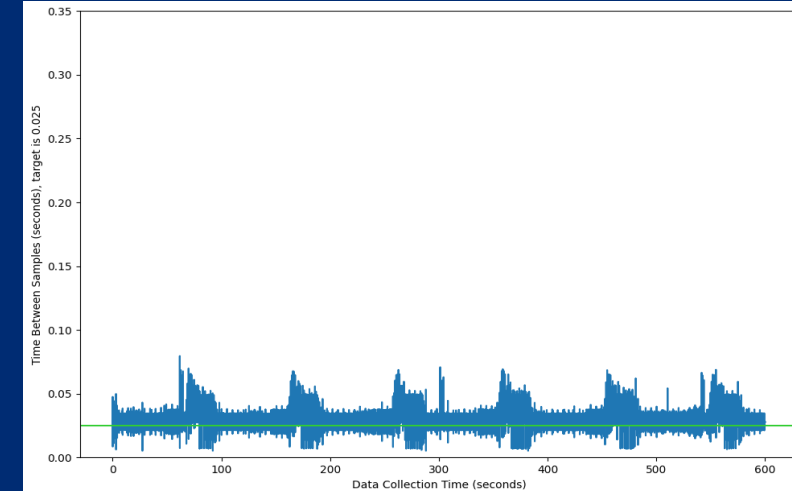
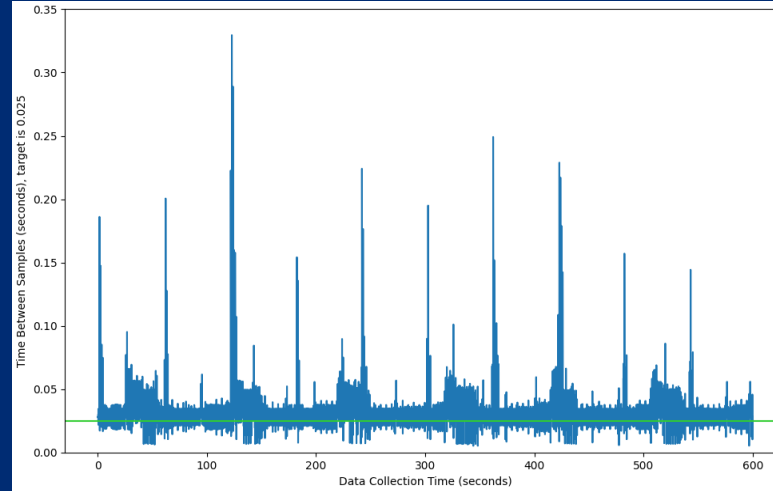
# Compared MSIM4 Commanded Attitude to Attitude Telemetry

- Verifying that the commanded EZIE spacecraft measurements, specifically the attitude, are equal to the actual measurements during testing
- Comparing planned attitude to attitude telemetry on the EZIE spacecraft using quaternions
- Comparing NETCDF files to .a files in two different time formats
- Converted quaternions into roll, pitch, and yaw to find the difference between the expected measurement and the actual measurement
- Exported all the data to an excel spreadsheet for easy graphing and analyzing

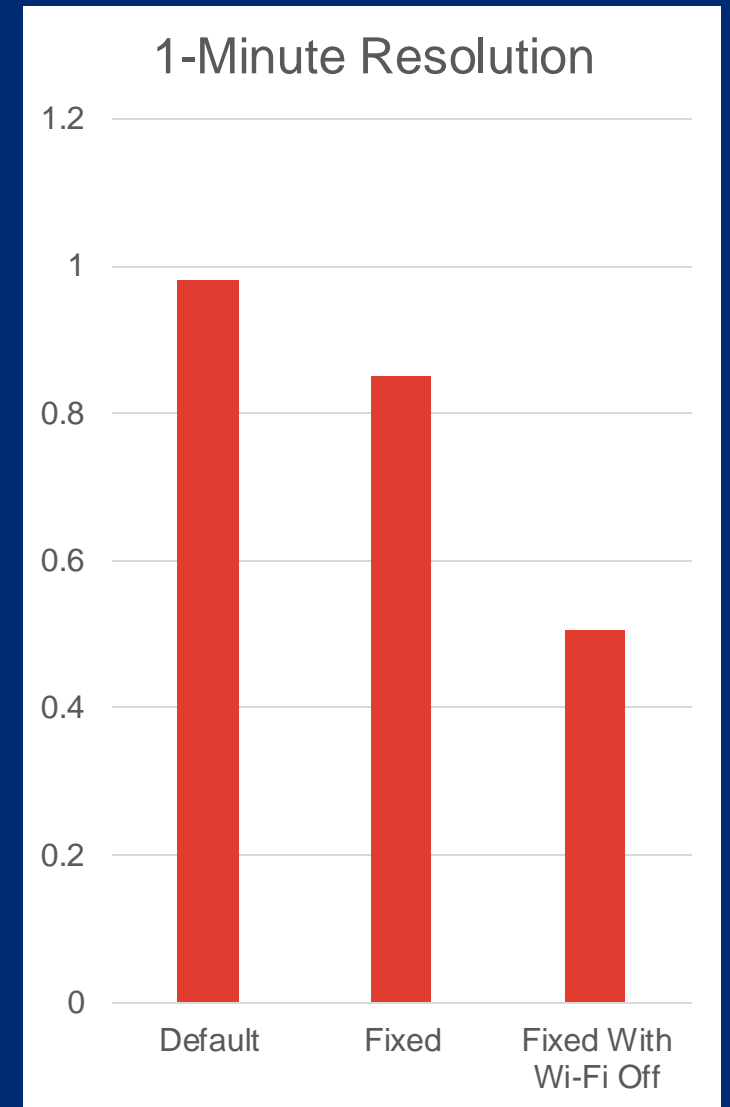
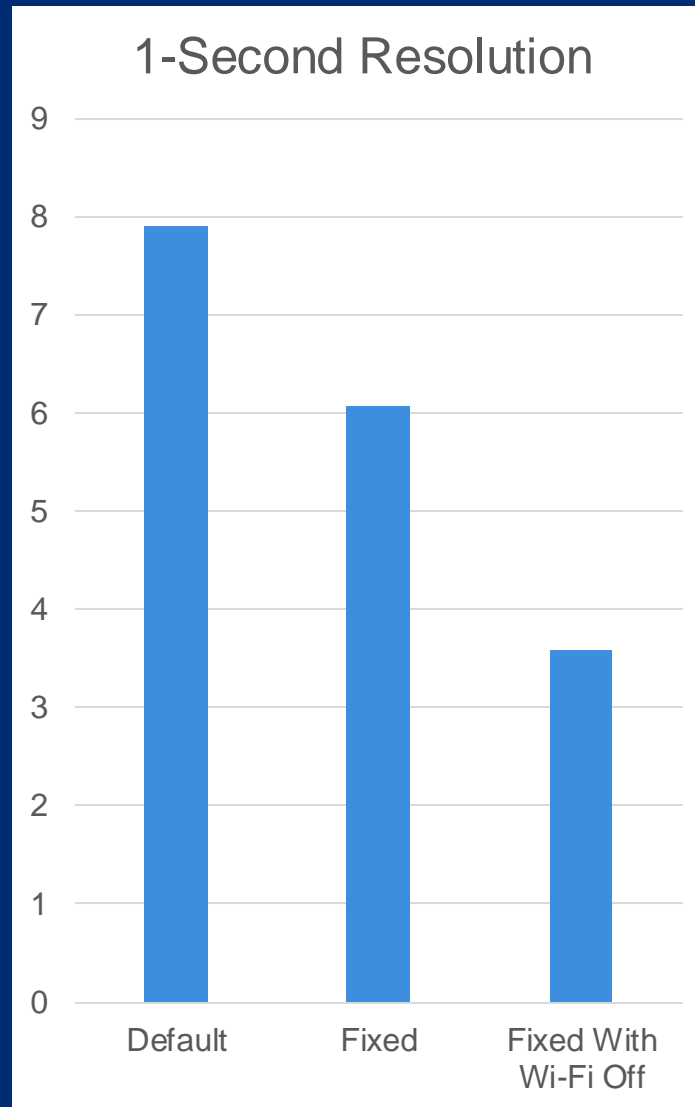
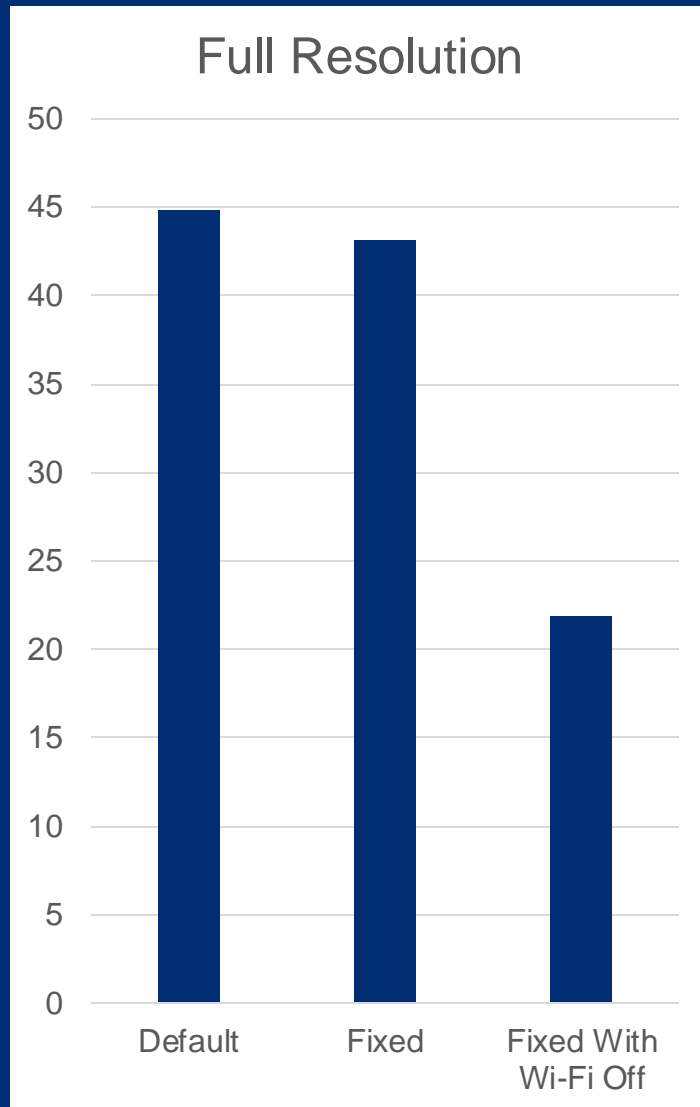


# Sampling Rate Bug

- Target sampling rate for EZIE-Mag is ~40 Hz
- Actual sampling rate hovered around this, but significantly dropped every minute
- Sporadic sampling rates were problematic for data quality
- Discovered that this was caused by a scheduling issue with Cron Jobs
- Resolved the issue by rescheduling Cron Jobs on the EZIE-Mag



# Data Improvement (Standard Deviation, nT)



# Data Visualization: netCDF, cdl, & Excel Viewer

- Problem:
  - .cdl, .nc, .nc4 files can be hard to understand
  - Need to verify EZIE spacecraft data pipeline
- Solution:
  - Interactive File Viewer
  - Can also convert to Excel
- Full stack development utilizing:
  - Python, HTML, CSS
  - Flask (Python web framework)
  - Docker (Open-source containerization)
  - Pandas
  - Numpy
  - Subprocess (Executing external functions)
  - Logging (Because things go wrong sometimes)

```
.
├── Dockerfile
├── README.md
├── app.py
├── docker-compose.yml
├── output
│   ├── Excel
│   │   └── ezie.l1.xlsx
│   ├── app.log
│   └── netCDF
│       ├── ezie.l0a.nc
│       ├── ezie.l0b.nc
│       ├── ezie.l1.nc
│       ├── ezie.l2.nc
│       ├── foo.nc
│       └── refs_data.nc
├── pd_test.ipynb
├── requirements.txt
├── static
│   └── styles.css
├── templates
│   ├── display.html
│   └── upload.html
├── uploads
│   ├── ezie.l0a.cdl
│   ├── ezie.l0a.nc
│   ├── ezie.l0b.cdl
│   ├── ezie.l0b.nc
│   ├── ezie.l1.cdl
│   └── foo.cdl
└── 7 directories, 23 files
```

```
netcdf ezie_l1 {
    // CDL For EZIE L1 netCDF Files
    // =====
    // Author: R.J.Barnes & H.Nair
    //
    // (c) 2024 JHU/APL

    :mission = "EZIE";
    :product = "L1";
    :description = "Geolocated, calibrated brightness temperatures";

    dimensions:
        ObsRate = UNLIMITED;           // Number of observations in file
        Cart = 3;                       // Cartesian (x,y,z) coordinates
        Quaternion = 4;                 // Quaternion components
        Freq_Array = 1024;              // Frequency channels in spectra
        Stokes_Array = 4;               // Received polarization channels (V,H,S3,S4)
        Stokes_Array_VH = 2;           // Only V and H linear polarizations
        Four = 4;                       // Four element dimension for 4x4 matrix
        CalAccumRate = UNLIMITED;      // Calibration accumulation rate

    group: Metadata {
        variables:
            string SpaceVehicle;
            SpaceVehicle: long_name= "Space Vehicle Identifier";
            SpaceVehicle: description= "Space Vehicle Identifier (EZIE-A, EZIE-B, or EZIE-C)";
            string CreationTimeString;
            CreationTimeString: long_name="Creation Time";
            CreationTimeString: description="File creation date in UTC (ISO8601)";
            string StartTimeString;
            StartTimeString: long_name="Start Time";
            StartTimeString: description="Start time of data in the file in UTC (ISO8601)";
            string EndTimeString;
            EndTimeString: long_name="End Time";
            EndTimeString: description= "End time of data in the file in UTC (ISO8601)";
            string DataProductName;
            DataProductName: long_name="Product Name";
            DataProductName: description= "Long product name";
            string DataProductLevel;
```

# Data Visualization: netCDF, cdl, & Excel Viewer

- Provides both interactive and conventional “scientist-readable” formats
- Found and fixed errors in files used by the EZIE team
- Usable on other NASA missions as these are all commonly used file types

Upload netCDF or CDL File

Choose File old\_ezie.l1.cdl

Interactively View  
Convert to Excel

Interactive File Overview

**Attributes**

mission: EZIE
product: L1
description: Geolocated, calibrated brightness temperatures

**Dimensions**

ObsRate: 0
Cart: 3
Quaternion: 4
Freq_Array: 1024
Stokes_Array: 4
Stokes_Array_VH: 2
Four: 4
CalAccumRate: 0

**Groups**

- Metadata
- FrameHeader
- FrequencyGrid
- Time
- Geolocation
- Ancillary
- InstrumentTemperatures
- ChannelOrderedCounts
- Calibration
- CalibratedSceneTemperatures

**Variables**

SpaceVehicle
CreationTimeString
StartTimeString
EndTimeString
DataProductName
DataProductLevel
DataProductIdentifier
DataProductVersion
SoftwareVersion
CalibrationVersion

Tabular Output

Name	Dimensions	Shape	description	long_name	units	decription	unirs
Metadata/SpaceVehicle	0	0	Space Vehicle Identifier (EZIE-A, EZIE-B, or EZIE-C)	Space Vehicle Identifier	Unknown	Unknown	Unknown
Metadata/CreationTimeString	0	0	File creation date in UTC (ISO8601)	Creation Time	Unknown	Unknown	Unknown
Metadata/StartTimeString	0	0	Start time of data in the file in UTC (ISO8601)	Start Time	Unknown	Unknown	Unknown
Metadata/EndTimeString	0	0	End time of data in the file in UTC (ISO8601)	End Time	Unknown	Unknown	Unknown
Metadata/DataProductName	0	0	Long product name	Product Name	Unknown	Unknown	Unknown
Metadata/DataProductLevel	0	0	Data product level (LO.L1.L2, etc.)	Data Product Level	Unknown	Unknown	Unknown
Metadata/DataProductIdentifier	0	0	Space Vehicle Identifier (EZIE-A, EZIE-B, or EZIE-C)	Data Product Identifier	Unknown	Unknown	Unknown

# Special Thanks

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- Leonardo Regoli
- Jesper Gjerloev
- Ryan Poffenbarger
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- Rebecca Kelly
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- Ralph McNutt
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- Matt Potter
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- Helena Hahn
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- And everyone else who helped us along the way!



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