The upcoming Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS) Small Explorers Mission

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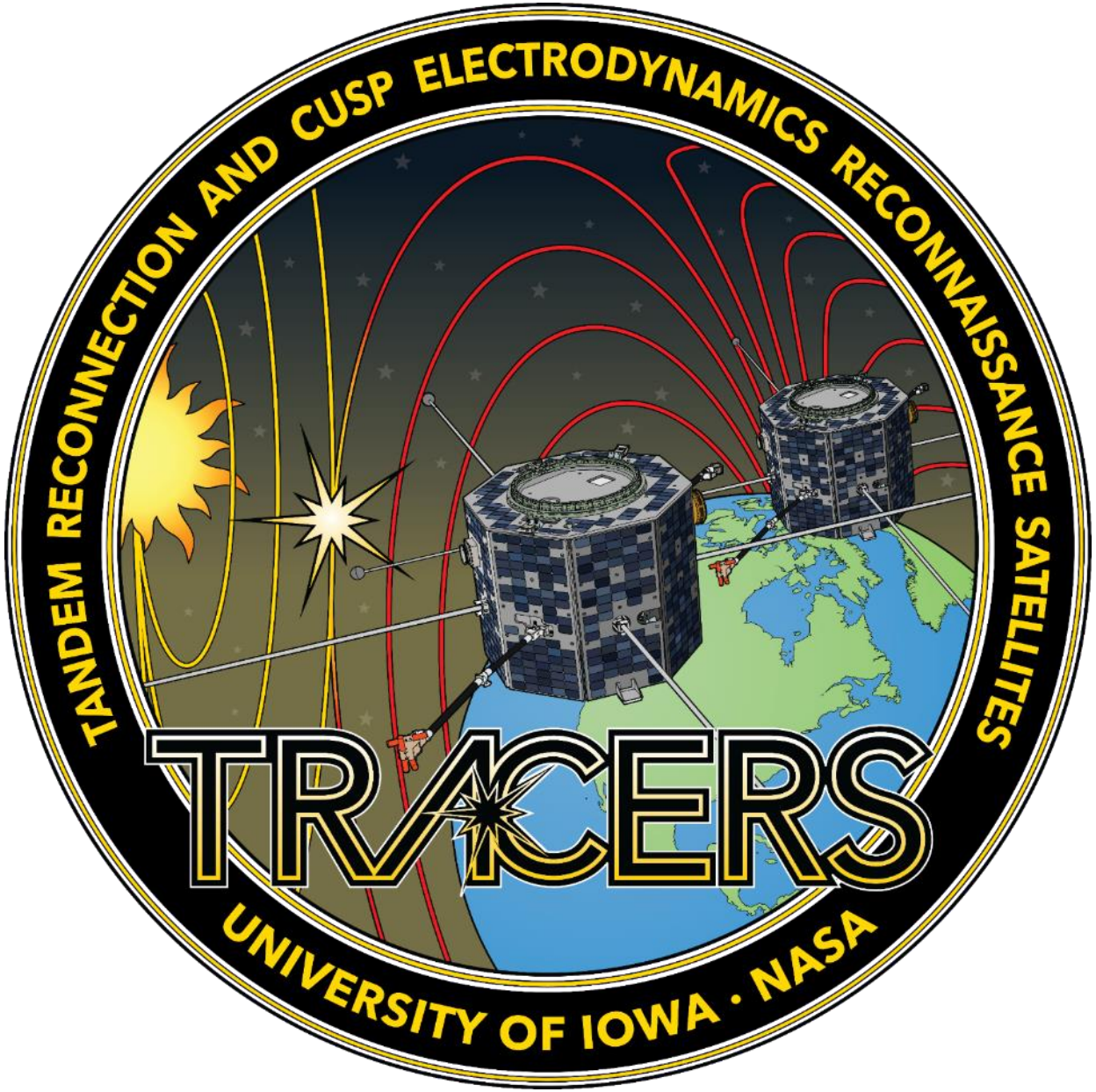
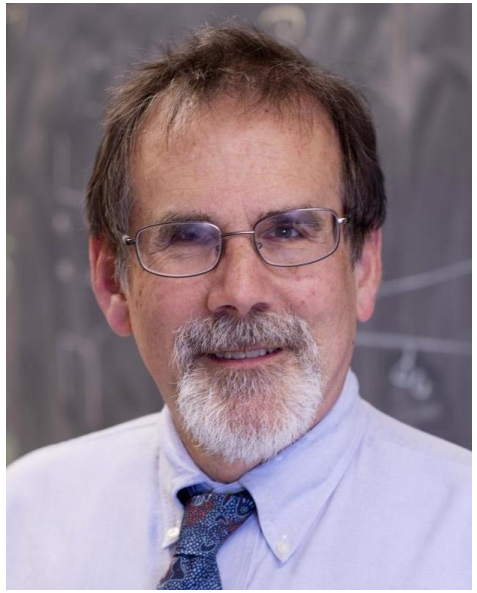
DASP 2024, Edmonton, AB

February 21, 2024

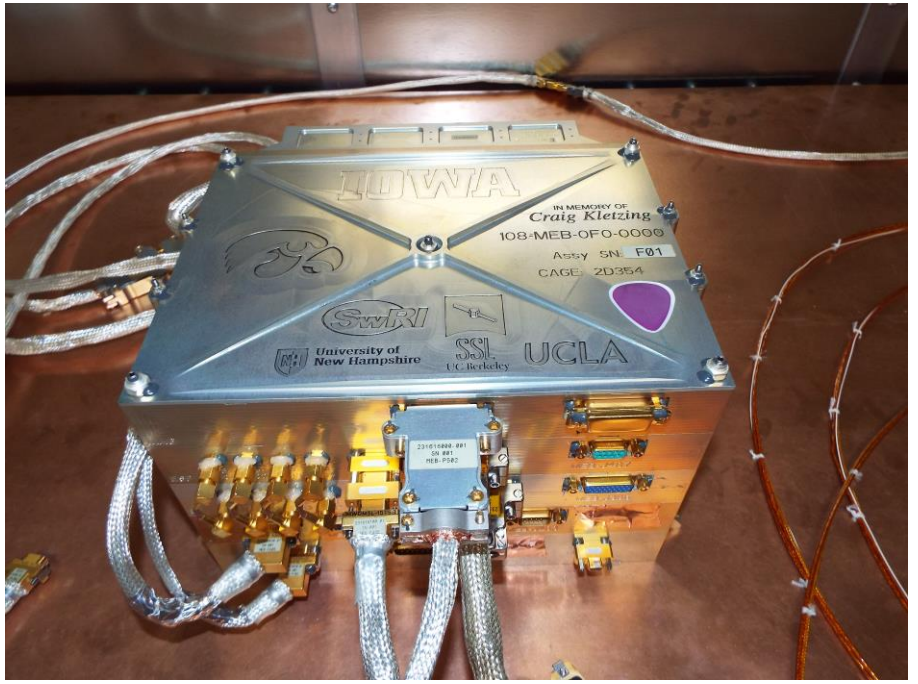


Passing of TRACERS PI Prof. Craig Kletzing



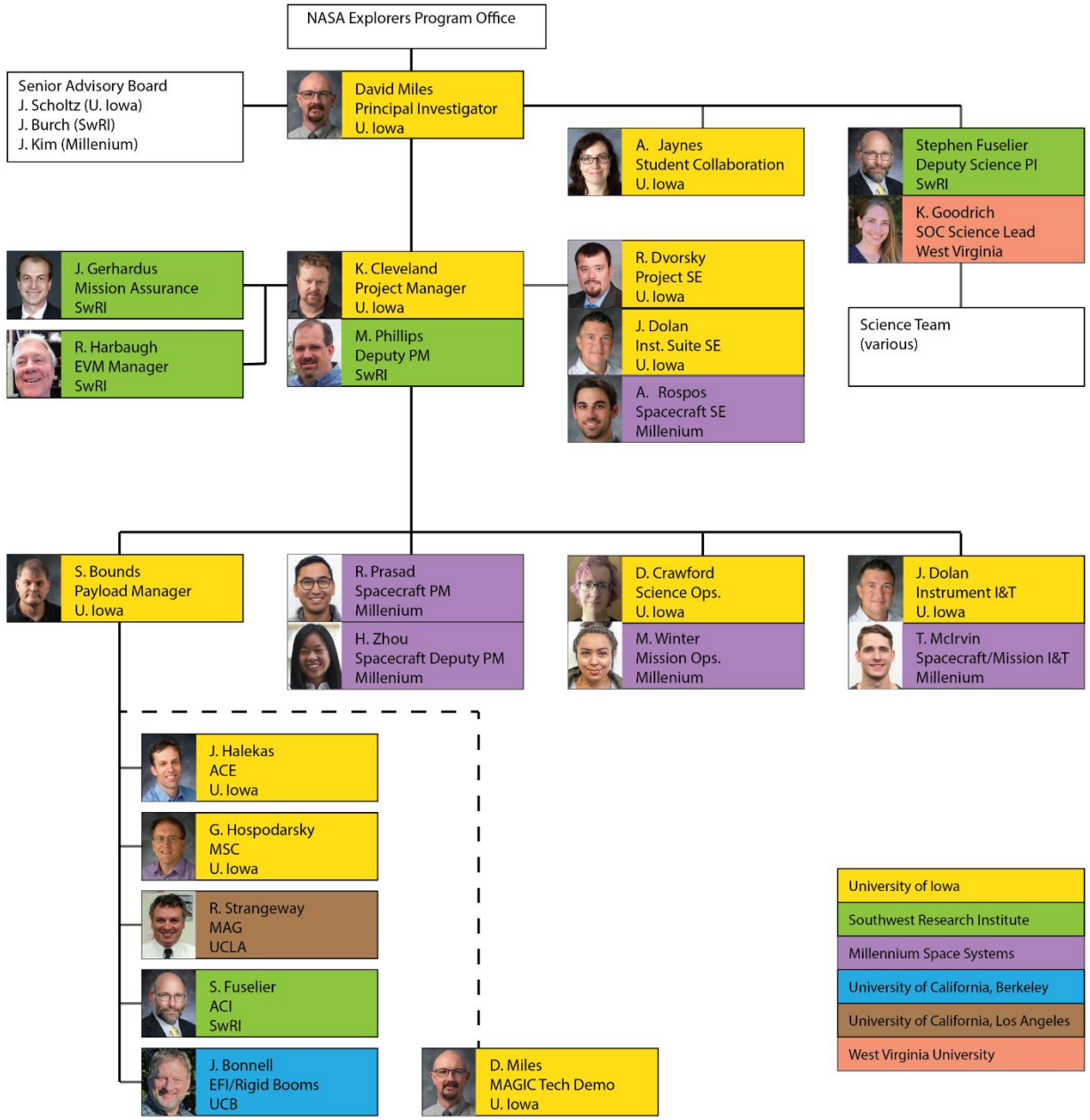
- Prof. Craig Kletzing died peacefully at home on August 10, 2023.
- The University of Iowa will hold a celebration of Craig's career on June 15, 2024 immediately after a TRACERS Science Team Meeting.

https://now.uiowa.edu/news/2023/08/renowned-iowa-physics-professor-researcher-craig-kletzing-dies



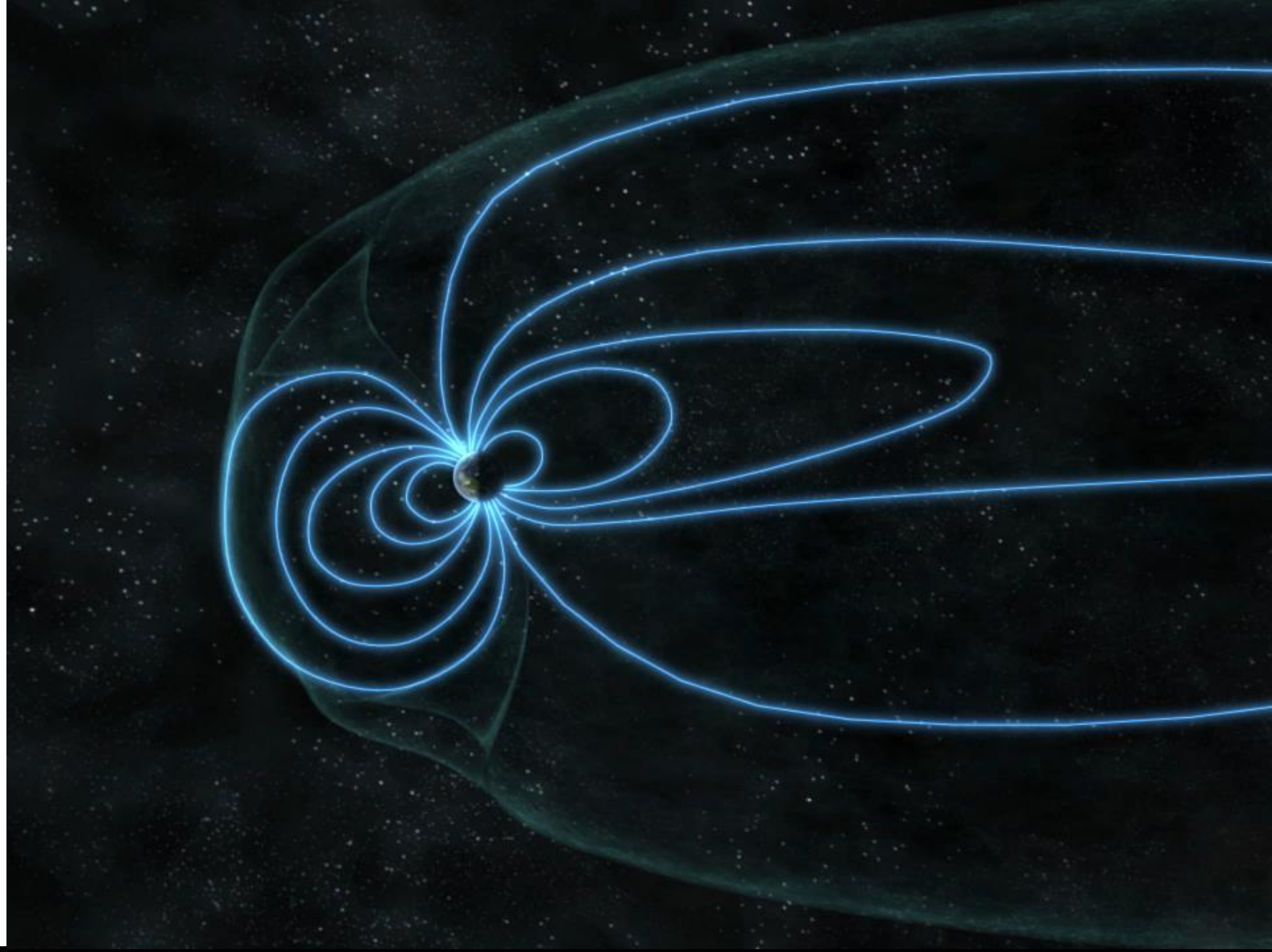
What is a SMEX Mission?

- NASA's Explorers Program has been around since the start of the space age - Explorer 1!
- The Principal Investigator (PI) and their team are responsible for everything but the launch.
- Small Explorers (SMEX) are cost-capped with focused science objectives.
- $165 M PIMCC with a NASA-provided launch.



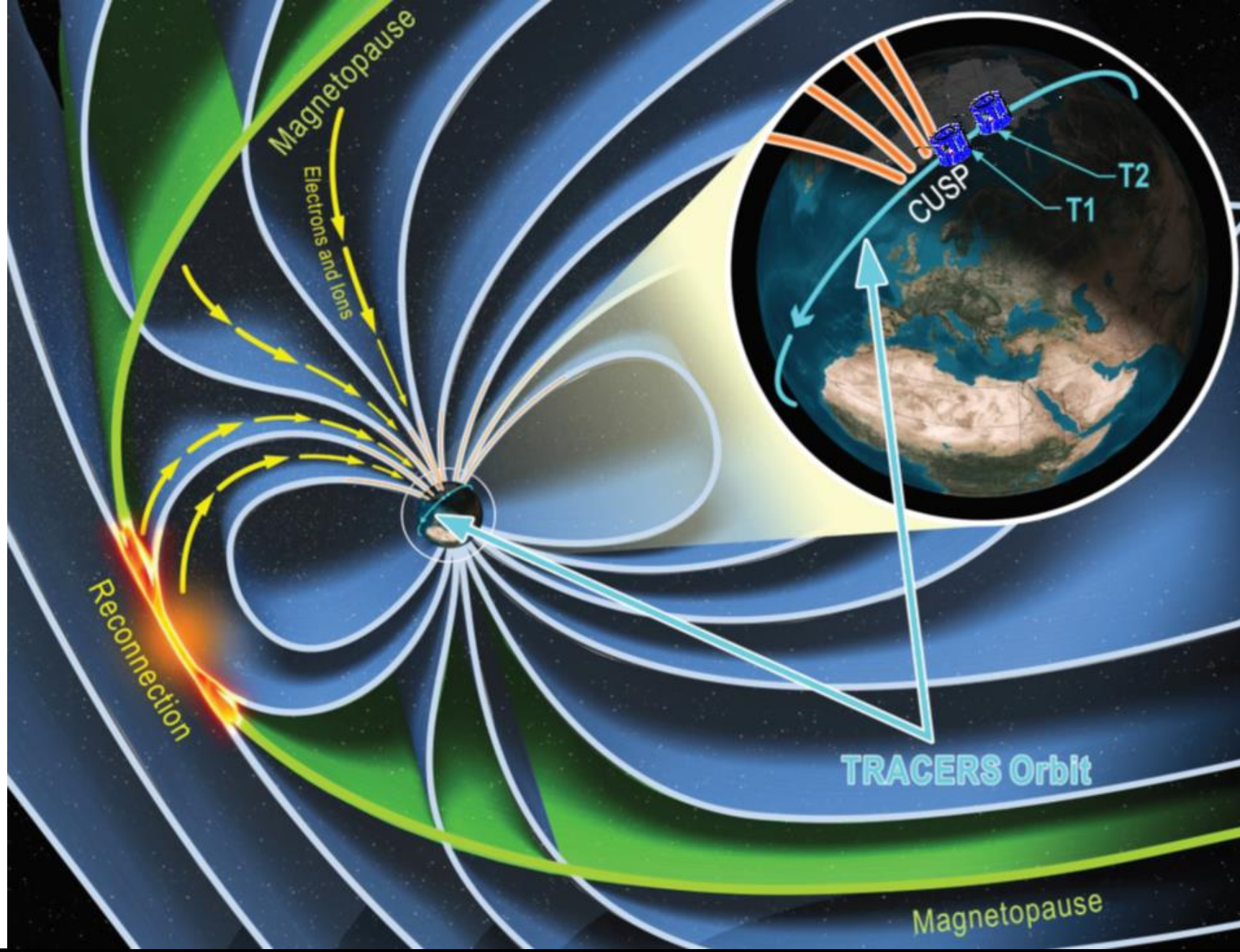
Goals & Objectives

- When, where and why does the solar wind connect to near-Earth space through the Cusp?
- Connecting the Cusp to the Magnetosphere.
- Discovering how spatial or temporal variations in magnetopause reconnection drive Cusp dynamics.



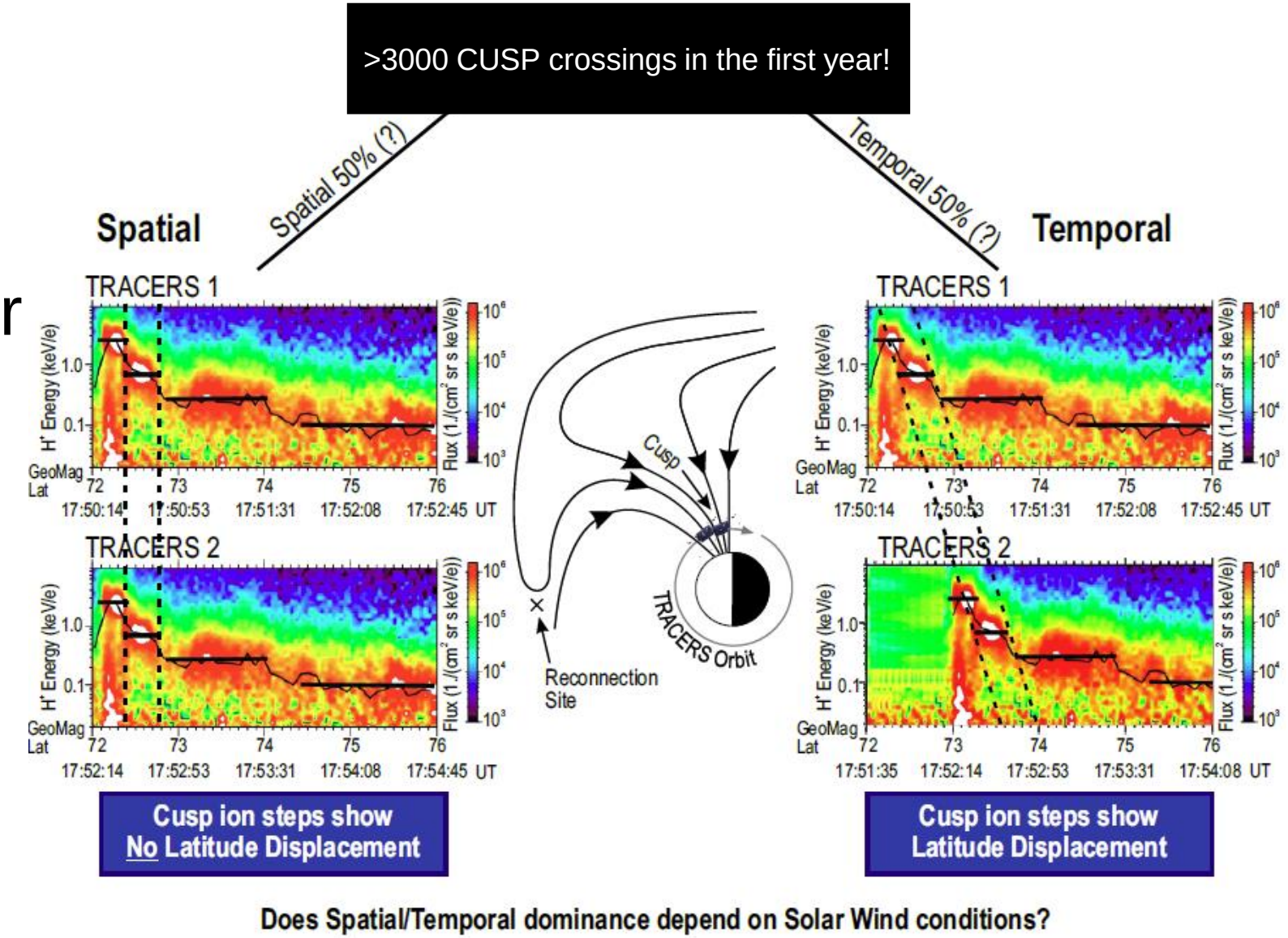
Science Rationale for Mission Design

- Two identical satellites to distinguish spatial vs temporal phenomena
- ~600 km sun-sync orbit
- Orbital plane intersects the northern Cusp
- >3000 Cusp crossings in the first year
- 10-120 s separation
- Fields, particles, waves
- 7120.8 magnetometer tech demo (MAGIC)



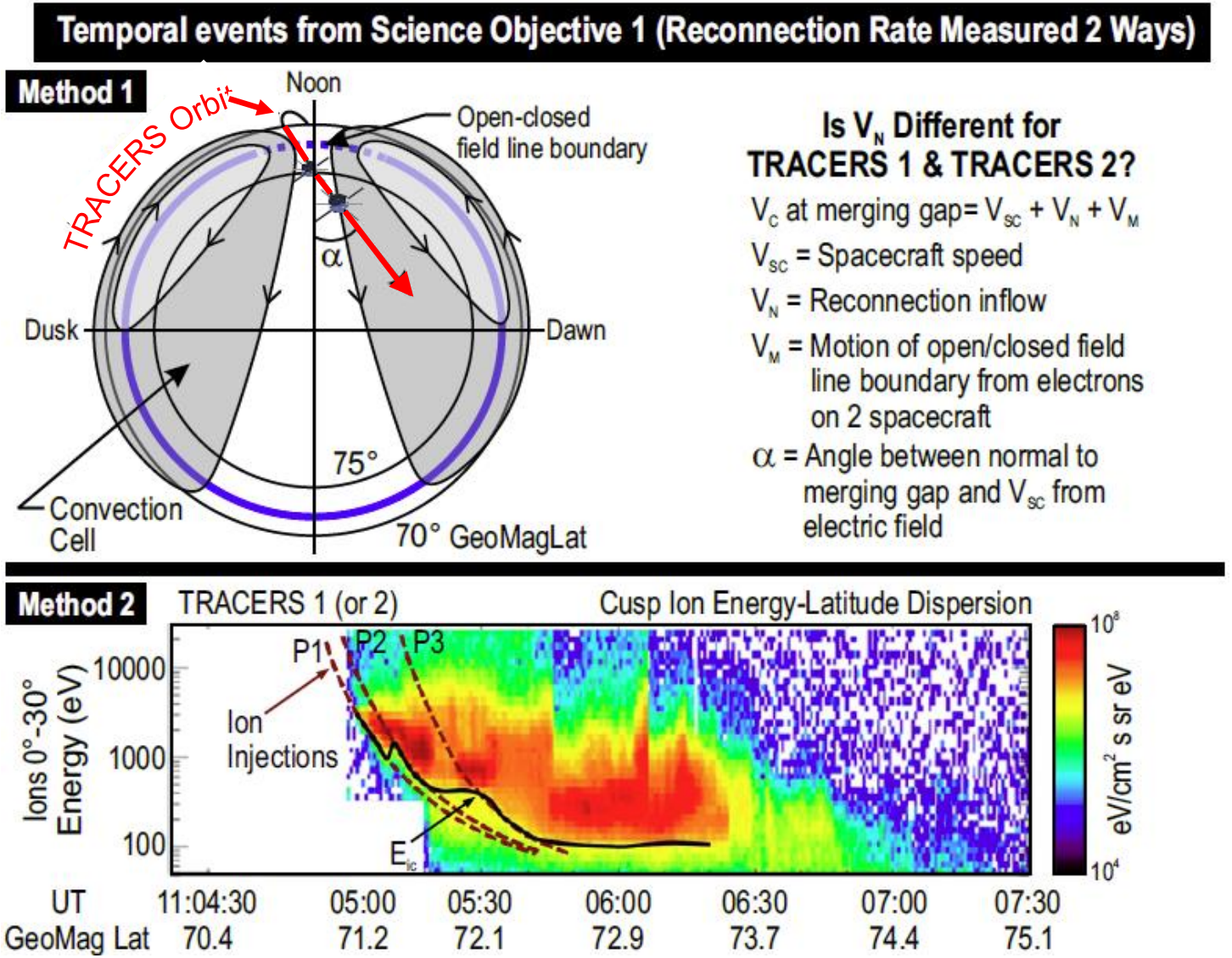
Science Objective 1

Determine whether magnetopause reconnection is primarily spatially or temporally variable for a range of solar wind conditions.



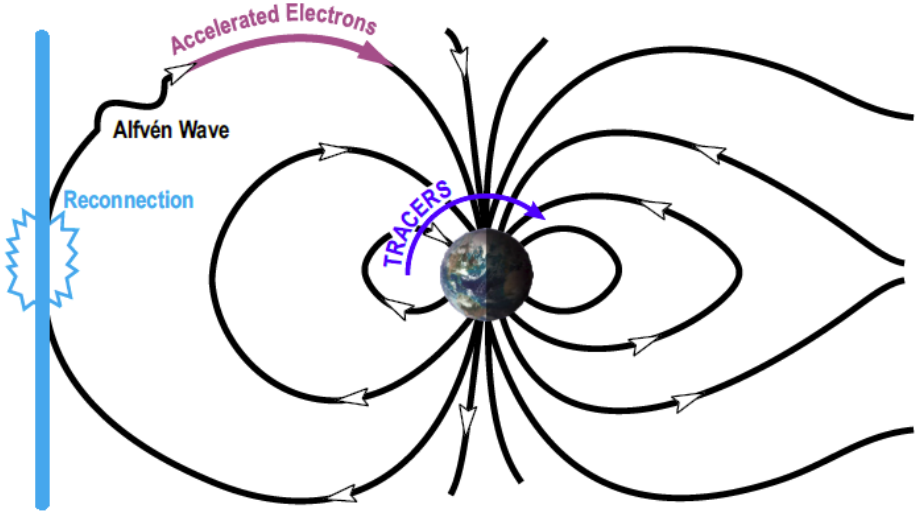
Science Objective 2

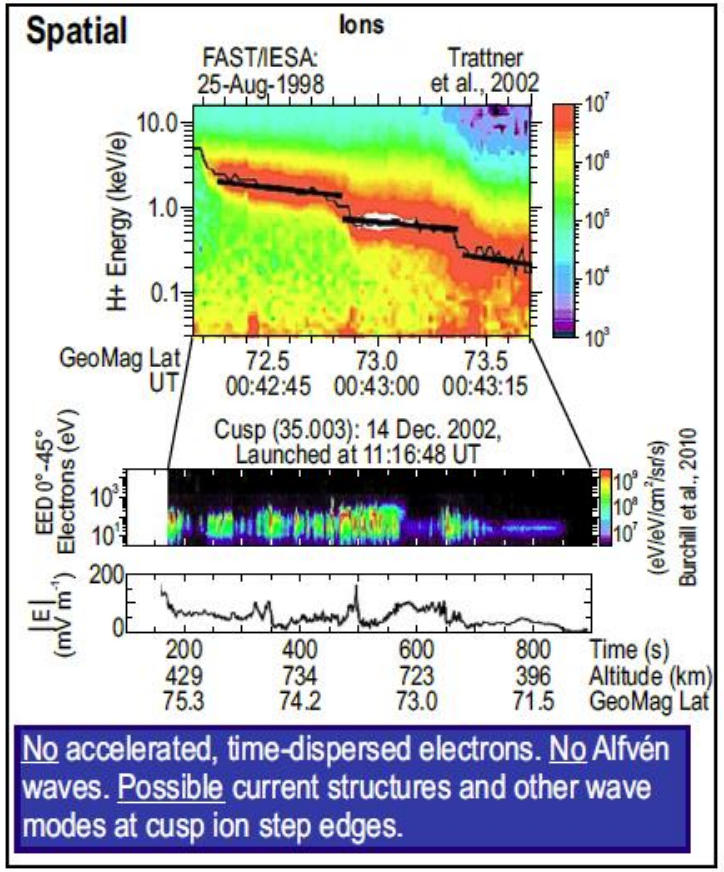
For temporally varying reconnection, determine how the reconnection rate evolves.

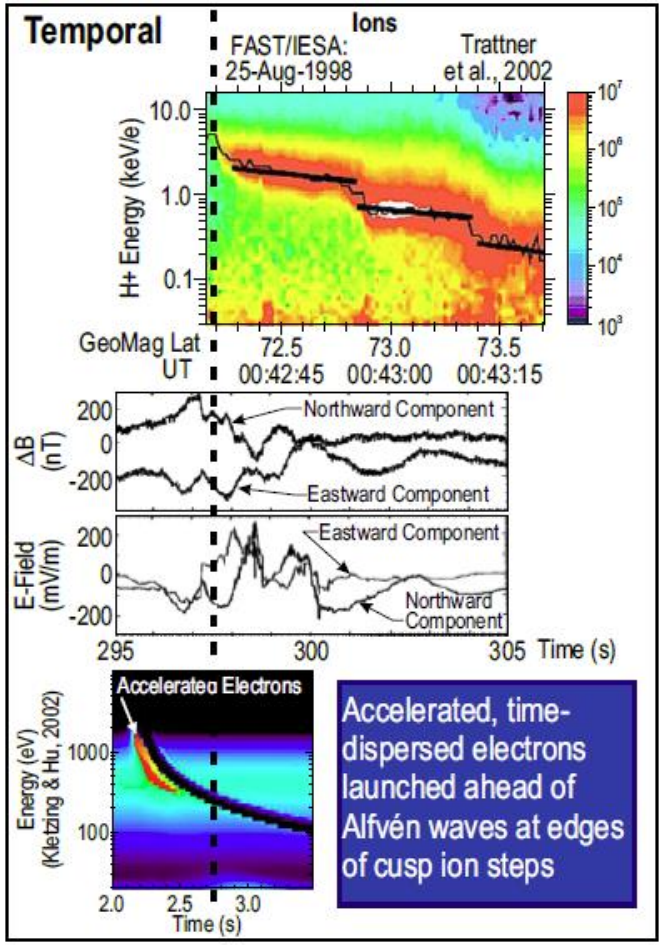


Science Objective 3

Determine to what extent dynamic structures in the cusp are associated with temporal versus spatial reconnection.







Mission Science Concept of Operations

Science Region of Interest (ROI)

- ~7 min/orbit during Cusp transit
- High-rate data

Back Orbit (BOR)

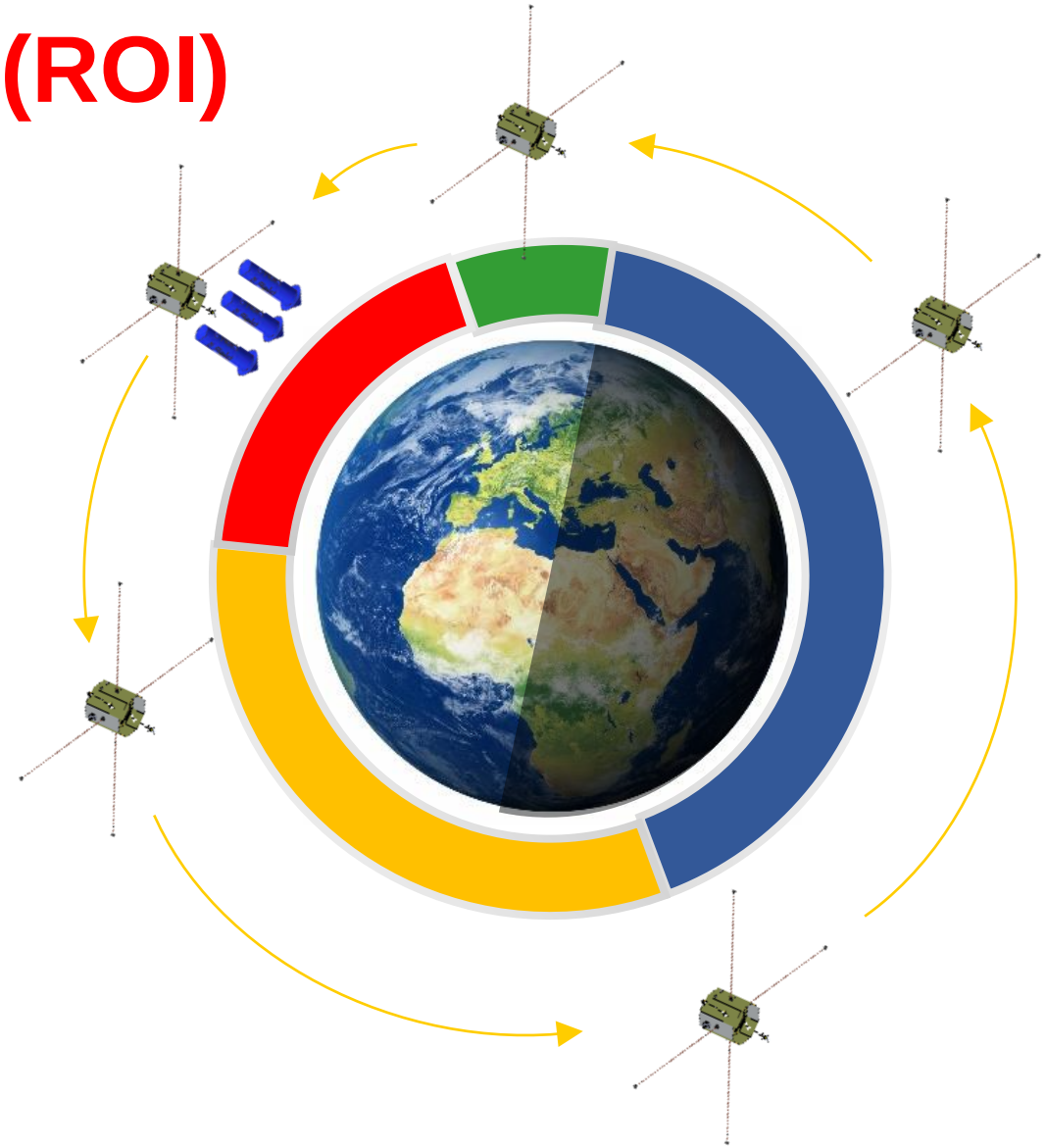
- Once/day alignment of spin-axis
- Housekeeping and low-rate data

Eclipse

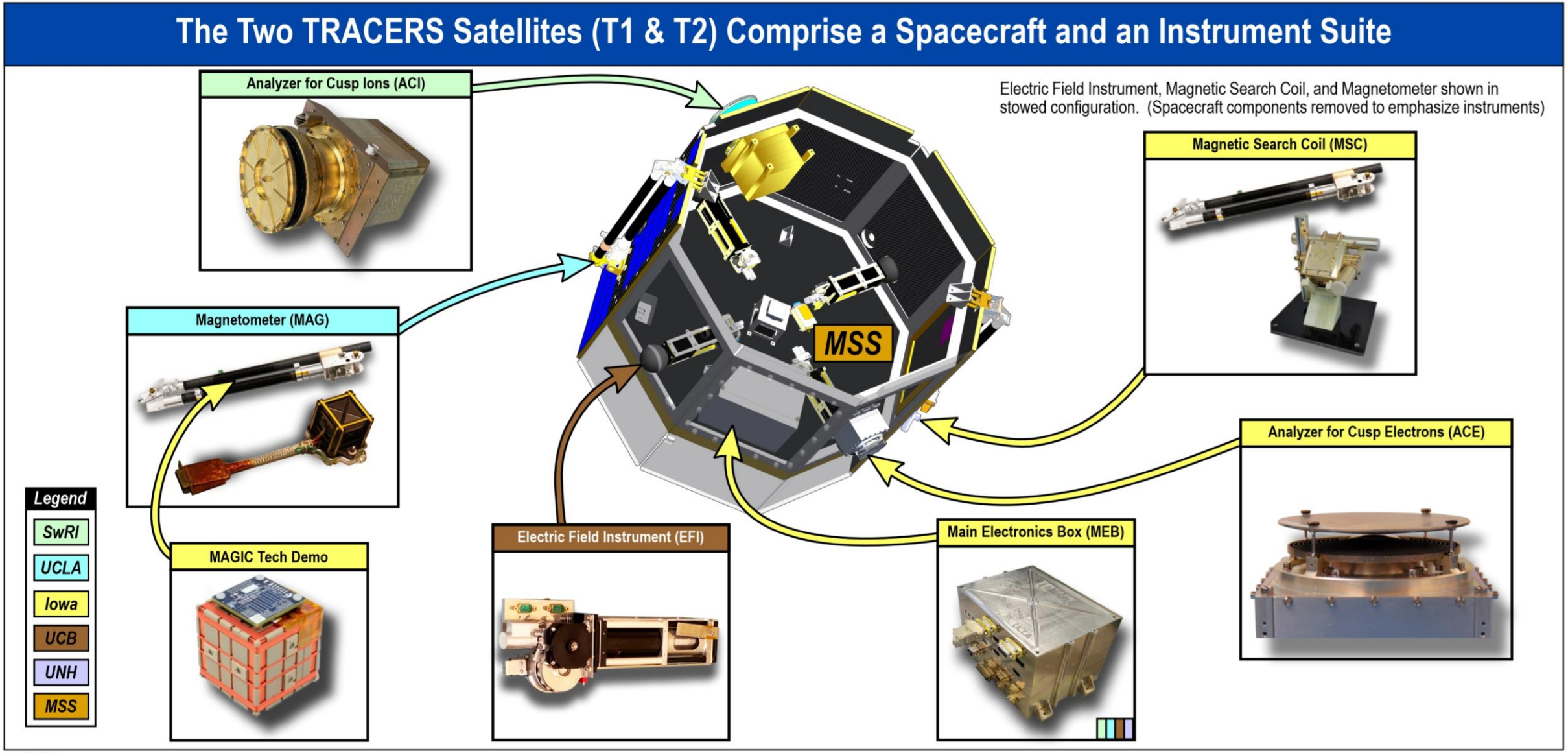
- Usually occurs in back orbit
- 35-minute worst-case duration

Communications

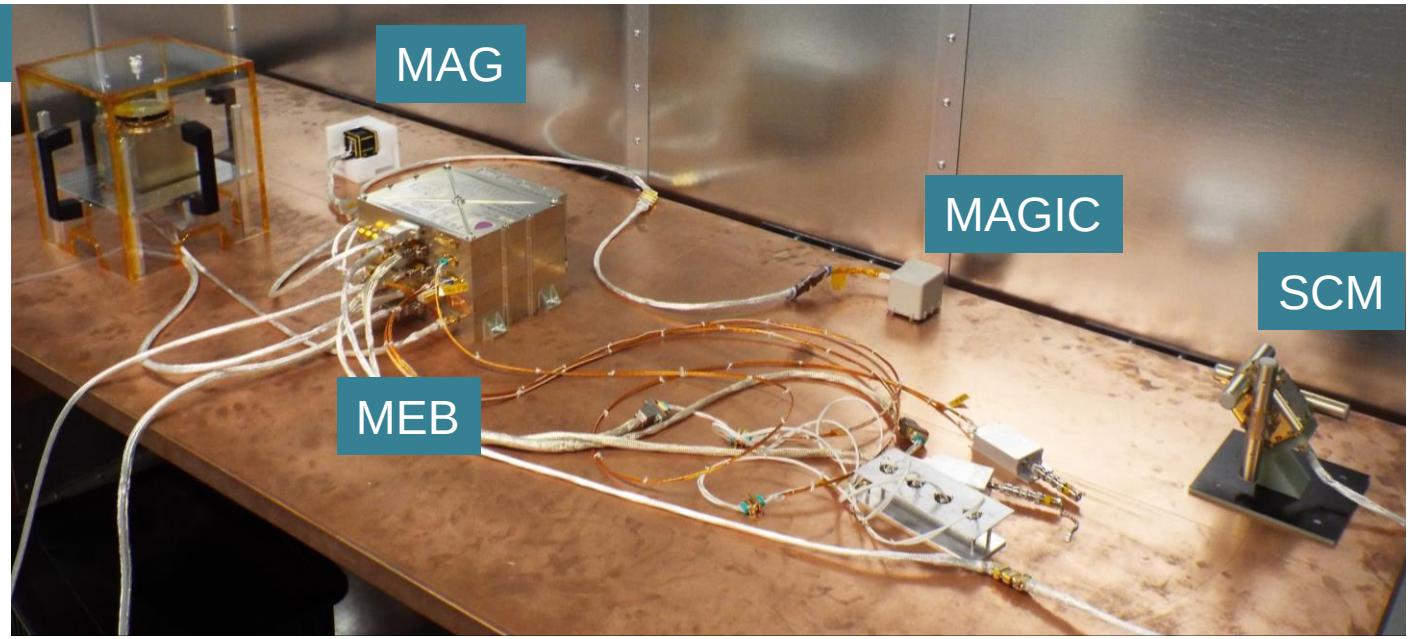
- Usually in back-orbit
- 14-day forward plan stored commands
- Sequence refreshed every 7 days

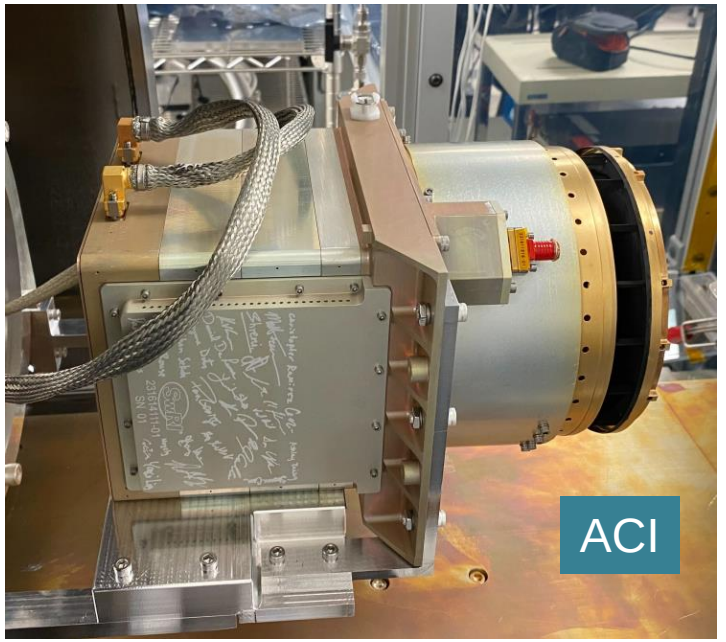


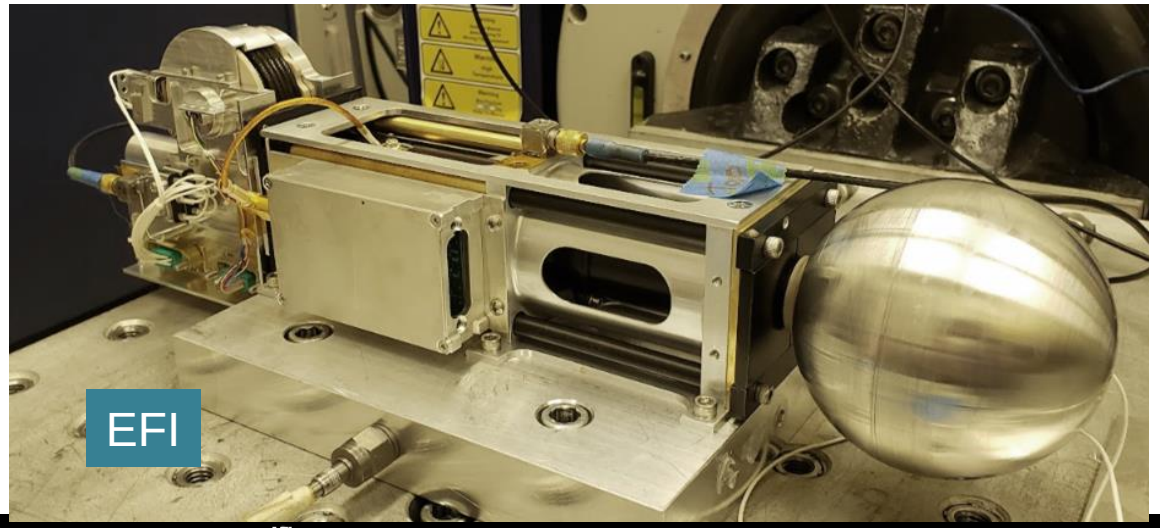
TRACERS Instrument Complement

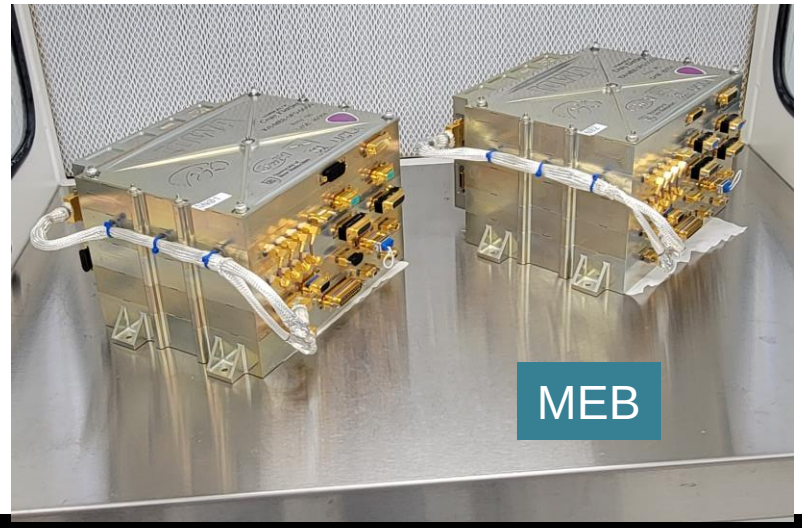


TRACERS Instrument Complement Status

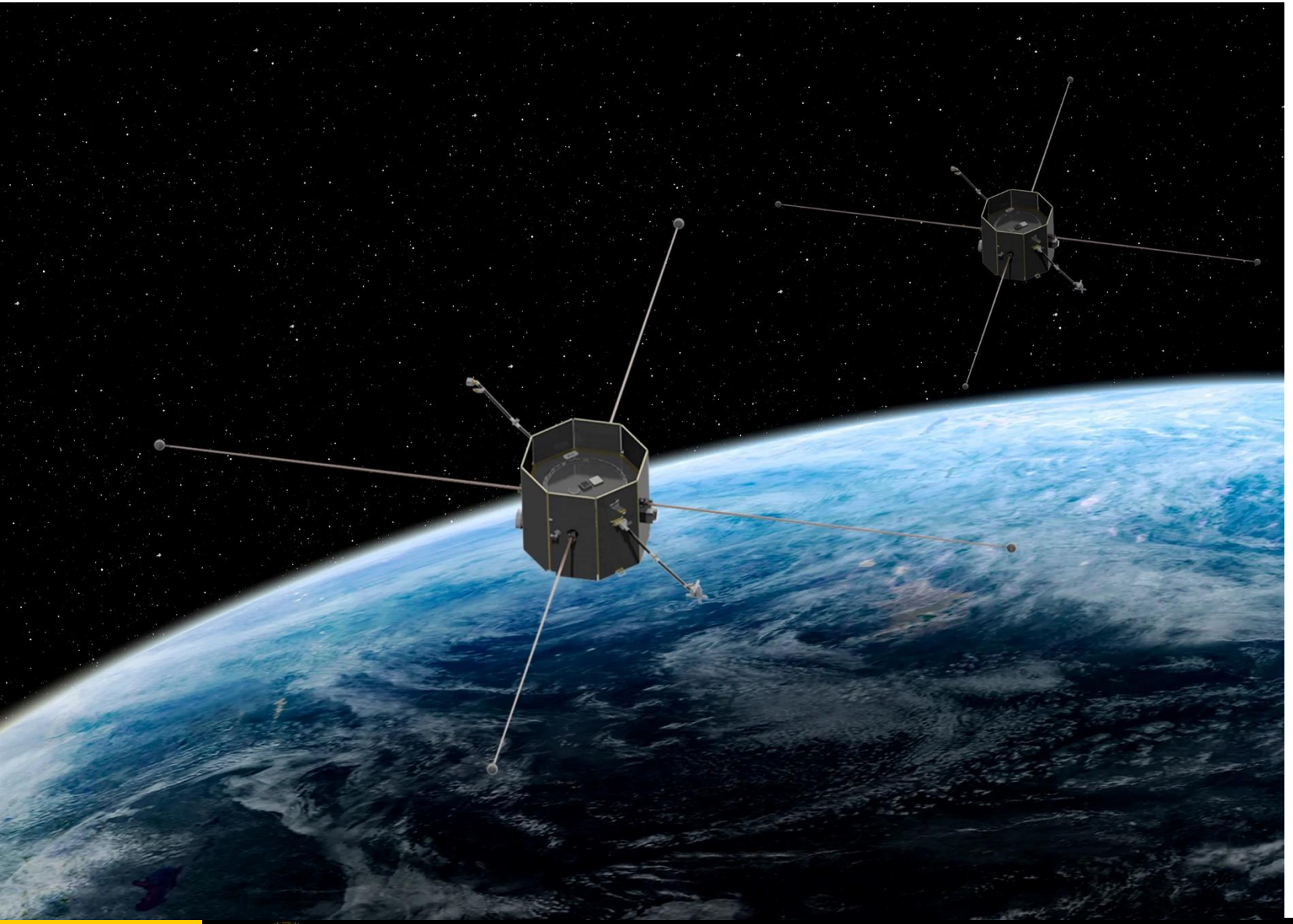








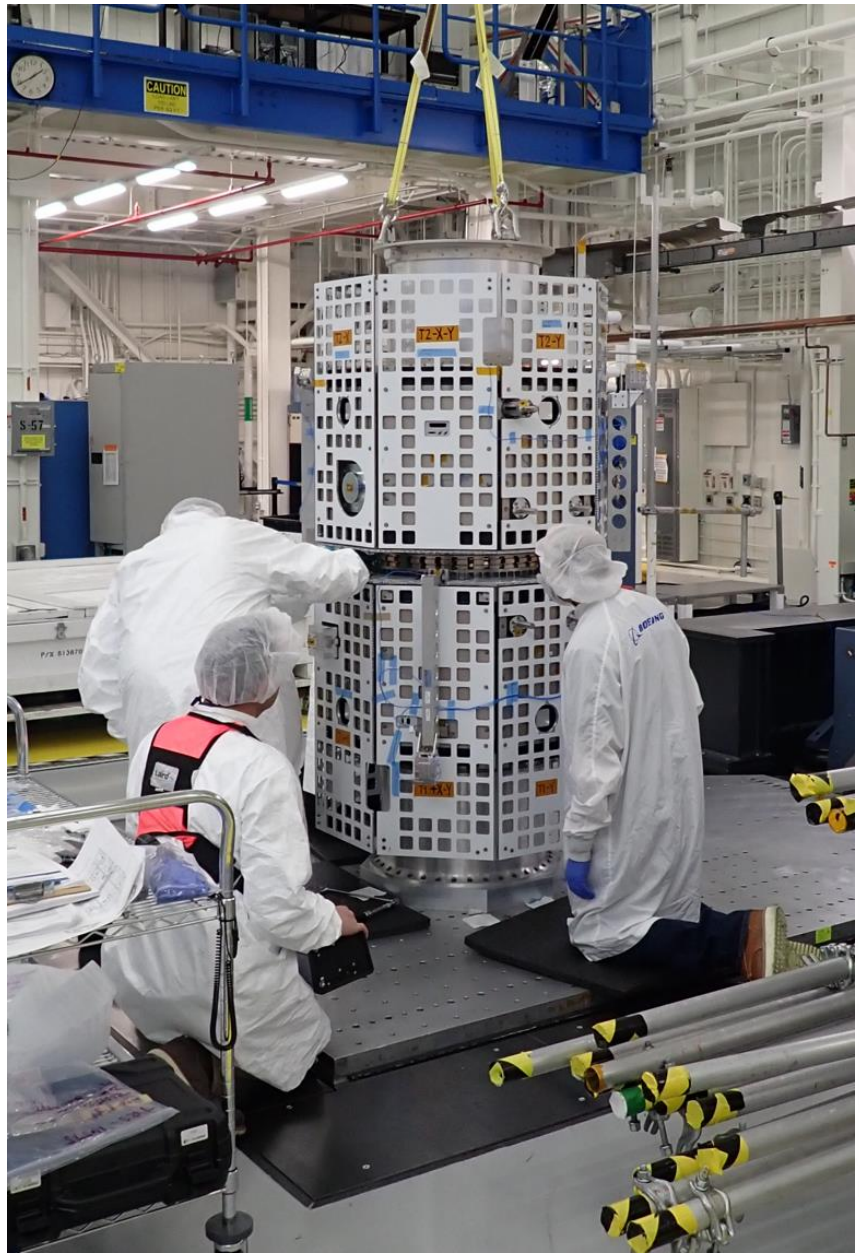
TRACERS Spacecraft

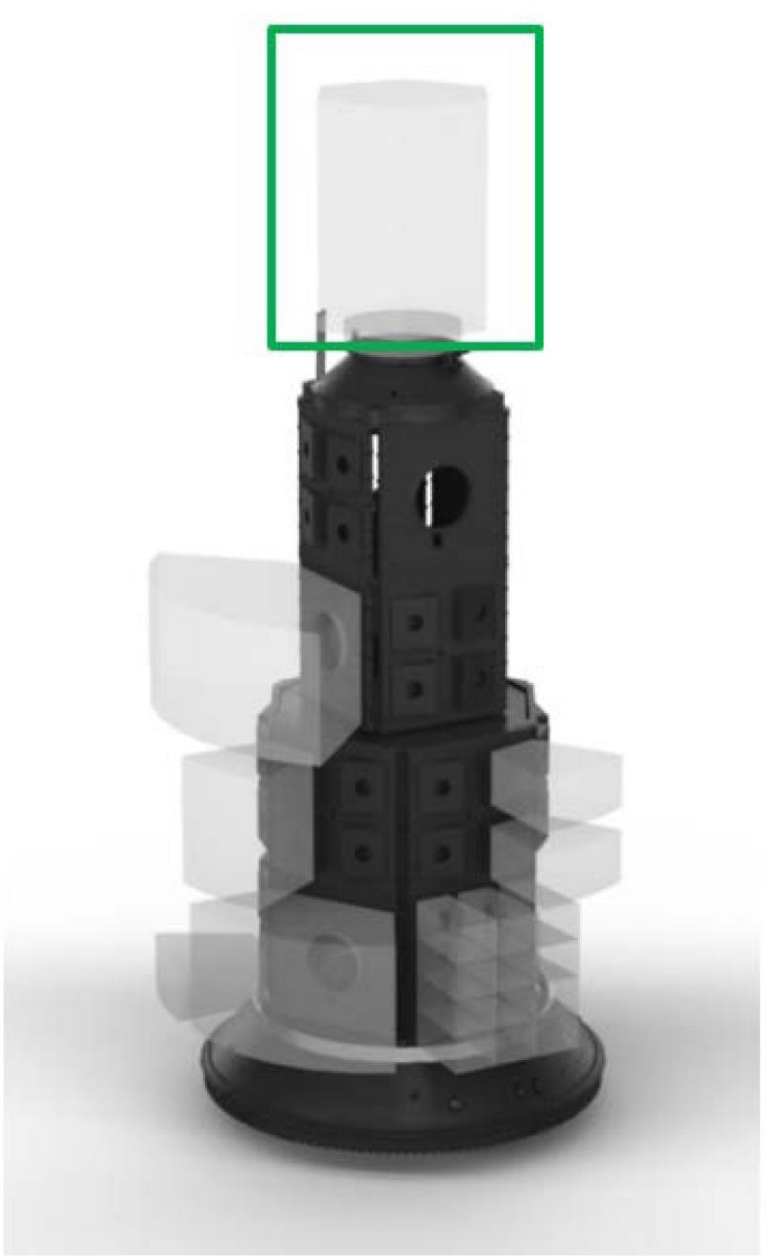


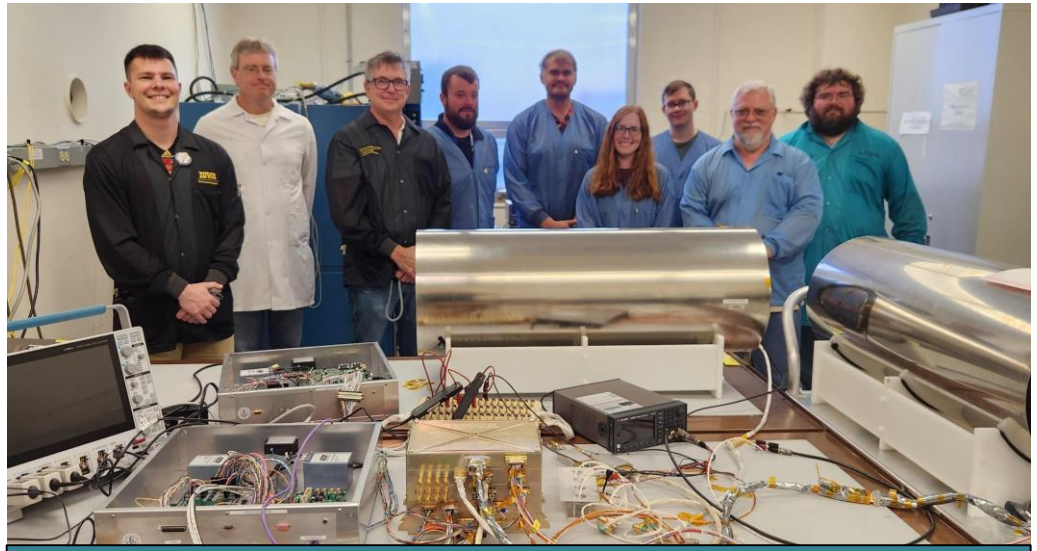
- Two ALTAIR small spacecraft.
- Passively spin stabilized.
- Formation flying.
- Provided by Millennium Space Systems (a Boeing Company).

SpaceX Launch

- On September 29, 2023 NASA announced SpaceX as the Launch Services Provider.
- Primary rideshare (“Cake Topper”) on a Falcon 9.
- Expecting a direct injection to our ideal science orbit.

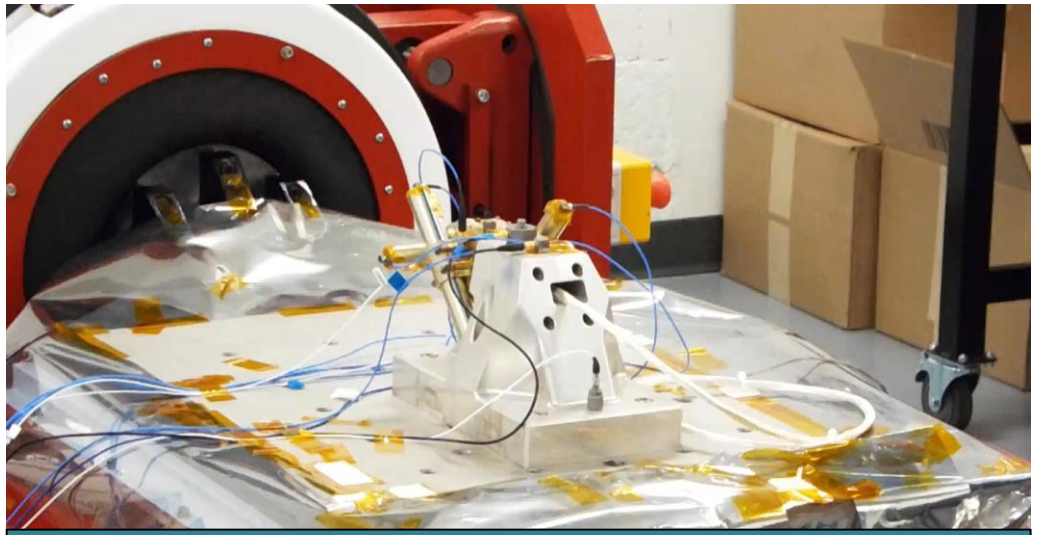




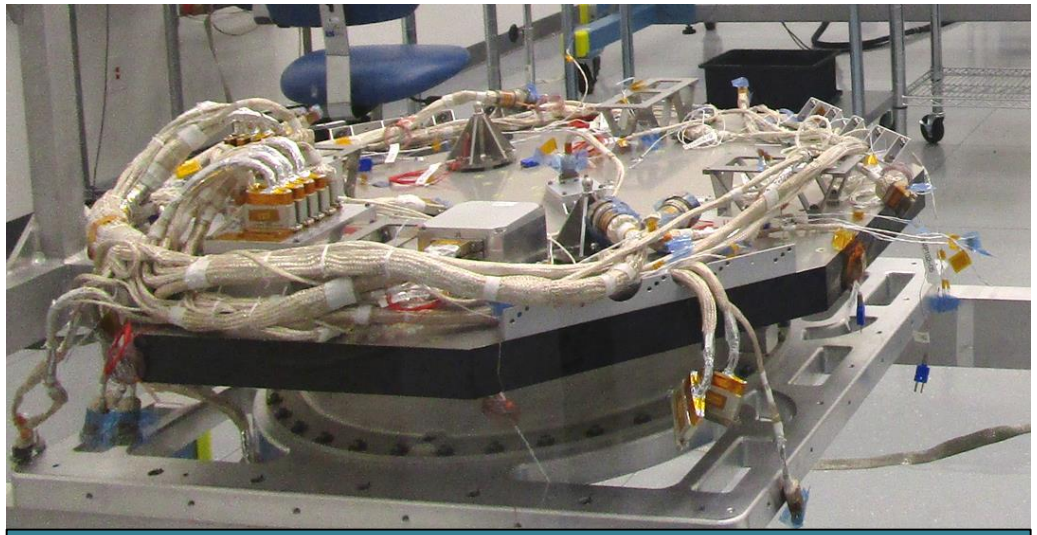


Main Electronics Box (MEB) Integration

Spacecraft Propellant Tank Integration



Instrument Vibration Testing



Spacecraft Deck Awaiting Instruments

TRA-SR (TRACERS student Sounding Rocket)!

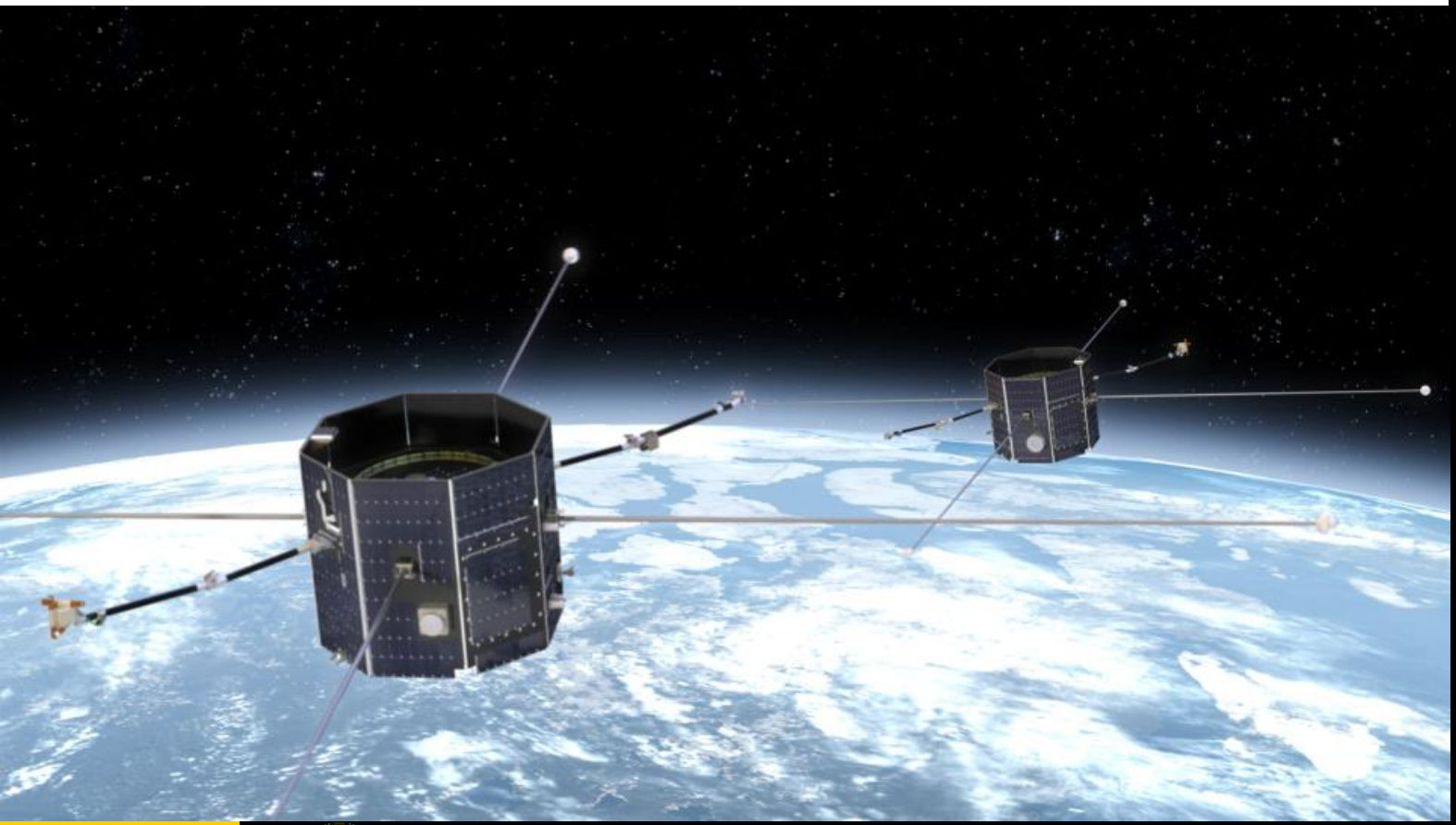
- Sounding rocket to be flown in coordination with TRACERS.
- TRACERS-like instruments built and led by graduate and undergraduate students.
- Competed and selected through the Heliophysics Low-Cost Access to Space (H-LCAS) program.
- Led by Prof. Allison Jaynes at Iowa.
- Campaign is managed and run by NASA WSFC.
- Nominal launch window: winter 2025-2026.

Mission Schedule

Milestone	Date
Instrument Environmental Test	Ongoing
Instruments delivered to Spacecraft 1	June 2024
Instruments delivered to Spacecraft 2	July 2024
Satellite Pre-Environmental Review	August 2024
Operational Readiness Review	December 2024
Launch Readiness Date	April 2025
Start of Operations	May 2025
Public Release of Initial Dataproducts	September 2025
End of Baseline Mission	May 2026
End of Mission	November 2026

TRACERS in April 2025!

- TRACERS will resolve long-standing problems in magnetospheric physics.
- Two identically spacecraft with relatively simple instruments provides new science at low risk.



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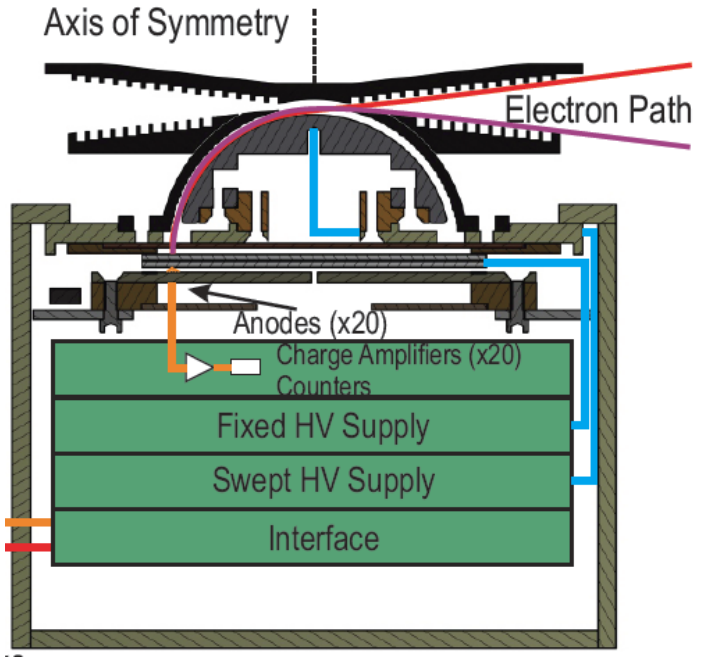
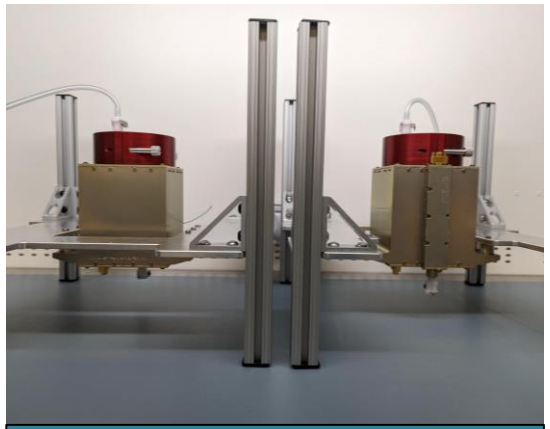
Analyzer for Cusp Electrons (ACE)

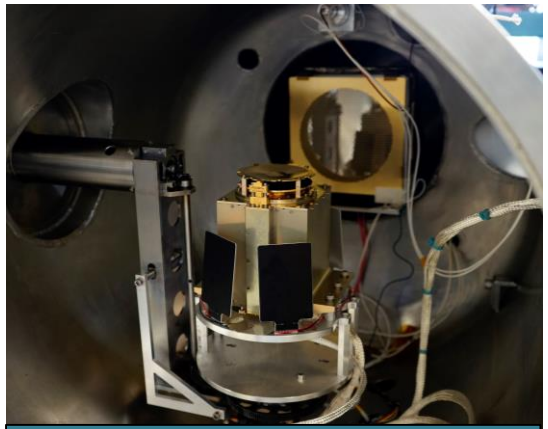
- Energy range: 20 eV–15 keV with 15% ΔE/E.
- Angular resolution of 200°x7° instantaneous and FOV 10° (PA) resolution.
- Per pixel sensitivity of 10^{-4} cm^2-sr-eV/eV.
- 50 ms time resolution.



Prof. J. Halekas
Iowa



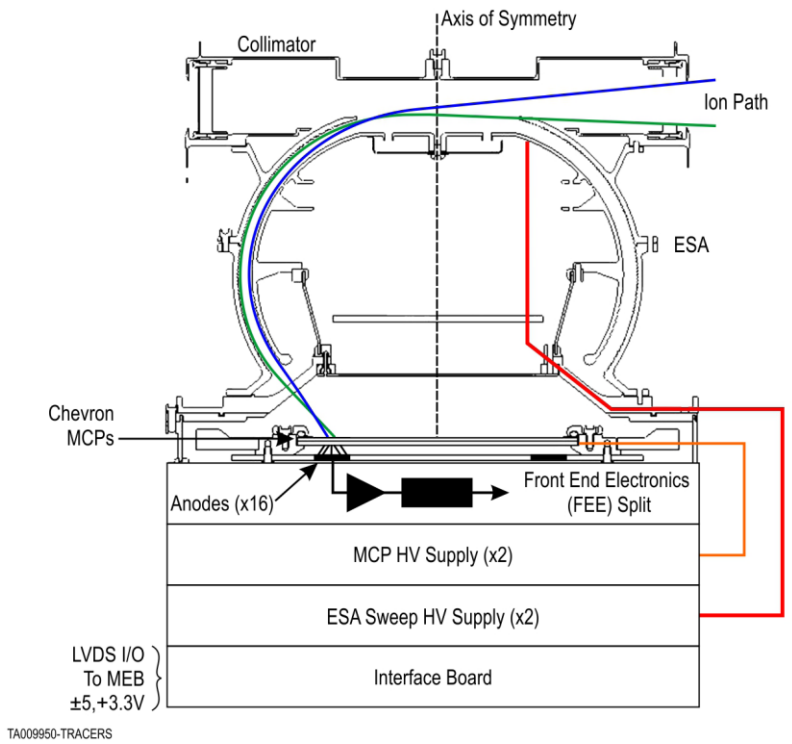
ACE F01 & F02



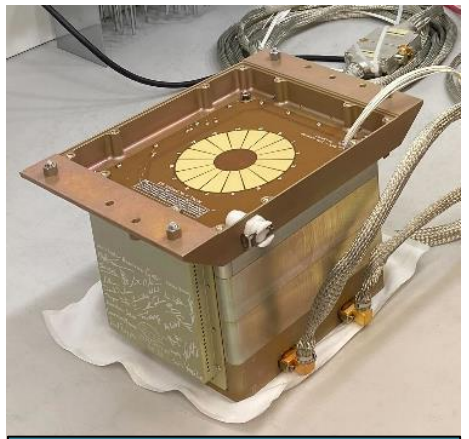
ACE F01 Under Test

Analyzer for Cusp Ions (ACI)

- Energy range: 10 eV–20 keV with 17% ΔE/E.
- Angular resolution of 360°x10° FOV and 22.5° (PA) resolution.
- Per pixel sensitivity of $3x10^{-4}$ cm^2-sr-eV/eV.
- 312 ms time resolution.



Dr. S. Fuselier SwRI

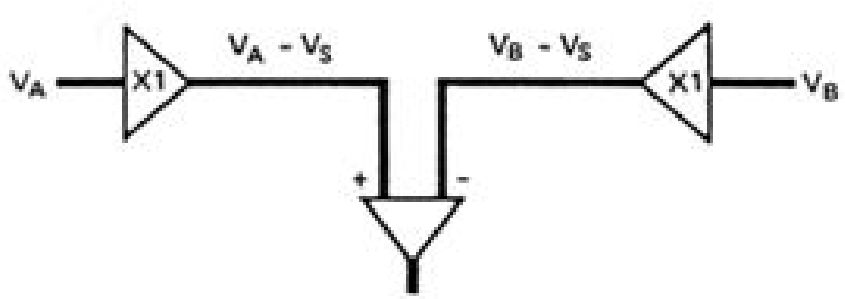


F01 Ebox

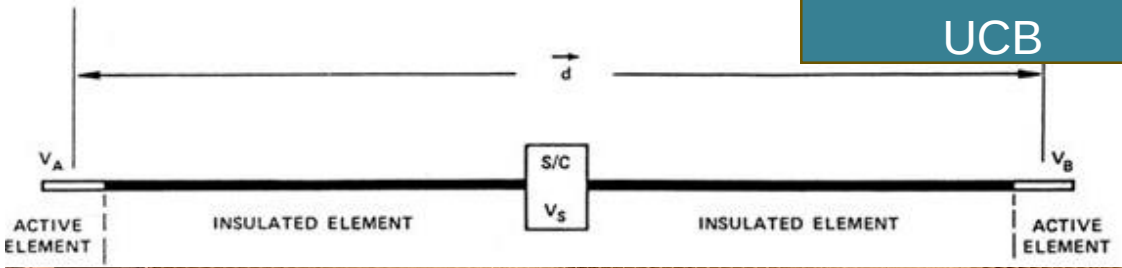
F01 ACI in Chamber

Electric Field Instrument (EFI)

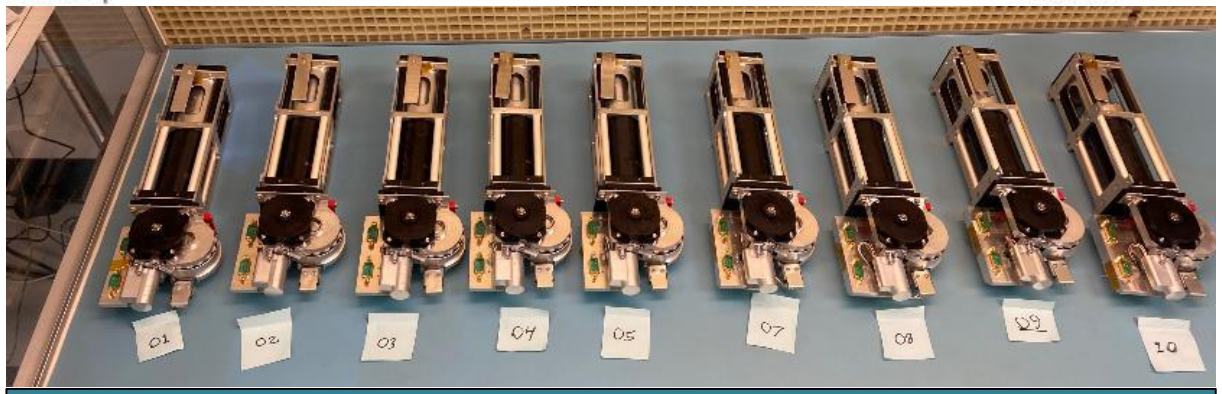
- ±1 mV/m absolute accuracy (S/C frame).
- 31 µV/m resolution (DC E).
- DC-coupled time resolution: 2048 S/s (4V, 2E).
- AC-coupled time resolution: 4 MS/s (1E).
- Four stacer booms.



$$(\Phi_1 - \Phi_2)/|d| = (\mathbf{E} + \mathbf{v} \times \mathbf{B}) \bullet \mathbf{d}$$



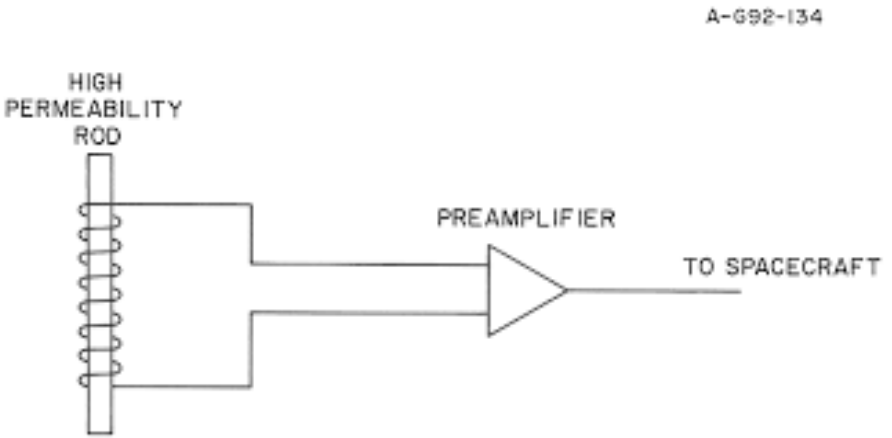
Dr. J. Bonnell
UCB



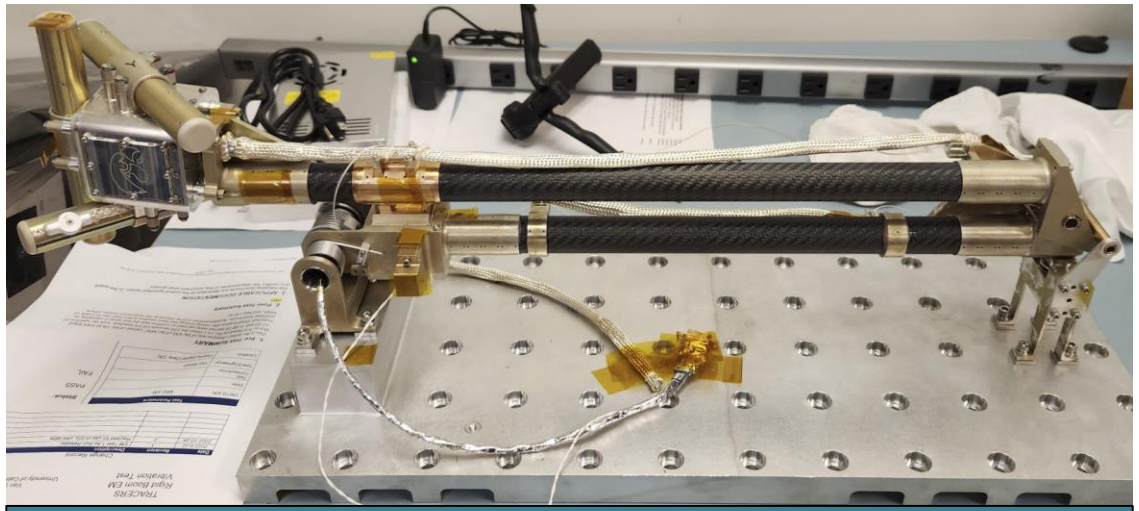
EFI Stacers

Magnetic Search Coil (MSC)

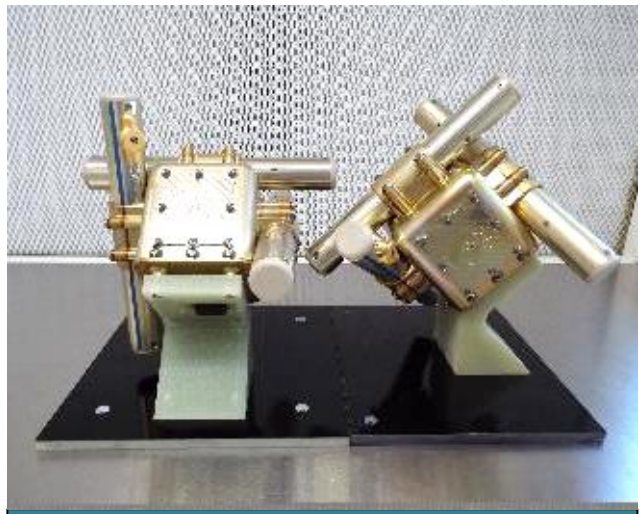
- Frequency: ~1 Hz to 1024 Hz.
- Spectral: 10^{-7} nT @ 10 Hz.
- Spectral: 10^{-9} nT @ 100 Hz.
- Boom mounted.



Dr. G. Hospodarsky
Iowa



MSC/MAG EM Rigid Booms

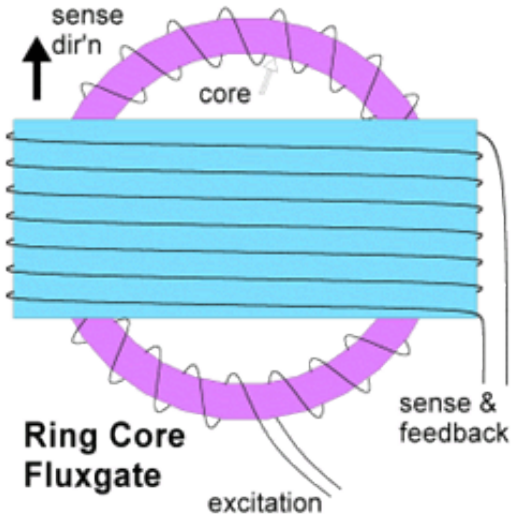


MSC F01/F02

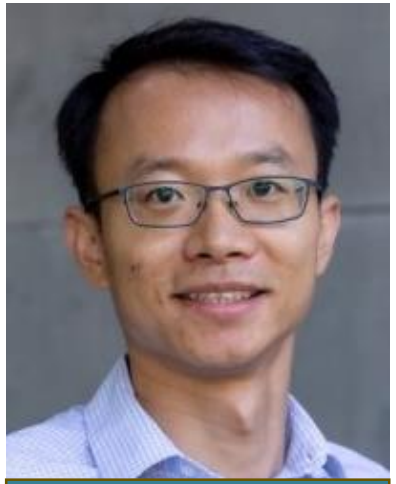
MSC F01+EFI F01

Fluxgate Magnetometer (MAG)

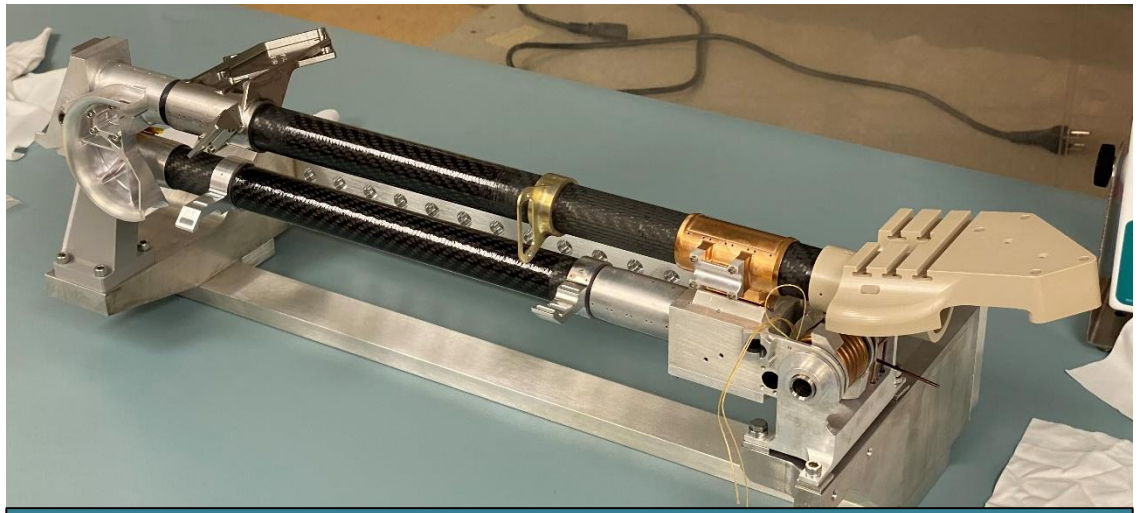
- Dynamic range: ±60,000 nT.
- Resolution: 0.5 nT.
- Accuracy: 10 nT.
- Boom mounted.



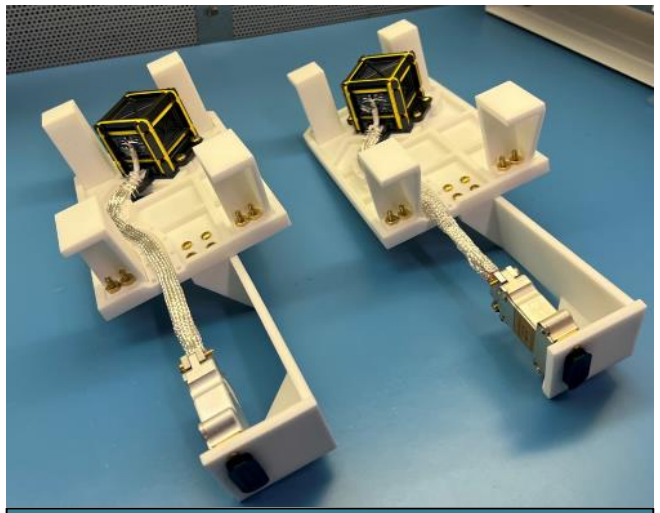
Dr. R. Strangeway
UCLA



Prof. H. Cao
UCLA



MSC/MAG EM Rigid Booms



Sensors F01 and F02

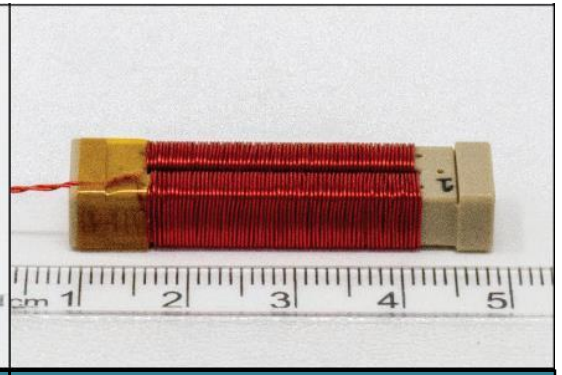
Flight Board S/N2

MAGIC NPR 7120.8 Tech Demo

- Low-noise fluxgate cores (5 pT/√Hz at 1 Hz).
- Heritage ringcore sensor.
- New Tesseract sensor.
- Boom mounted.

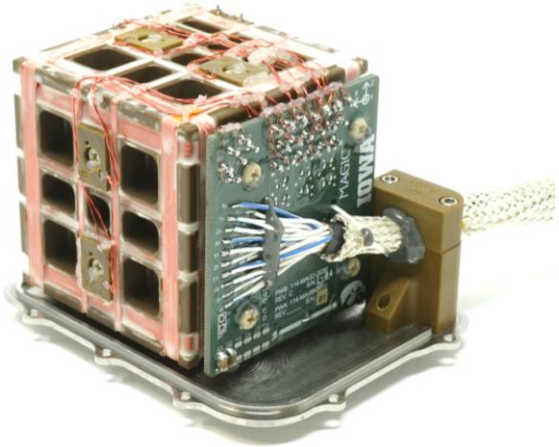
Prof. D. Miles
Iowa

Ringcore



Racetrack Core

Ringcore Sensor



Tesseract Sensor

Simulation and Science Team

- Context for TRACERS data from global hybrid simulations.
- Field line tracing allows direct comparison with TRACERS particle measurements.
- Focused science team with relevant domain expertise.

Prof. Y. Lin
Auburn

Dr. S. Fuselier
SwRI

Prof. K. Goodrich
WVU