The DSX Science Mission

Initial Results

DR JAMES McCOLLOUGH / DSX PRINCIPAL INVESTIGATOR

SPACE VEHICLES DIRECTORATE / 11 DECEMBER 2019

AFRL

The DSX Science Team

AFRL

- Bob Johnston
- Yi-Jiun Su
- Michael Starks
- Patrick Roddy
- David Cooke
- Jenny Sanchez
- Jay Albert
- Alan Ling
- Steve O'Malley
- Andy Sinclair

MIT-Lincoln Laboratory

- Greg Ginet
- Rick Lambour
- Shawn Allgeier
- Jon Schoenberg
- Urban Gillespie
- Brent Parham

TNT

- Paul Song
- Ivan Galkin
- Steve Stelmash
- Bodo Reinisch
- Jiannan Tu
- Kevin Roche

ACE

- Larry Davis

SET-1

- Mike Xapsos
- Yihua Zheng
- Michael Campola
- Hugh Barnaby
- Clive Dyer
- Peter McNulty
- Raoul Velazco

BBR/TASC

- Umran Inan
- Dave Lauben
- Ivan Linscott
- Bill Farrell
- Phil Scherrer

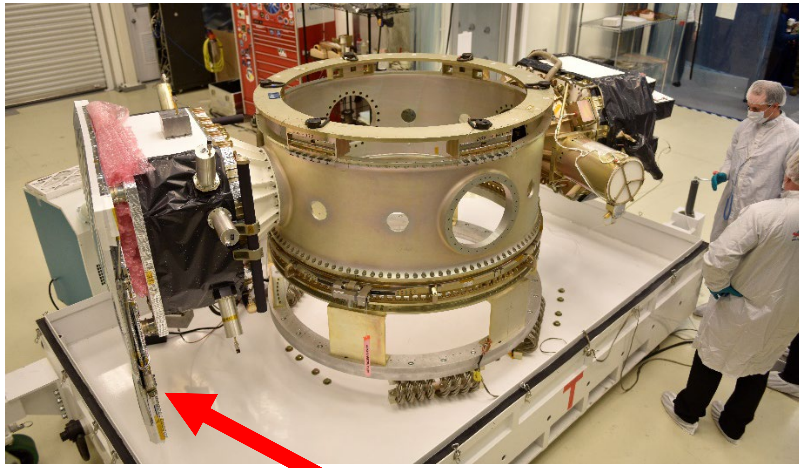
LCI

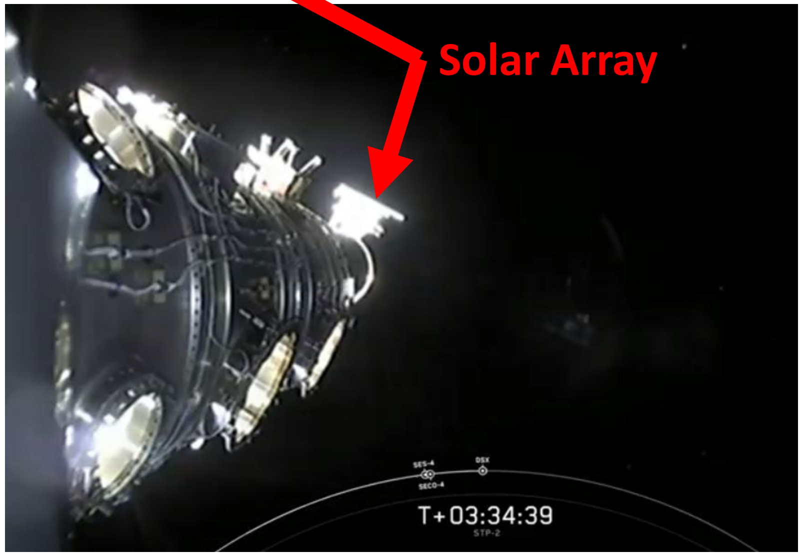
- Ted Fritz
- Chad Parker

DSX Mission Status

- Launch occurred at 12:30 AM MDT Tuesday, June 25
  - Nominal one year mission
  - 6000 x 12000 km orbit, 42° inclination, 5.3 hour period
- On orbit, concluding “Learn to Transmit” campaign
- Primary experiment: **Wave Particle Interactions (WPIx)**
  - Transmit and measure waves and precipitating particles to understand VLF direct injection performance and diagnose effects
- Secondary Experiment: **Space Weather (SWx)**
  - Measure distributions of protons and electrons to map the MEO environment and diagnose the environment for WPIx experiments
- Secondary Experiment: **Space Effects (SFx)**
  - Advance our understanding of on-orbit degradation and directly measure changes due to MEO radiation environment
- Mission will coordinate campaigns with **VLF Propagation Mapper (VPM)** mission to LEO
  - Deployment planned for mid-January from ISS

DSX undergoing final closeout before shipment



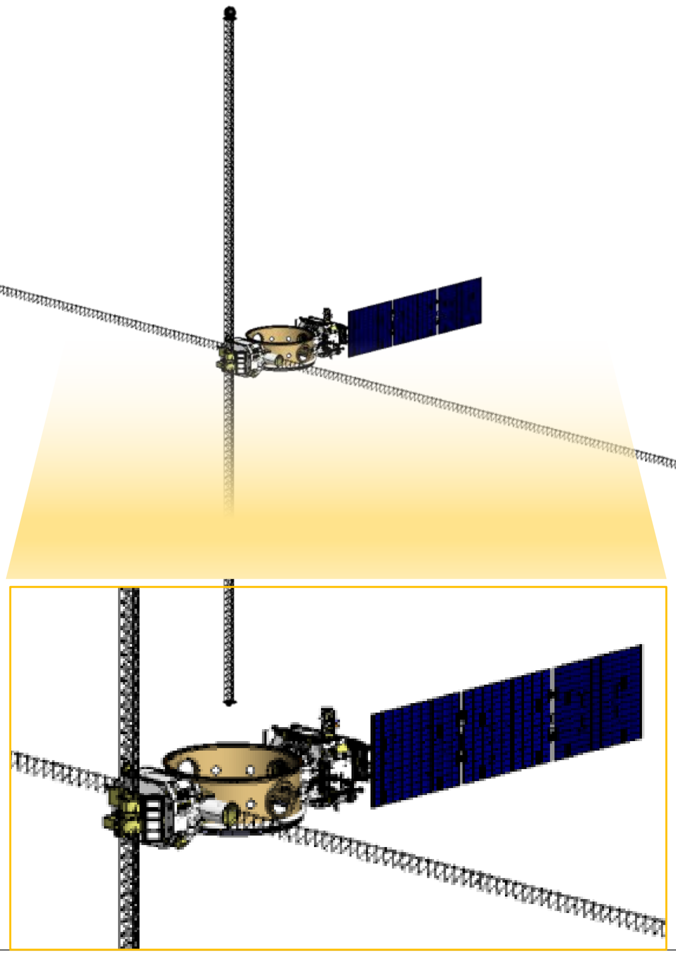


DSX separating from Falcon Heavy upper stage

Demonstration and Science Experiments (DSX) Spacecraft

Largest unmanned self-supporting structure ever flown in space

- 80 m Y-axis boom
  - VLF Tx & Rx
- 16 m Z-axis boom
  - VLF Rx
  - DC magnetic field
- ~ 500 kg
- 3-axis stabilized



Payload Module (PM)

- Wave-particle Interactions (WPIx)
  - VLF transmitter & receivers
  - Loss cone imager
  - DC Vector Magnetometer
- Space Weather (SWx)
  - 5 particle & plasma detectors
- Space Environmental Effects (SFx)
  - NASA/Goddard Space Environment Testbed
  - AFRL effects experiment
- NASA/JPL deployable structures payload

Avionics Module (AM)

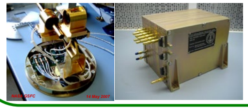
- Attitude Control System
- Power
- Thermal Control
- Communications
- Computer/Avionics
- Experiment Computer
- Space Weather (HEPS)

First spacecraft design with integrated ESPA Ring

DSX WPIx and SWx Payloads

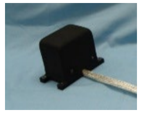
Transmitter (TNT):
3 – 50 kHz at up to 5 kV (9 kV EOL),
50 – 750 kHz at 1W (local density)

Receiver (BBR/SRx):
3 **B** components,
2 **E** components,
100 Hz – 50 kHz



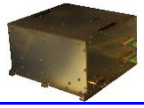
Loss Cone Imager (LCI):
HST: 100 – 500 keV e-
FSH: 3 angular zones, 50 – 700 keV e-

Vector Magnetometer (VMAG):
0 – 8 Hz three-axis DC **B**-field,
±0.1 nT accuracy

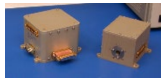


Compact Environmental Anomaly Sensor (CEASE):
100 keV—6.5 MeV e-,
20—100 MeV p+

Low Energy ElectroStatic Analyzer (LEESA):
5 angular zones,
30 eV—50 keV e-, ions

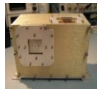


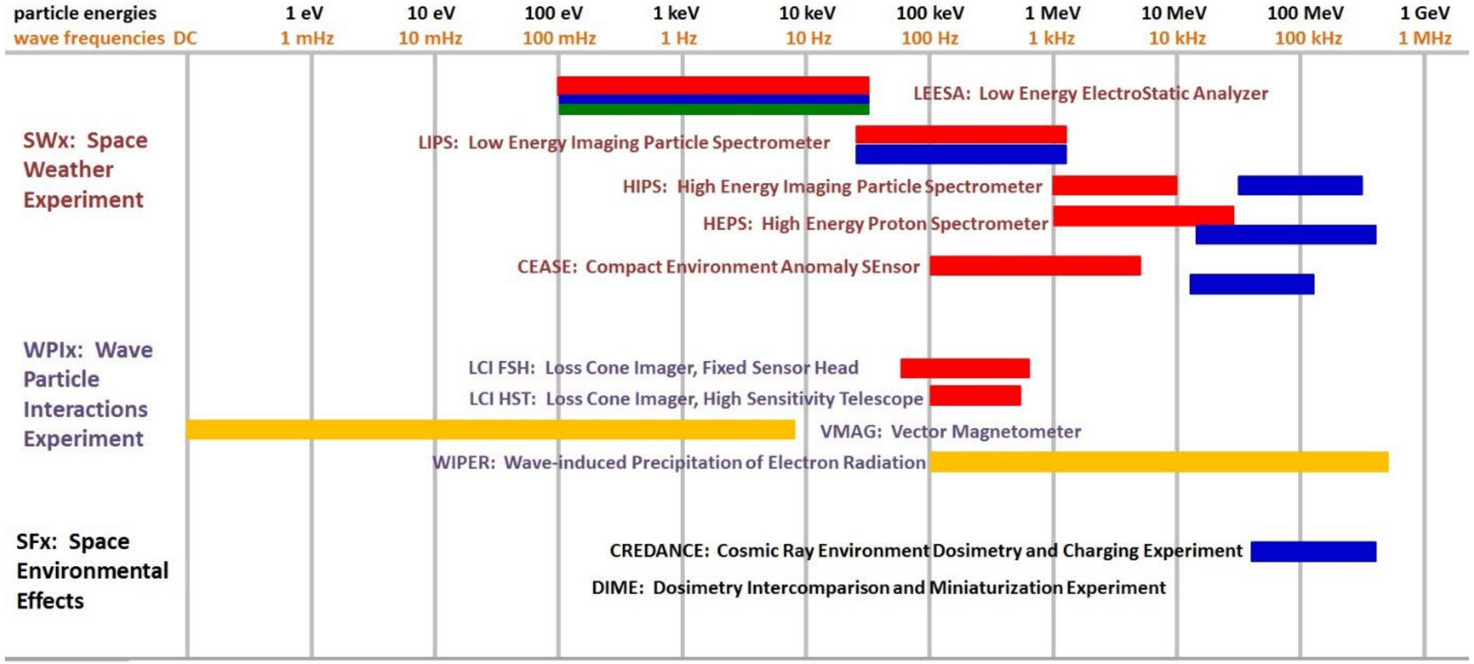
High Energy Proton Spectrometer (HEPS)
1 look direction
20—440 MeV p^+



High-energy Imaging Particle Spectrometer (HIPS):
8 angular zones,
1—10 MeV e^-,
30—300 MeV p^+

Low-energy Imaging Particle Spectrometer (LIPS):
8 angular zones,
30 keV—2 MeV e^-, p^+

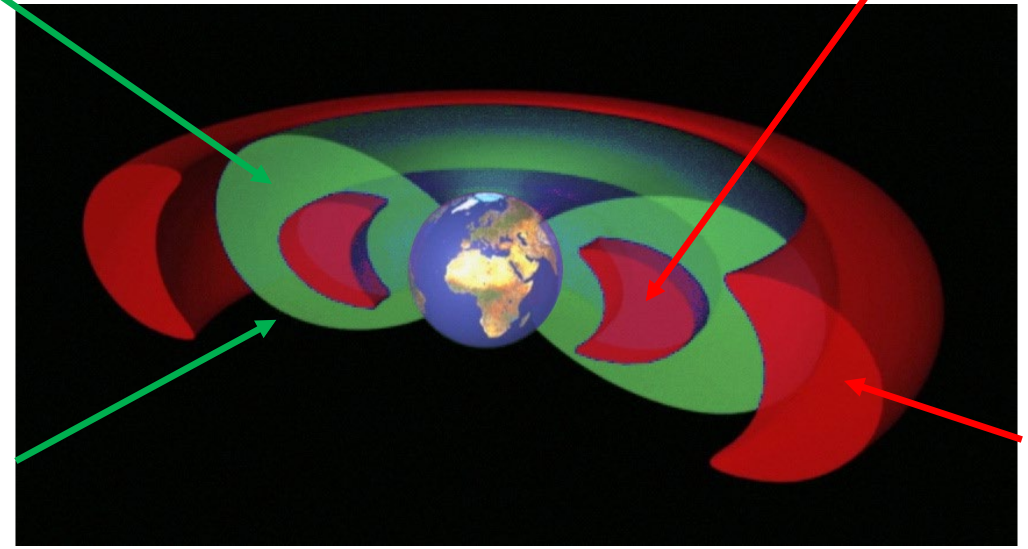


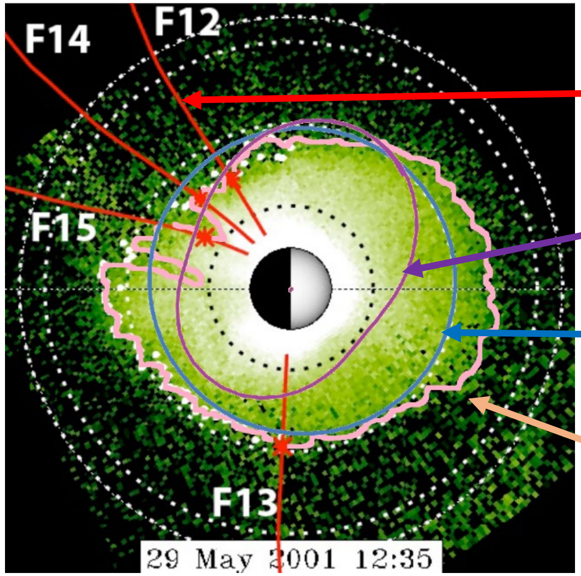


Unprecedented space environment sensing capability at Medium Earth Orbit

electrons
protons
ions
EM waves

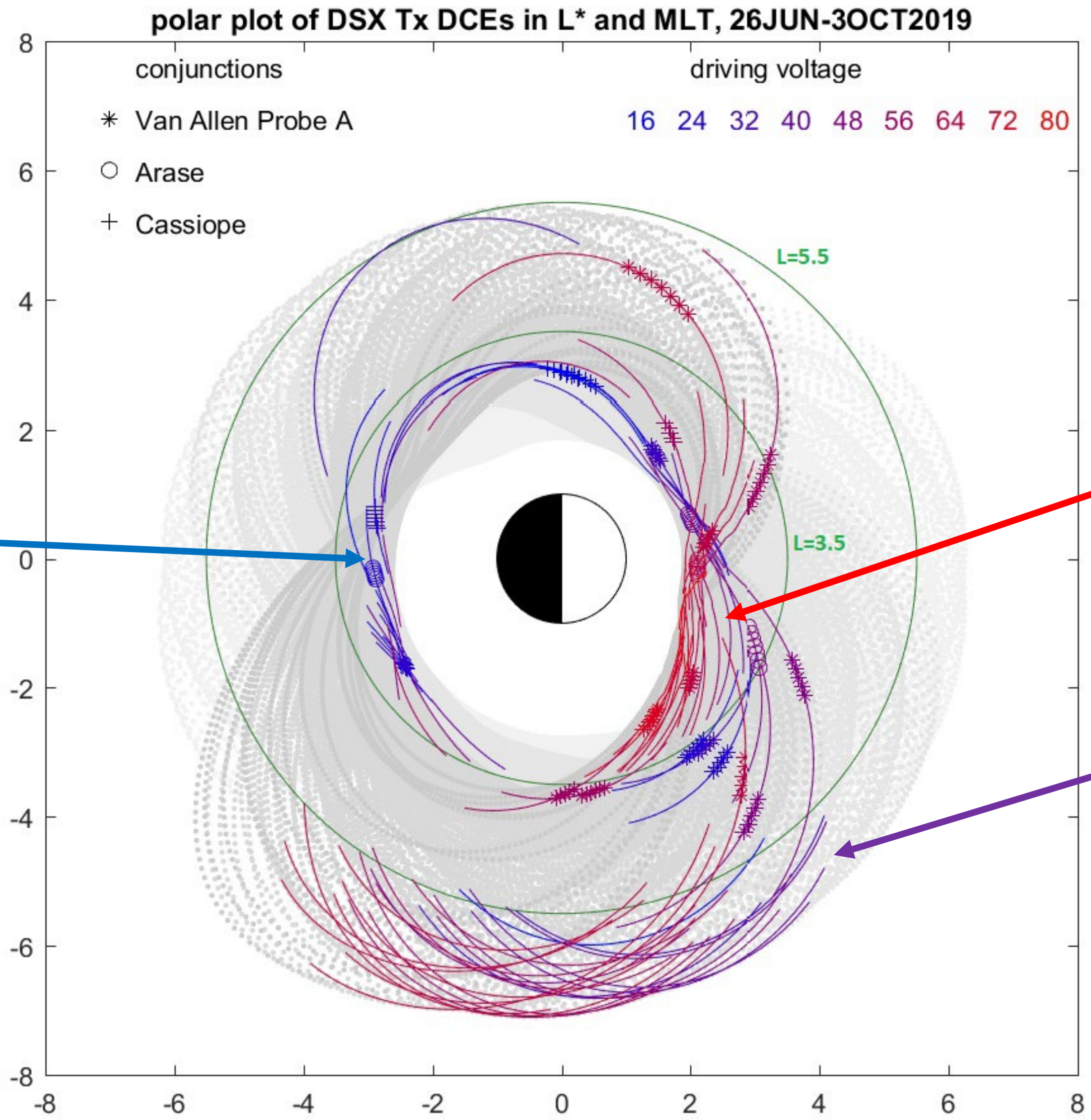
VLF Transmissions and Earth's Plasmasphere





- The Plasmapause (PP) separates cold near-Earth plasma (plasmasphere) from lower density, hot plasma of the outer magnetosphere
- The plasmasphere is very dynamic and unpredictable—PP migrates inward/outward, and has longitudinal structure
- The characteristics of the transmitter are very sensitive to magnetoplasma parameters
  - Higher antenna charging outside plasmasphere
- Most DSX high power Tx experiments need to be inside PP: we use a conservative PP rule to accommodate dynamic and unpredictable nature
  - We are using a plasmapause rule of "L<3.5" for high power transmissions
  - "L>5.5 and on the dawnside" for transmissions outside the plasmasphere

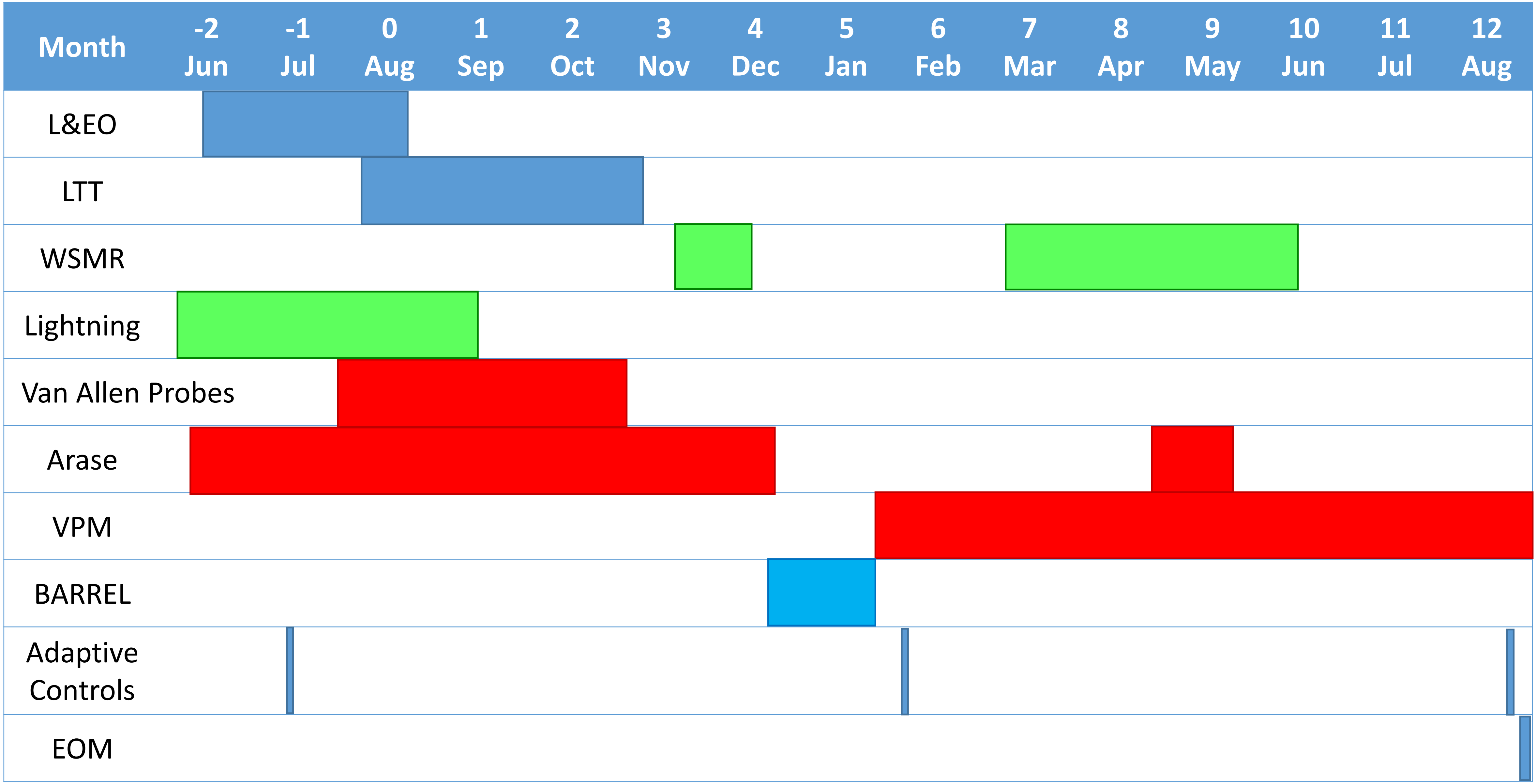
DSX Experiment CONOPS



- Targeted conjunction transmissions may occur at other locations but with lower driving voltages

- Polar plot shows L*-MLT coverage of DSX orbit with 3 months' precession (grey)
- Blind transmissions occur at L<3.5, inside nominal plasmasphere
- "Cavity" transmissions occur at L>5.5 on the dawn side, outside nominal plasmasphere

DSX Science Campaigns

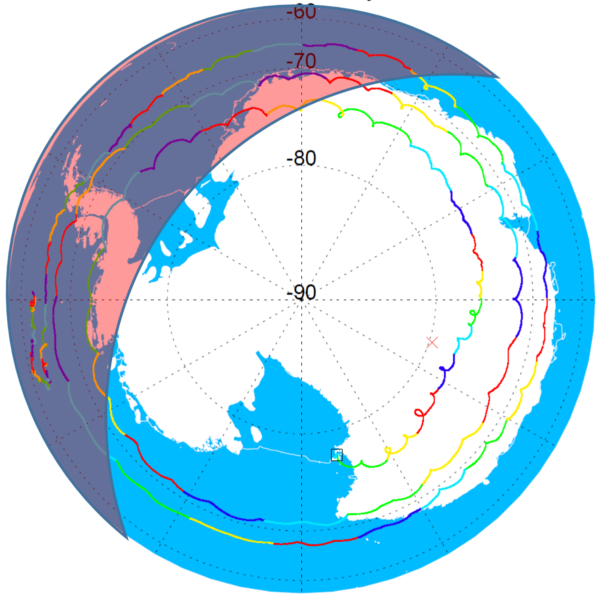


Conjunctions and Cooperation

We use conjunctions with other assets for coordinated campaigns

- Detect transmitted waves and resulting particle effects
- Diagnose the environment during transmission
- Augment global coverage of particles and waves
- Assess terrestrial VLF transmitter wave power
- Data has been cleared for release to collaborators

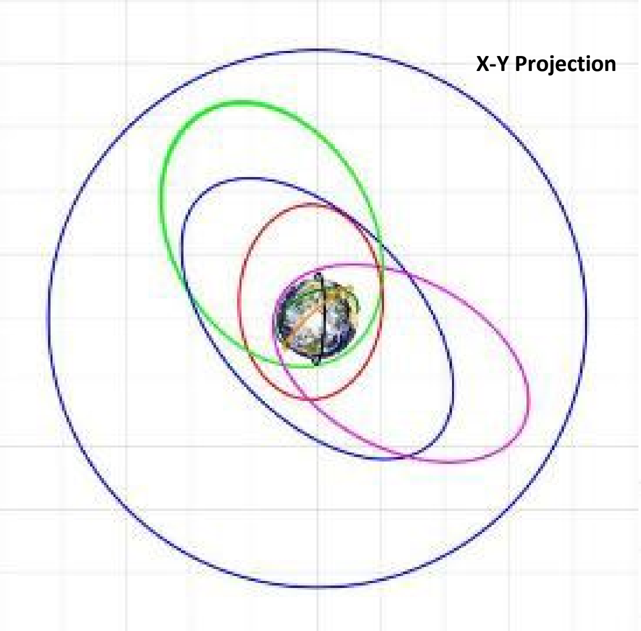
BARREL 2018B Payload 6A

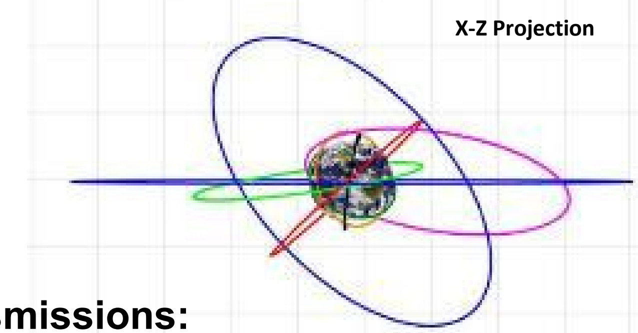


DSX magnetic footprint region

BARREL Trajectory

DSX
VPM
Van Allen Probes
ARASE
CASSIOPE
GEO/GPS
POES





High Power Transmissions:

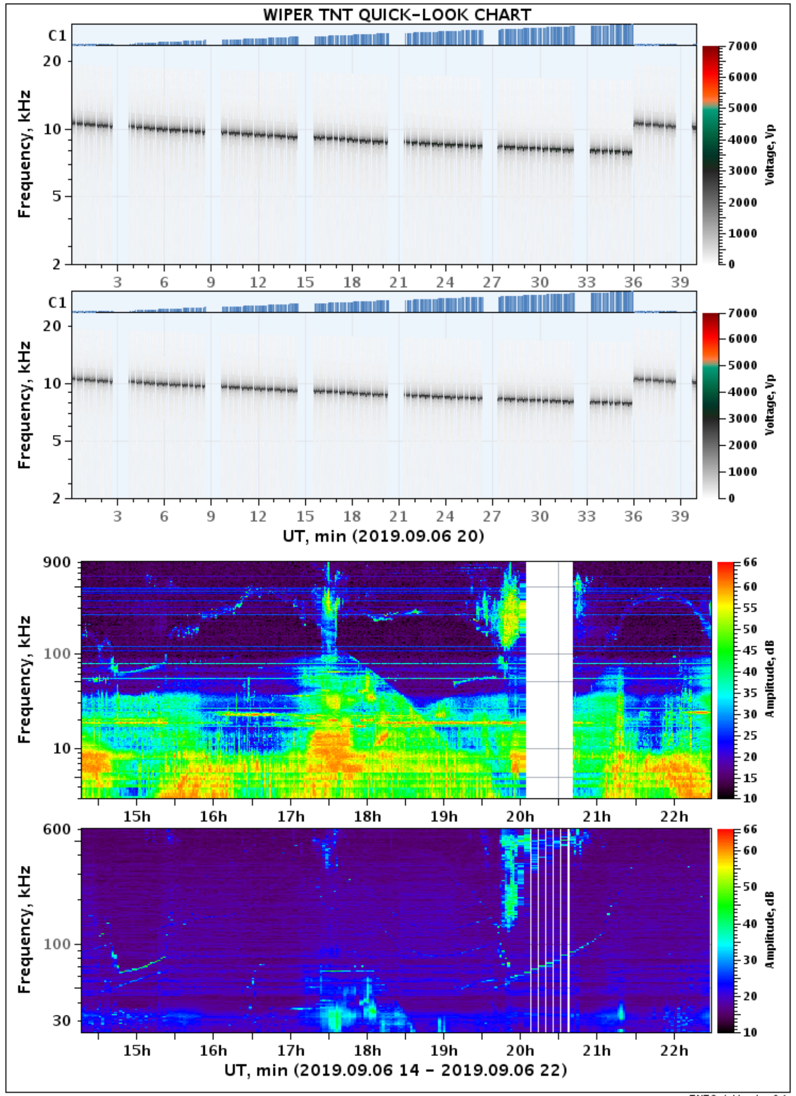
- Tx at the kV level at 2-50 kHz
- Up to 30 min per orbit occurring near the magnetic equator (|MLAT|<20° or L<3.5)
- Coordinating with conjunction target teams with specifics

Wave Particle Experiment Initial Results

AFRL

UML SPACE SCIENCE LAB

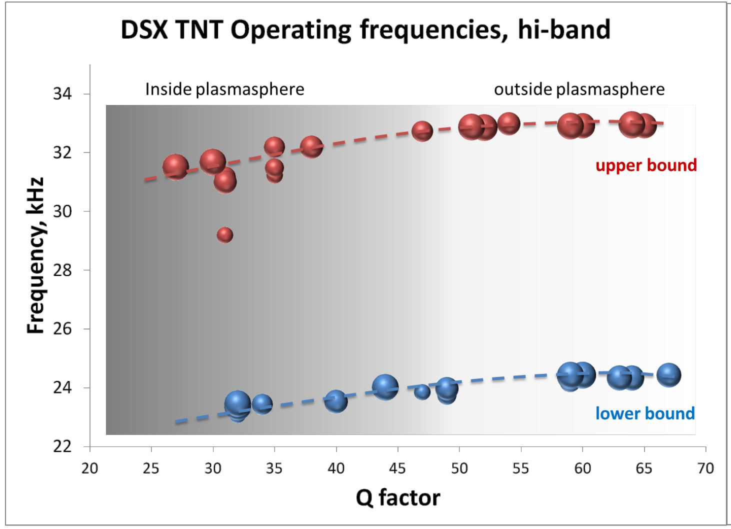
Learn to Transmit Phase I: Resonance Discovery



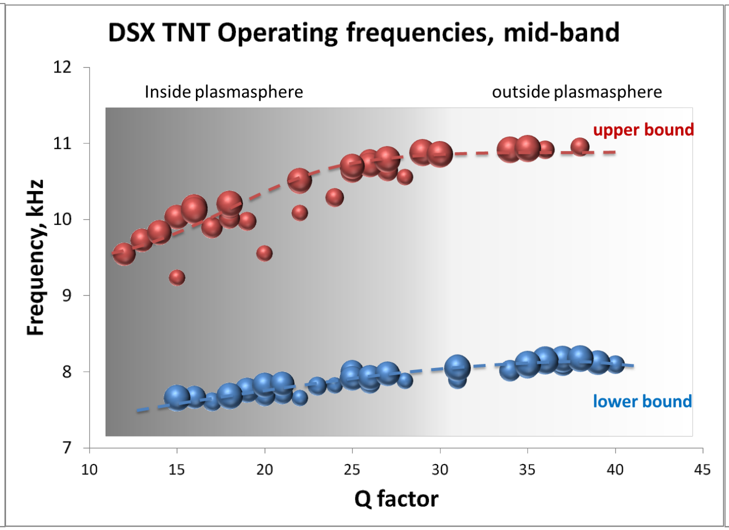
- Phase 1 explores circuit capacitor configurations to assess antenna performance as a function of frequency in varying plasma conditions
  - Driven by fail-safe driving voltage ramp-up process
- Data Collection Events consist of 40-minute transmissions at a specified driving voltage
- The transmission for this schedule is a pattern that repeats every 7 seconds
  - This pattern consists of 3 sweeps from high to low frequency for ~1.3 s each, narrowing in frequency range each time around the resonant value
  - This is followed by a pulse at the resonant frequency lasting ~0.3 s
  - Finally 2.8 s of no transmission (housekeeping)

Phase I results

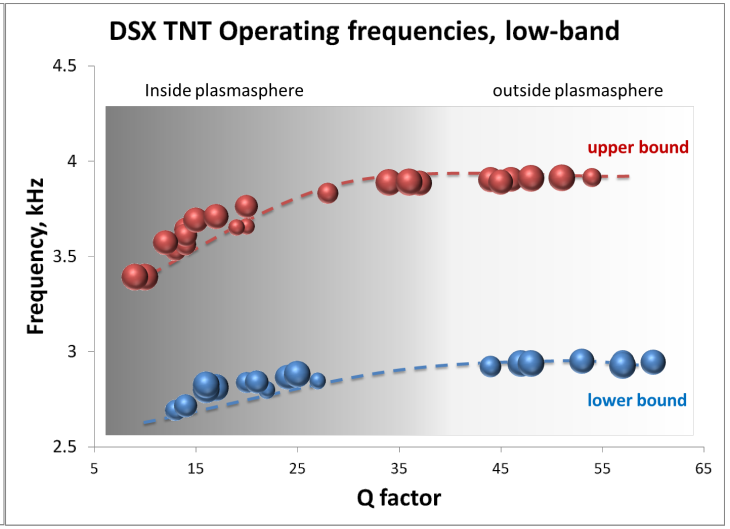
- Band of operating frequencies that TNT can use to transmit as a function of Q
  - Shaded background: plasma density (approximate)
  - Size of bubbles: driving voltage (Tx power)
- Fundamental frequency only
  - Addition of C3 will lower the lower bound
- Transmissions outside the plasmasphere:
  - Antenna capacitance determined to be ~255 pF
  - Reached 5 kV threshold at 64 V driving



TNT LEARN TO TRANSMIT PHASE I • RESONANCE DISCOVERY CAMPAIGN • FUNDAMENTAL-FREQUENCY ONLY



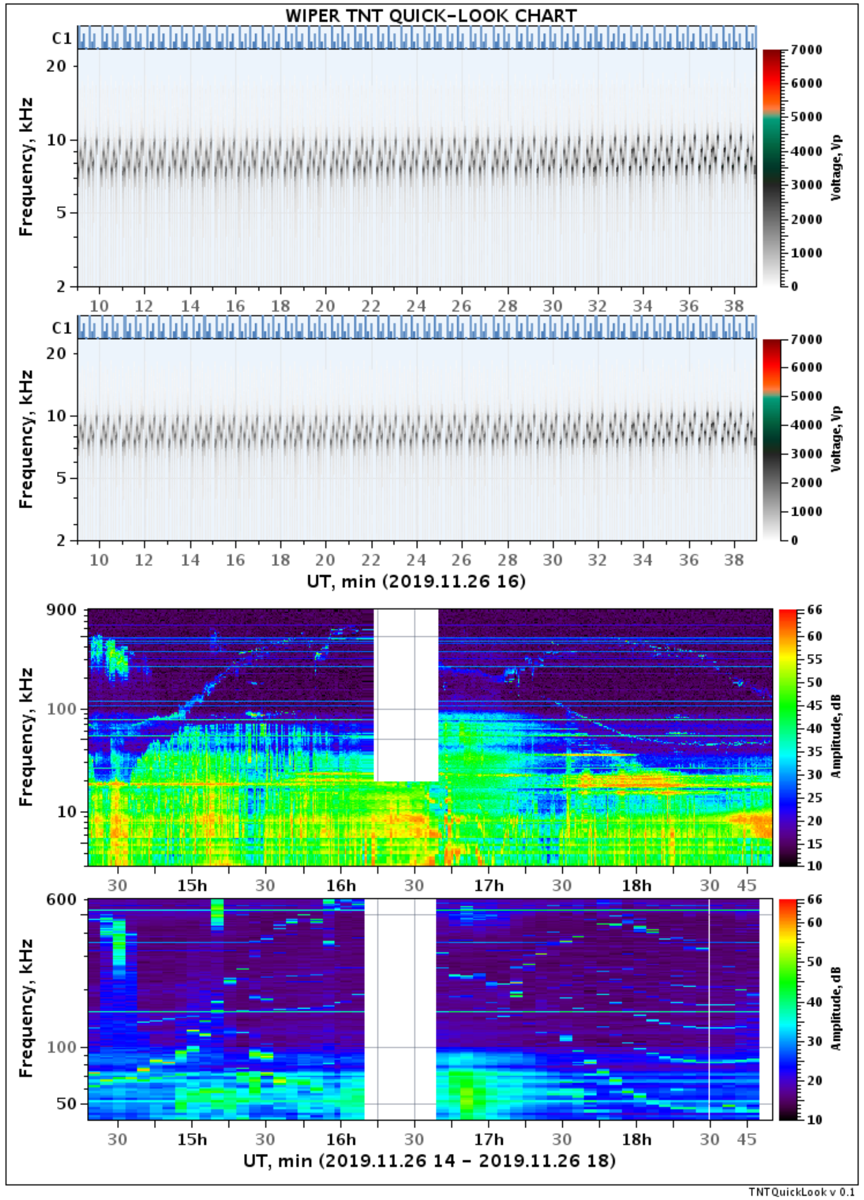
TNT LEARN TO TRANSMIT PHASE I • RESONANCE DISCOVERY CAMPAIGN • FUNDAMENTAL-FREQUENCY ONLY



TNT LEARN TO TRANSMIT PHASE I • RESONANCE DISCOVERY CAMPAIGN • FUNDAMENTAL-FREQUENCY ONLY

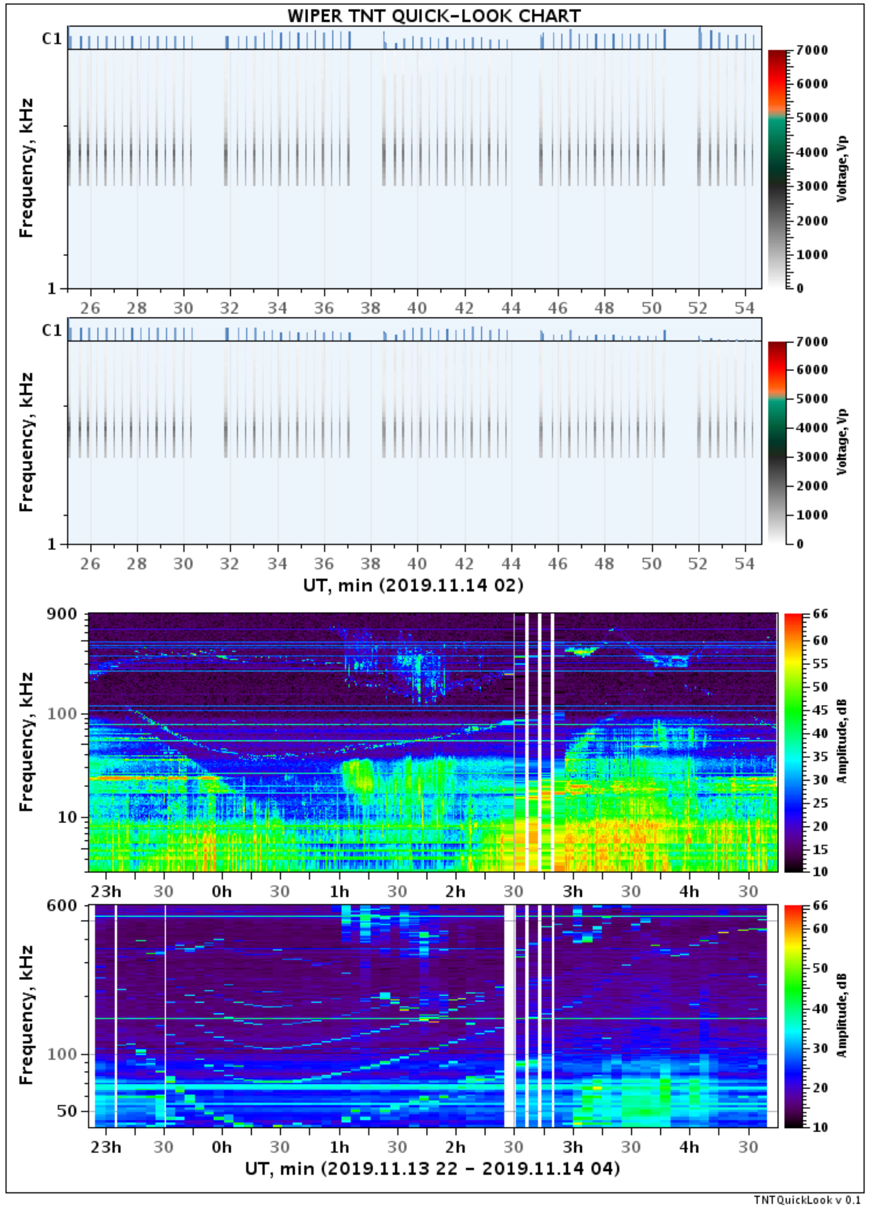
TNT Conjunction Pattern

- Capacitances "jump around," providing a distinct signature easier to pick out in a spectrogram
- Performed transmissions against space-borne receivers, including:
    - 7 to RBSP-A
    - 12 to CASSIOPE
    - 8 to Arase

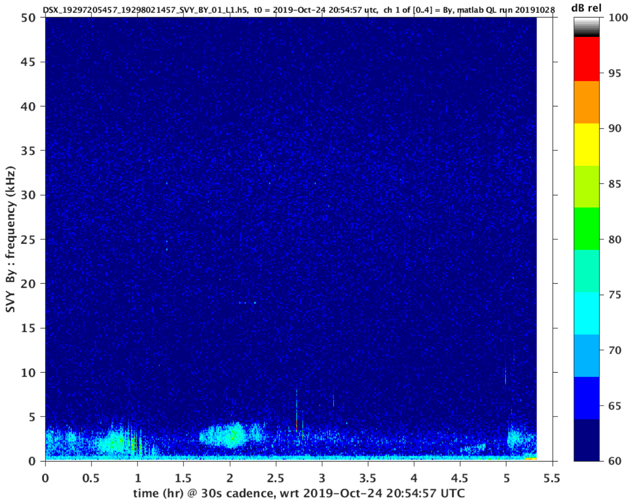


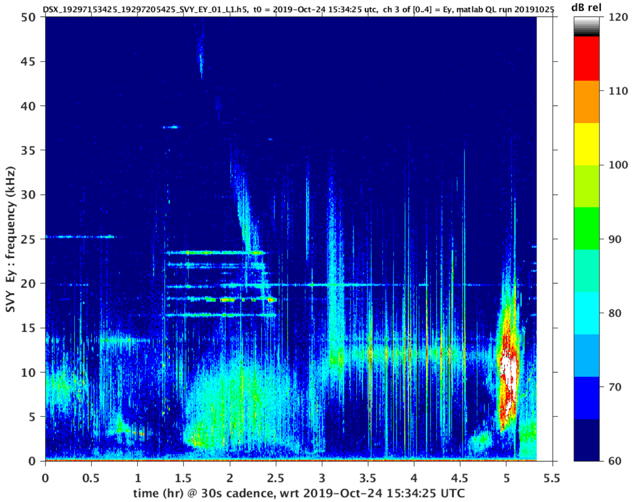
Learn to Transmit Phase 2: TNT Boomerang Pattern

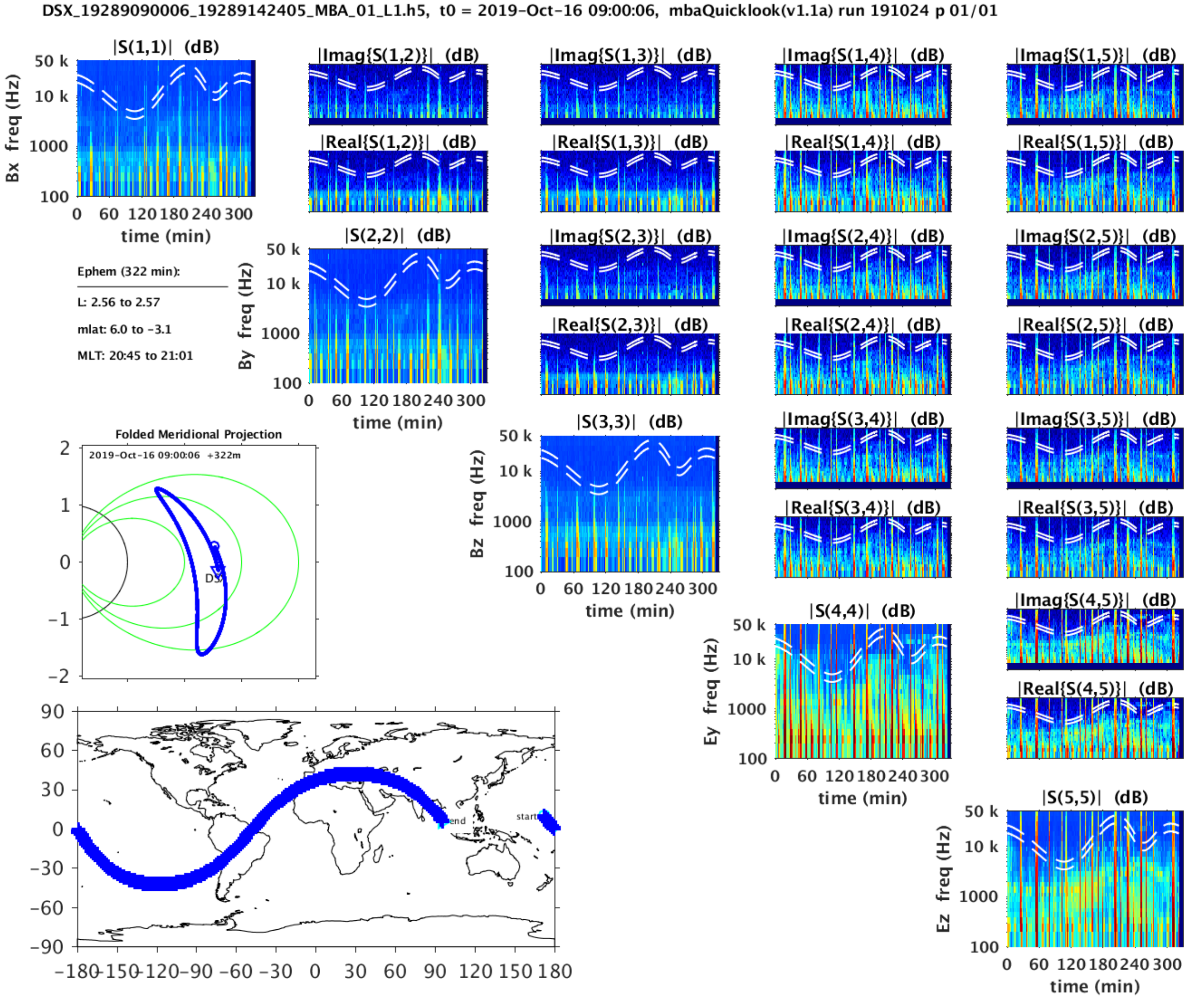
- Attempt to hear "ourselves" via waves that magnetospherically reflect after propagating away from the spacecraft
- Transmissions at frequencies likely to MR
  - 2.8, 3.0, 3.2, 3.4, 8.2 kHz
- Utilize NBR to "listen" alongside BBR for return signals
  - Began scheduling on Nov 9
  - Have had some successful TNT and BBR data collected, still being analyzed
  - Operating at 104 V
  - Looking for ~5 kV in plasmasphere, have reached 4.1 kV



BBR Survey Data

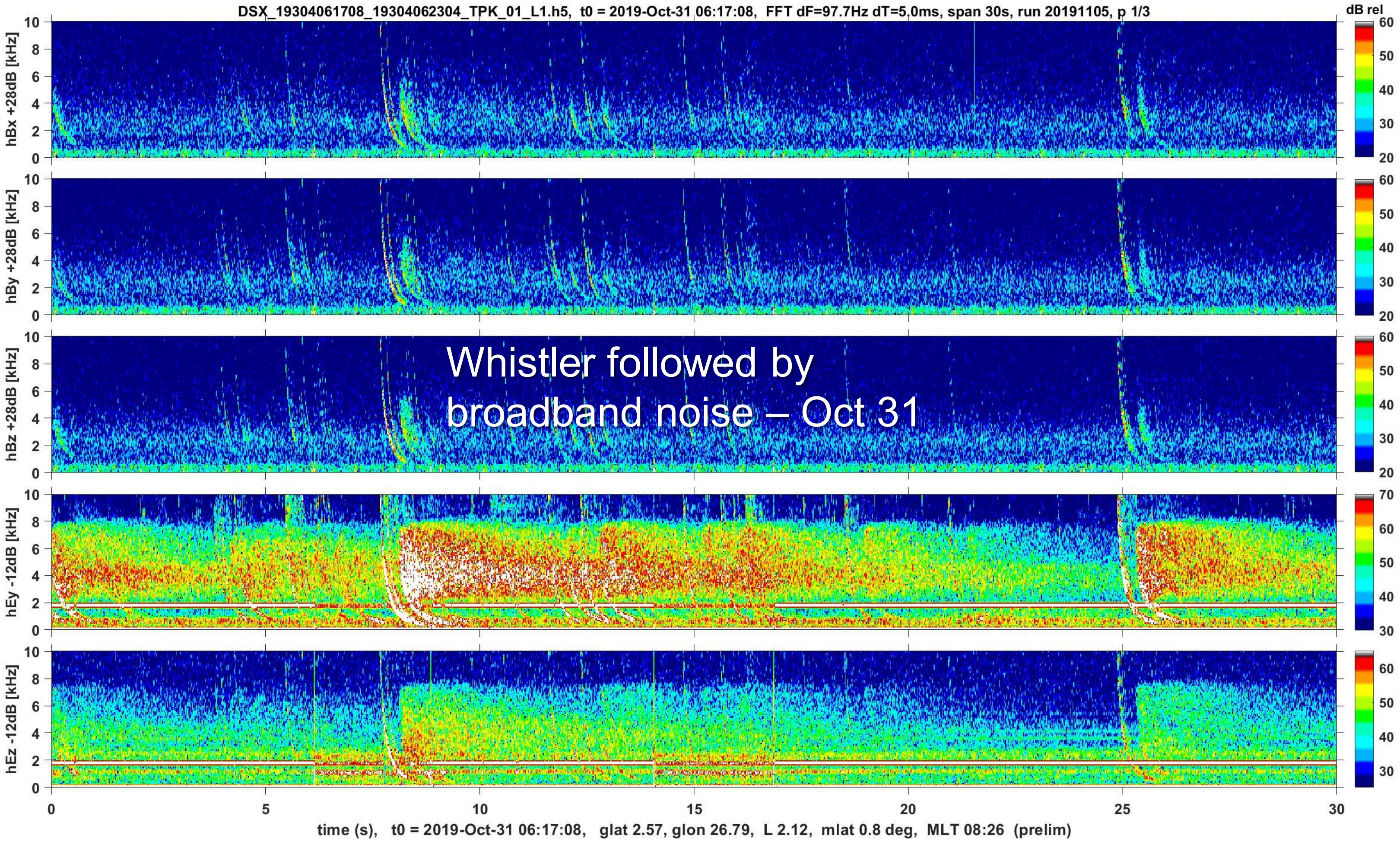






AFRL

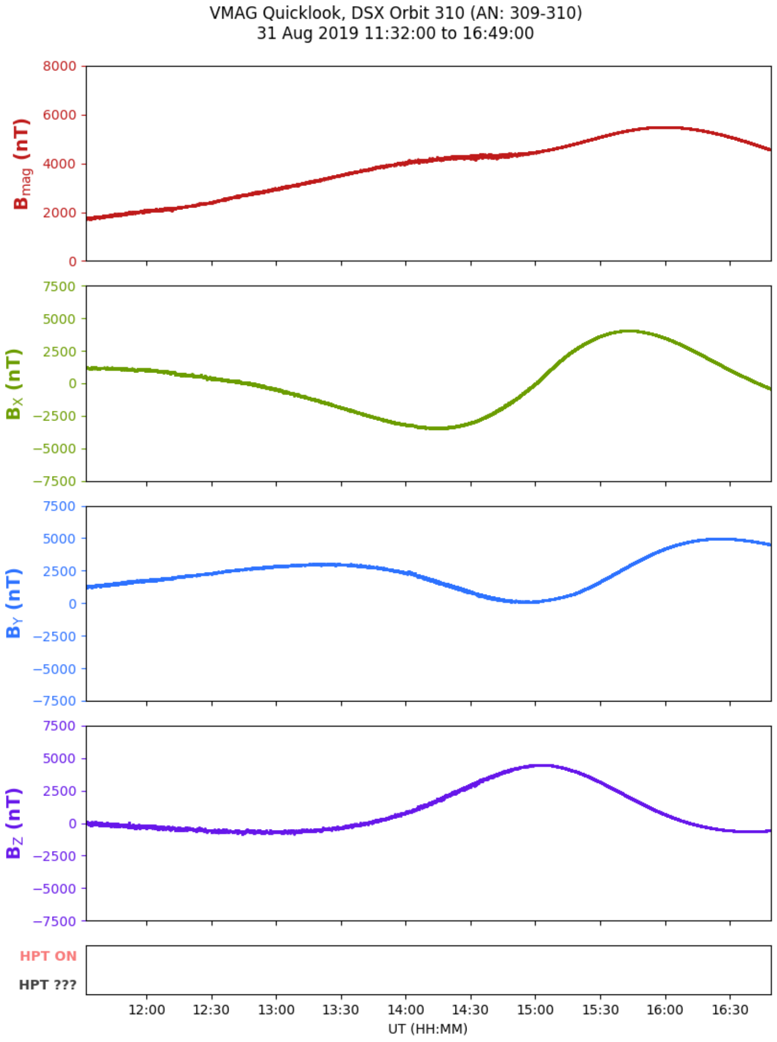
BBR Burst Data

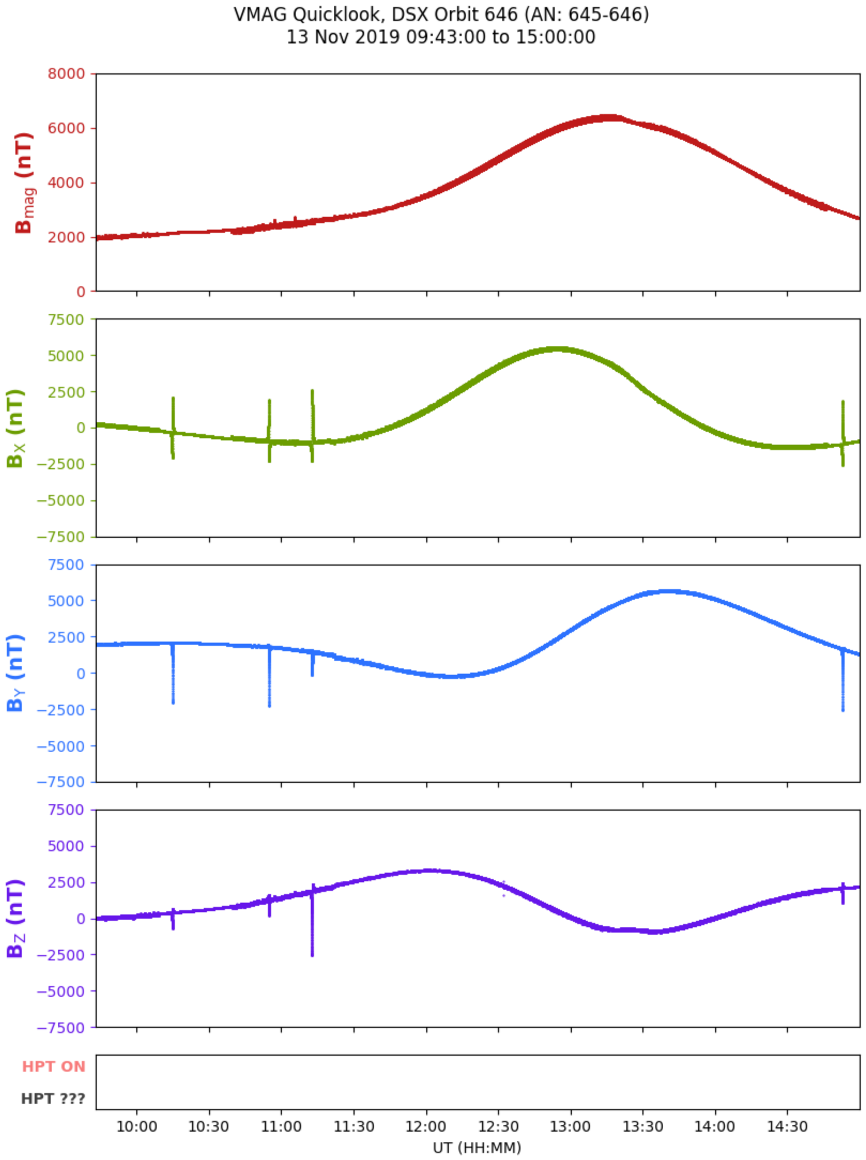


Lightning Whistlers Observed on Oct 25

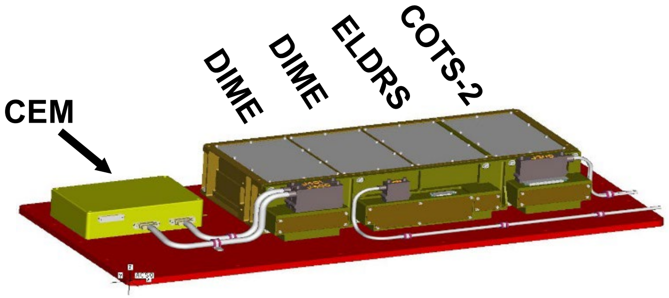
Created by W. M. Farrell and J. Miller

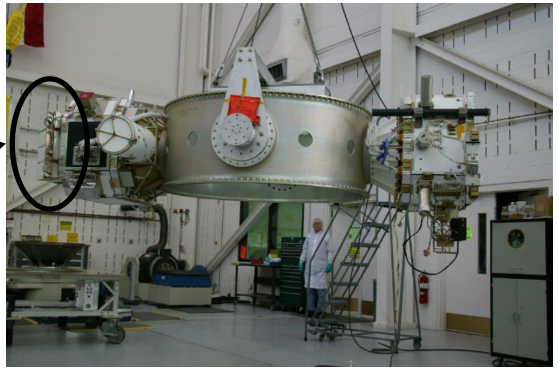
Vector Magnetometer





Space Effects (SFx) Payloads





SET on DSX

NASA Space Environment Testbed (SET)

- **Correlative Environment Monitor** (QinetiQ): European dosimeter & deep-dielectric charging instrument
- **DIME** (Clemson Univ): SEE and total dose environments using miniaturized COTS parts
- **ELDRS** (Arizona State): Low dose-rate and proton impacts to performance of 24 transistors
- **COTS-2** (CNES and NASA): Virtex2 SRAM single event upset sensitivity

SET advances our understanding of on-orbit degradation

AFRL “COTS” Sensors

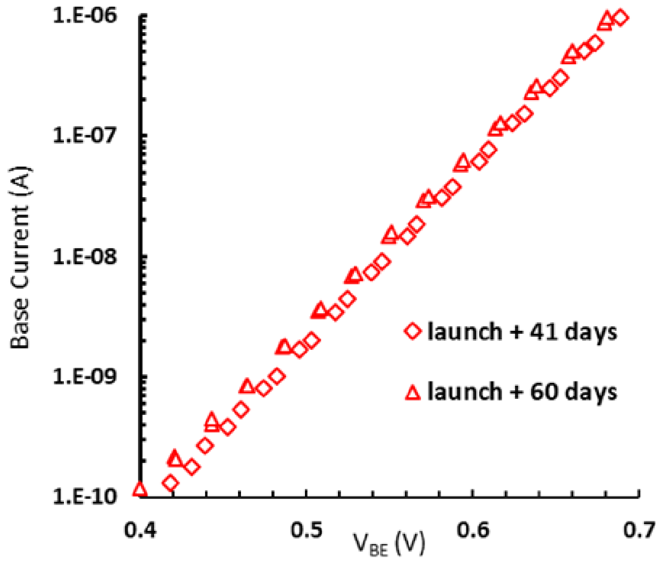
- Objective: directly measure changes due to MEO radiation environment
  - Thermal absorption and emission—heat gain/loss of thermal control paints
  - Optical transmission—erosion of quartz windows, re-deposition of material on adjacent optics
- Results applicable to thin-film photovoltaics

Radiometer

Photometer

Provider: AFRL/RQ

Space Effects Data

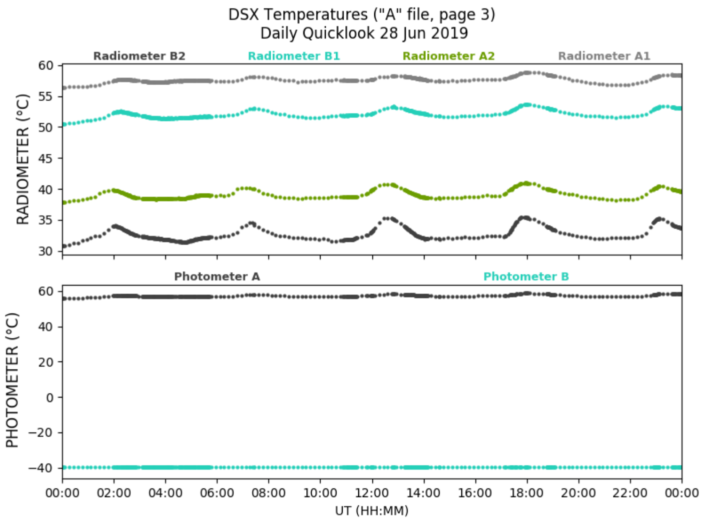


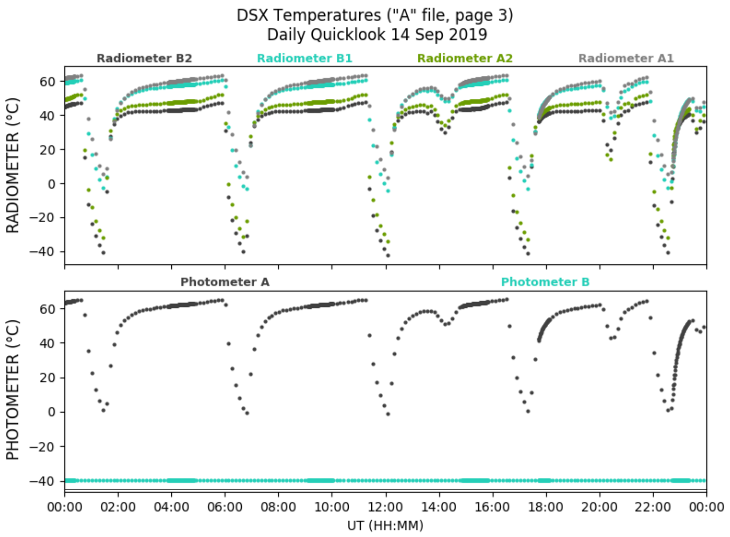
SET Data

- Initial look at base current inflight data from a gated bipolar junction transistor with thick oxide on board the ELDRS suite
- The plot shows data 41 days and 60 days after launch
- The increase in base current will be analyzed to better understand the total ionizing dose degradation of bipolar devices in space to help improve ground test protocol for such devices

Radiometer/Photometer Data

- Data from shortly after launch (left) and data during eclipse season (right)
- Radiometers show increased temperature readings after being on orbit for about 3 months
- Photometer A shows similar increase





Questions?

Space Weather Experiment Poster **SM41E-3288**