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Overview of the DSX Satellite Mission

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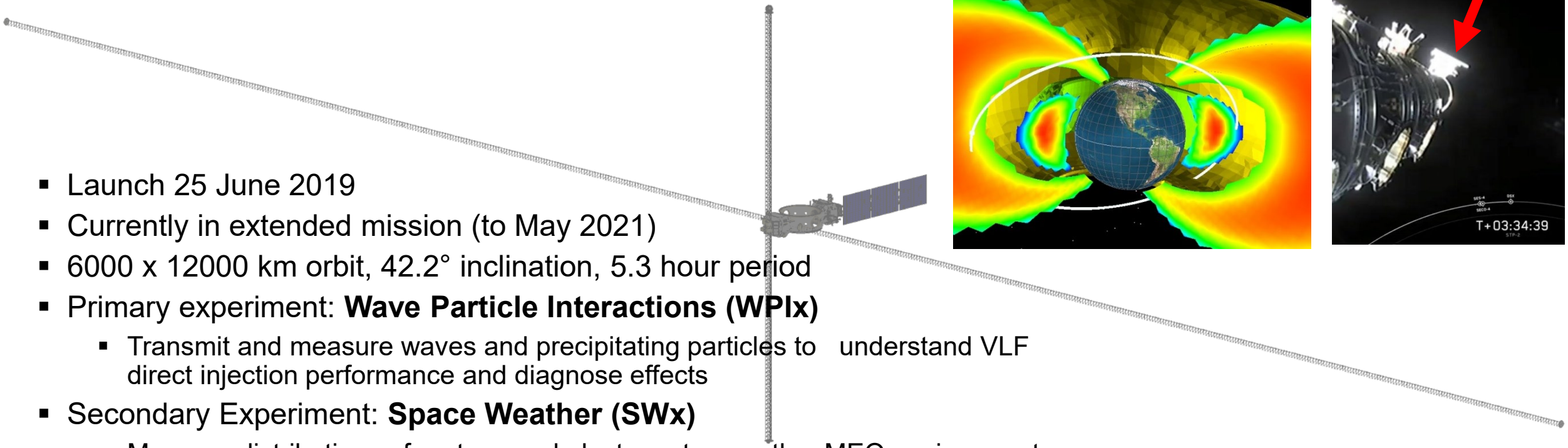
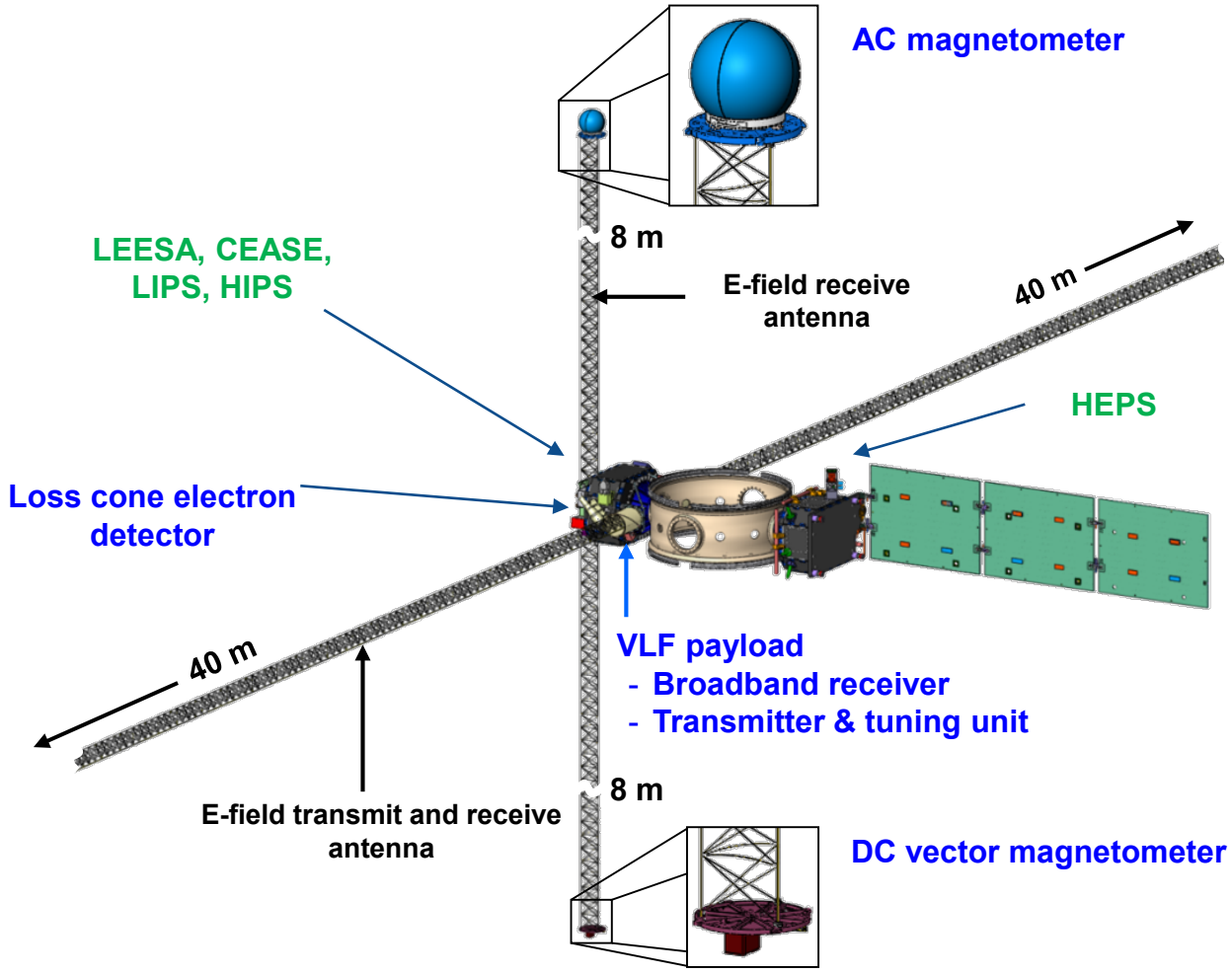
The DSX Mission



- Launch 25 June 2019
- Currently in extended mission (to May 2021)
- 6000 x 12000 km orbit, 42.2° inclination, 5.3 hour period
- 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

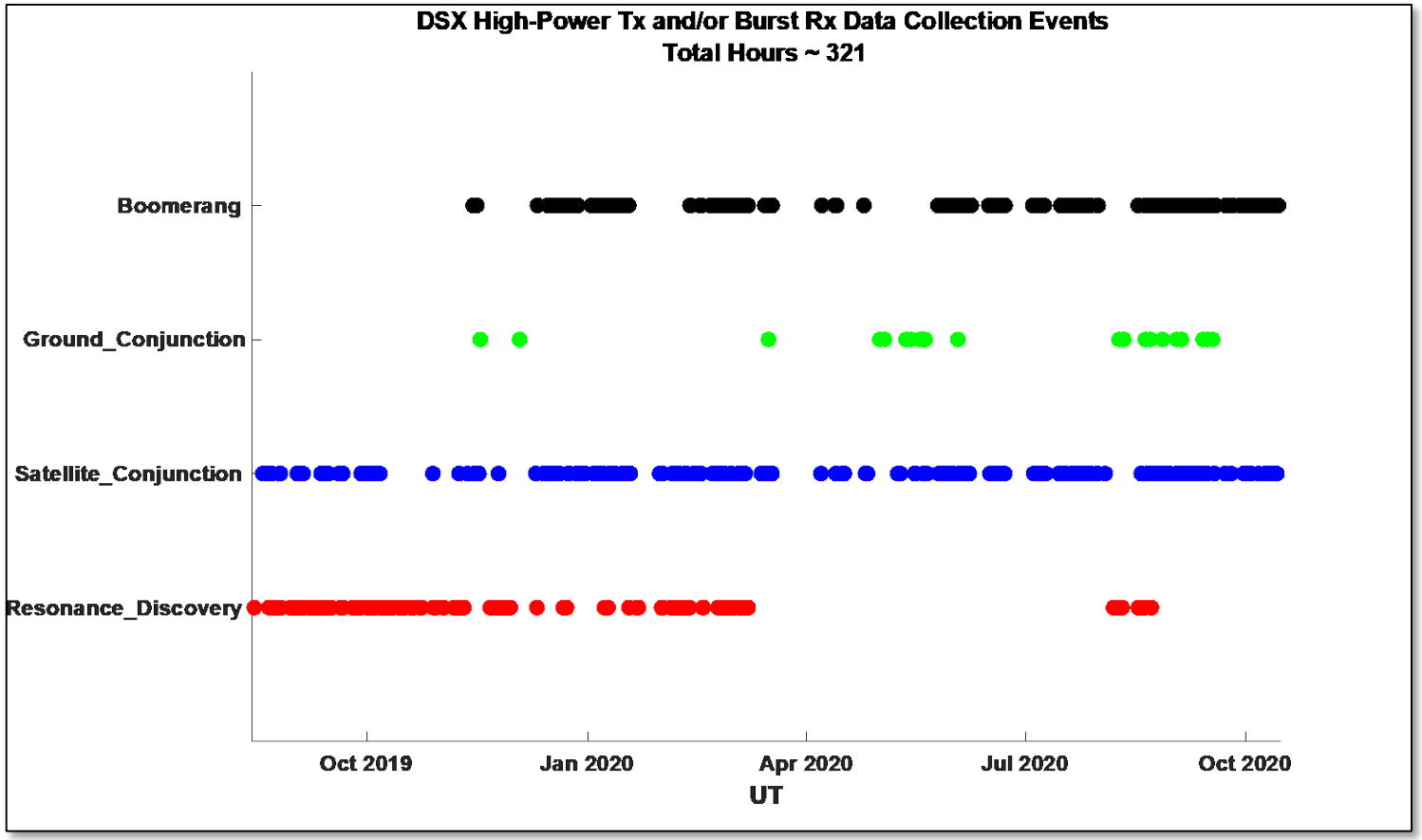
The DSX Satellite



Three experimental payloads

- **Wave-Particle Interactions (WPIx)**
  - VLF transmitter & receivers (Stanford, UMass/Lowell, NASA/Goddard)
  - Loss cone imager (BU)
  - Vector magnetometer (UCLA)
- **Space Weather (SWx)**
  - LEESA (AFRL)
  - CEASE (ATA/AFRL)
  - LIPS (PSI)
  - HIPS (PSI)
  - HEPS (ATA)
- **Space Environmental Effects (SFx)**
  - NASA Space Environment Testbed
  - AFRL radiometer effects experiment

Data Collection Events



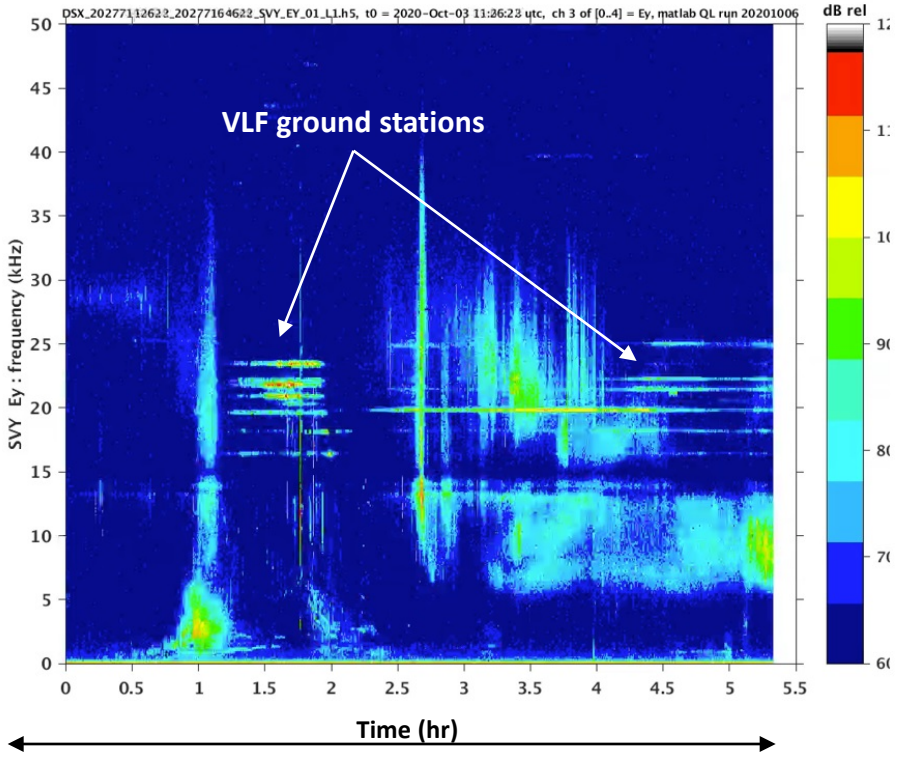
- **Boomerang – high-power transmission of pulses then listen for reflection off the bottom of the magnetosphere.**
- **Ground Conjunction – coordinated observations of ground based transmitters or passes over lightning intense regions.**
- **Satellite Conjunction – high-power transmissions coordinated with other satellite wave and particle detectors.**
  - **Arase – waves**
  - **Van Allen Probe A – waves**
  - **Cassiope – waves**
  - **VLF & Particle Mapper (VPM) – waves**
  - **Firebird 4 - particles**
- **Resonance Discovery –transmissions to establish optimal transmitter circuit parameters and frequencies**

- **Receivers, particle detectors and low-power sounding always in low date rate survey mode**
- **High-power transmit and burst data collection events limited to ~30 min/orbit (or less)**

Listening to VLF

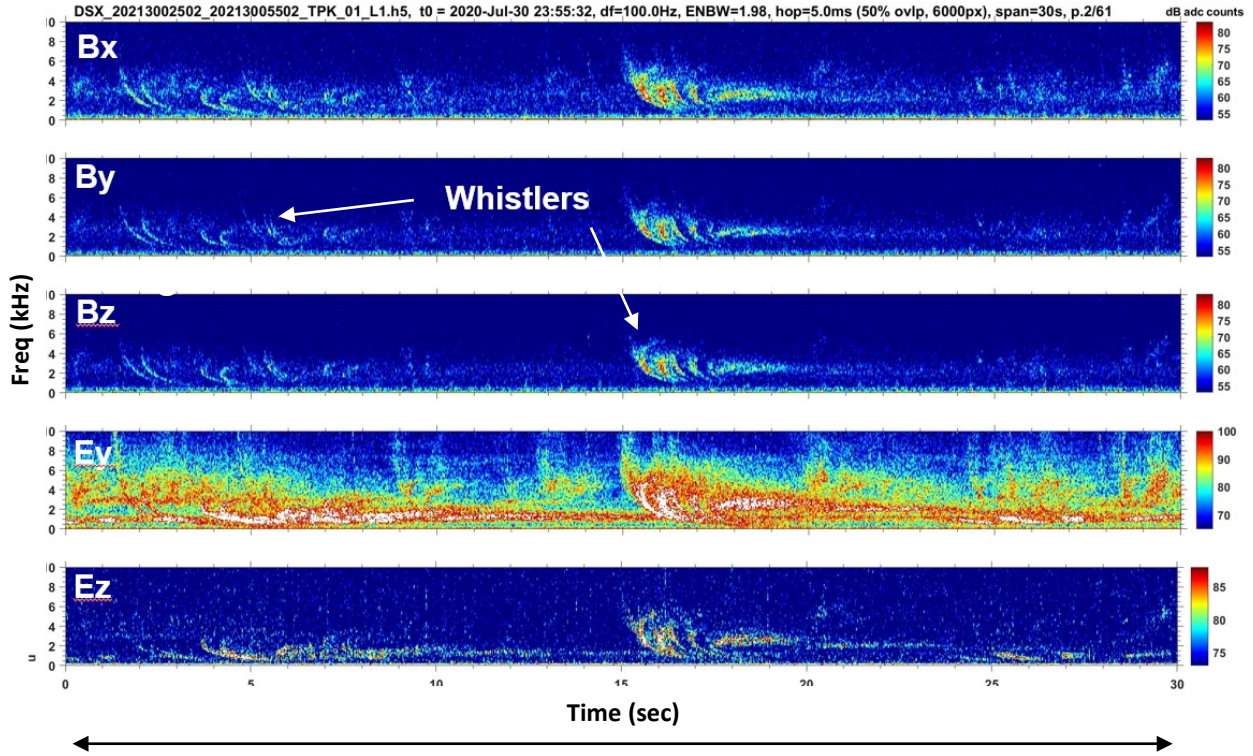
Broad Band Receiver (BBR)

• Survey mode • 20201003 11:25:22 UT



One DSX orbit (5.27 hrs)

• Burst mode • 20200730 23:55:32 UT

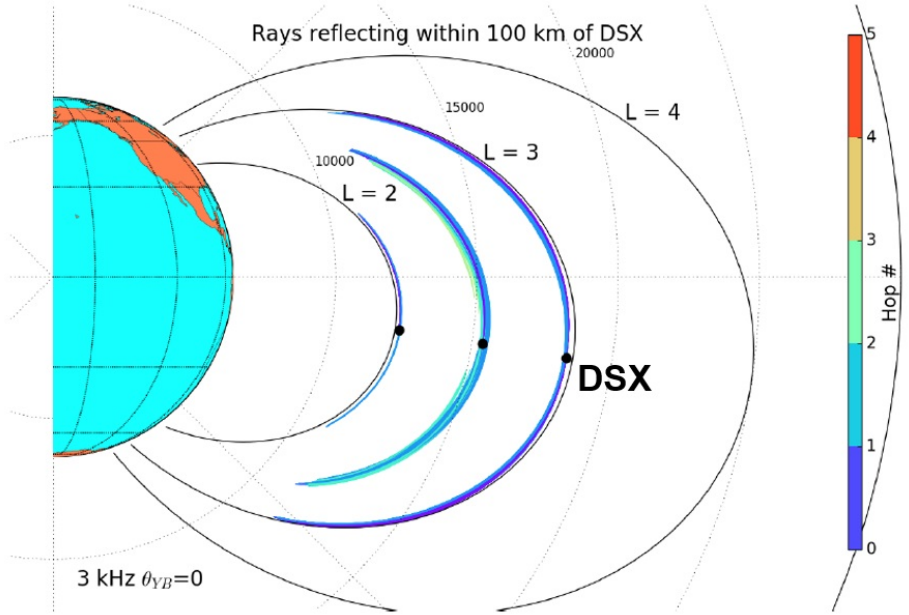


30 seconds

- **DSX detects a wide range of VLF waves from natural and man-made VLF sources**
  - **Data from relatively high-inclination MEO compliments equatorial measurements (e.g. Van Allen Probes, Arase)**

Boomerang Detection

Ray-tracing at 3.0 kHz



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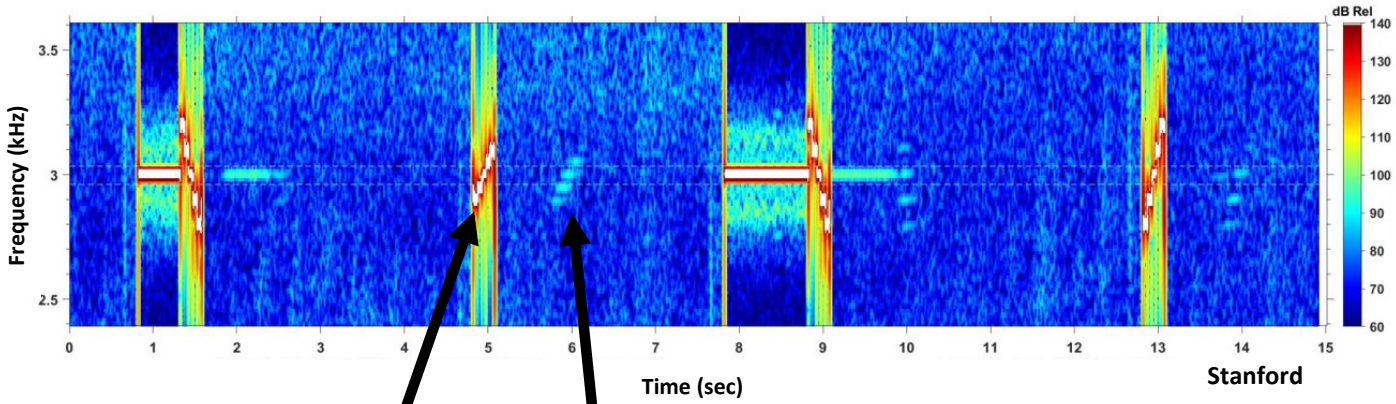
DSX data

• 3.0 kHz • E_y electric field • 20201005 22:20:20 UTC



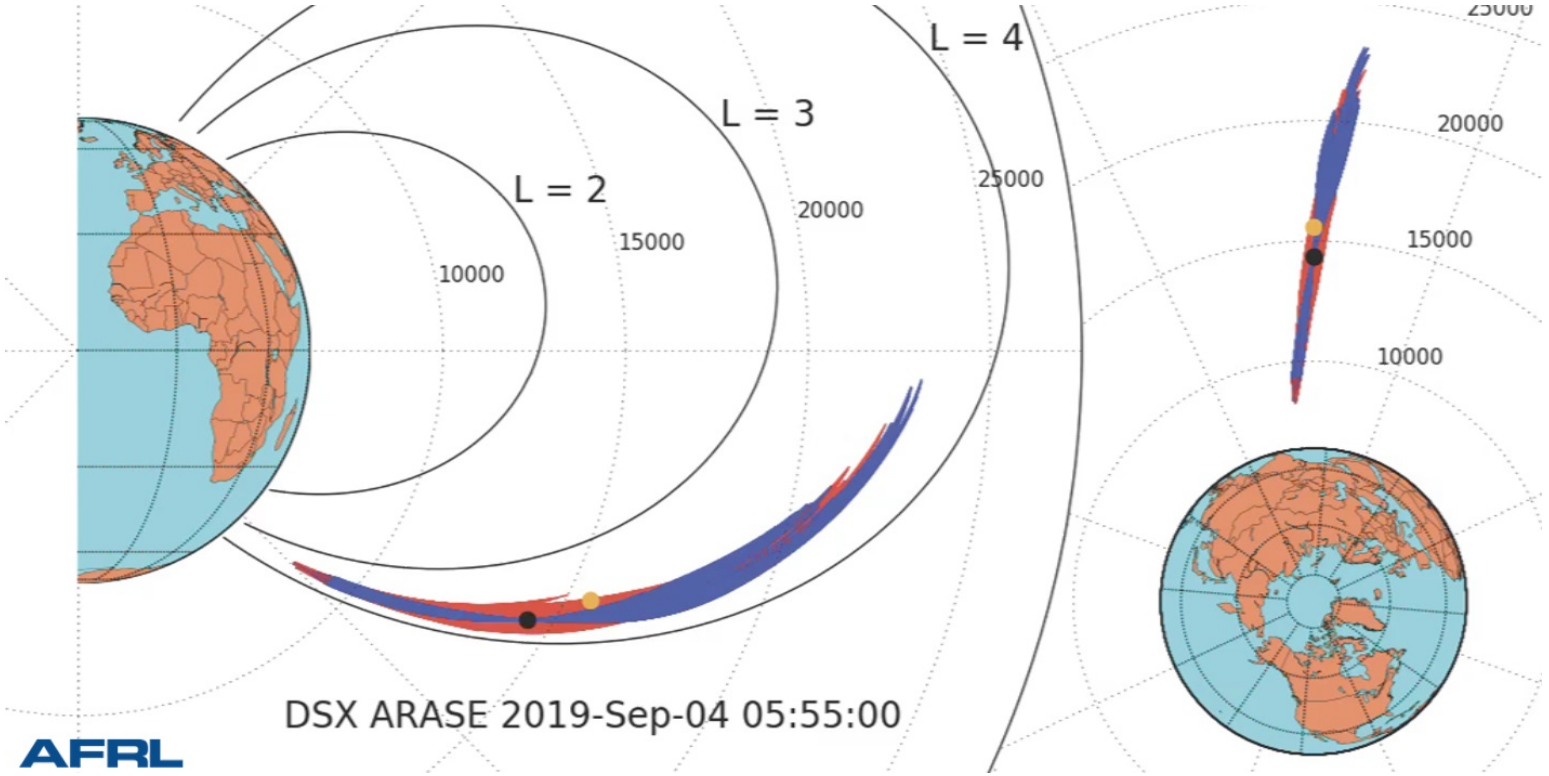
Initial pulses at DSX

Reflected pulses detected at DSX

- Successful detection of pulses reflecting off the bottom of the magnetosphere
  - Repeatable – seen on many data collection events
- Time-of-flight, intensity and frequency dispersion data will provide quantitative validation of propagation and wave injection models

Arase Conjunction—4 Sep 2019

- JAXA's Arase satellite is in GTO designed to study the radiation belts
  - Arase includes a VLF receiver
- Occasional magnetic field line conjunctions, even less frequent spatial conjunctions
- Spatial+magnetic conjunction occurred on 4 Sep 2019
  - ~440 km spatial
  - ~220 km magnetic field line separation



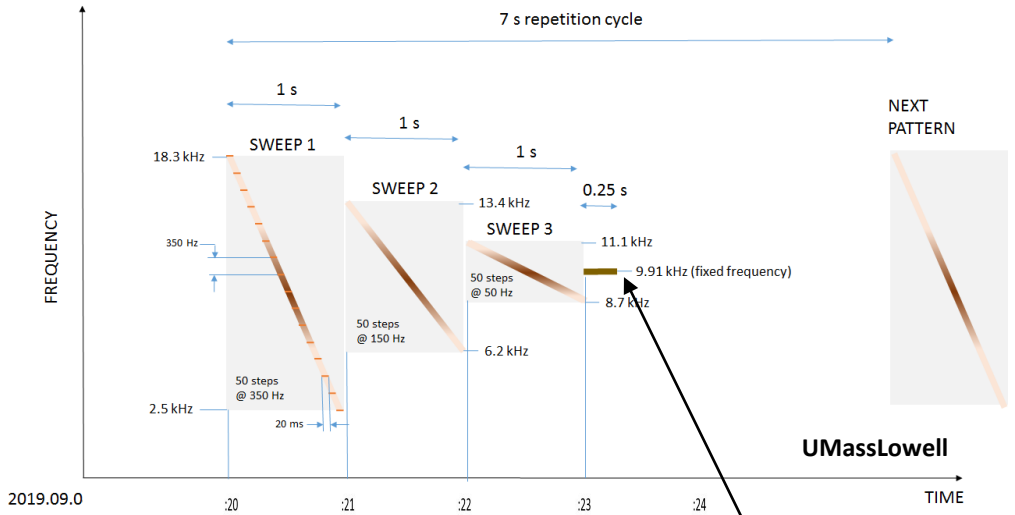
ARASE
DSX

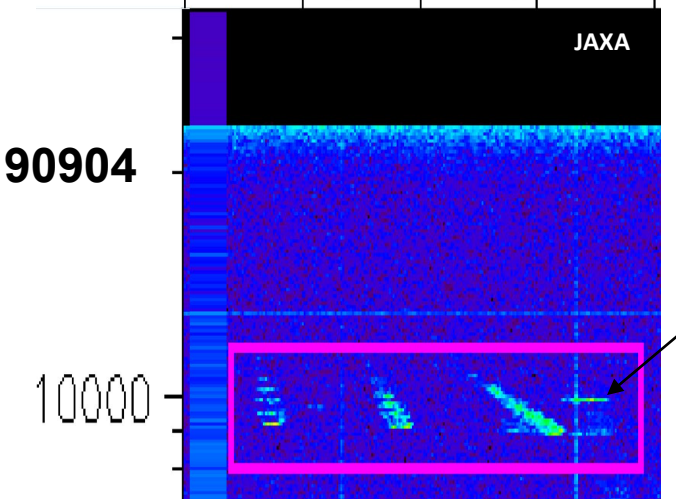
Model results: Blue = direct VLF rays from DSX
Red = VLF rays after reflecting off the bottom of the magnetosphere

Arase Detection

- DSX transmission pattern included pulses of decreasing frequency followed by a longer pulse at resonance
- These patterns were identified in the Arase data
- Arase detected the DSX signal near time of shortest distance to the same magnetic field line—but not at the time of shortest spatial separation
- This conforms to models indicating the wave power is focused along the magnetic field

DSX resonance discovery waveform



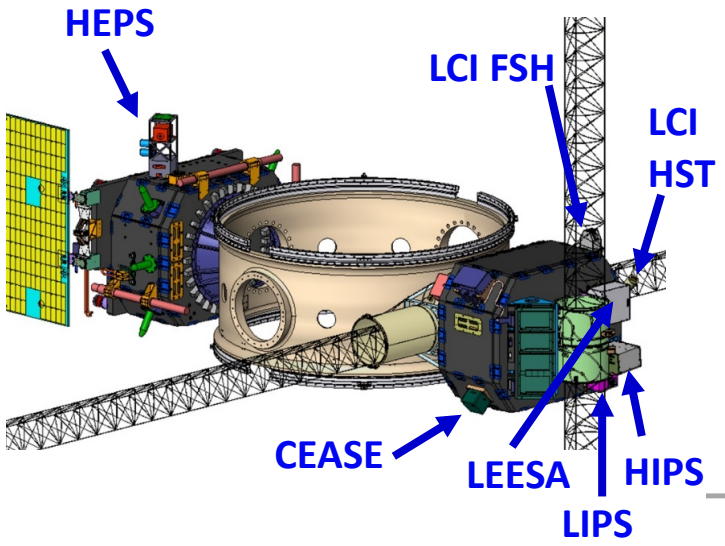


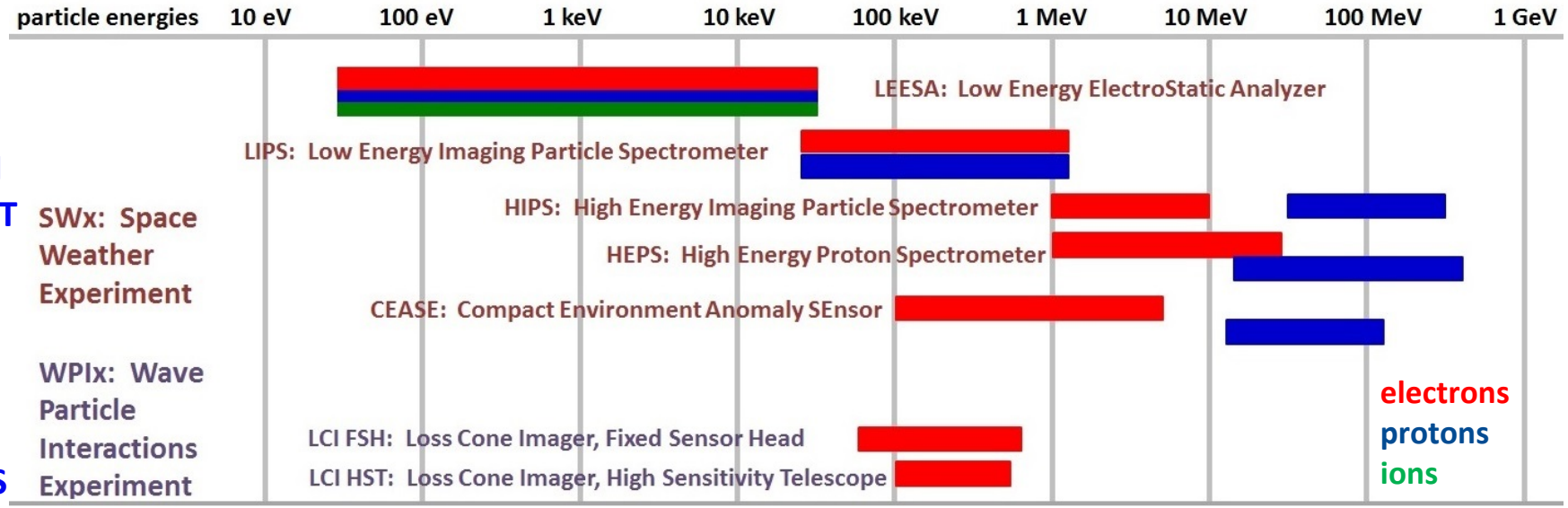
ARASE data 20190904

9.91 kHz resonance frequency

Close-range bistatic measurement provides opportunity to evaluate injection and propagation models in "simple" geometry (i.e. no reflection)

DSX SWx and WPIx Particle Instruments

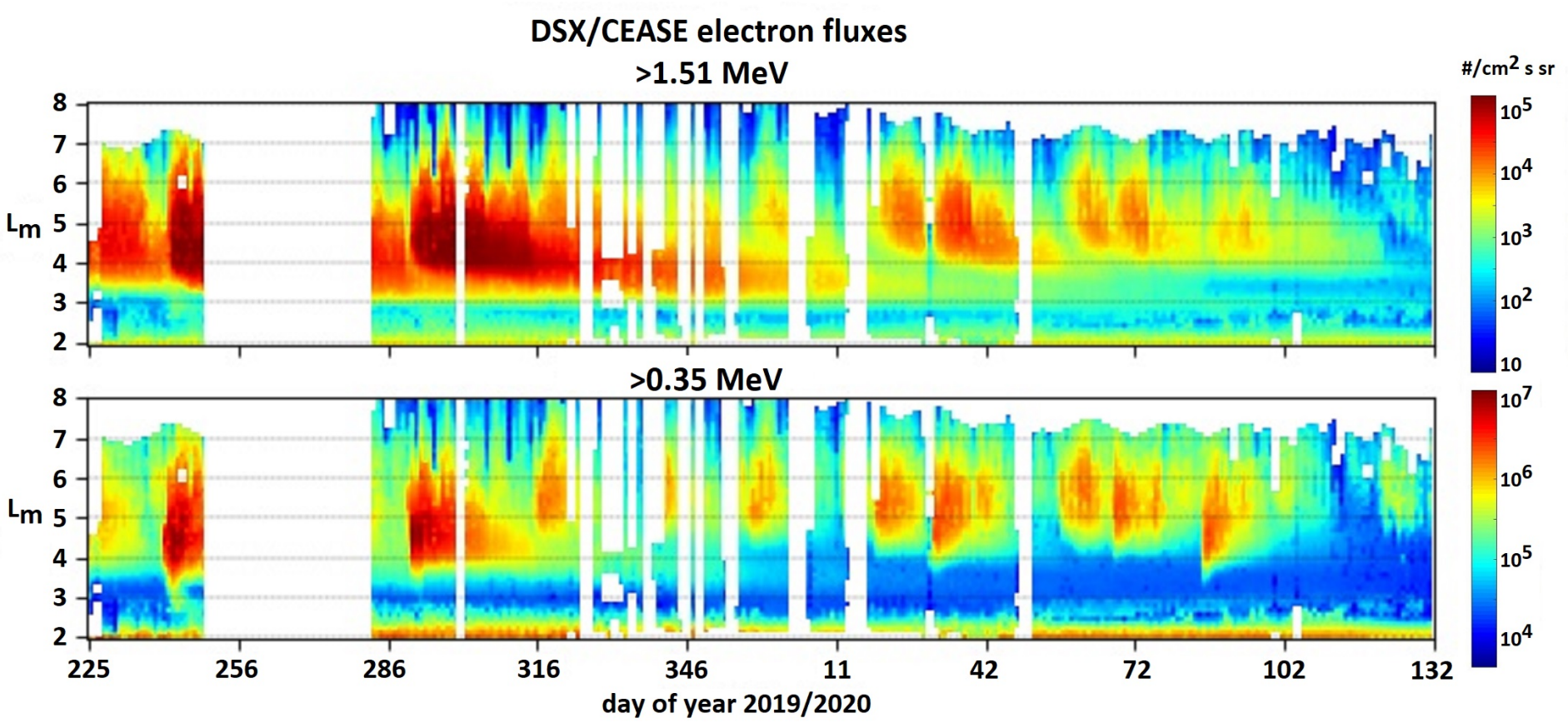




- **LEESA** is an electrostatic analyzer for electrons and ions with 5 angular zones and flexible survey modes among up to 256 energies from 10s of eV to 30 keV
- **LIPS** has 8 imaging scintillator pixels detecting electrons and protons from 60 keV to >2 MeV
- **HIPS** is a particle telescopes with 8 pixels observing 9 proton channels from 14 to 300 MeV and 5+ electron channels from 1.1 to 12 MeV

- **CEASE I** includes a particle telescope and two dosimeters, providing 9 electron channels from >0.13 to >3.5 MeV and 12 proton channels from >16 to >79 MeV
- **HEPS** is a particle telescope with 22 proton channels from 20 to 440 MeV, 15-25° field of view
- **LCI FSH** has three pixelated telescopes for 18 look directions observing electrons from 50 to 700 keV
- **LCI HST** is a particle telescope with electron channels from 100 to 500 keV

Climatology from DSX Space Weather Payloads



- CEASE monitoring shows dynamics of outer electron belt following end of Van Allen Probes mission
- LEESA data show effects of high power transmissions on local plasma, results under analysis
- Calibration still underway for LIPS, HEPS, LEESA

Summary

- DSX has been successfully gathering wave and particle data in MEO since Aug 2019
  - Mission extended to 31 May 2021
  - Data will be available to the public through NASA/SPDC after mission conclusion
- The first successful space-to-space VLF transmission was accomplished in a coordinated DSX-Arase experiment 4 Sep 2019
  - Experiments with transmissions to Arase will continue through the end of mission
- DSX has repeatedly observed reflected VLF signals in boomerang DCEs
- Particle observations in MEO compliment radiation belt observations from Van Allen Probes and Arase