Radio Beacon Monitoring for Ionospheric Scintillation Specification and Total Electron Content from the FORMOSAT-7/COSMIC-2 Science Mission

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COSMIC-2 RF Beacon

Outline

- FormoSat-7 / COSMIC-2 Mission
- RF Beacon System
  - Space/Ground components
- Early sensor Checkout & Commissioning
- Beacon system Cal/Val

FormoSat 7: Program name used by the Taiwan National Space Organization (NSPO)
COSMIC-2: Constellation Observing System for Meteorology, Ionosphere, and Climate

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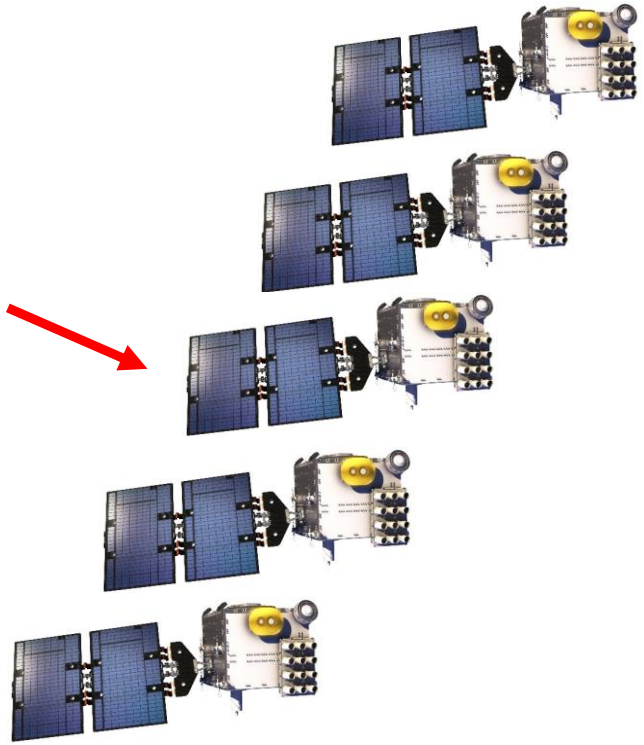
FORMOSAT-7 / COSMIC-2 Mission

- Joint mission between US and Taiwan
- Successful launch 25 June 2019
- 6 Satellites, 24° inclination
- Initial altitude of ~720 km, will come down to ~550 km one at a time

Goal: *Provide a revolutionary increase in the number of atmospheric and ionospheric observations greatly benefiting research & operational communities*



- Space Situational Awareness Environmental Monitoring (SSAEM) Sensor Package

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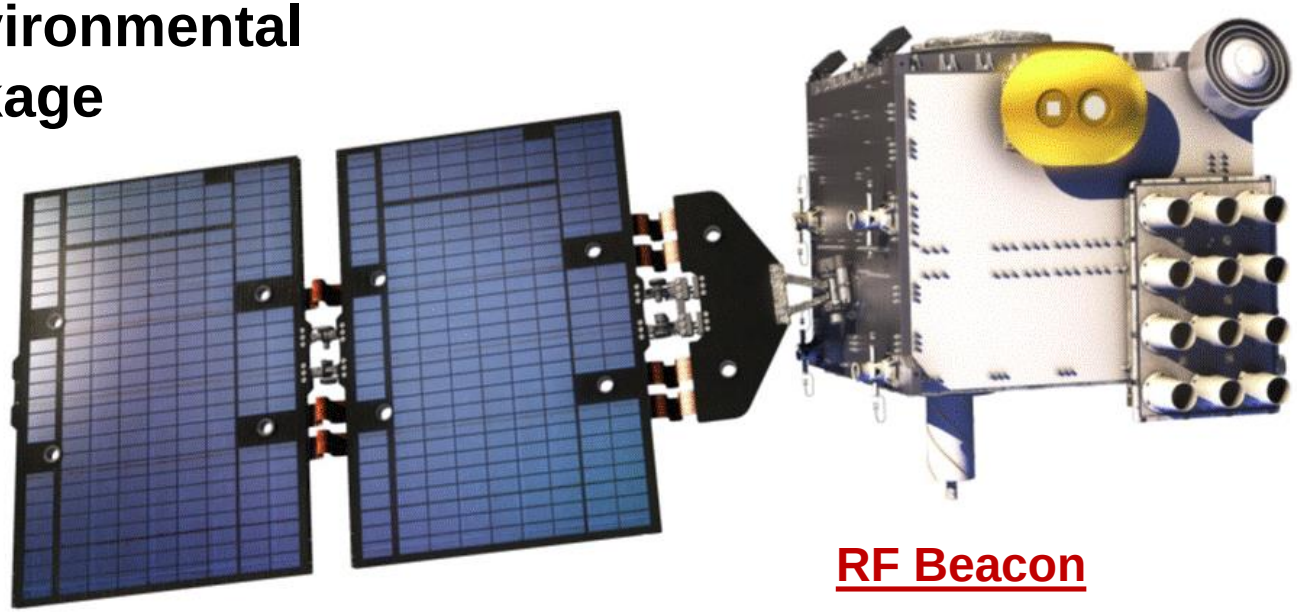
FORMOSAT-7 / COSMIC-2 Mission

Space Situational Awareness Environmental Monitoring (SSAEM) Sensor Package

Ion Velocity Meter (IVM)

Gridded electrostatic analyzers for *in-situ* ion density, temperature, & 3D drifts (E-Fields)



Tri GNSS RO Sensor (TGRS)

Fore & Aft looking RO sensors capable of tracking GPS & GLONASS at high-rates for space-based ionospheric scintillation measurements

RF Beacon

3-Frequency Beacon (plus Channel Probe) for ground-based measurement of scintillation and total electron content (TEC)

Scintillation Goal: *To develop a fully coupled system to take advantage of Space/Ground-based data from COSMIC-2 to improve the global characterization of scintillation.*

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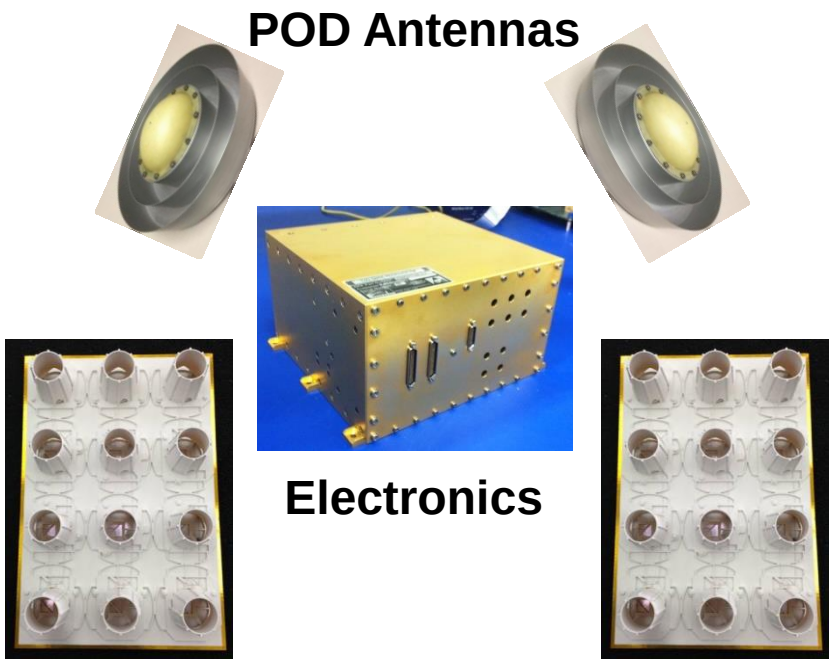
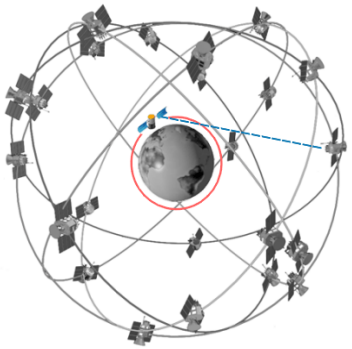
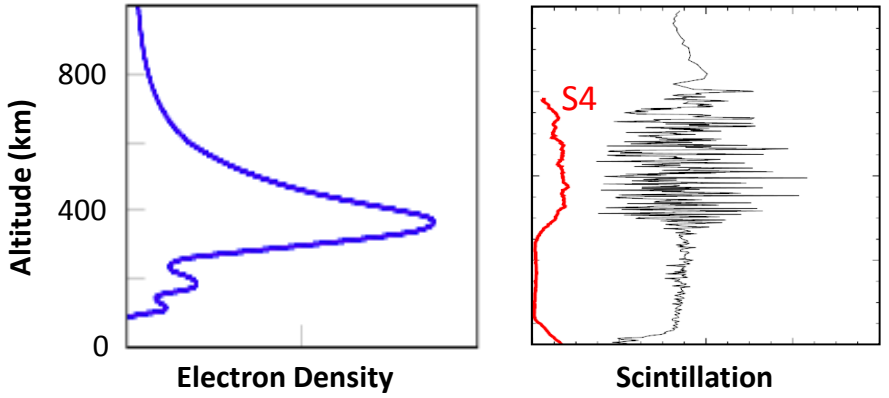
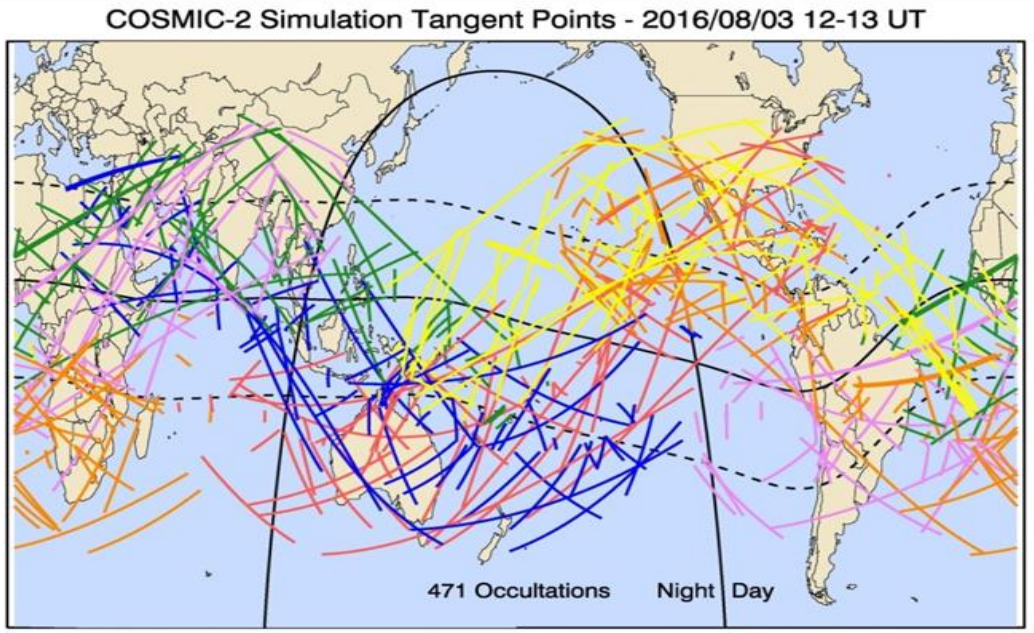
FORMOSAT-7 / COSMIC-2 TGRS







- Multi-GNSS capabilities
- Fore & Aft antennas
- Scintillation & TEC
- **>1000 occultations/day/satellite**



TGRS pictures courtesy JPL

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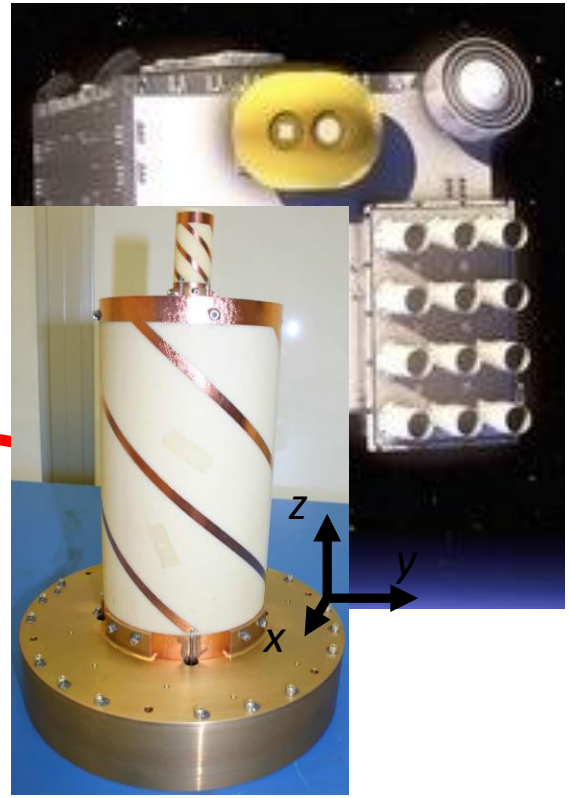
FORMOSAT-7 / COSMIC-2 RF Beacon

- <u>Three Frequency Beacon:</u>
  - UHF (400 MHz), LBAND (965 MHz), SBAND (2200 MHz)
- Nadir pointing RF Beacon Antenna
- System designed with consideration for RFI impact to other spacecraft sensors
- 100% duty cycle
- Primary products from beacon signals:
  - S_4
  - σ_φ
  - *TEC*



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FORMOSAT-7 / COSMIC-2 RF Beacon

- Ground Segment:
  - Designed to meet requirements at 20° elevation:
    - S_4: range 0 to 1.5, uncertainty to 0.1
    - σ_φ: range 0 to 20 *rad*, uncertainty to 0.1 *rad*

- This translates to an SNR requirement of 23 dB
- To meet this requirement, the team is evaluating of a Radio Frequency Beacon Receiver (RFBR) unit with a steerable antenna system
- The RFBR system collects and records raw data at each frequency with a bandwidth of 500 kHz along with processed data sets including S_4, σ_φ, and TEC in real-time

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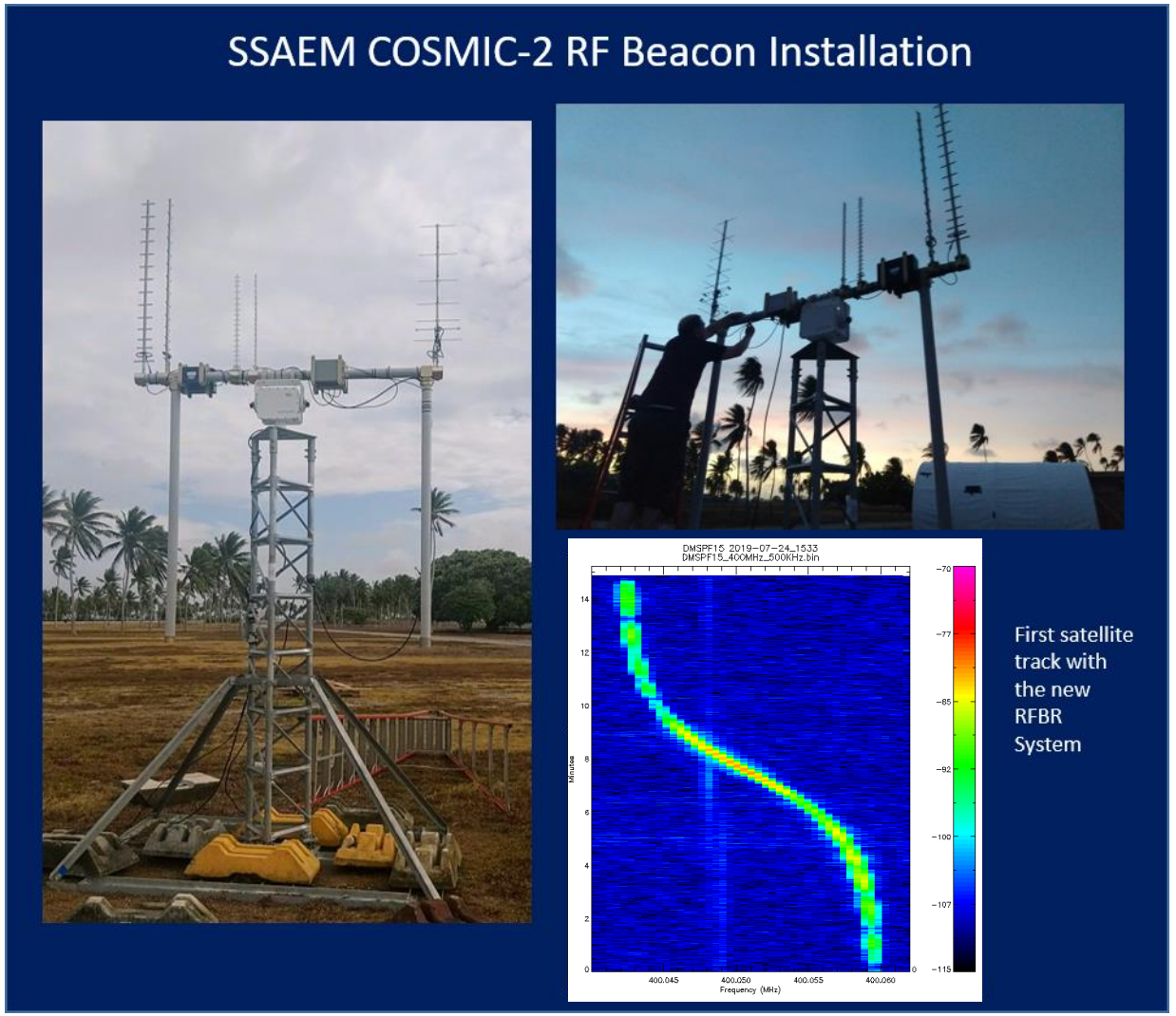
FORMOSAT-7 / COSMIC-2 RF Beacon

- The first RFBR was installed at Kwajalein Atoll with a high gain steerable antenna prior to launch
- Initial tests were performed tracks of available 400 MHz beacons in polar orbit
- COSMIC-2 launch on 25 June
- Payload Checkout in July
- Beacon instrument cycled (not transmitting)
- Scheduled to begin transmitting on 25 August



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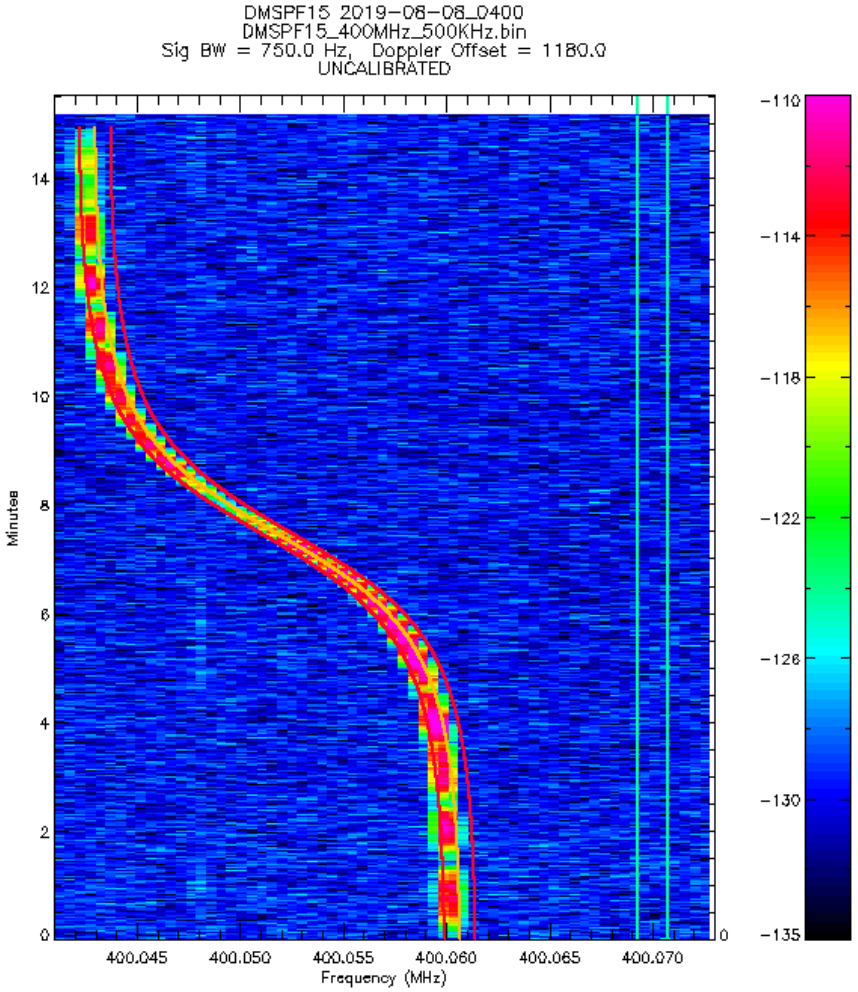
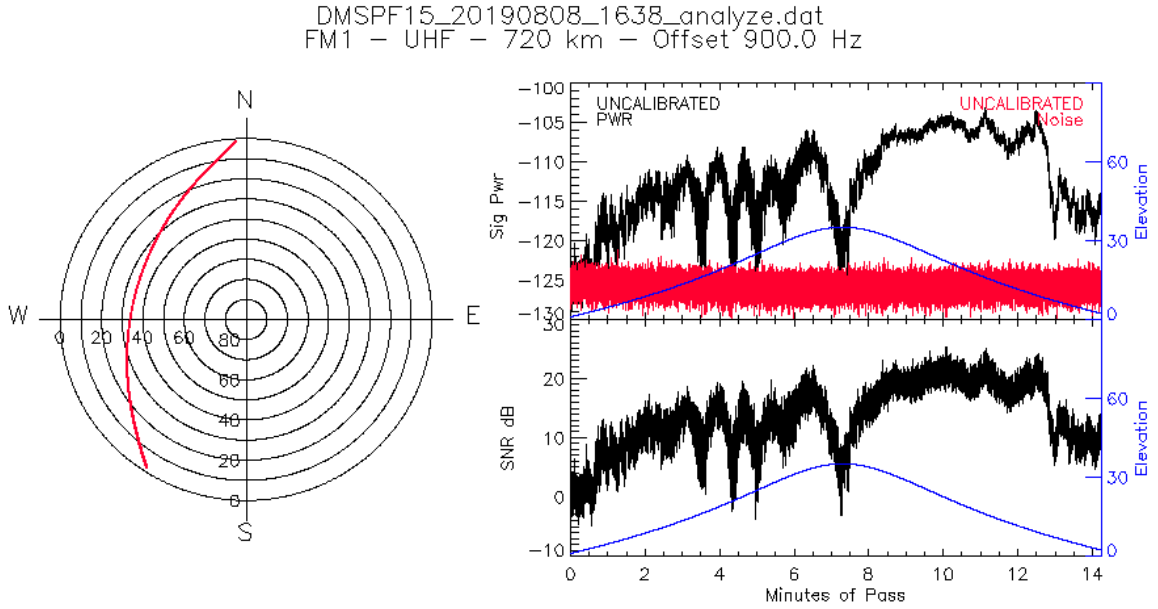
FORMOSAT-7 / COSMIC-2 RF Beacon

RF Beacon Checkout





- Intention for this talk was to show first COSMIC-2 RF Beacon observations from Kwajalein
  - instead, 400 MHz tone from DMSPF15
- Initial payload checkout slip → transmitting next week
- We'll be at Kwajalein beginning 07 Sept for RF Beacon checkout

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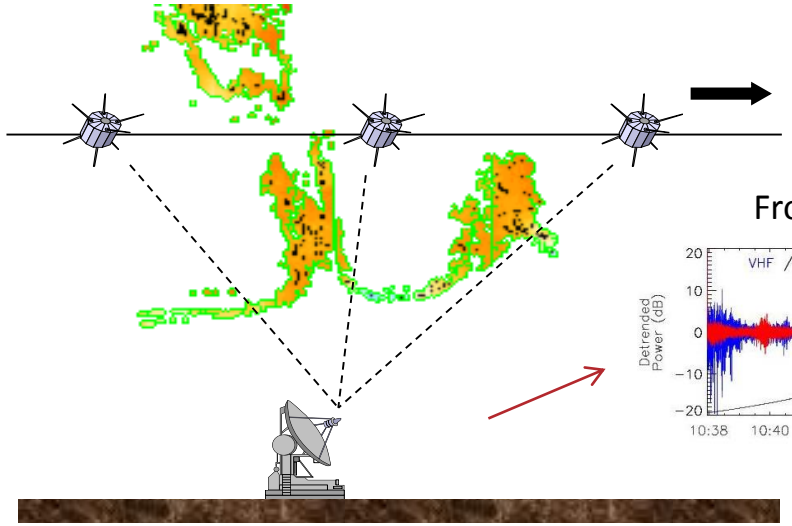
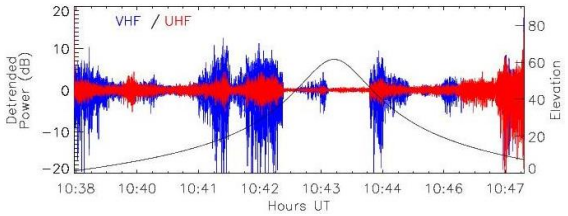
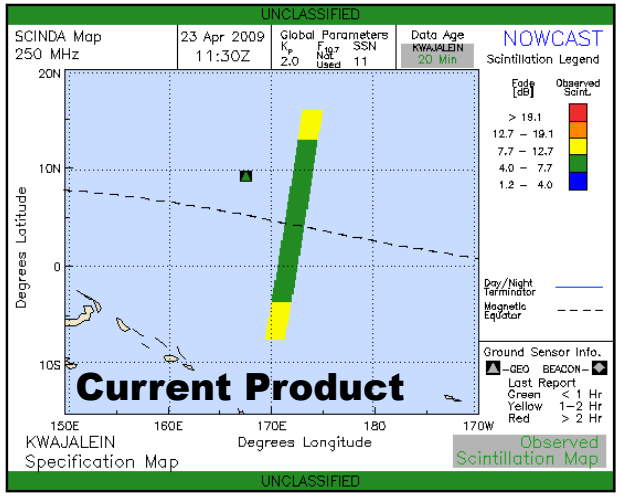
FORMOSAT-7 / COSMIC-2 RF Beacon



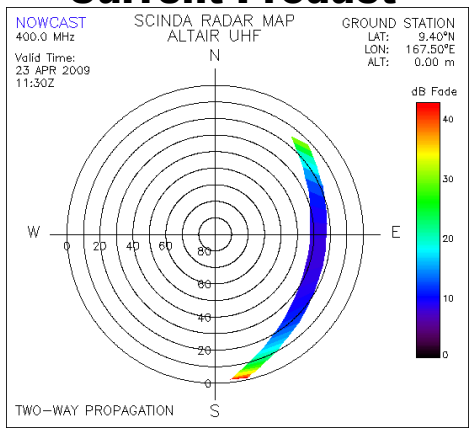
Beacon Data
From 1038 UT Overflight





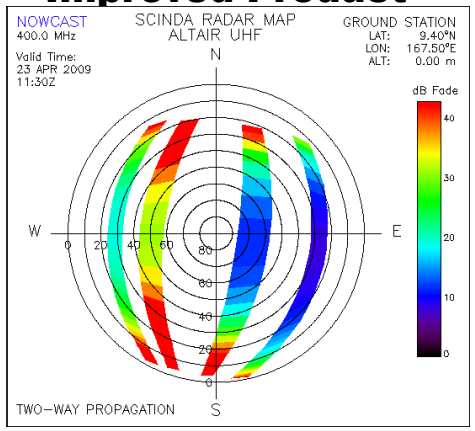
SCINDA RADAR MAP

Current Product

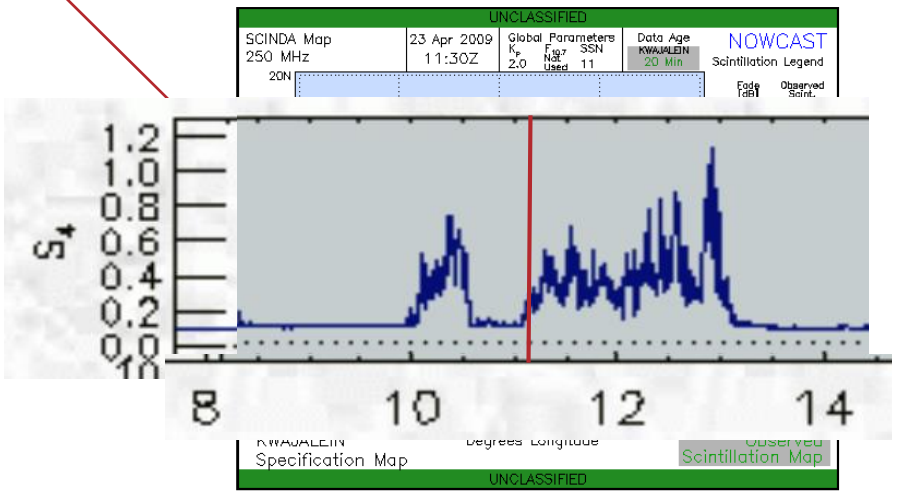


Single look direction to GEO satellite

Improved Product



Increased spatial coverage with beacon



- Improved scintillation specification
- Six satellites provide ~15 min refresh
- Expanded spatial & temporal coverage

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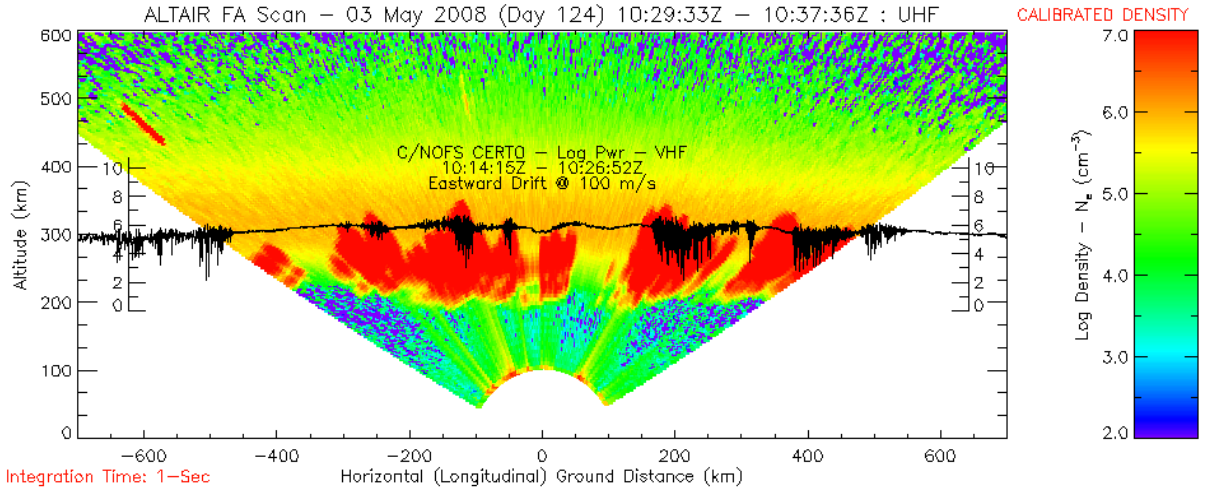
FORMOSAT-7 / COSMIC-2 RF Beacon

RF Beacon System Calibration/Validation

- An extensive Cal/Val effort being coordinated to begin in Sept 2019
- End-to-end validation including development of advanced algorithms to incorporate RF beacon data into real-time ionospheric specification tools
- Multiple RFBR ground sites
- Truth data from ground-based systems & radars
- Cal/Val to include:
  - Evaluation of beacon instrument performance
  - Mapping/Evaluation of spacecraft antenna gain patterns
  - Validation of RFBR observable parameters



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Questions?

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