COSMIC*-2: A Platform for Advanced Ionospheric Observations

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*Constellation Observing System for Meteorology, Ionosphere & Climate

The COSMIC-2 Partnership

Organization	Responsibilities
Taiwan NSPO	• 12 Spacecraft (From SSTL) • Command & control (1 ground site) • Secondary sensors for polar SVs
NOAA	• Lead US agency • COSMIC-2 ground sites • TGRS ground processing • TGRS sensors for polar SVs
USAF	• All sensors for equatorial SVs • Launch • RF Beacon ground system • RF Beacon/IVM ground processing
NASA	• TGRS TriG Electronics Development at JPL

- The COSMIC-2 constellation
  - *6 satellites at 24° inclination (Launch in May 2016)*
  - *6 satellites at 72° inclination (FY18 launch) – not yet fully funded*

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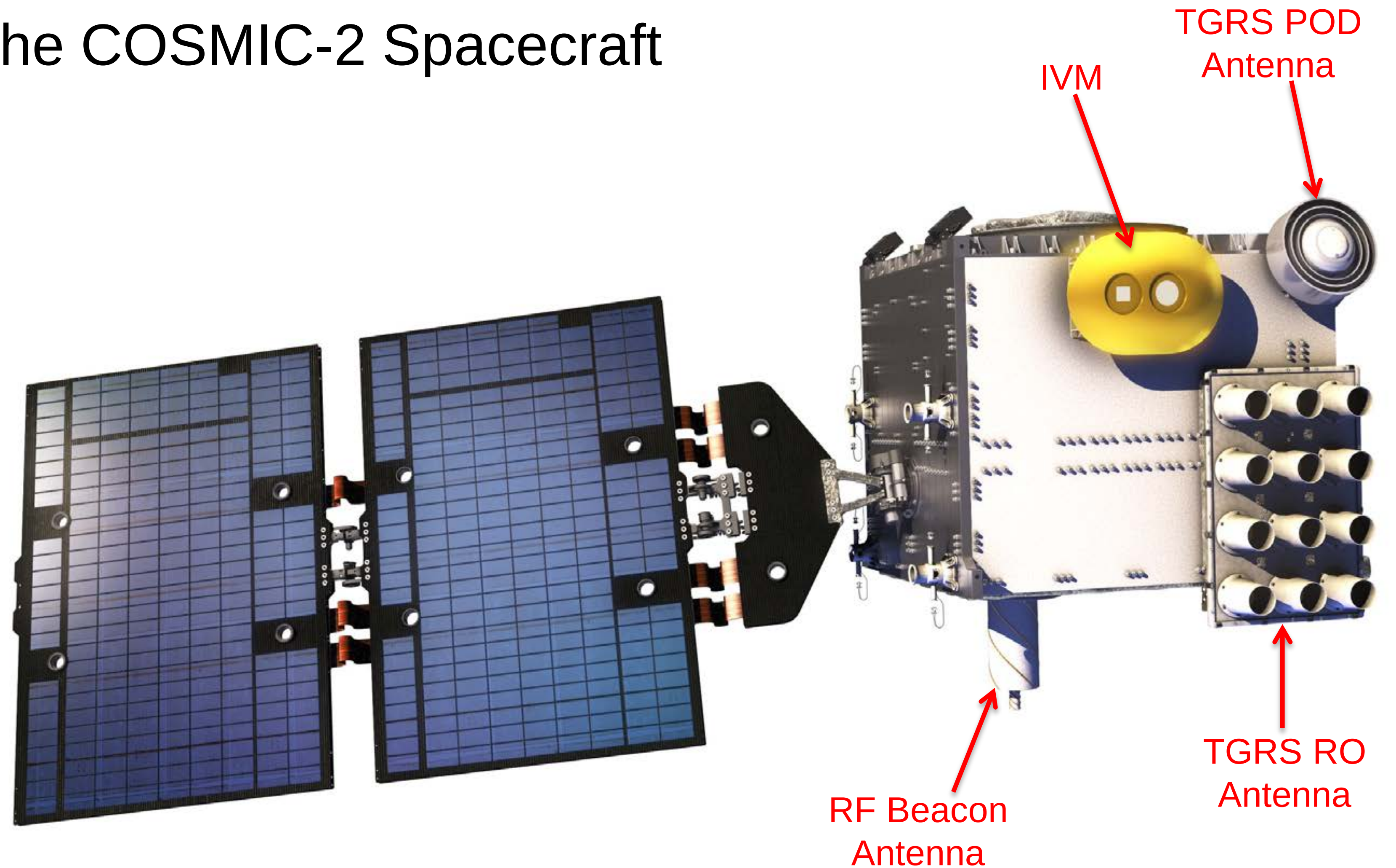
The COSMIC-2 Spacecraft



The COSMIC-2 spacecraft are being developed by Surrey Satellite Technologies Limited (SSTL) Under Contract to Taiwan's National Space Agency

Graphic courtesy SSTL

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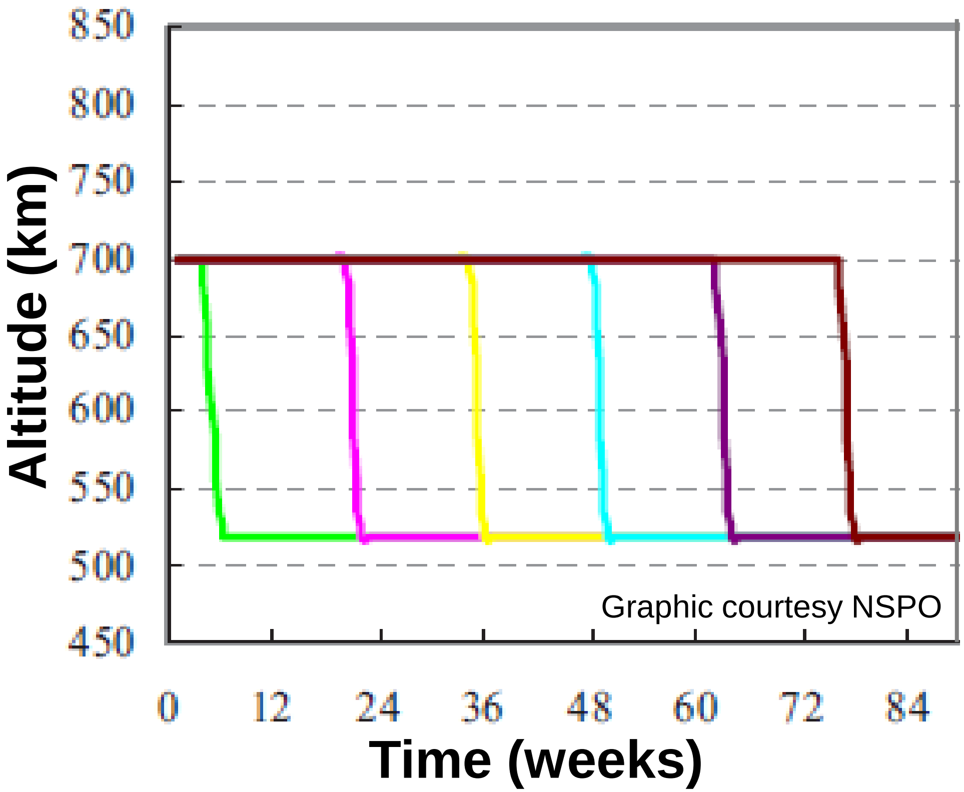
COSMIC-2 (Equatorial) Launch & Deployment



Graphic courtesy NSPO


Graphic courtesy SSTL

- COSMIC-2 (equatorial) is the co-primary payload on the STP-2 mission
- Falcon Heavy vehicle out of Cape Canaveral
- 6 COSMIC-2 spacecraft on two ESPA-Grande-like rings
- Initial altitude: 700 km
- Final altitude: 520 km (closer to F-region peak) achieved w/ on-board propulsion
- Differential orbit precession separates the orbit planes, resulting in a uniformly spaced constellation

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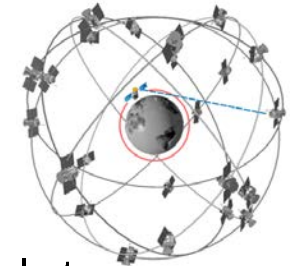
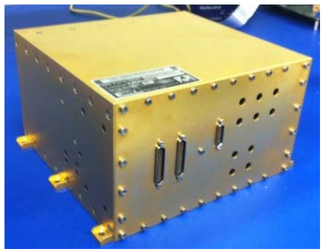
Equatorial Ionospheric Science

- COSMIC-2 will provide data that will significantly enhance operational space weather products and also improve understanding of the equatorial ionosphere
- Two focus areas
  - *Large & medium scale ionospheric structure*
    - Plasma density distribution is driven by
      - *Production and loss mechanisms*
      - *Neutral composition*
      - *Plasma transport caused by electric field and neutral winds*
    - Research focus: improvements to advanced assimilative specification models
  - *Small scale structures*
    - Plasma instabilities generate turbulent "bubble structures" containing irregularities that cause ionospheric scintillation
    - Instability regions "live within" the larger scale ionospheric background and are affected by E-fields and winds
    - Research focus: provide a complete specification of global irregularity regions to improve understanding of this phenomena
  - *Both areas are affected to atmospheric coupling from below*

TGRS GNSS Radio Occultation Sensor



POD Antennas

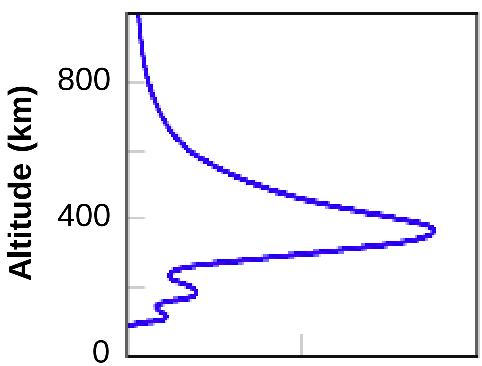


Electronics

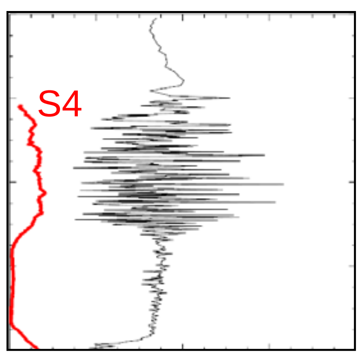
RO Antennas

TGRS pictures courtesy JPL

- Special purpose receiver tracks GPS & GLONASS satellite signals to measure carrier phase, pseudorange, and SNR
- Derived parameters
  - Limb & upward looking TEC
  - L-band scintillation
  - Tropospheric/stratospheric bending angle & refractivity
- Key inputs for both ionospheric and terrestrial weather models

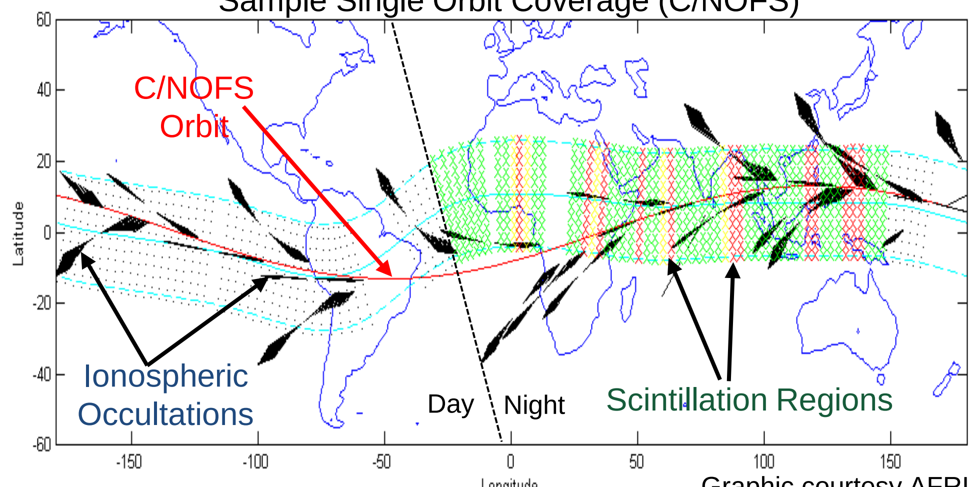


Electron Density



Scintillation

Sample Single Orbit Coverage (C/NOFS)

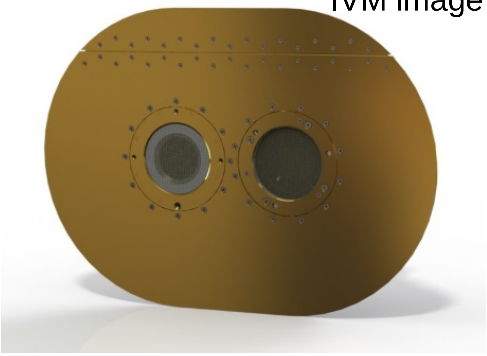


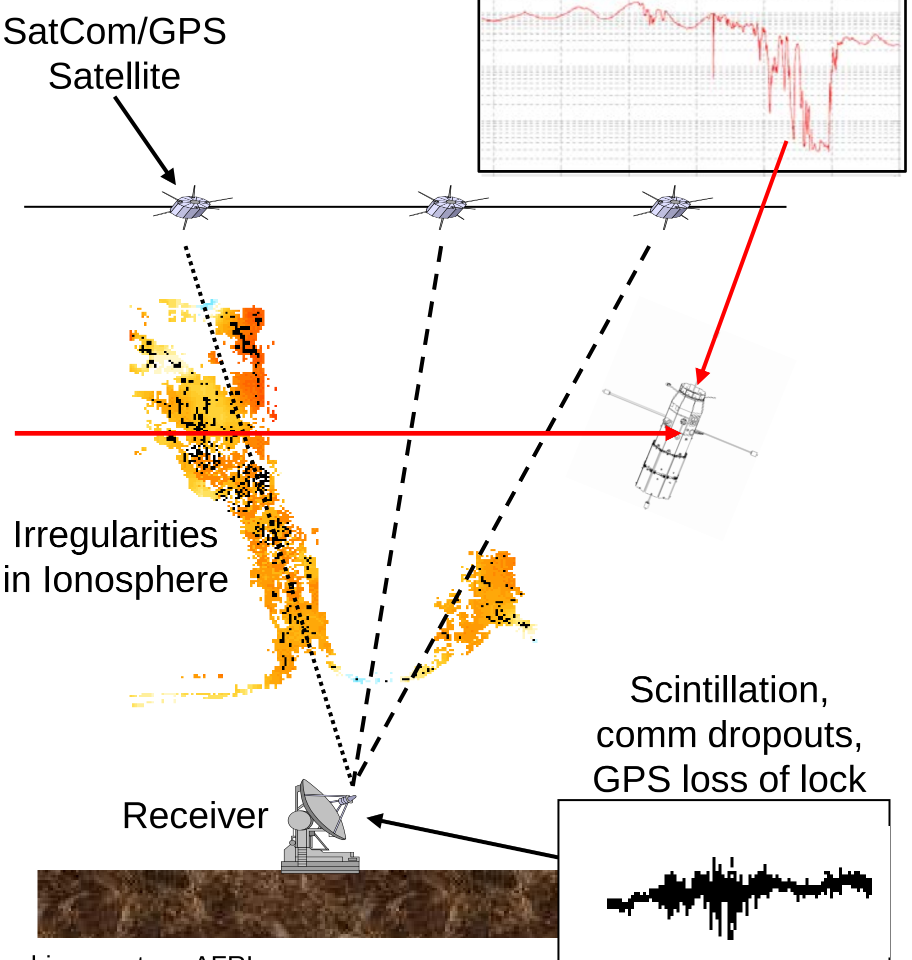
Graphic courtesy AFRL

IVM In-Situ Sensor

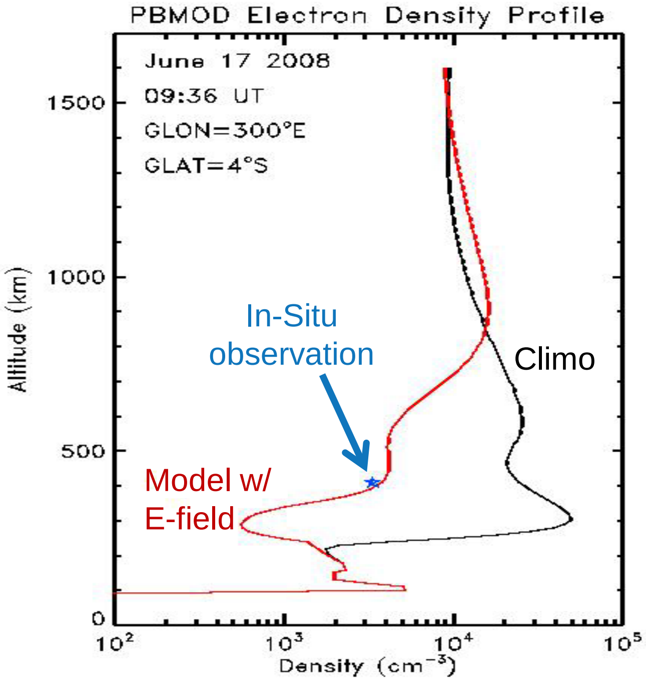
- IVM employs gridded electrostatic analyzers designed to observe & characterize in-situ plasma
- Key observations include plasma drifts (E-fields), density, and irregularity region locations
- In-situ observations near F-region peak drive COSMIC-2 (eq.) 520 km altitude

IVM image courtesy UTD





Graphics courtesy AFRL



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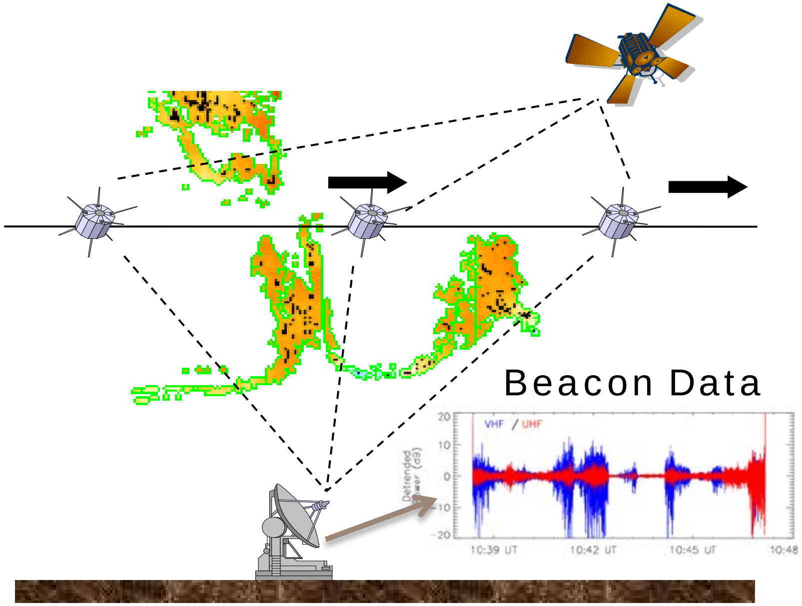
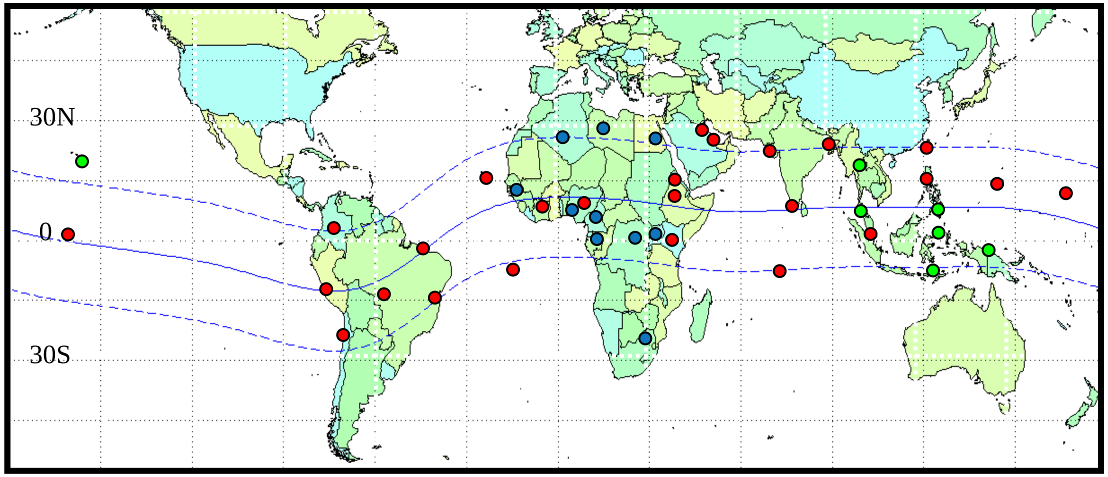
RF Beacon Sensor

- Ground-based receivers measure RF Beacon signals (amplitude & phase) to determine scintillation environment
  – 400, 965, 2200 MHz signals
- Ancillary two-frequency TEC measurements provide data for ionospheric assimilative models
- Coupling North-South morphology of irregularity regions with East-West geometry of COSMIC-2 (Equatorial) orbit enables better scintillation region mapping (relative to polar orbits)

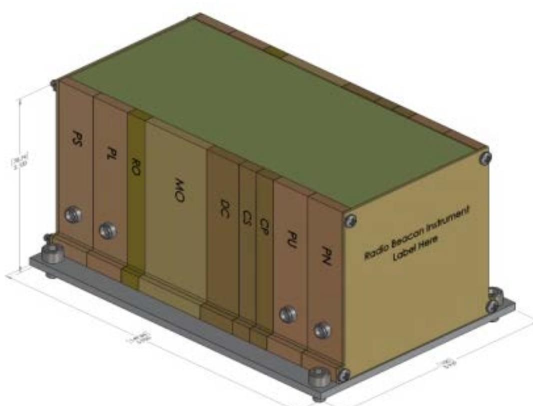


Graphic courtesy AFRL

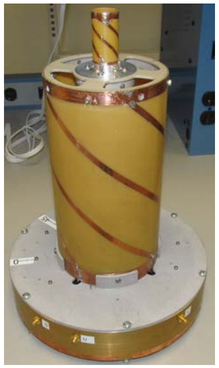
Potential RF Beacon Ground Sites



Graphic courtesy AFRL



Beacon Electronics Unit

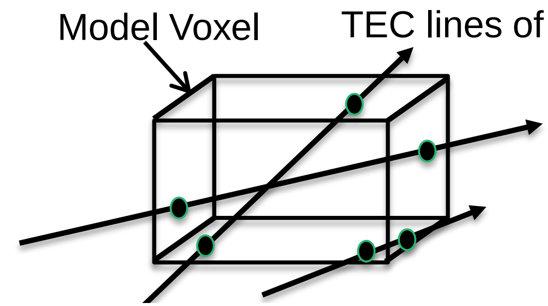


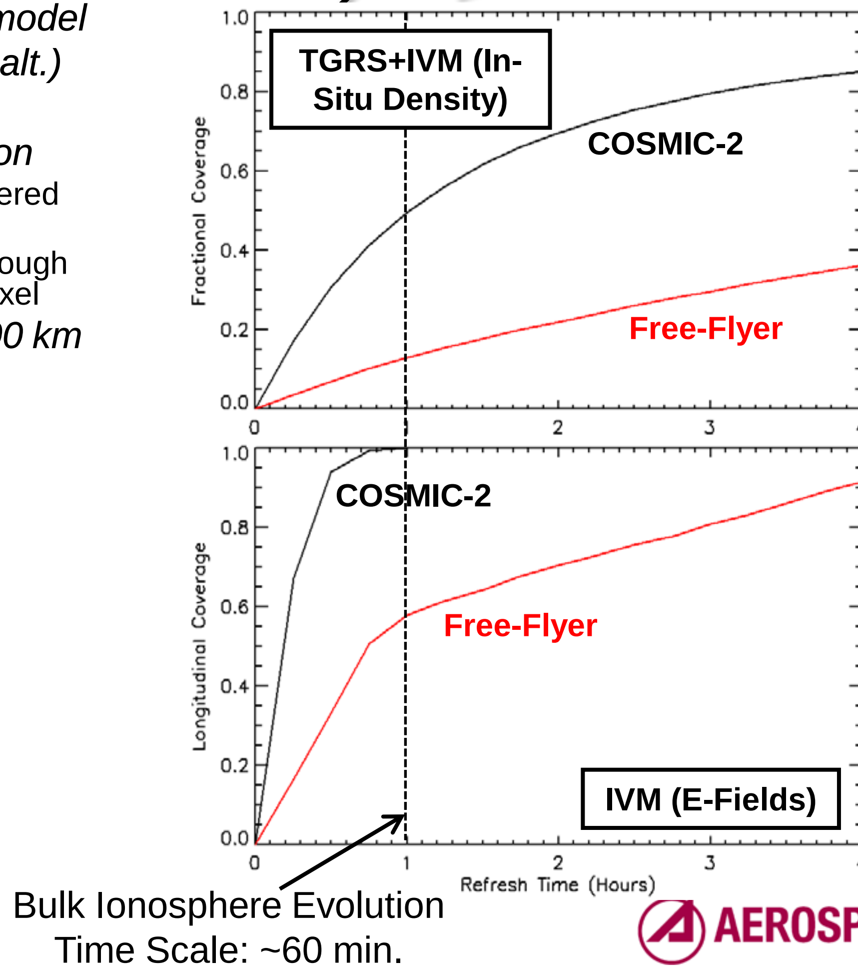
Antenna Unit

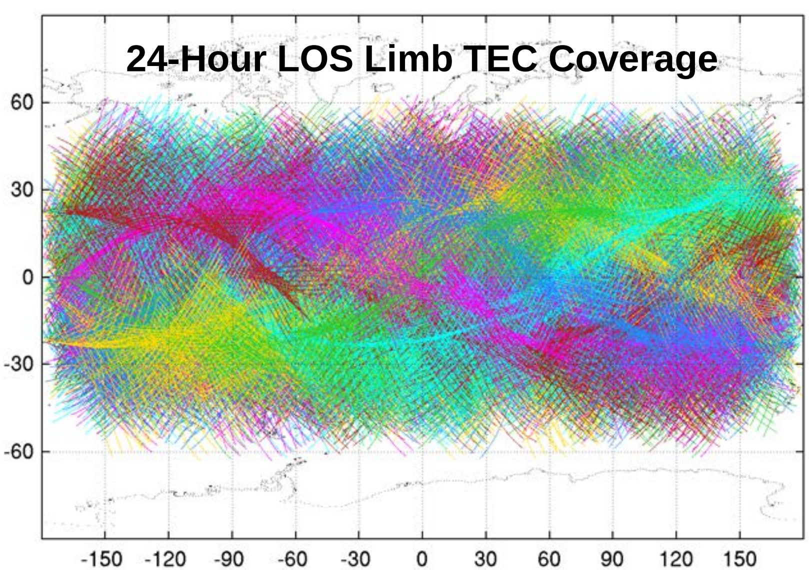
RF Beacon drawing/picture courtesy SRI

Ionospheric Characterization Via Assimilative Modeling

- COSMIC-2 (eq) will provide exceptional low latitude ionosphere coverage/refresh
  - *TGRS: limb and overhead TEC*
  - *IVM: in-situ density & E-fields*
  - *RF Beacon: regional TEC*
- Coverage analysis assumptions
  - *Evaluation of ability to “populate” an assimilative model*
  - *1°×2.5°×20-50 km voxel granularity (lat. × long. × alt.)*
  - *IVM exactly specifies voxel density*
  - *TGRS TEC data for tomographic-like reconstruction*
    - Require two observations through a voxel to be considered fully specified
    - “Data utility scoring” approach weighs LOS passing through much of a voxel more heavily than those “skirting” a voxel
  - *Analysis region: ±30° geomagnetc latitude/100-800 km altitude, bounded by 300 km field lines at ±30°*







24-Hour coverage graphic courtesy UCAR

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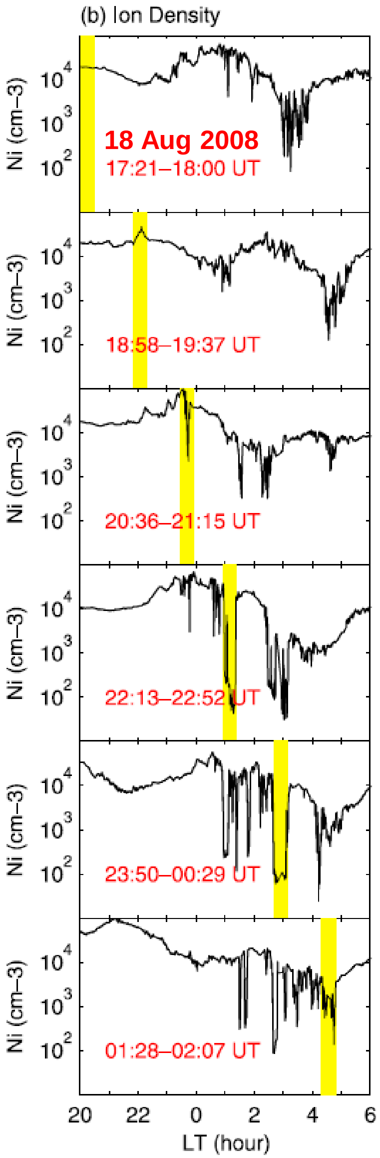
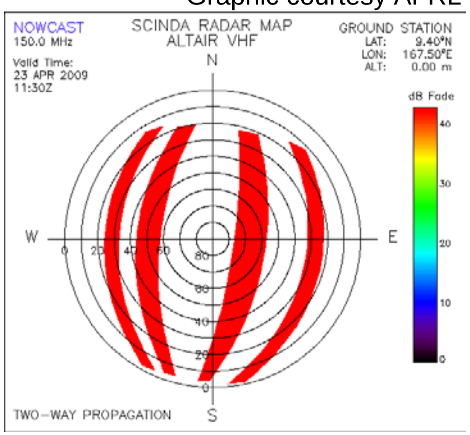
Scintillation Region Characterization



- The IVM will provide detailed information regarding localization of irregularity regions on timescales associated with their evolution
- The RF Beacon provides a precise characterization of scintillation behavior in regions with ground sites, augmented by limb L-band observations from TGRS

Graphic courtesy AFRL



RF Beacon Spatial Coverage

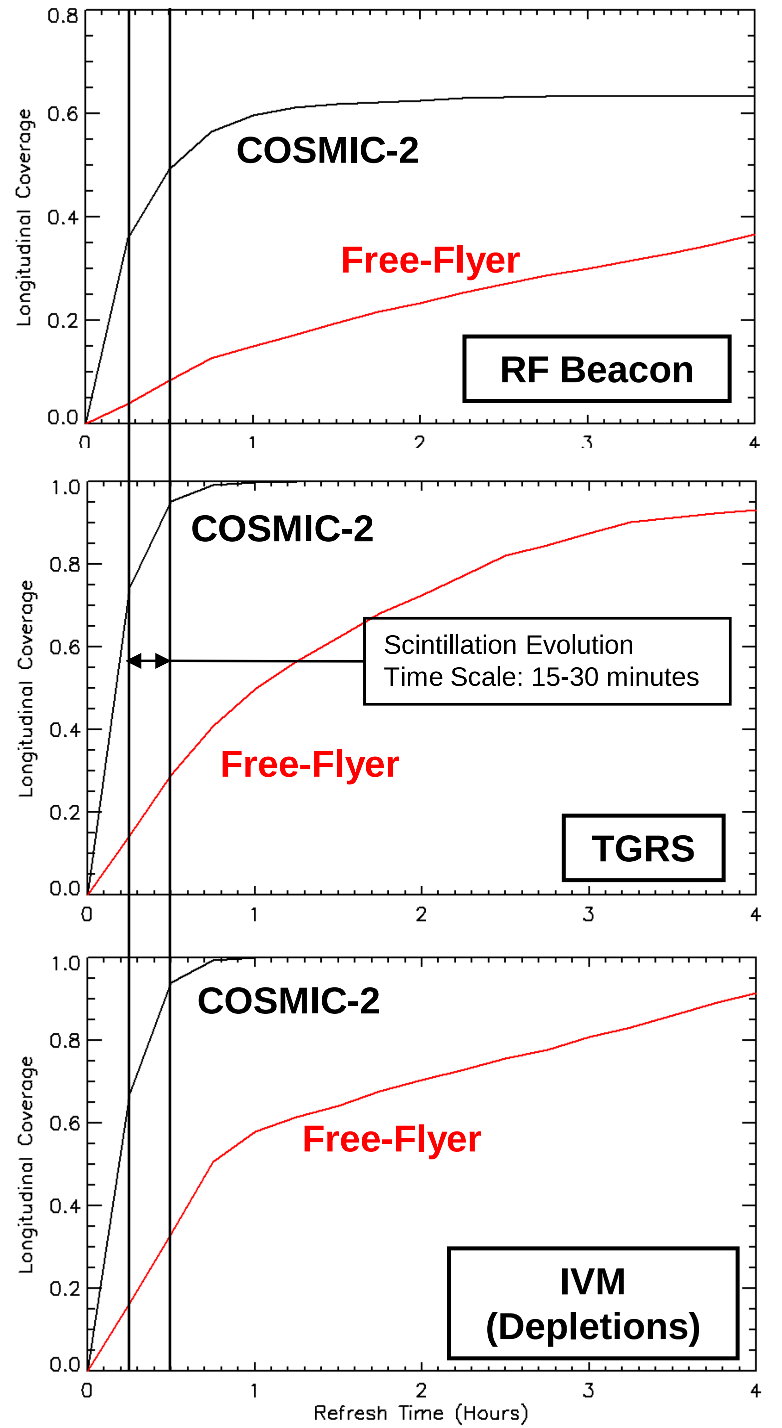
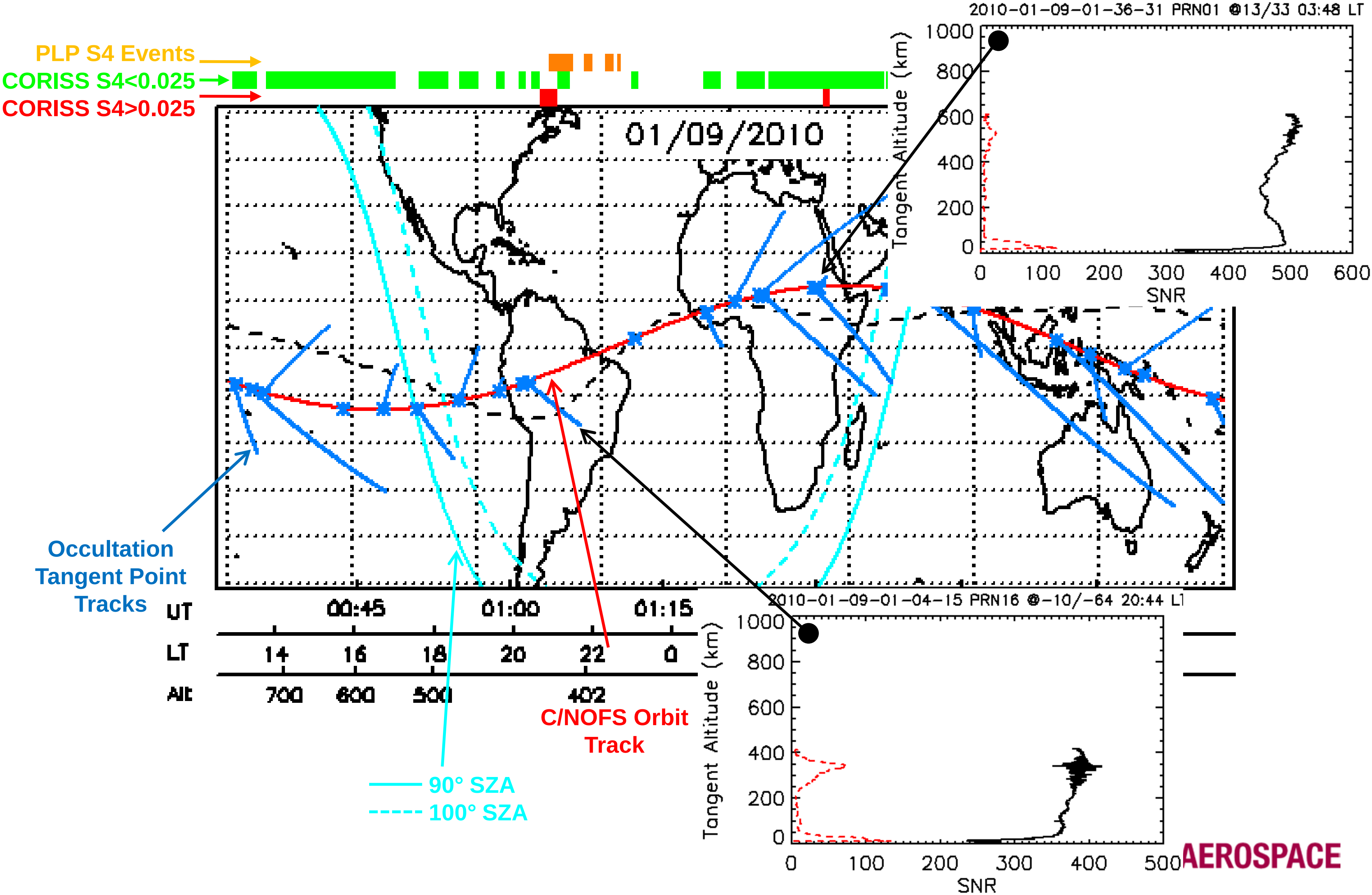


Figure from Huong, et. al., JGR , doi: 10.1029/2010JA015982 (2011).

Example RO Scintillation MAP (C/NOFS)



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Summary

- The COSMIC-2 program is on track to launch six satellites into low inclination orbits in 2016
- The sensor complement on these satellites will provide unprecedented coverage and refresh to support operational space weather applications and to advance scientific understanding of equatorial ionospheric structure & irregularities