The Scintillation Prediction Observations Research Task: An International Science Mission using a CubeSat

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What is SPORT?

A science mission to understand the preconditions leading to equatorial plasma bubbles and scintillation

6U CubeSat deployed from ISS

International partnership between NASA, the Brazilian National Institute for Space Research (INPE), and the Technical Aeronautics Institute under the Brazilian Air Force Command Department (DCTA/ITA)

Value: $7.5M mission - cost to NASA: $3M

Significant DoD interest
• Joint United States / Brazil Science Mission Concept

• United States
  – Science Instruments

• Brazil
  – Spacecraft
  – Operations

Joint Science Data Analysis
Science

• The equatorial ionization anomalies

• Plasma Bubbles

Why do bubbles form and sometimes not at Different Longitudes?


GUVI (Same Local Time, Different Longitudes)
Scintillation and GPS

Courtesy Keith Groves
Boston University
Science Goals

1) What is the state of the ionosphere that gives rise to the growth of plasma bubbles that extend into and above the F-peak at different longitudes?

2) How are plasma irregularities at satellite altitudes related to the radio scintillations observed passing through these regions?
SPORT Mission and ORBIT

Launch from ISS, 400 km Alt
~3 year life

Orbit Track

20° latitude or 1.3 hr LT across an EIA arc

Magnetic Equator

Depletions
### Measurement and Instrumentation

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma motion</td>
<td>RPA/Drift meter</td>
</tr>
<tr>
<td>Plasma density / density profiles</td>
<td>GPS Occultation</td>
</tr>
<tr>
<td>Small scale structures and waves</td>
<td>Langmuir</td>
</tr>
<tr>
<td>Scintillation Index</td>
<td>Impedance</td>
</tr>
<tr>
<td>Magnetic field structure</td>
<td>E-Field</td>
</tr>
<tr>
<td>Plasma temperature</td>
<td>Magnetometer</td>
</tr>
</tbody>
</table>

- **Instruments**
  - **RPA/Drift meter**
  - **GPS Occultation**
  - **Langmuir**
  - **Impedance**
  - **E-Field**
  - **Magnetometer**

- **GPS Occultation Patch Antenna**
- **Impedance Probe**
- **Star Camera**
- **E-field/Wave**
- **Floating Potential**
- **Ion Velocity Meter**
- **Magnetometer**
- **Nadir Velocity**
- **Langmuir**

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**Logos:**
- NASA
- AEROSPACE
- UTD
- UAH
- Utah State University
SPORT Instruments

- Ion Velocity Meter
  - UTD

- GPS Occultation Receiver
  - Aerospace

- Langmuir, E-field, Impedance Probe
  - USU

- Fluxgate Magnetometer
  - NASA Goddard
Mission ConOps

- **Launch**
- **Soft Package**
- **Installation**
- **SPORT Checkout**
- **Deploy from NANORACKS 400 km alt**
- **SPORT Operations**
  - On-orbit Operations (> 12 months)
- **Disposal 300 km alt**

Images: Charlie Gray

[Logos and affiliations]
The state of the ionosphere at early local times is related to the occurrence of scintillations at later local times.

- How does this relation vary with longitude?

Use case studies when SPORT ascending or descending node is within 17 to 24 LT sector.

Examine ~15 degree longitude sectors
**Methodology Strategy 1**

Measure the state of the ionosphere in situ at early LT with SPORT.

Observe if scintillations occur at later LT using GPS RO from SPORT.

Satellite Pass 1

92 minutes later
Earth rotates under satellite orbit

Target longitude region moves East

Satellite Pass 2

Target 1.5 hours later in local time

Scintillation detection by GPS RO
Methodology Strategy 2

Satellite Pass 1

Target longitude region moves East

92 minutes later

Night

Satellite Pass 2

Scintillation detection by in situ instruments

Target 1.5 hours earlier in local time

Measure the profile of the ionosphere at early LT with GPS RO.

Observe if scintillations occur at later LT using in situ instruments.
How often are ideal occultation

• Study using SPORT in ISS orbit.
• Over one orbit in the region within ±30°
  – ~2 profiles over the previous orbit traces
  – ~2 profiles occur over successive orbit traces.
Ground Network

- Magnetometers
- Scintillation sensors
- TEC stations
- Imagers
- Ionosondes
Value of Science

Curiosity & Knowledge vs. Application & Use

Neils Bohr
Louis Pasteur
Thomas Edison
Conclusions

• CubeSat missions can be developed with a full/regular suite of science instruments.

• Mid inclination ISS orbits allow for the deconvolution of local time and longitude at low-latitudes.

• A String of pearls mission to increase time resolution.
Backup
Neutral Winds and Conductivities

The importance of winds in different regions to triggering EPB particularly wind shears on the bottom of the ionosphere

Electrodynamics of the equatorial evening ionosphere: 1. Importance of winds in different regions
Authors A. D. Richmond, T.-W. Fang, A. Maute First Published: 7 March 2015 Vol: 120, Pages: 2118–2132 DOI: 10.1002/2014JA020934
What is the state of the ionosphere here?

That leads to bubbles here?

When bottom side seeding perturbations seem to always be present

Most ground/radar observations come from the American sector of unique magnetic geometry.
## SPORT Telemetry

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<th>Channel Name</th>
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**50 Mbit/second Downlink giving a safety factor of 14**