Tethered Satellites as an Enabling Platform for Operational Space Weather Monitoring Systems


**ABSTRACT**—Tethered satellites offer the potential to be an important enabling technology to support operational space weather monitoring systems. Space weather “nowcasting” and forecasting models rely on assimilation of near real-time (NRT) space environment data to provide warnings for storms events and deleterious effects on the global societal infrastructure. Typically, these models are initialized by a climatological model to provide “most probable distributions” of environmental parameters as a function of time and space. The process of NRT data assimilation gently pulls the climate model closer to the observed state (e.g., via Kalman smoothing) for nowcasting, and forecasting is achieved through a set of climatological and semiempirical physics-based forward prediction simulations. Many challenges are associated with the development of an operational system, from the top level architecture (e.g., the required space weather observatories to meet the spatial and temporal requirements of these models) down to the individual instruments capable of making the NRT measurements. This study focuses on the latter challenge: we present some examples of how tethered satellites from 100 m to 2 km are uniquely suited to address certain shortfalls in our ability to measure critical environmental parameters necessary to drive these space weather models. Examples include long baseline electric field measurements, magnetized plasmasphere conductivity measurements, and the ability to separate the temporal from spatial irregularities in environmental parameters. Tethered satellite functional requirements are presented for two examples of space environment observables.

**Motivation**

- The Near-Earth Space Environment varies over spatial and temporal scale sizes covering many orders of magnitude
- Cross-scale coupling between physics processes often plays an important role in the instigation, evolution, and dissipation of each other
- Plasma waves and instabilities imply spatiotemporal complexity, which presents a challenge to separate temporal evolution from spatial propagation and deformation

**Unique Capabilities of Space Tethers**

- Multipoint In-Situ Measurements
  - Long Baseline (up to 20 km) electric field measurements
  - A more efficient VLF antenna for remote sensing (WLF probe of magnetosphere)
- Fixed distance transmitterreceiver for radio wave probing of ionospheric layers between the two s/c (e.g., via Faraday rotation, phase shift irregularities indicating changes in TEC, etc.)
- Fixed distance electron gun/imagers for probing ionospheric E-region electric fields (e.g., if deployed downward by space plane at 110 km, can image auroral emissions stimulated by downward propagating beam to map neutral electric fields)

**Basic Electrodynamic and Tether Physics**

**Example Technique Proven**

Observations from AE-E IMF data (Table of [110]) show similar behavior as the spherical model followed by more shallow ones as the center moves to the satellite. The change in separation of spatial versus temporal effects

**Example Technique Proven**

Measurement to enable Science Closure: A low altitude (<100 km) tethered satellite would provide simultaneous multimeasurements of both large and small plasma structures

**Enabling Technology For Space Weather Tethers**

- Tethers for CubeSats
- ISS & CubeSat launches
- Sounding Rocket Tethers

**Enabling Technology For Space Weather Tethers**

- Tethers Unlimited (TRL) CubeSat
- Enables Cubesat with miniature plasma and/or field sensors
- NanoRack launches Cubesats via ISS
- Enables launch tethered Cubesats into low altitude orbit
- Tethered Sounding Rocket Sections
- Enables unique observations of space environment (e.g., E|B, plasma turbulence)

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