Ionospheric TEC Mapping through a 3U CubeSat Mission

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1 Introduction

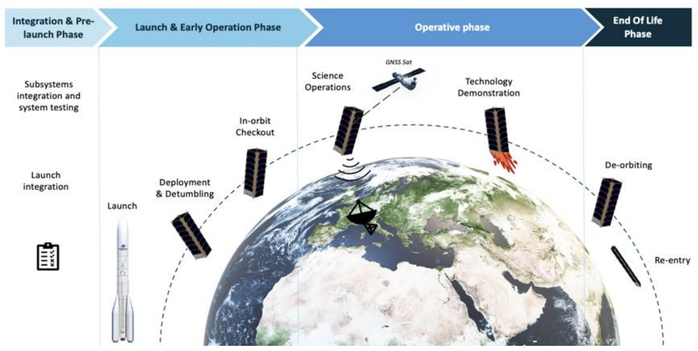
Post-processed ionospheric data, coming from **CubeSats**, offer valuable insights into space weather effects in the LEO region, with a particular focus on **Total Electron Content (TEC).** CubeSats observe beyond the **F2 layer**, unreachable by ground-based receivers, enables *multilayer* ionospheric mapping by combining space- and ground-based data.

This improves ionospheric modeling, GNSS accuracy, and mitigation of space weather-related disruptions in satellite communications. Italy's scientific community, especially INGV, is supporting the ELECTRA CubeSat mission to advance research in **ionospheric dynamics** and space weather forecasting, highlighting the increasing role of CubeSats in scientific and technological *innovation*.

2 ELECTRA Mission & System Overview

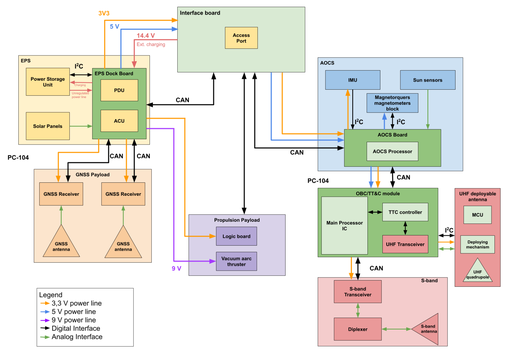
2.1 ELECTRA Mission

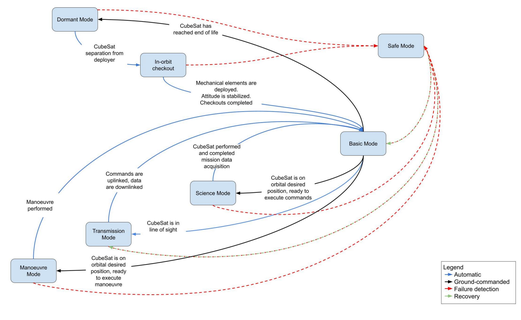
The ELECTRA - *Electron Layer Exploration using CubeSat for TEC Research and Analysis* mission is a **3U CubeSat mission** with the primary goal of analyzing and mapping the **ionospheric TEC** in LEO using **dual frequency GNSS signals**. Additionally, the mission acts as a demonstration for an innovative **solid-state micro thruster**.



2.2 ELECTRA System

ELECTRA's system is a 3U CubeSat with **propulsion capabilities**, through the *Solid-State Propulsion* micro-thruster to be tested in-orbit, and an **in-house AOCS.**





2.3 ELECTRA GNSS payload

The GNSS payload includes two *AsterRx-m3 Pro* **GNSS receivers** and two *TAOGLAS GVLB258.A* **GNSS Antennas,** positioned one pointing to *zenith* and the other pointing towards the *direction of the velocity vector*.

Signal Tracked	Frequencies
GPS	**L1 C/A, L1C**, L2C, L2P, **L5**
Galileo	**E1**, E5 AltBOC, **E5a**, E5b, E6

Downlinked data includes essential telemetry for *estimating TEC* and *performing POD*, such as *pseudorange*, *pseudorange rates*, and *carrier phase measurements* plus additional info such as *timestamps* and *C/N0*.

3 TEC Mapping in ELECTRA

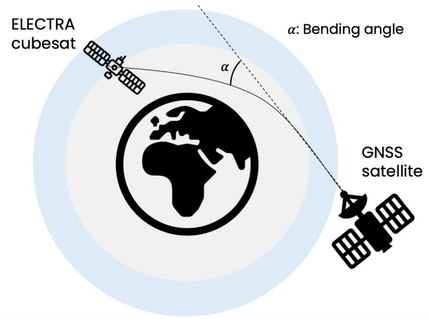
3.1 STEC estimate from GNSS measurements

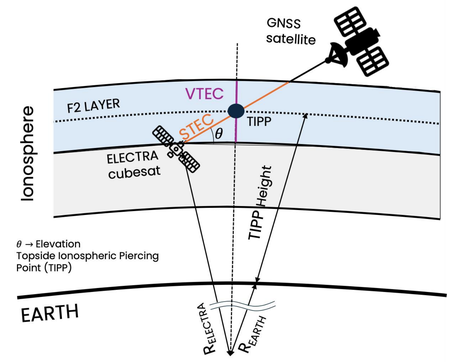
The **Total Electron Content** (TEC) is an important parameter for applications such as weather forecasting and geophysical studies. It is defined as the integral of electron density along the signal path L between the transmitter and the receiver.

$$TEC = \int n_e dl = -\frac{f}{40.3}\int (n-1)dl$$

where, n_e is the electron density, n is the refractivity index of the ionospheric medium and f is the radio wave frequency. Slant TEC (STEC) can be estimated using the different effects of the ionosphere on L1/E1 and L5/E5 GNSS signals, applying the **ionosphere-free combination**. The STEC is measured in TEC units, where 1 TECU equals 10^{16} electrons/m².

3.2 Radio Occultation and Precise Orbit Determination antenna

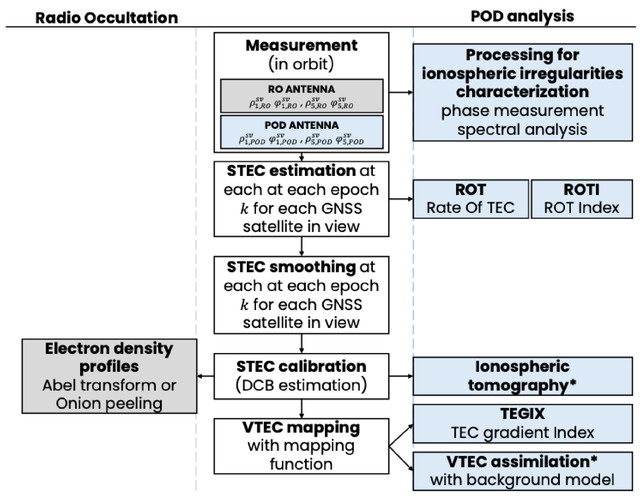




3.3 Data processing and analysis

The ionosphere is analysed through a specific *processing pipeline* that, depending on the data source (POD or RO) can produce indices such as **electron density profiles** or **ROT, ROTI, TEGIX ,VTEC** and indexes to **study ionospheric irregularities**, respectively.

- ELECTRA → single satellite → **single-track analysis**
- If future *constellation* → **ionospheric tomography** or **VTEC assimilation**



4 Conclusion

Besides its primary objective of studying the ionosphere, the ELECTRA mission also serves as an important first step toward evaluating the feasibility of a **future constellation** of similar CubeSats. Such a *constellation* would not only enhance ionospheric sensing capabilities but also enable global mapping of **Total Electron Content** (TEC) and **ionospheric tomography**, in support to *space weather* monitoring and forecasting.

5 References

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Peter J. Teunissen and Oliver Montenbruck, eds. Springer Handbook of Global Navigation Satellite Systems. Cham: Springer, 2017