Constellation for Measurements of Near Earth Weather in Space (CME-NEWS)

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Requested

Real operative D3S SWE mission

Featuring

- Scientific quality measurements
- High TRL components
- Rapid development time
- Low cost

We propose to apply

- Novel techniques used in the development of new commercial small satellite applications
- Newly developed and up-to-date methodologies

New Space

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CubeSat constellation

can be applied to achieve the objectives which shows that disruptive technologies can be utilized in creating high quality operative space systems

Operating at LEO

Advantages in delivery time and cost

- COTS components
- A number of successful IODs during the past 5 years
- Existing small satellite assets with successful flight heritage
- More already waiting for launch during the next few years

Advantages of Constellation and Distributed Space Weather Sensor System (D3S) approach

- Retains the potential to be scaled up later on for better performance and both time and spatial resolution
- Upgrading of the payload technology in a cycle of a few years at modest cost

Traditional large platforms

- Considerably longer lead time for a new mission
- Considerably higher cost of for development and launch
- A fixed system for at least the following decade
- Due to the long development time, payload at least 10 years old technology already by the time of launch

+ Bigger, more powerful and more versatile payload possible
+ Radiation hard technology proven to operate longer time
+ More powerful telemetry and on-board computer systems
+ Bigger data storage and better data handling system

THUS

BOTH ARE NECESSARY AND COMPLEMENT EACH OTHER

LET'S COMBINE THEM

The proposed CME-NEWS includes a constellation of CubeSats with selected SWE payload

Designed to fly in Low Earth Orbit

Payload for Space Weather measurements that provide needed but non-existing (or scarce) near Earth data, and constellation that enables sufficiently dense grid of measurement points to enable global space weather maps that are verified by in-situ measurements

- Indications of upcoming events and their intensity by monitoring solar X-rays
- Maps of RF signal propagation variations and radiation intensity based on in-situ measurements and data-based ionospheric models
- Validation of Space Weather models derived from data of higher orbit space weather platforms
- Data assimilation to gain better spatial and temporal resolution of space weather nowcasts/forecasts
- Ultimate goal: The forecasts fulfil the operational needs of aviation (ref. PECASUS), and also the needs of other user sectors

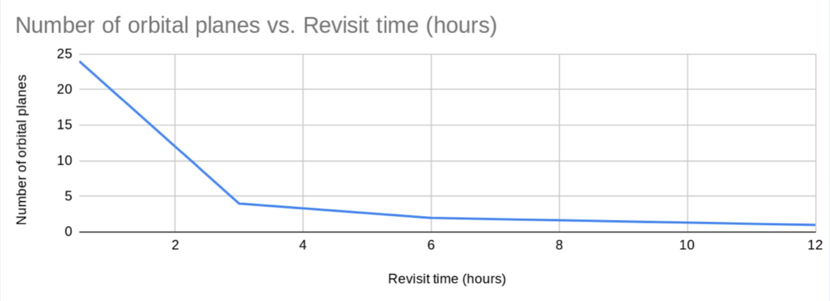
Constellation design concept

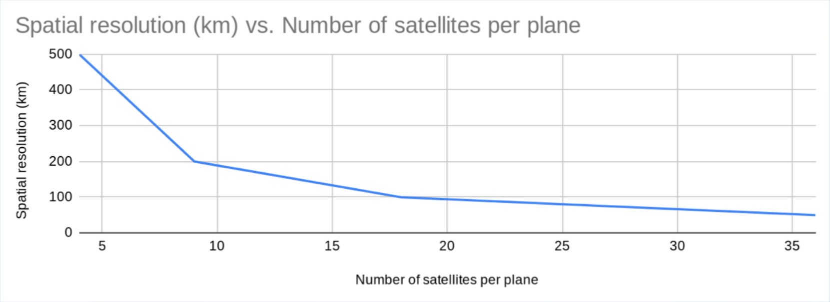
Polar areas targeted with high spatial resolution and fast revisit time.

Polar coverage by a Walker star constellation:

- Polar orbits in multiple RAAN planes
- Widely available rideshare SSO launches can be used too
- The amount of satellites on an orbital plane increases the lowest latitude fully covered by the constellation
- Number of orbital planes increases the time resolution

Polar orbits provide simpler constellation deployment and ramp-up





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Ramp-up concept

Phase 1:

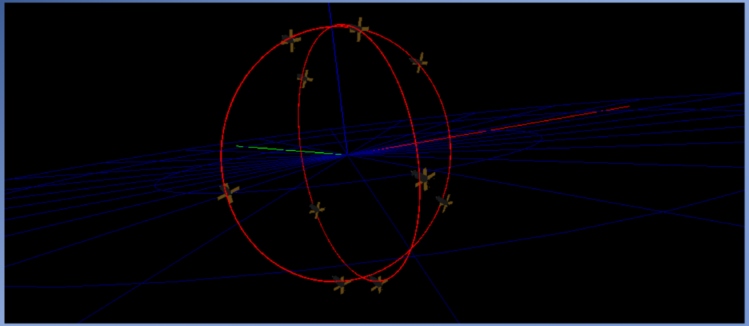
- Initial constellation, 5 A-satellites on each 2 orbital planes = 10 A-satellites
- 2 X-satellites in terminator orbits
- 6 hour refresh rate, constant coverage above 70 degrees latitude

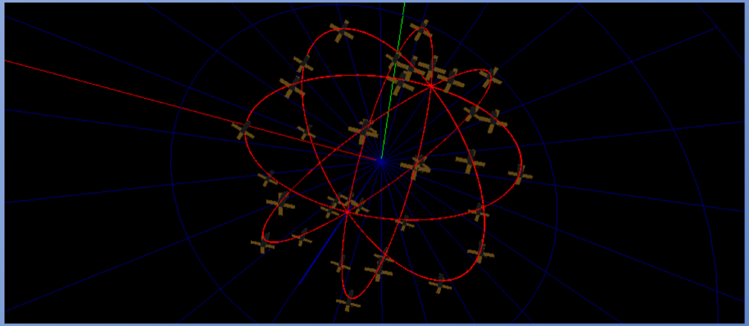
Phase 2:

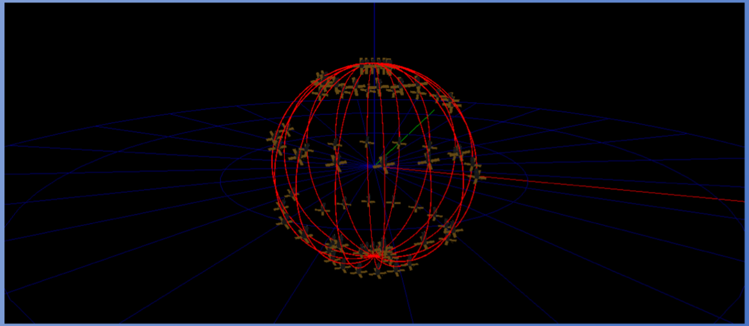
- Medium constellation, 9 A-satellites on 4 orbital planes = 36 A-satellites
- 3 hour refresh rate, constant coverage above 50 degrees latitude

Phase 3:

- Full constellation, 9 satellites each on 8 orbital plane = 72 satellites total
- 1.5 hour refresh rate, constant coverage above 50 degrees latitude







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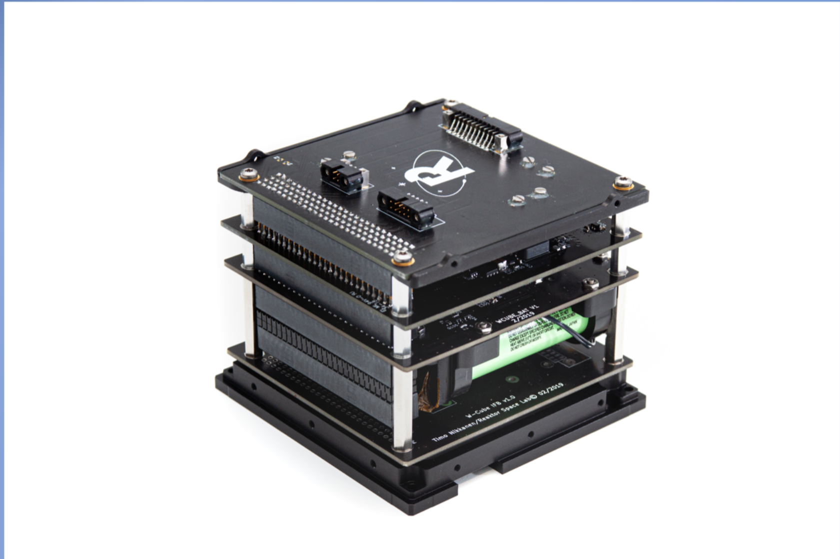
Communication options

Challenge is to achieve fast response time. Data rate can be relatively low.

Option 1: Ground station network
- Simplest option, requires multiple ground stations but remains scalable

Option 2: Inter-satellite link (ISL)
- More complex but does not require widely distributed ground stations from start to finish

Option 3: ISL using a telecommunication constellation
- Existing implementation using Iridium etc. Radio (ITU) licensing is really challenging, especially in Europe



RSL avionics stack

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Reaktor Space Lab in-house subsystems

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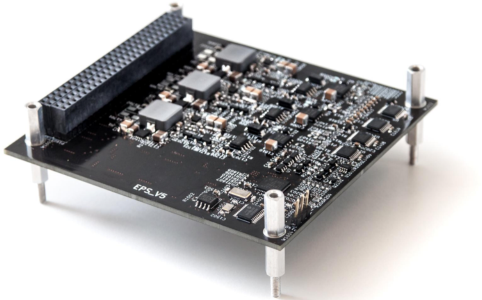
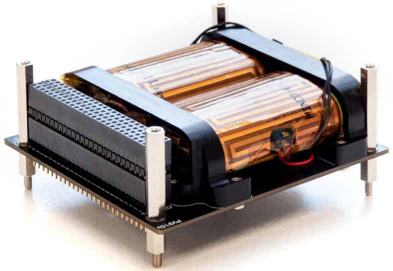
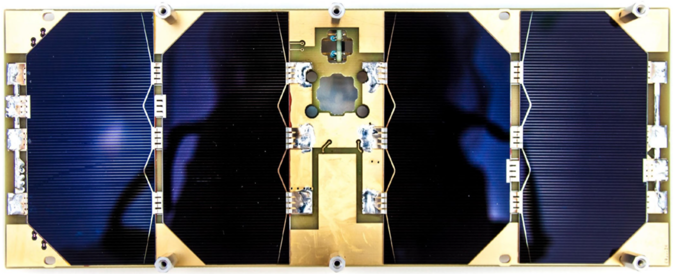
S-Band radio
TRL 7 / 9



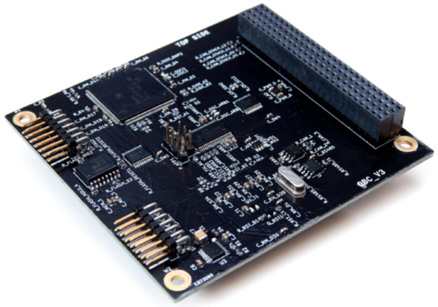
Power supply
TRL 9



Battery pack
TRL 7 / 9



Solar panel
TRL 9



Onboard computer
TRL 9

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CME-NEWS A-Satellite

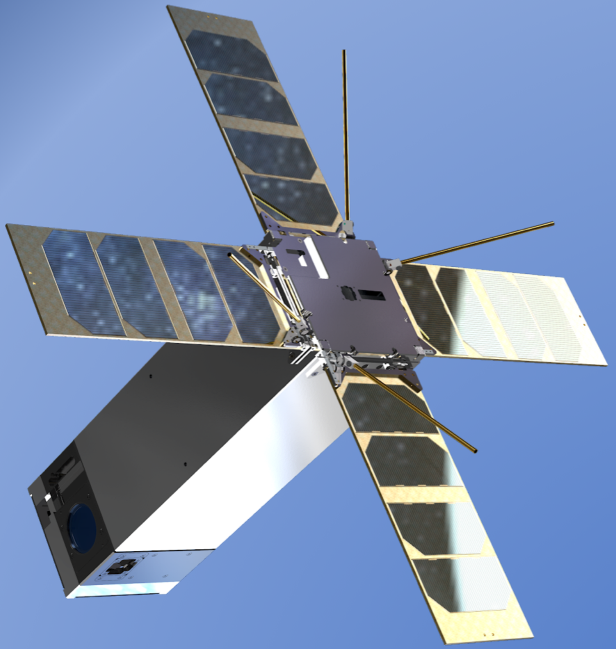
Radiation tolerant 3U CubeSat design

Platform

- Low power consumption S-Band radio and ISL (TBC)
- ARM-based onboard processor
- Precise sun-pointing attitude control system
- Deployable panels
- 0.5U Propulsion module
- GNSS receiver integrated in the OBC board

Payload

- Radio beacon
- Particle instrument
- Radio spectrometer



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CME-NEWS X-satellite

Baseline: SUNSTORM IOD

- 2U CubeSat with XFM-CS payload

SUNSTORM Mission

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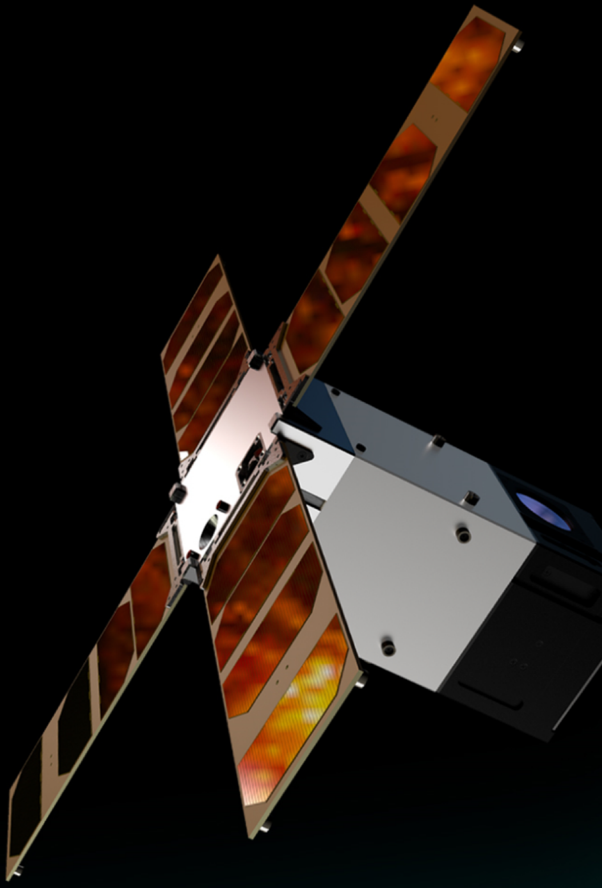

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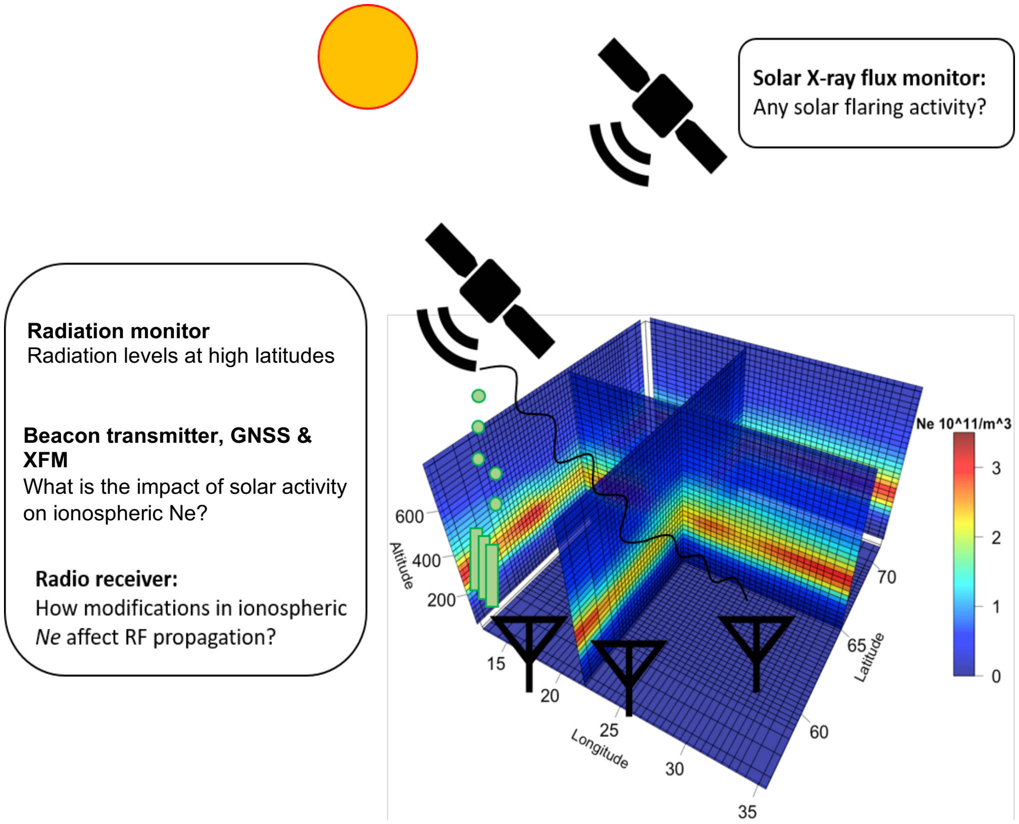
Logic of measurements

Monitoring simultaneously the solar activity, ionospheric electron density variations and disturbances in RF wave propagation enables the characterization their relationships, and derivation of RF propagation effects in each measurement path from groundbased radio transmitters to satellite receivers.

Monitoring of high energy particles enables characterization of radiation levels at high latitudes

Instruments

- **Solar X-ray Flux Monitor (XFM)**
- **Radio spectrometer**
- **Radiation monitor**
- **Radio beacon transmitter**



XFM-CS (X-ray Flux Monitor for CubeSats)

Physical properties
Mass: 0.6 kg, Dimensions: 10 x 10 x 8 cm^3
Power consumption: 1.8 W (normal case), 2.7 W (extreme case)
Detector: Si drift detector, 0.6 mm circular aperture, FoV 10 degrees

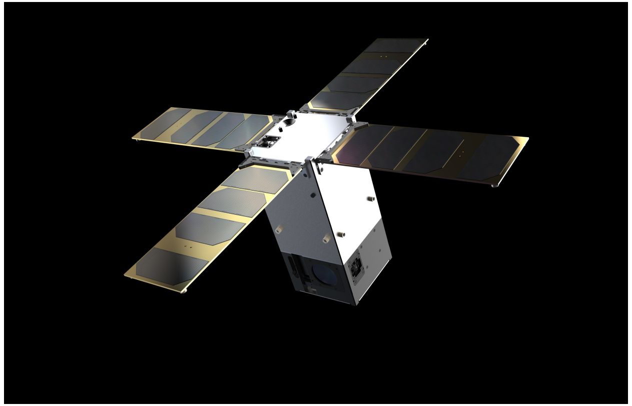
Performance
Spectrum resolution: 160 eV @ 6 keV (BOL)
Sensitivity: 2.5 cps (A 2 flare), 255000 cps (X10 flare), GOES Long

Data
Data rate: 75.5 bytes/s (default)

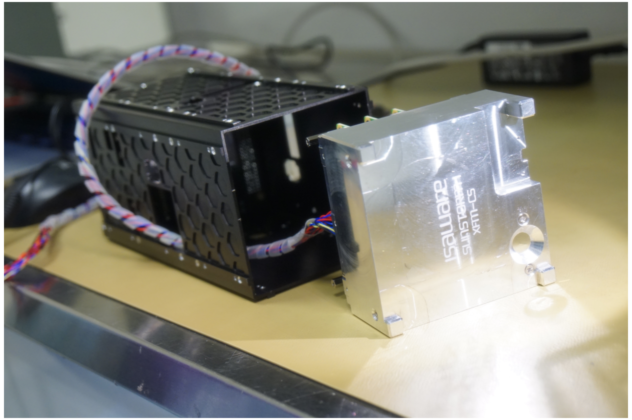
Spectrum
1 - 30 keV range, divided in 512 equally spaced channels
Integration time: 60 s/spectrum (default, adjustable 1 – 60 s/spectrum)

Flux channels	**GOES Channel correspondence**
CH 1: 1000 -1550 eV;	
CH 2:: 1550-3100 eV;	GOES Long: CH2+CH3+CH4
CH 3: 3100 - 6200 eV;	GOES Short: CH3+CH4+CH5
CH 4: 6200 - 12400 eV;	
CH 5: 12400 - 24800 eV;	
CH 6: 24800 - 30000 eV;	

Integration time: 1 s



SUNSTORM 1 (2U CS, payload: XFM)



XFM-CS (EQM) & CubeSat mechanical interface test unit

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Radiation monitor

Rami Vainio et al.

Based on Aalto-1/RADMON (TRL 9), but with significant improvements to cover

- Protons: 10–250 MeV, ten differential channels
- Electrons: >1 MeV, five integral channels

Foreseen specs:

- Mass <500 g
- Volume <0.5 U
- Power <1.5 W
- Dynamic range up to 1 MHz in counting
- Nominal GF ≥ 0.2 cm^2 sr (increasing with energy)
- Data rate: configurable

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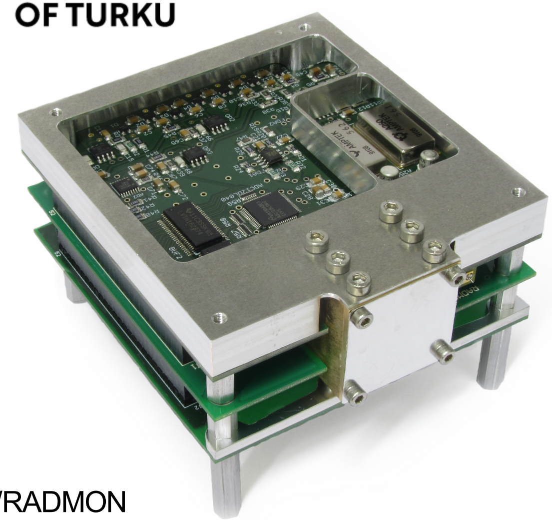
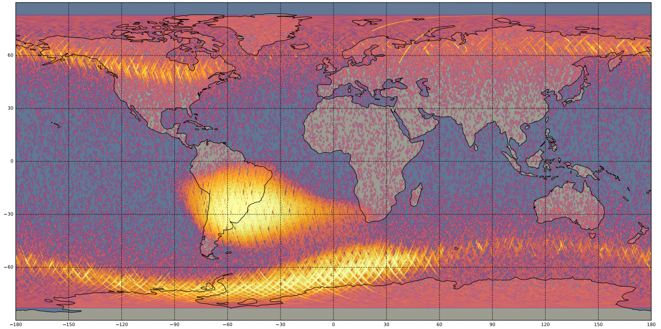


Aalto-1/RADMON



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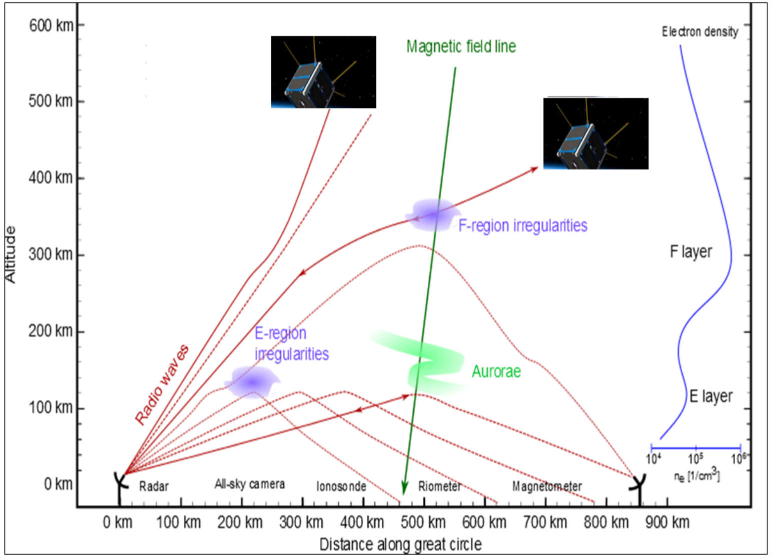
Beacon transmitter is a dual frequency radio tomography beacon for measuring total electron content (TEC) and ionospheric scintillation at UHF/VHF. The instrument radiates coherent, unmodulated 150MHz and 400 MHz carrier waves compatible with existing CERTO receiver ground networks, such as the TomoScand network.

The instrument provides a signal source for space-to-ground tomography using the existing ground infrastructure, as well as augments the ground-based GNSS tomography observations, especially at high latitudes. It is also a viable radiation source for space-to-space tomography, using receivers such as CITRIS. The instrument has flight heritage from earlier missions.

The beacon consists of a single RF circuit board and TX antenna.

Board mechanical interface	PC/104 compatible mounting holes
Board dimensions	64 x 64 x 18 mm
Data budget	No data produced in orbit
Mass	Max 400 g
Beacon TX frequency	150 MHz and 400 MHz
Beacon TX power	27 dBm
Power consumption (TX on)	2 W



An illustration of joint measurements of CME-NEWS and ground-based instruments

Radio spectrometer measures natural and manmade radio waves in the frequency range 1 – 10 MHz. The instruments consist of backend PCB and a small ferrite antenna located at one end of the satellite.

The spectrometer can be used in radiometer mode, where it measures a constant frequency, or as a spectrometer, where it sweeps different frequencies. The instrument has two sampling modes: (i) raw data mode, where waves as observed at a given sampling rate (in the ***Suomi 100 satellite*** at 1 kHz), and (ii) an average mode, where the observations are used to derive statistical parameters over a specified duration of time (in the Suomi 100 satellite typically 1 s).

Radio Spectrometer, main parameters

Board Size	Max one PC/104 board
Board mass	70 g
Antenna type	Ferrite antenna
Antenna mass	80 g
Power consumption mean/maw (RX on)	70 / 190 mW
Data Budget	2 bytes/sample at 0.5 ...1000 Hz

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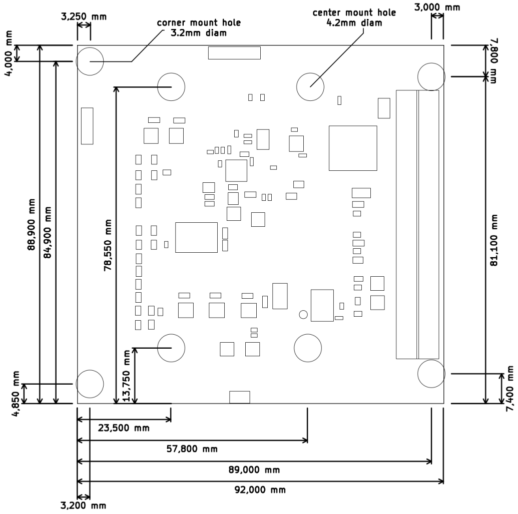

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CME-NEWS CONNECTS WITH

GROUND-BASED FACILITIES

- **The TomoScand Beacon and GNSS receiver networks** in Fennoscandia
- **The EISCAT incoherent scatter radars**
- **The EISCAT heating facility**
- **EISCAT ionosonde**
- **Other space weather instruments** (e.g. magnetometers, ionosondes, cosmic ray detectors) in polar region

&

SWE FACILITIES AT HIGHER EARTH ORBITS

AND L1 & L5

THANK YOU !