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Searching for Small Debris by Measuring Space Plasma Properties, Electric Fields, and the Kurtosis of Radio Signals?

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Background

- There is evidence that sub-centimeter debris generates plasma solitons at altitudes of up to 2,000 km (Truitt and Hartzell, 2020).

- There is evidence that electric discharges between colliding debris might emit broadband nonthermal radiation (e.g., Renno et al., 2003; Ruf and Renno, 2009; Renno and Ruf, 2012).

- Thus, measurements of space plasma properties, electric fields, and non-thermal radiation might allow the detection of sub-centimeter debris.

Space Environment Modeling at UM

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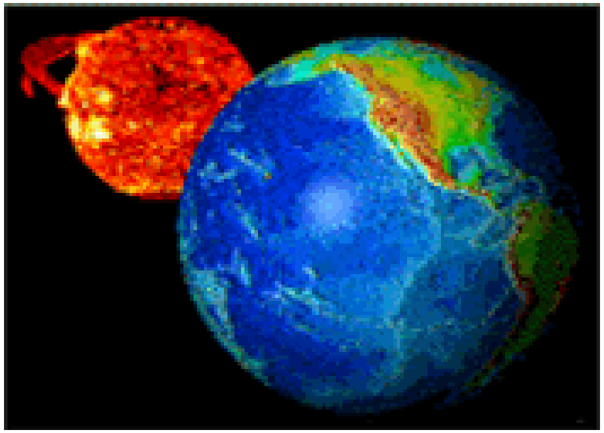
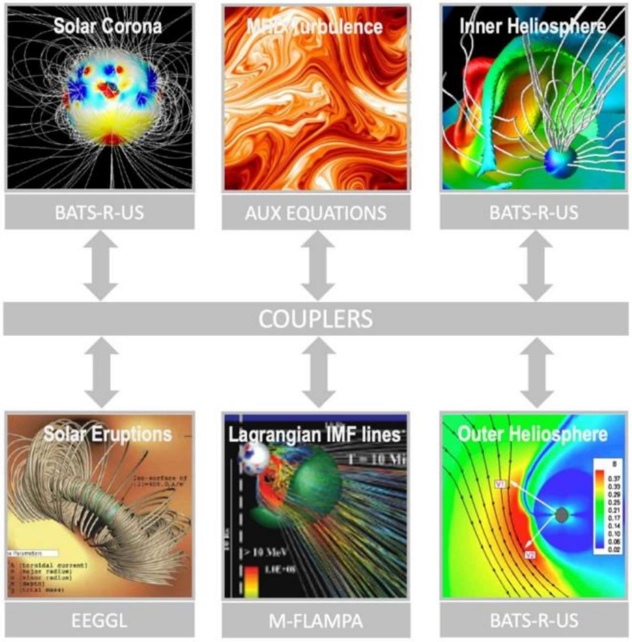
The UM Center for Space Environment Modeling (CSEM) developed high-performance, first-principles computational models to describe and predict hazardous conditions in the space environment, including near-earth space environment.

The center developed a software package (the Space Weather Modeling Framework - SWMF) that provides a common operating environment for the various modeling physics modules.

The SWMF can be used to model solitons generated by sub-centimeter space debris.

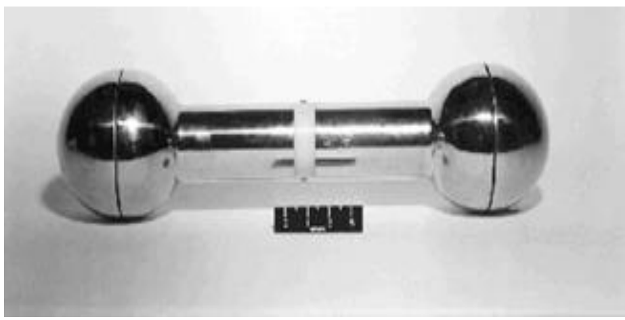
Space weather modeling



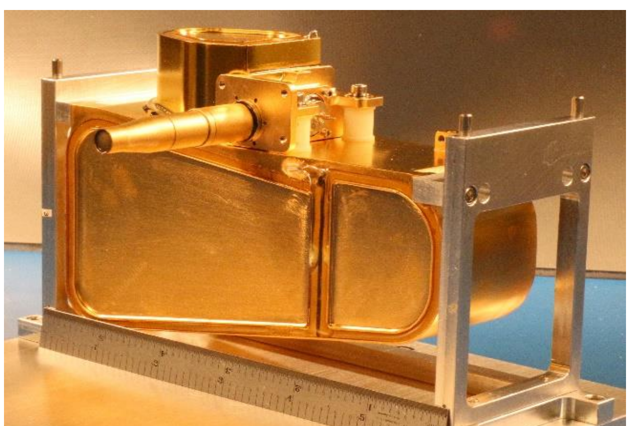


Space Instrument Fabrication at UM

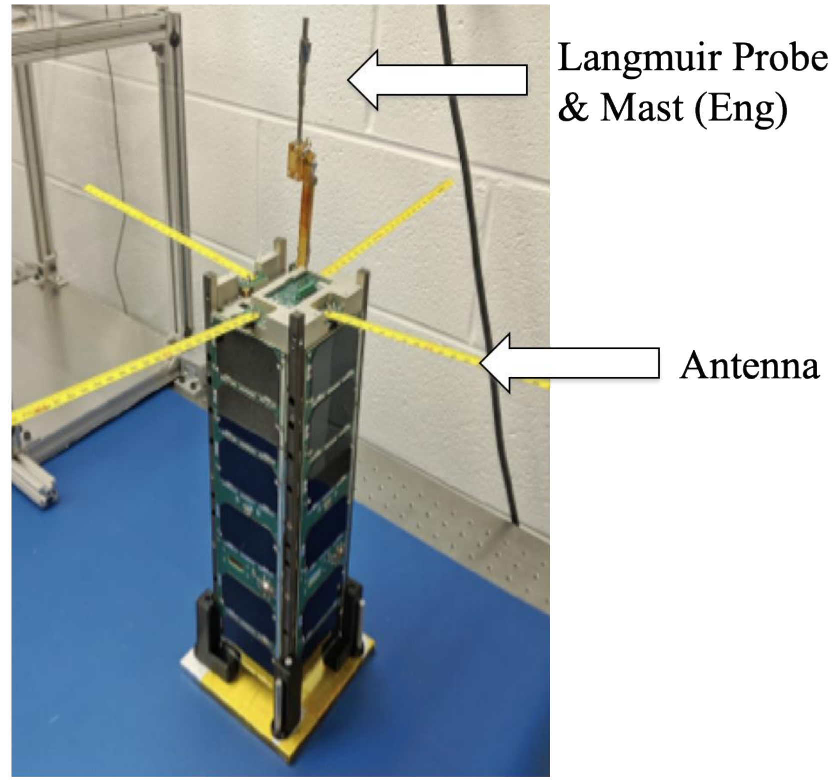
- Developed more than 100 rocket, aircraft, and balloon experiments.
- Developed more than 40 innovative space instruments.



Double Langmuir probes flown on V2s.



Mars 2020 Planetary Instrument for X-ray Lithochemistry.



MiTEE-I Langmuir probe and antenna deployed.

Emission of Non-Thermal Radiation

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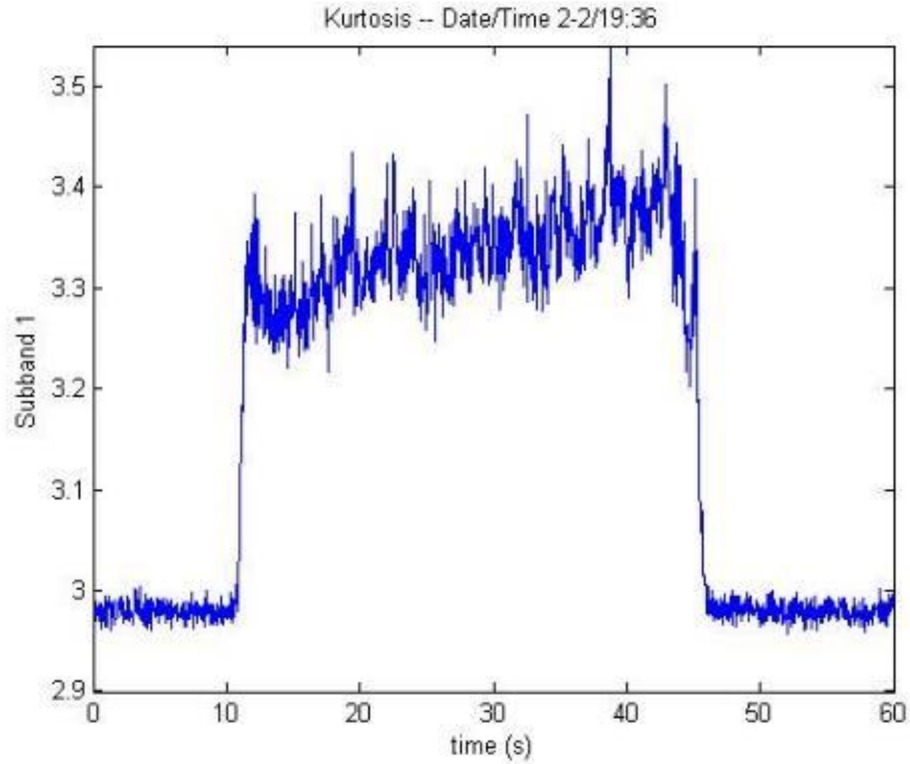
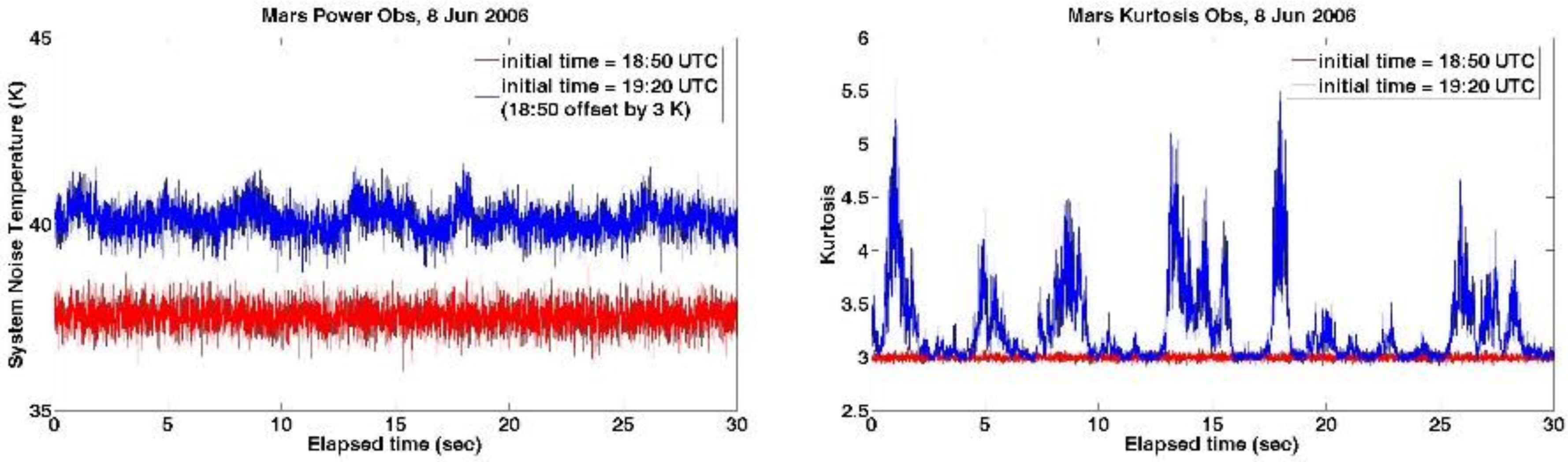


Evidence that microdischarges between colliding dust particles produce nonthermal microwave radiation (Renno *et al.*, 2003).

Power vs Kurtosis



The kurtosis of the signal is a much more sensitive than the power (ruf and Renno, 2009).

Electric Field Sensor (EFS) Concept

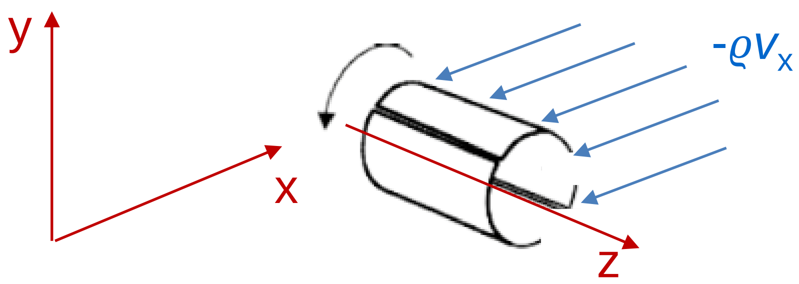
The current induced by the space electric field and by charge transfer to a cylindrical field mill is

rotation rate | ~ collision cross section

$$i(t) = \omega K_1 (E_x \sin \omega t_x + E_y \cos \omega t) + K_2 (I_x \cos \omega t + I_y \sin \omega t)$$

rotation dependent term | rotation independent term

where E_x and E_y are the two components of the electric field in the plane perpendicular to the sensor's rotation axis (the x-y plane), ω is the sensor rotation rate, $K_1 = 4r\varepsilon_o$, $K_2 = kr/2$, k is a constant that depends on the sensor length, ε_o is the air permittivity, $I_x = \varrho v_x$, $I_y = \varrho v_y$, ϱ is the plasma volumetric charge density, v is the dust cloud speed with respect to the sensor, r is the sensor radius (Kok and Renno, 2008).



EFS makes floating electric field measurements.

CubeSat EFS Concept

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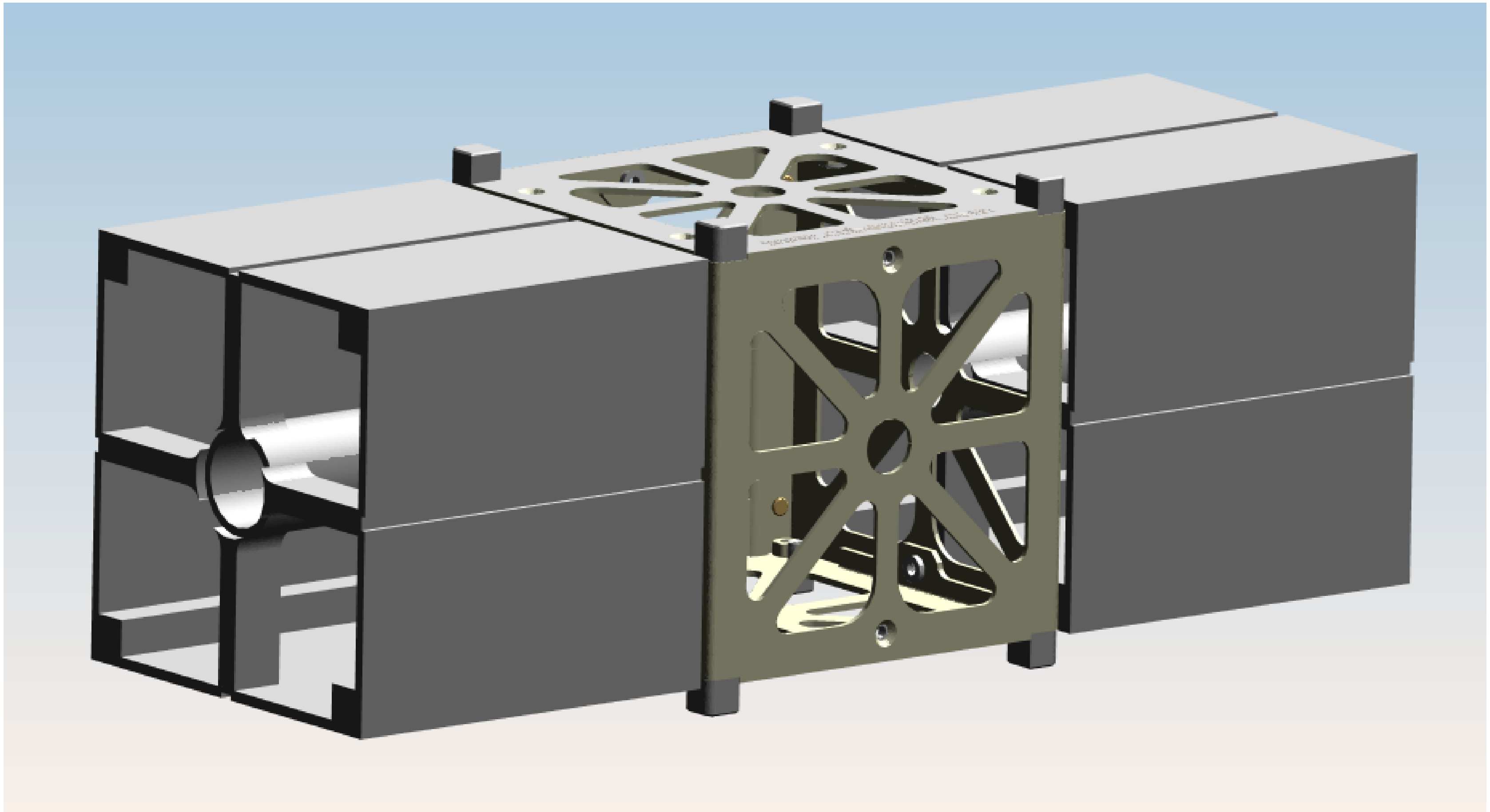

Thank you!

The Various EFS Versions

The Relative Size of the Various Sensors

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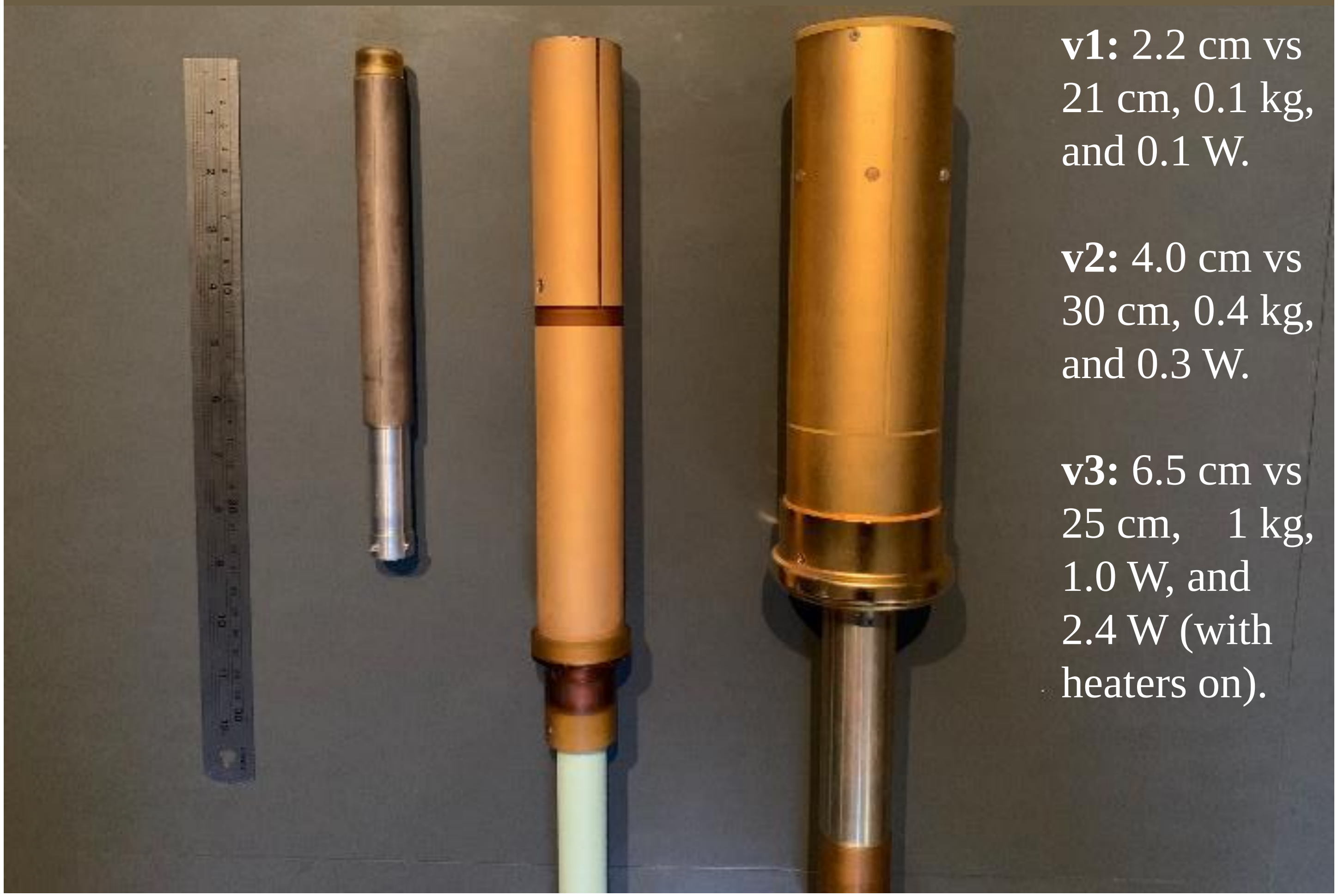
v1.0	v2.0	v3.1	SWaP

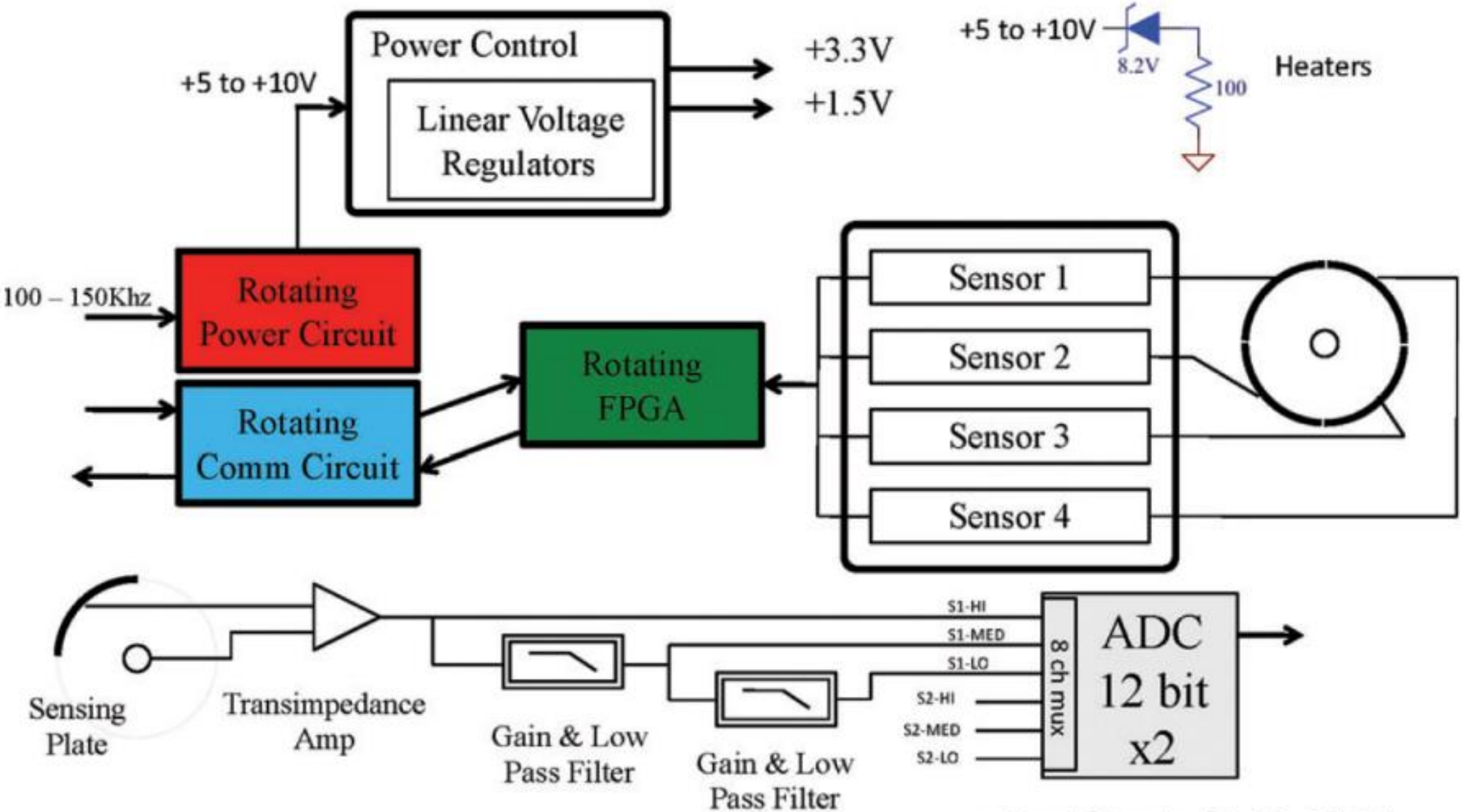


v1: 2.2 cm vs 21 cm, 0.1 kg, and 0.1 W.

v2: 4.0 cm vs 30 cm, 0.4 kg, and 0.3 W.

v3: 6.5 cm vs 25 cm, 1 kg, 1.0 W, and 2.4 W (with heaters on).

EFS v3 Block Diagram



- *Quad Signals: S1-S3, S2-S4*
- *2 Ch / ADC for houskeeping*

Flight Tests of EFS v3.0

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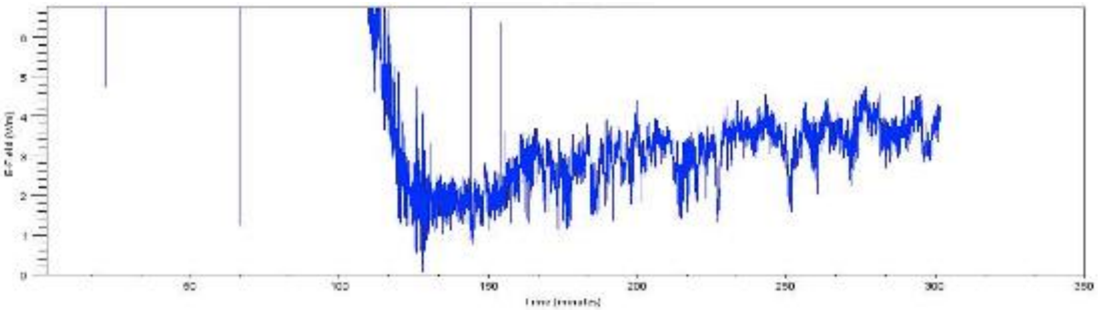
The prototype v3.0 sensor operated successfully in balloon flights in February and March of 2011. Each flight lasted between 4 and 6 hours.

By operating successfully in the space like stratospheric environment, EFS v3 reached TRL ~ 7.

PIDDP Award # NNX07AM99G



Small stratospheric electric fields measured by the EFS v2 prototype during a flight in an ESA balloon launched from Kiruna, Sweden.