The Hot Plasma Environment Monitor (HOPE-M) for telecoms satellites

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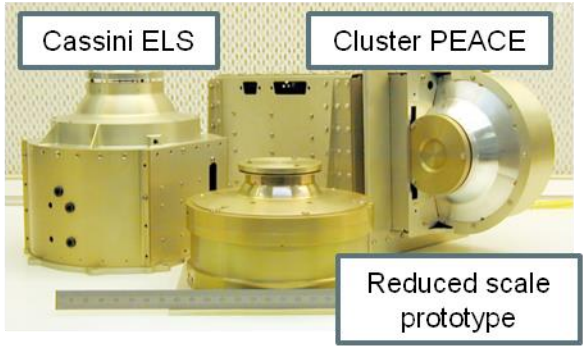
Plan

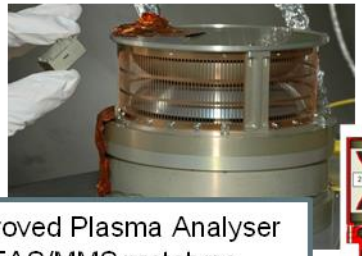
- Introduction
- Hot Plasma Environment Monitor (HOPE-M)
  - Design overview
  - Key technology developments
- Some results from ChaPS
- Summary

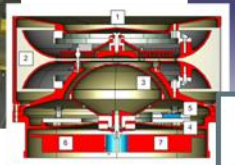
In-situ Plasma Instrumentation

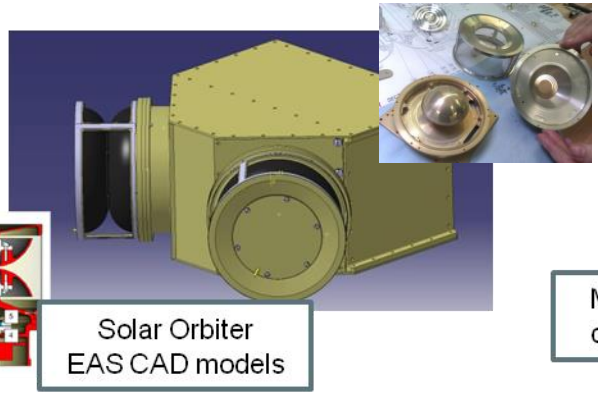
- Strong plasma instrumentation heritage
  - Planetary environments: Cassini, Mars and Venus Express (built by SWRI), Mars 96 (launcher failed), AMPTE-UKS
  - Magnetospheric missions: Cluster, Double Star, Polar, CRRES, STRV
  - Cometary studies: Giotto
  - Technology Demonstration: TechDemoSat
- Current missions
  - Solar Orbiter
  - JUICE
- Highly miniaturised particle sensors
  - QB50 – INMS and UCLSat CubeSat

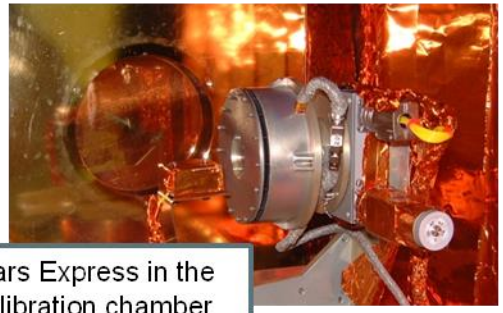

FONEMA on MARS96




Improved Plasma Analyser EAS/MMS prototype



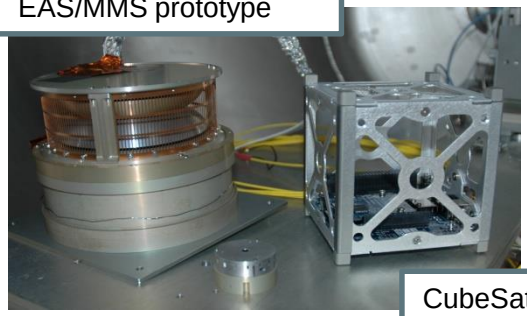

Solar Orbiter EAS CAD models


Mars Express in the calibration chamber

Instrument Miniaturisation

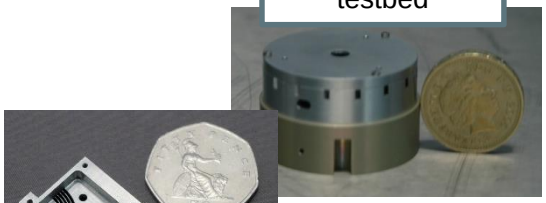
- Driven by CubeSat and Space Weather
  - Horses for courses
- Generic technology development
  - Electronics miniaturisation – HV, readout, digital
  - Detection systems – combined e-ion
- Alternative geometries to top-hats
  - Cylindrical, Bessel box
- Technology demonstration on UK TechDemoSat, QB50 precursor missions

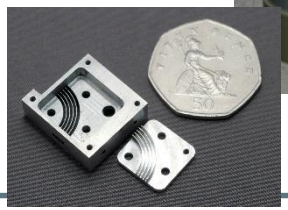
Improved Plasma Analyser EAS/MMS prototype



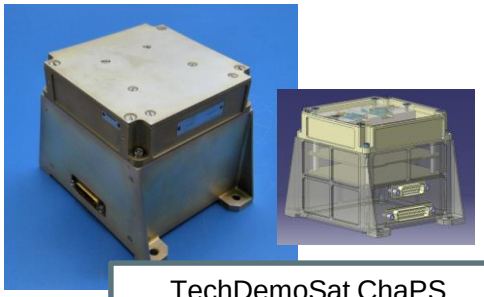
CubeSat

EJSM prototype testbed

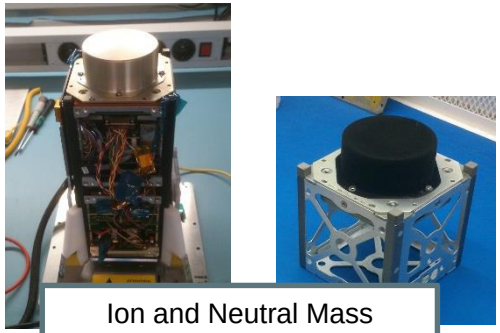




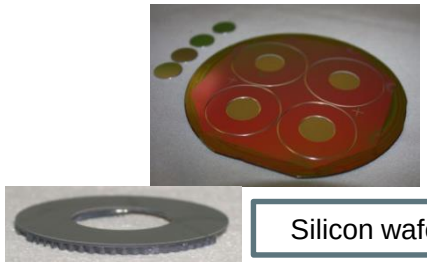
High temporal resolution proof-of-concept analyser



TechDemoSat ChaPS instrument and EM model

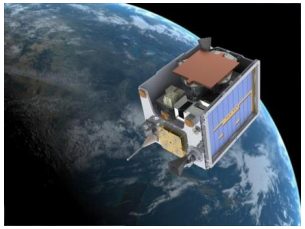


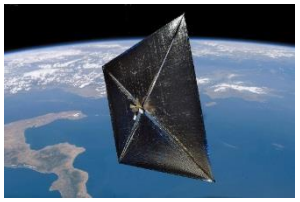
Ion and Neutral Mass Spectrometer for QB50

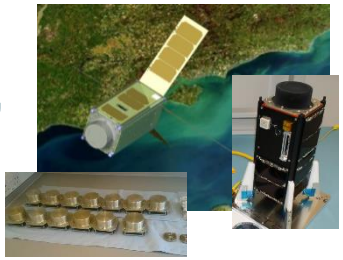


Silicon wafer analyser

Flight Missions and Space Weather



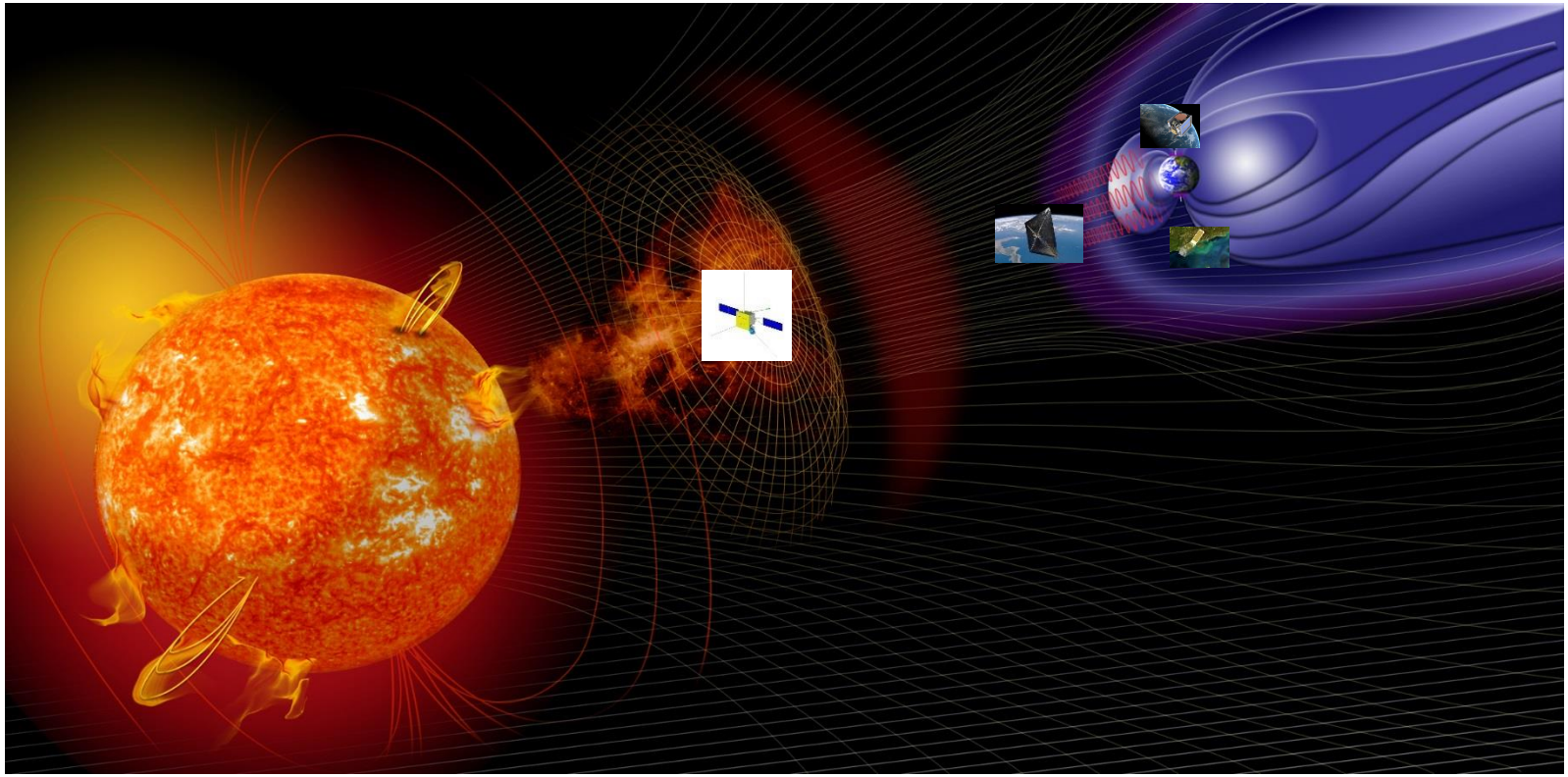




- Charged Particle Spectrometer (ChaPS), TechDemoSat – launched July, 2014
- Solar Wind Analyser (SWAN), Sunjammer - recently cancelled
- 14 x Ion and Neutral Mass Spectrometer (INMS), QB50 - launch precursor June 2014, main 2016
- UCLSat – 2U CubeSat for QB50, launch 2016
- Solar Wind Analyser (SWA) Suite, Solar Orbiter - launch 2018

Image credits: SSTL, L'Garde, NASA, ESA

Flight Missions and SSA



Background Image credit: NASA

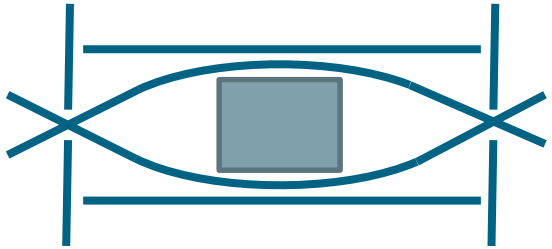
Hot Plasma Environment Monitor (HOPE-M)
Key requirements

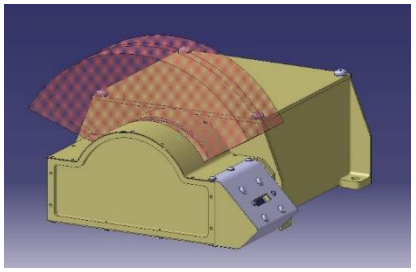
- Telecoms satellites at GEO
- Surface charging monitor, post-anamoly data
- Combined electrons and ions
- 30 eV – 30 keV
- Low resource: 0.5 kg
- Compact digital electronics
  - Complex capabilities, rad hard memory
- 15 year lifetime

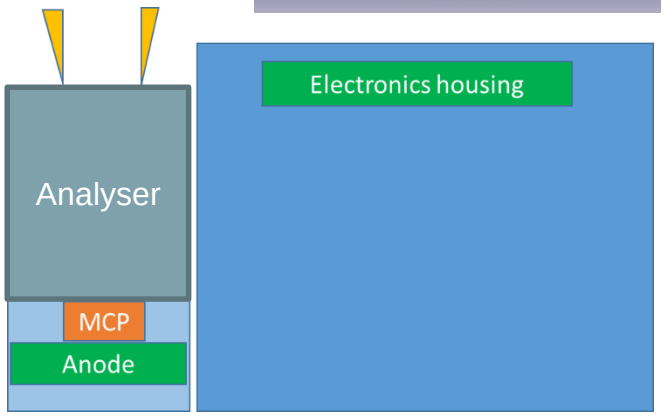
Hot Plasma Environment Monitor (HOPE-M)

Design overview

- 2 x Bessel box variants
  - Compact geometry
  - Considerable design flexibility
    - Ability to “tune” performance
    - High/low analyser constants
  - Used on STRV
- ± 22° x ± 60° Field of view
- Modular design
  - Analyser head, electronics box
- Single MCP, polarity flipping
- Four readout channels
- Silicon detector development in parallel







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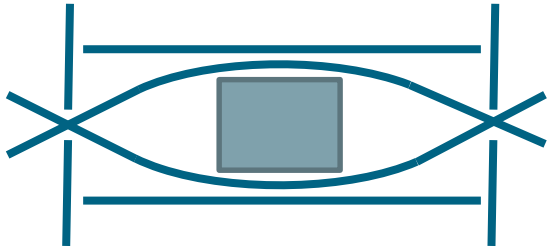
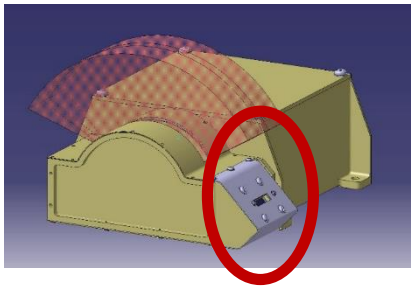
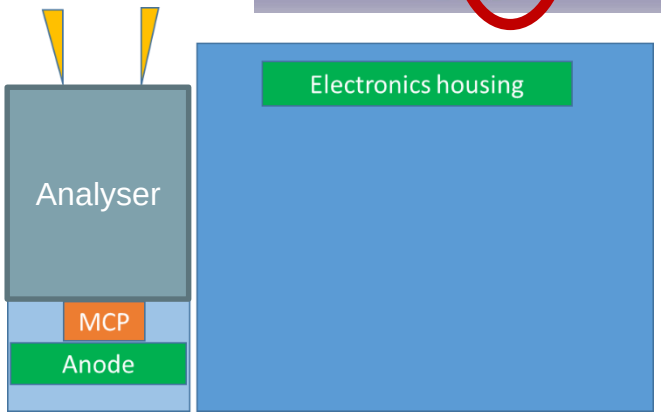
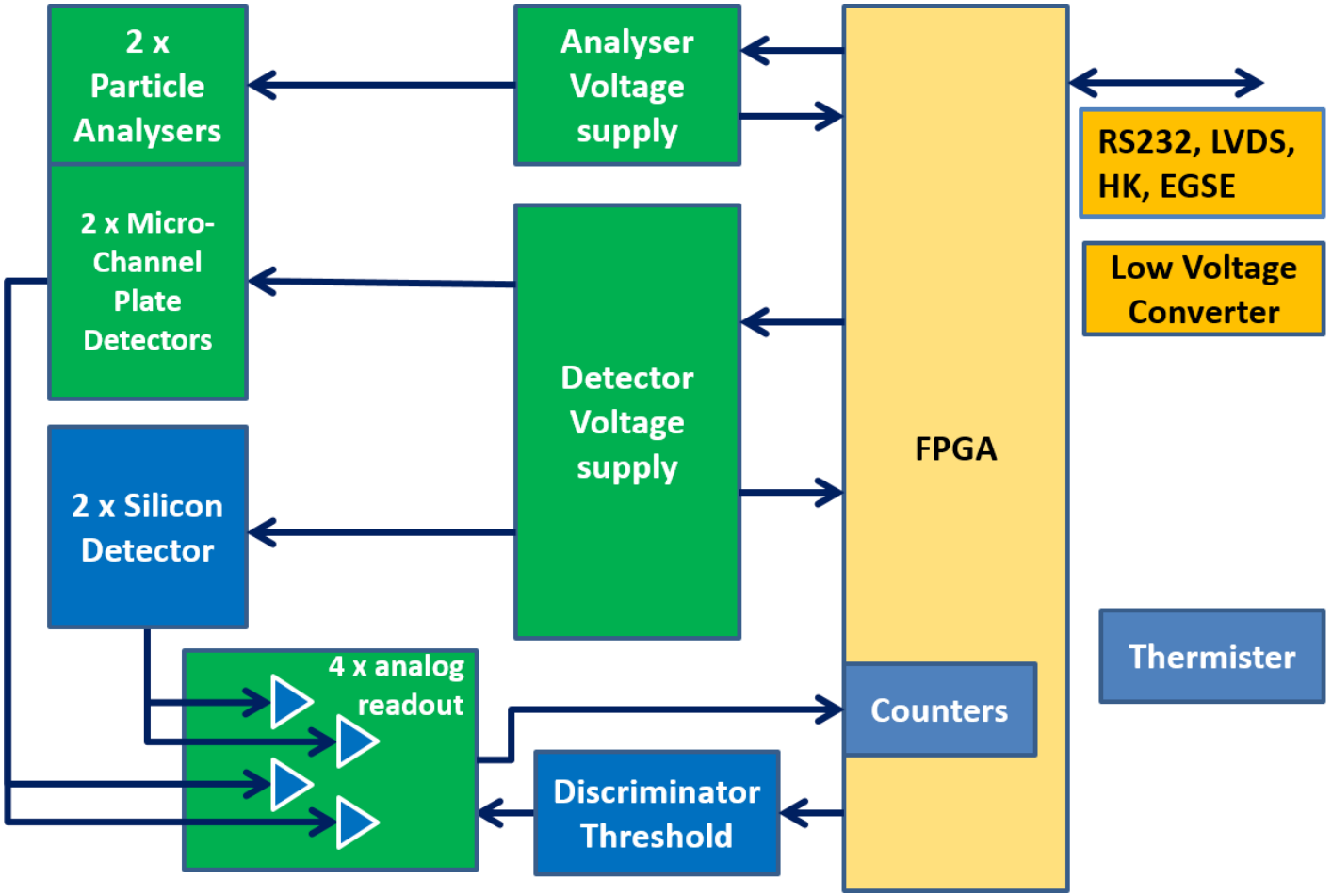




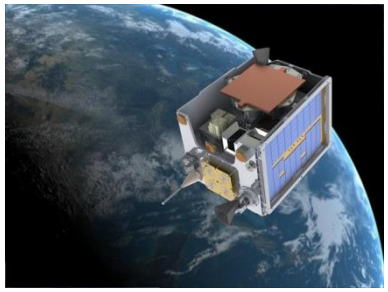


Current HOPE-M architecture

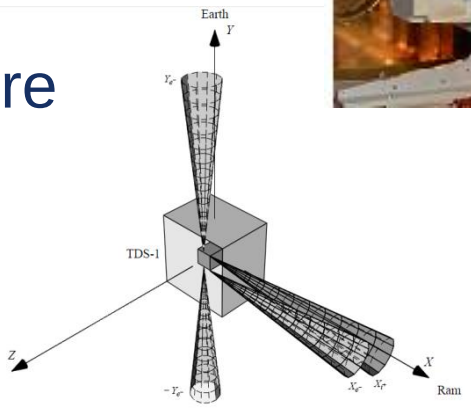


TechDemoSat ChaPS

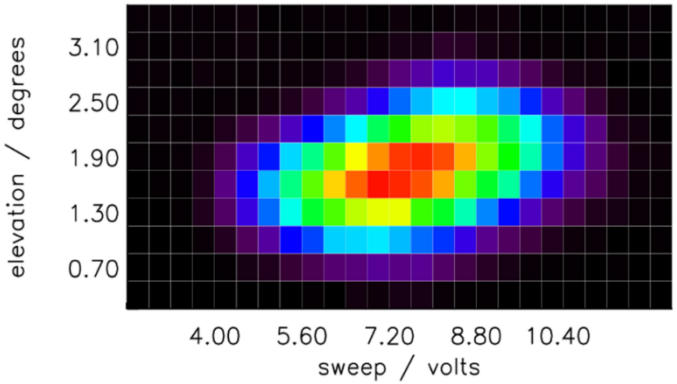
Dhiren Kataria, Hubert Hu, Gethyn Lewis, Richard Cole, Mark Hailey, Eric Ueberschaer, Andrew Coates

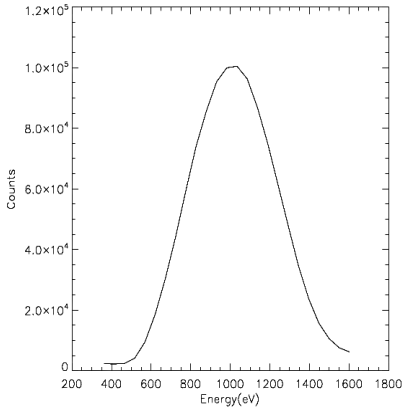


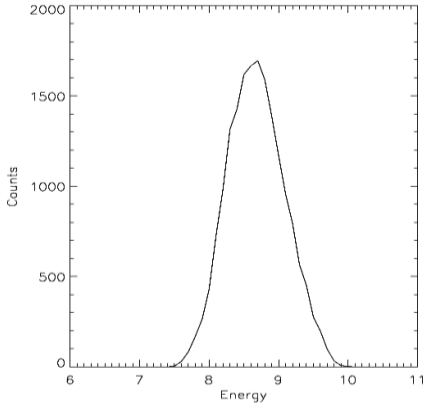
- ChaPS (Charged Particle Spectrometer)
  - Suite of miniaturised Bessel Boxes
  - Electron and ion analysis
- Three modes
  - Electrons in the auroral regions
  - Electrons and ions in the ionosphere
  - Spacecraft potential
- Delivered March 2012
- Launched July 2014

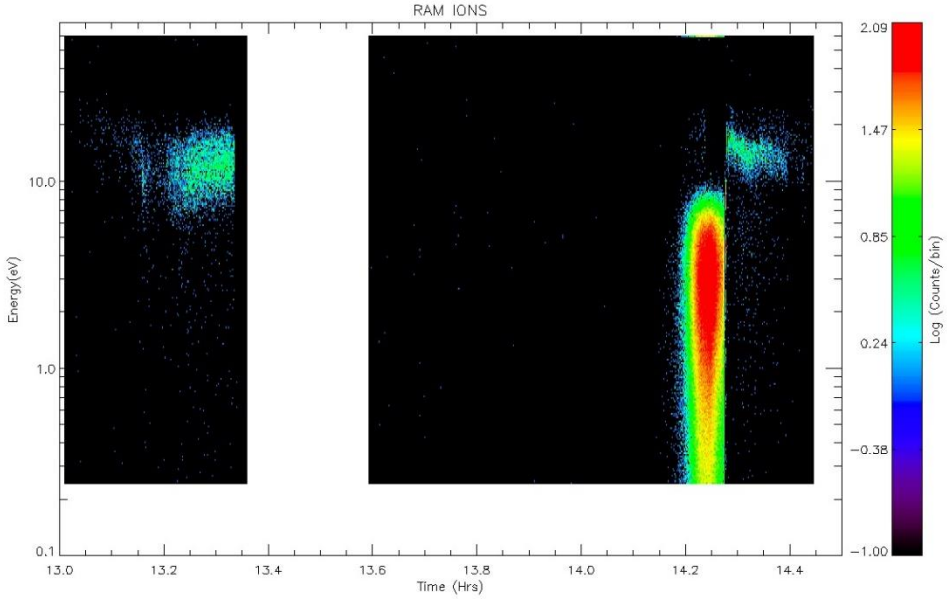


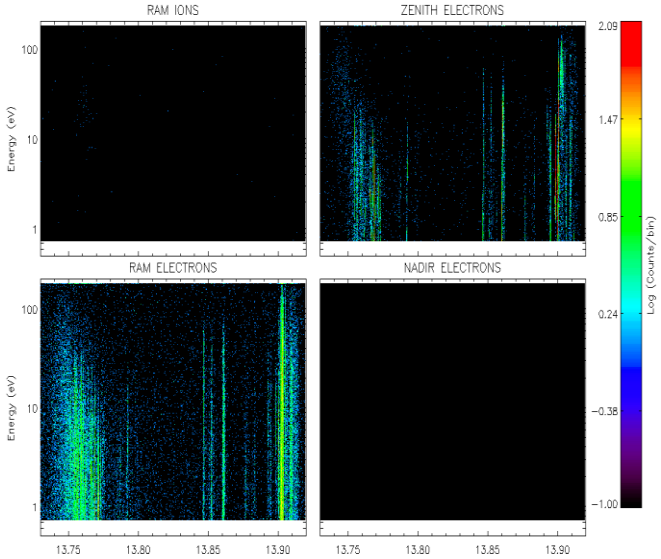
Data from ChaPS





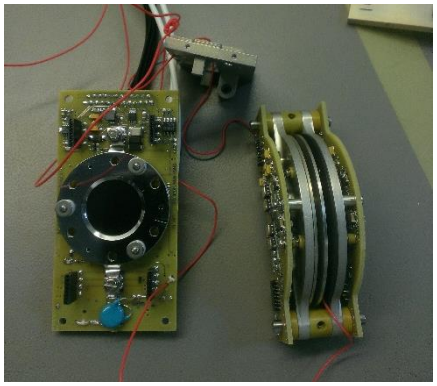


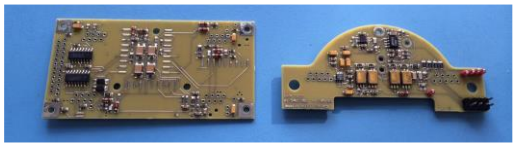


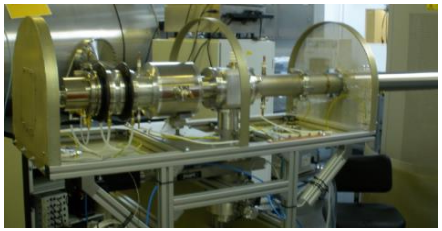


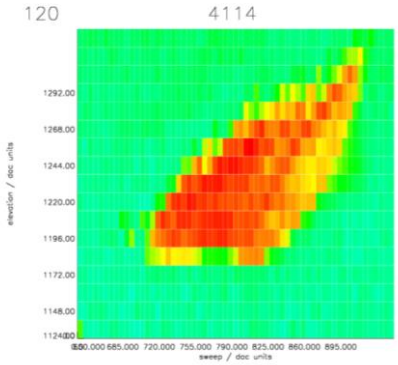
HOPE-M breadboard

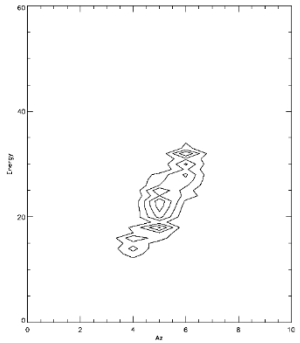
- HV modulator and front end electronics integrated and tested with ions
- Throughput issues
  - Widened acceptance on one channel
  - Removed detector aperture – increased noise
  - DAC offset, beam stability
- Reconfigured for further testing









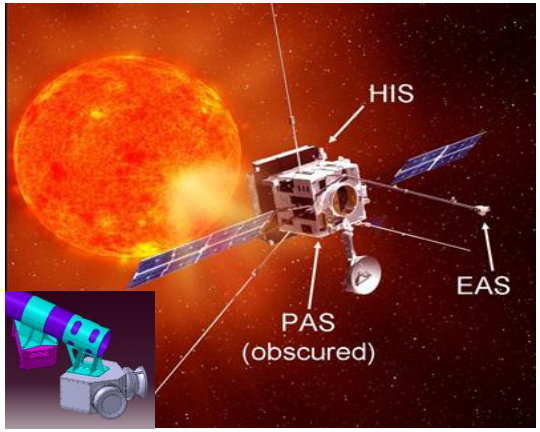


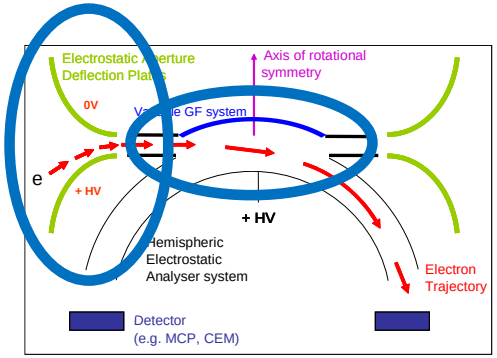
Performance parameters

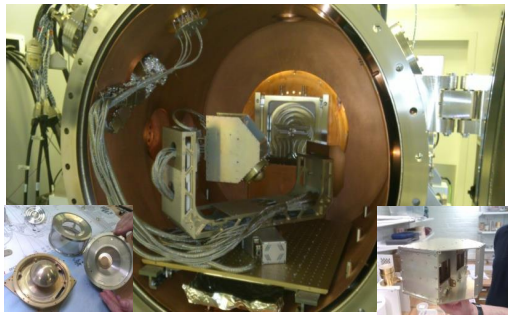
	ChaPS - Magnetosphere	HOPE-M (breadboard)
Primary sampling region	Auroral Electrons at the poles	GEO
Particle Type	Electrons	Electrons, Ions
Key View direction	N-S	Earth pointing
PROPERTIES		
Energy range (eV)	10 to 4,000 eV	30 to > 30,000 eV
Energy resolution (%)	< 40	< 30
Elevation acceptance	< 1.8°	± 11°
Azimuth acceptance	< 20°	± 60°
Energy Sweep time	1s	30s
Energy Sweep steps	64x4	64

SWA-EAS Implementation

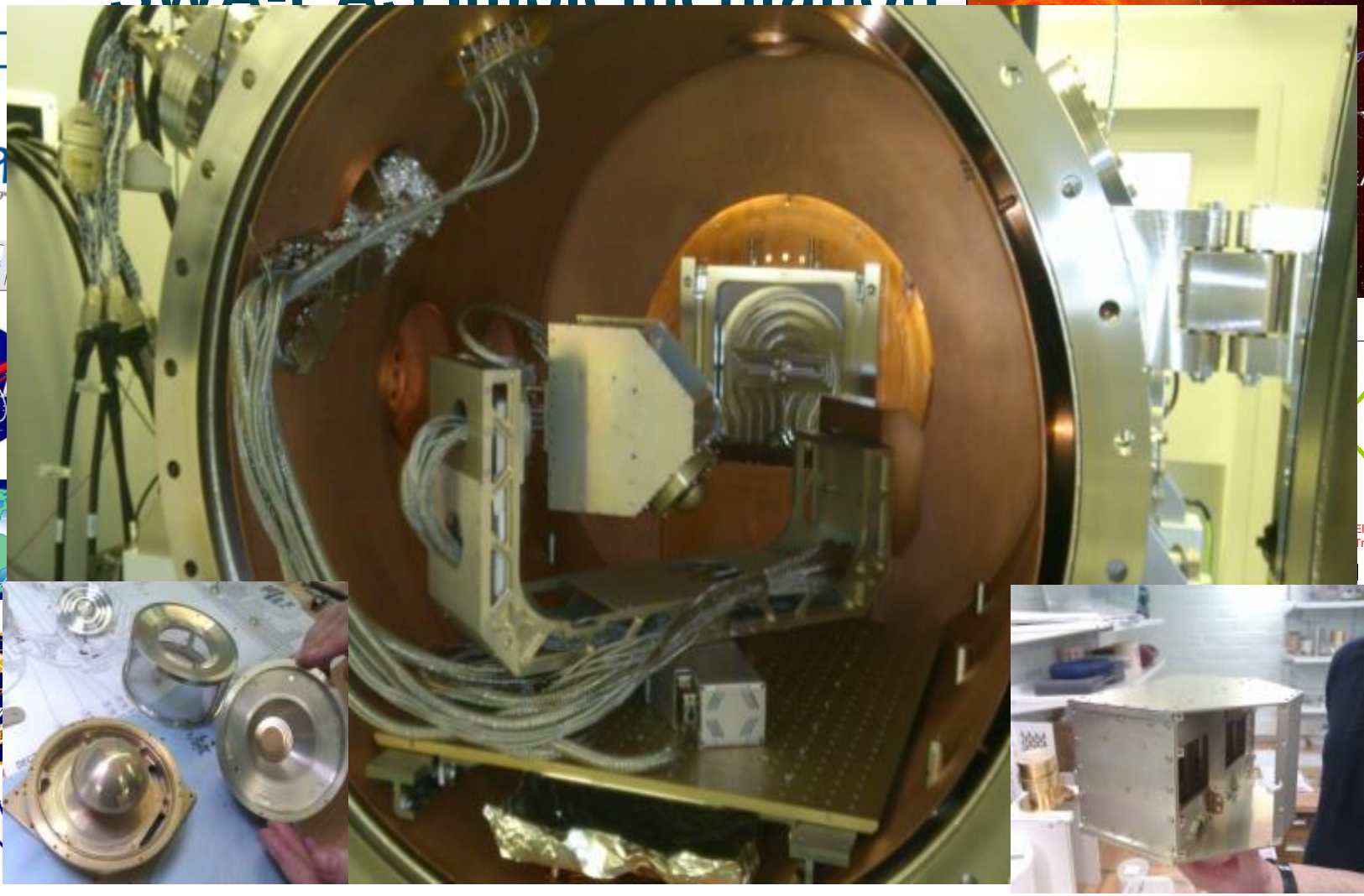
- SWA Instrument
  - HIS, PAS, EAS
  - Suite Instrument Science
  - EAS lead
- SWA-EAS Sensor
  - Two Boom Mounted Top Hats with enhanced features
  - Size reduced by 1/√2 compared to Cluster PEACE LEEA
  - Deflector plates, Variable Geometric Factor System
  - High speed High Voltage modulation

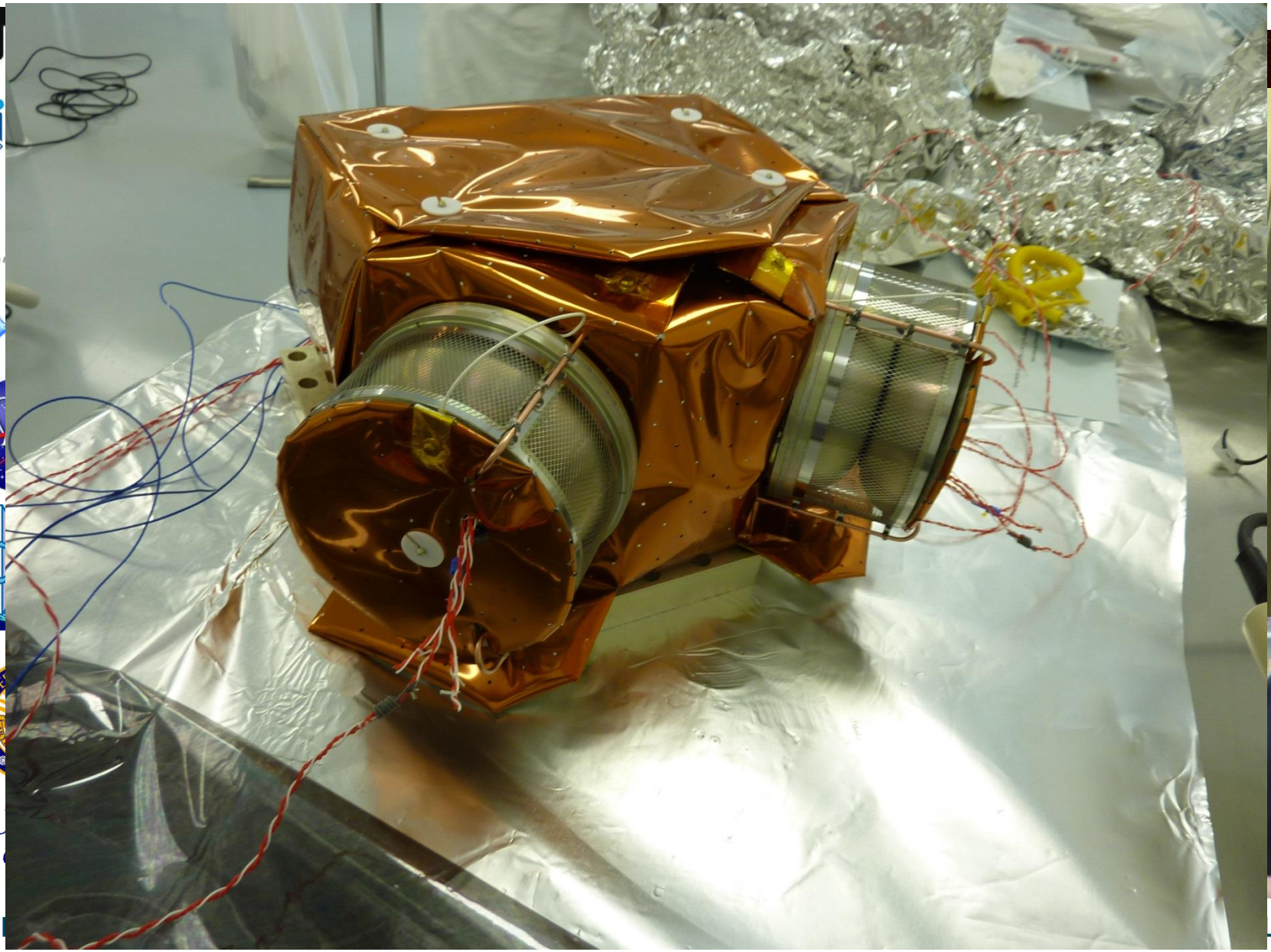






SWA-EAS Implementation





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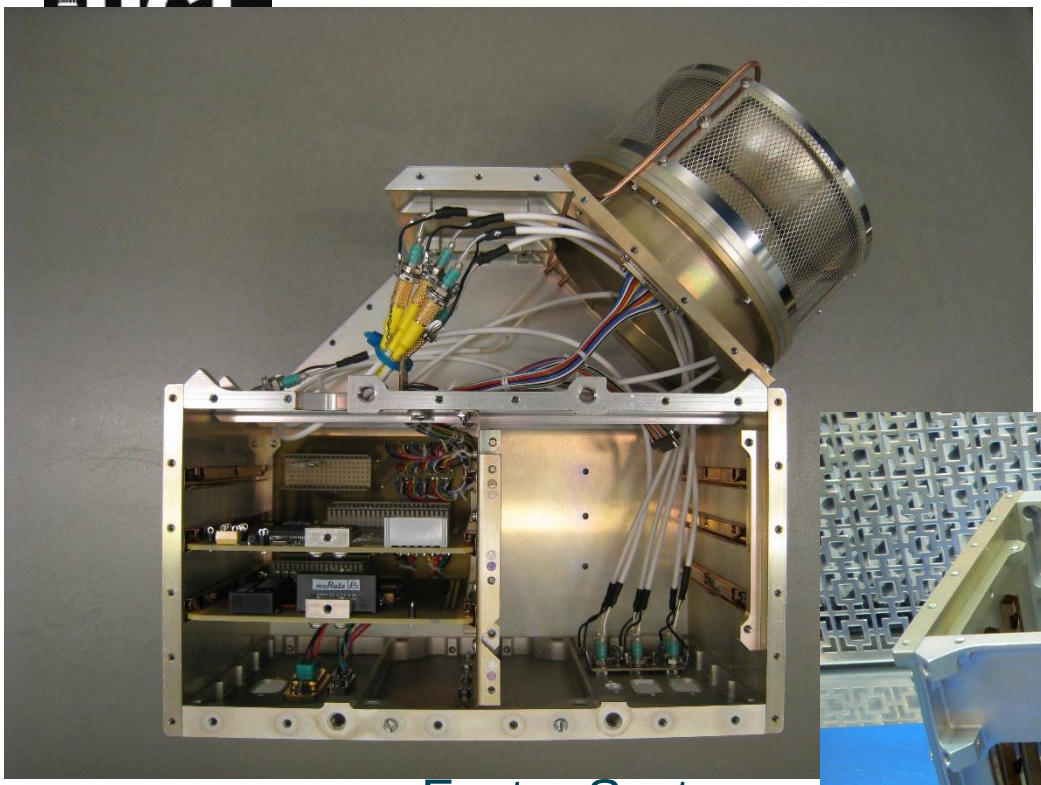
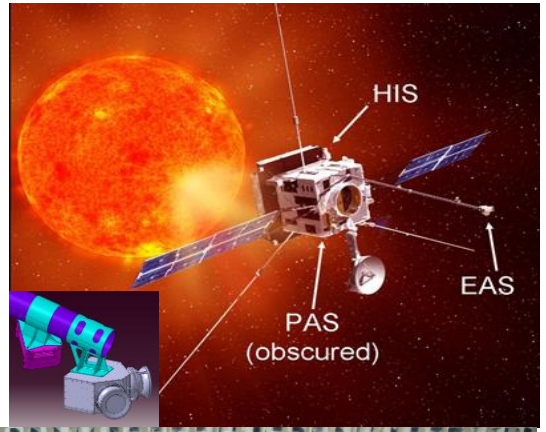
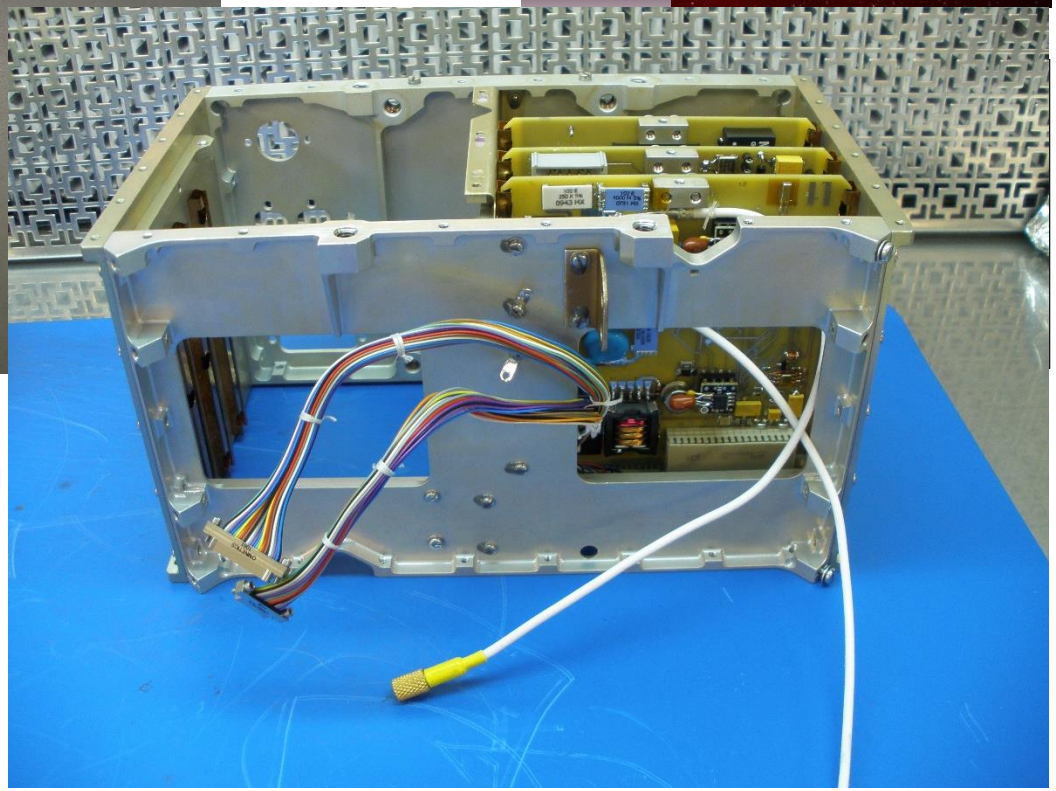


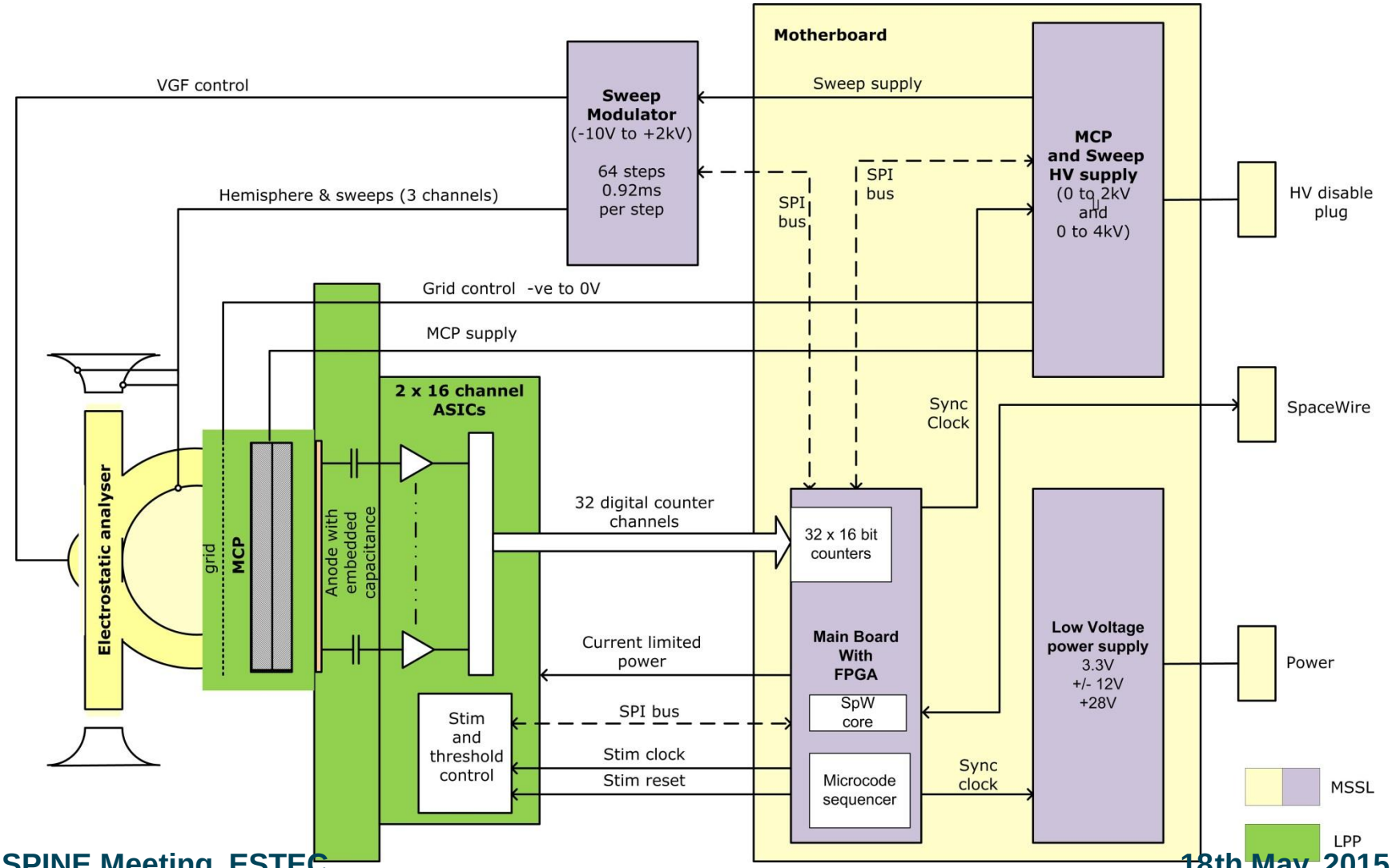


Factor System

– High speed High

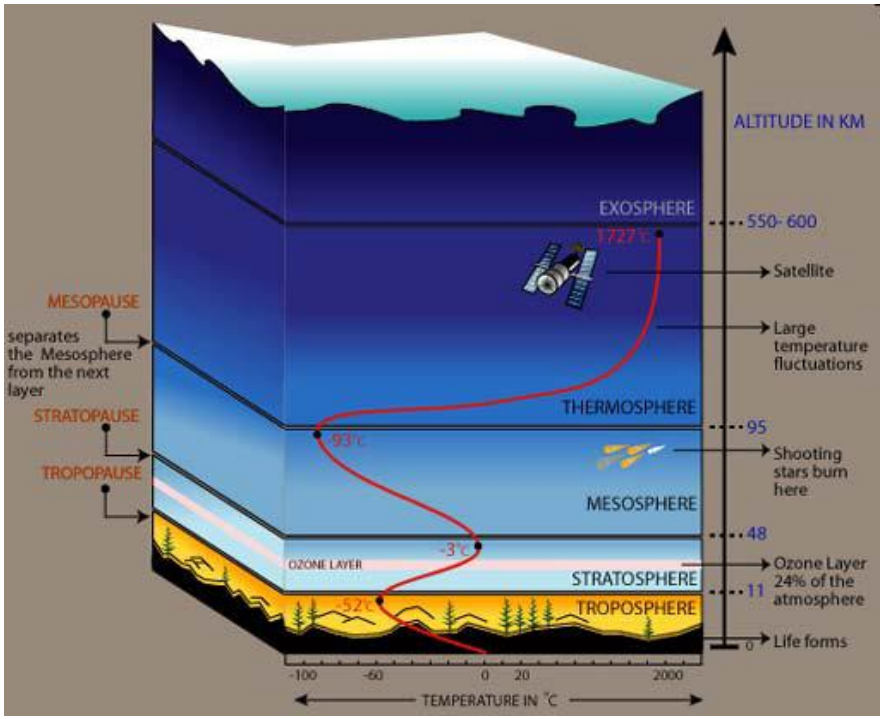


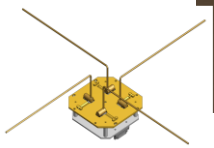
EAS Technical Description

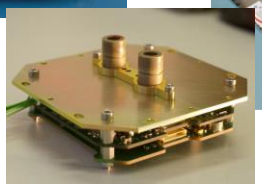


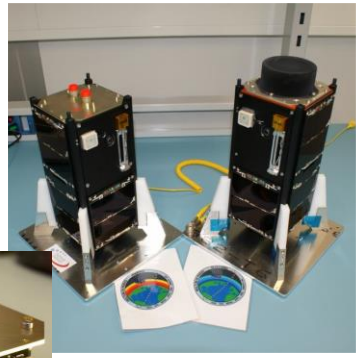
QB50 Mission

- Mission Overview
  - Lower Thermosphere Science
  - 40 2U +IOD CubeSats
  - Built by different universities
  - 380 km Circular Orbit
  - String of pearls configuration
  - Q2, 2016 launch
- Selected “standard” sensors
  - Ion/Neutral Mass Spectrometer
  - Flux-(Phi)-Probe-Experiments (FIPEX)
  - Langmuir Probe
  - Thermistors



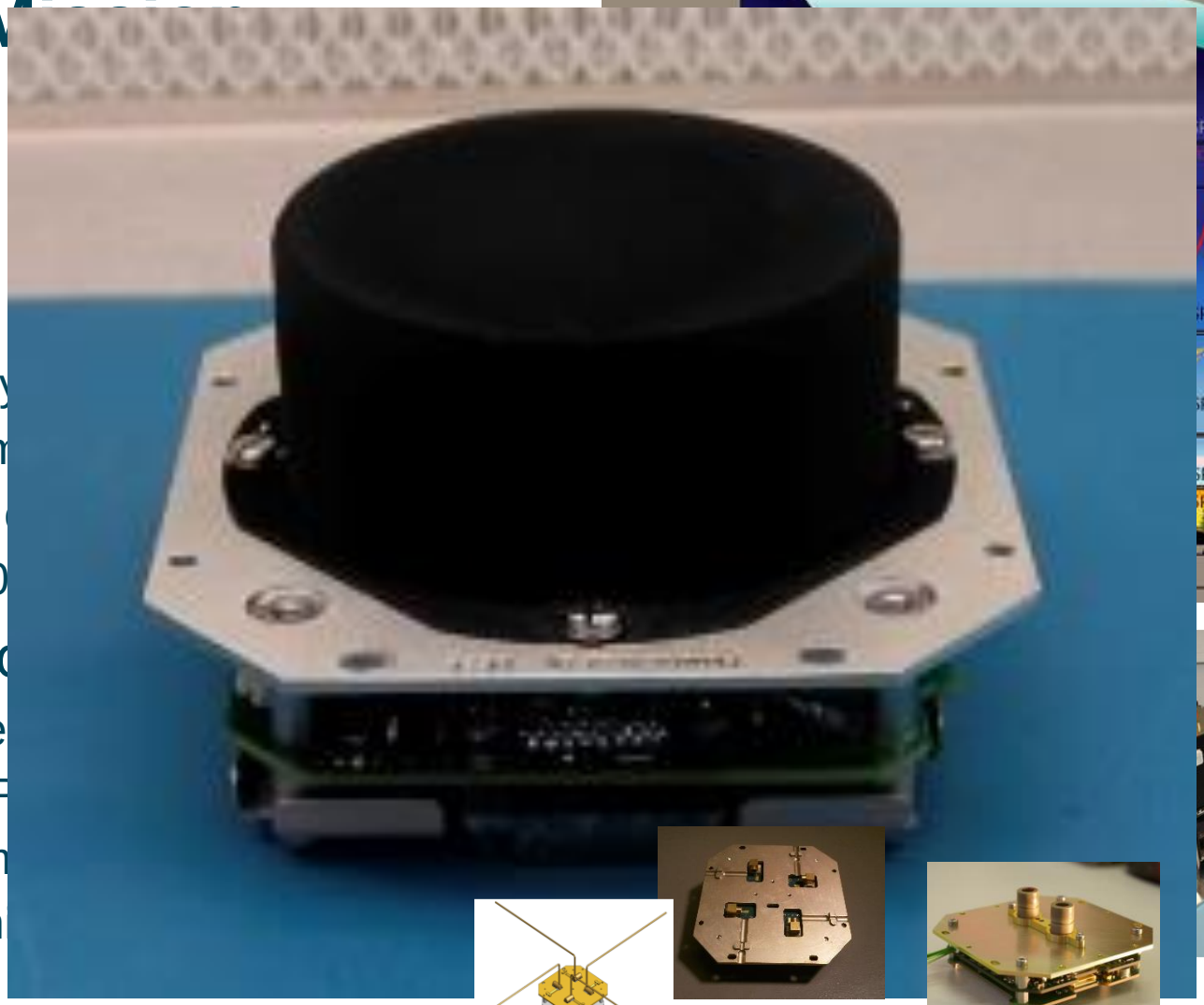


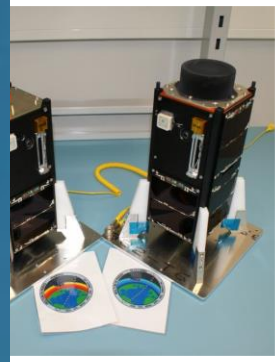




QB50 M

- Mission
  - Lower
  - 40 2U
  - Built by
  - 380 km
  - String
  - Q2, 20
- Selected
  - Ion/Ne
  - Flux-(F
  - Langm
  - Therm





Technical Budgets

Unit	Mass (gms)	Power (W)	CubeSat Volume (litres)
INMS	220	0.78	0.3
	10%	20%	20%
FIPEX	160	1.95	0.3
	10%		10%
LP	<300	0.85	0.3
	25%	20%	10%

- Power: Orbit average 0.5W with duty cycling
  - CONOPS refined to fit within power and data budgets
- Science Unit Documents on the web
  - https://www.qb50.eu/index.php/tech-docs/category/3-sensor-units

Summary

- Strong Heritage, Aggressive Miniaturisation Programme
- Developments for flight missions
  - Solar Orbiter EAS, ChaPS, QB50, SWAN for L1
- HOPE-M for geostationary satellites
  - Combined low resource electron-ion analyser
  - Modular design, ability to tune for science/monitoring
  - Target mass 0.5 kg
- Enabling technology for future missions
  - Generic technologies
  - Silicon wafer fabrication

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