"Heliophysics in Europe" Workshop



ESA D/TEC activities in area of Heliophysics

Piers Jiggens on behalf of D/TEC ESA ESTEC 30/10/2023

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Presentation Overview and Contributors

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<u>1. TEC Missions</u>

- PROBA Series
- CubeSats

2. Instrumentation

- Remote Sensing
- In-Situ

3. Data Archiving and Provision

- Data Exploitation and Open Data Interface (ODI)
- Contributions to JHelioviewer

4. Modelling Activities

- Specification Modelling
- Planetary Environments in the Solar System
- Space Weather Modelling
- Radiation Storm Forecasting

TEC Missions





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PROBA Series of missions



PROBA-1

Launch: October 2001 Orbit: LEO-SSO 681 x 561 km



Embarked Earth Observation Imagers and Standard Radiation Environment Monitor

Orbit:

PROBA-2

Launch: November 2009 Orbit:

LEO-SSO 713 x 733 km QinetiQ Space nv

Embarked LYRA (Lyman Alpha Radiometer) and Solar Imager with APS Detector (SWAP)

Lifetime:

2-4 years

Distance, resizing : 25 – 250 m

PROBA-V QinetiQ Space nv Launch: Orbit: May 2013 LEO-SSO 820 km

Embarked optical imagers for vegetation plus the Energetic Particle Telescope (EPT) and Space Application of Timepix-based Radiation Monitor (SATRAM)

PROBA-3

Launch: 2024 (planned) Formation Flying: Mission

Occulter Spacecraft: 200 kg, 120 Mb/orbit, 50 m/s



600 x 60530 km at ~59° inclination

2 satellites with intersatellite links

Payload: Coronagraph, ~150 m, 1.08 R_{Sun}, Radiometer, 3D-EES (radiation)



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Royal Observatory of Belgium



Coronagraph planning, commanding, calibration, and dissemination to scientists



Verification benches

GPS visibility

Definition Implementation Launched



OPS-SAT (3U) new techniques in mission control OARMAN (3U) studying atmosphere re-entry .





GOMX-4B (6U) demonstrating constellation technologies

GOMX-3 (3U) demonstrating new platform technologies

PICASSO (3U) studying the atmosphere & insitu plasma



PRETTY (3U) demonstrating GNSS reflectometry



PROBA-V Companion (12U) Imaging Vegetation

> RadCube (3U) measuring space radiation and magnetic

> > field

Sunstorm (2U)

fluxes

measuring X-Ray

SROC (12U)



e.Inspector (12U) demonstrating debris inspection

demonstrating close inspection (Space Rider)

> VULCAIN (2x12U) formation flying for ; imaging of volcanos

LUMI0 (12U) measuring lunar surface

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\rightarrow ESA'S TECHNOLOGY CUBESAT FLEET

Funded in GSTP Fly unless otherwise stated

GENA-OT (16U) demonstrating commercial IOD/IOV services

CubeSpec (6U)

from space

stellar spectroscopy

M-ARGO & Satis (12U)

demonstrating asteroid rendezvous for in-situ resources (GSTP) & planetary defence (S2P)



Juventas & Milani (2x6U) observing asteroid deflection assessment funded by Space Safety Programme (Hera)

HENON [12U] space weather early warning from Distant Retrograde

chit

European Space Agency

impact hazards

Cubesat In-orbit Demonstration relevant to Heliophysics

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SunStorm

KUVA SPACE

Launch:

Orbit:

16/08/2021 on Vega VV-19 550 km SSO



Contractor: KUVA Space (FI) + Isaware-led payload team Platform: 2U CubeSat (KUVA) with 3-axis pointing Payloads:

- Solar X-ray flux Monitor (XFM) by Isaware (FI), ASRO (FI), Oxford Instruments (UK), Talvioja Consulting (FI)
- Candidate to be flown on the SWFO and Vigil follow-on space weather missions to Sun-Earth L1 and L5 Lagrange point

Status: nominal IOD mission successful, Post-Flight Review Sept 2022, excellent scientific results with payload, A2-X1 solar flares detected







RadCube Orbit: Launch: 16/08/2021 on Vega VV-19 550 km SSO Contractor: C3S (HU), MTA EK (HU), ICL (UK), Astronika (PL) Platform: 3U CubeSat (C3S) with 3-axis pointing Payloads:

- RadMag including electron/proton particle detector (EK), magnetometer (Imperial College) on 80 cm boom (Astronika)
- Radiation Hardness Assurance board for characterisation of Radiation effects EEE components (ESA TEC-EDD)

Status: Commissioning completed (Dec 2021), boom deployed successfully, magnetometer & radiation telescope scientific data acquired, nominal IOD operations completed





HENON CubeSat Mission developed under GSTP



HEliospheric pioNeer for sOlar and interplanetary threats defeNce (HENO), Launch: Orbit: December 2026 Distant Retrograde Orbit (DRO) via Sun-Earth L1/L2 transfer Contractor: Argotec, INAF, Uni. Calabria, Uni. Florence, SpaceDys + payload teams Platform: 12U XL CubeSat Mission: • Transfer from Sun-Earth L1/L2 to DRO using M-ARGO propulsion

- Space weather measurements in DRO for 3-hour advanced warning of solar storms (when on sunward side – in KR1 region)
- Spinning mode for the study of the anisotropy in the energetic particle flux. Mode triggered by the detection of SEP events in KR2

Payloads:

- Relativistic Electron and Proton Experiment (REPE University of Turku)
- MAGnetometer from Imperial College (MAGIC similar to RadCube) on boom
- Faraday Cup Analyzer (Charles University in Prague)

Status: PDR completed successfully in October 2023, Phase C1 to be kicked off



CubeSat Swarms (OSIP call) Selected mission concepts

> 74 ideas received by closure of campaign

- 61 ideas qualified for evaluation
- > 13 ideas selected for restricted ITT
- > 7 consortia invited to negotiations (on-going until mid-Sept.)



	Project Name	Description	Consortium
16Us SBSP Masser Concert	16U4SBSP	 Demonstrate the use of a Swarm of 16U CubeSats for Space-Based Solar Power Supply energy to end-users in remote areas with low power requirements (<mw)< li=""> Emergency power supply for operations in blackout zones. </mw)<>	Sirin Orbital Systems (P), TU Delft, University of Strathclyde
And a state of the	AltiCube+	 Autonomous in-space assembly of a tens of meters level radar antenna baseline. Each 16U CubeSat is a complete radar altimeter and together form a sparse array Will provide sub-km resolution cross-track and meter ~level along-track. 	TU Delft (P), COMET Ingenieria S.L., ISISpace Group
	Revealing Orbital and Atmospheric Responses to Solar activity (ROARS)	 In-situ observations (augmented by ground-based measurements) of distributed neutral, plasma, and magnetic field observations Will help understand the evolution of field-aligned and ionospheric currents, Joule heating and the response of the neutral atmosphere. 	University of Warwick (P), Open Cosmo, University of Bath, UCL, University of Warwick, University of Stuttgart, Northumbria University, University of Birmingham
	COMCUBE-S	 Swarm of Compton telescopes for all-sky detection and polarisation measurements of gamma-ray bursts First high-accuracy polarisation measurements of the prompt gamma-ray emission from a large sample. 	University College Dublin (P), IJCLab, Clyde Space
Plans Pl	PULSARS (Precision Ubiquitous Low-cost Synthetic Aperture Regional Satellites)	 Swarm of 16U CubeSats with deployable antenna in a geostationary orbit slot Will provide a high capacity and scalable bi-directional 5G Narrow-Band IoT service Exploits ground-based beamforming technology to dynamically create coherent beams over individual users. 	Space Application CATAPULT (P), Open Cosmos
	Radar Cluster for Earth Remote Sensing (RaCERS)	 Swarm of eight 16U radar satellites acting cooperatively in a controlled formation Concurrent altimetry, scatterometry, and synthetic aperture radar imaging. 	GeoOptics Switzerland (P), Tyvak International, University of Birmingham, CNIT, ETH Zurich.
SWARM GMSS-R Uncommer Venture Venture Venture Venture Venture Venture Venture Venture	HydroSwarm	 Increasing GNSS Reflectometry instantaneous coverage to address flood monitoring and soil moisture with a swarm of cooperative GNSS-R CubeSats Will demonstrate two different measurement techniques: individual coherent track mode and SAR mode 	Surrey Satellite Technology, ICE-CSI C/IEEC

Instrumentation





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Remote Sensing Instruments



EUV Solar Imager for Operations (ESIO)

A small, lightweight solar EUV telescope and total solar UV flux monitor for monitoring and forecasting of space weather phenomena



Solar Coronagraph for OPErations (SCOPE) Wide-angle (out to 30 R_{Sun}) solar coronagraph concept for space weather observations based on a compact design



→ THE EUROPEAN SPACE AGENCY

X-ray Flux Monitor (XFM) ISaluare X-ray radiometer/spectrometer planned to fly on NOAA SWFO follow-on and future Vigil follow-on missions based on novel Si drift detector technology



Vigil: Heliospheric Imager (HI) Similar instrument to STEREO HI to track CMEs from the outer corona to 1AU based on 2-camera solution



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Vigil: Photospheric Magnetic-field Imager (PMI) A compact and lightweight instrument to deliver full magnetic field vector maps of the Solar Photosphere



Spotlight: PMI Critical parts development





In-Situ Plasma and Magnetic Field Instruments





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In-Situ Particle Radiation Instruments





Data Archiving and Provision





Data Exploitation and Open Data Interface (ODI)

- Open Data Interface (ODI) Database for in-situ data programming interfaces for popular computing languages
- Including processed data from TEC initiatives to produce cross-calibrated data for widespread use.
- Involvement in the Global Space-based Inter-Calibration System (GSICS) initiative



Contributions to JHelioviewer





Modelling Activities





Specification Modelling



2.6 MeV/n

727.4 MeV/

- Radiation and Plasma Environments (also microparticle and ATOX) for mission specifications and requirements - requires modelling expertise.
- A number of developments funded: SAPPHIRE + IEM (solar particle radiation + Jovian electrons), SRREMS + LARB + TREPEM (Earth trapped particle environments), PEMEM (Earth magnetospheric plasma), JCAT (Jovian plasma environment), AREMBES (L2 environment), GloRaB (Global Earth Rad Belts)
- Contribution to international efforts: ecIRENE (trapped and solar)



Planetary Environments in the Solar System



Jupiter (JORE²M² + JCAT)

- Jovian Radiation Environment and Effects Models and Mitigation (JORE²M²)
- JUICE Charging Analysis Tools (JCAT)
- Developed radiation and plasma models for the Jovian system to be used in mission environment specification and feasibility

Saturn and Beyond (TRAPPED)

- Testbed for Radiation and Plasma Planetary Environments
- Development of a modelling framework for radiation and plasma in other gas giant magnetospheres
- Focus on Kronian system for future mission definition



QinetiQ ONERA



Mars Climate Database (MCD)

- models of the Martian climatological system.
- Covers altitudes from surface to exosphere, providing atmospheric temperature, wind, pressure, composition, dust content...
- Used widely for mission EDL (Entry-Decent-Landing), mission design, data analysis and modelling work (incl. dust storms)



Venus Climate Database (VCD)

- VCDv2.3 meets similar objectives as the MCD but for Venus
- Focus on modelling density variability and associated uncertainties
- Current reference for EnVision mission design (e.g. aerobraking) and planning





6.30e.01 5.50e.03 5.50e.03 5.32e.02 4.35e.01 4.35e.01 3.50e.03 3.5

Space Weather Modelling



Which simulation would you like to run?

WARNING: Support for the BAS-RBM model is uncertainty

Simulation coupling AMRVAC CME (demo)

EUHFORIA EUHFORIA + Indice:

AMRVAC Solar Wind (dem COOLFluiD Steady (demo)

AMEVAD ONE (NE

Duration: 3m 50

D Finished: 2 mo

 Main development (in coordination with S2P Space Weather Office) is the Virtual Space Weather Modelling Centre (VSWMC) which incorporates models across the following domains: Solar corona, solar wind, CMEs, solar particle radiation, radiation belts, magnetospheric plasma, plasmasphere, ionosphere interactions, thermosphere



Radiation Storm Forecasting



- Forecasting developments for Solar Energetic Particle (SEPs) Advanced Warning System (SAWS)
- There are 3 main physics-based radiation belt models represented in Europe (SALAMMBO, BAS-RBM, VERB) and various analytical models (NARMAX, ecIRENE model + others Machine Learning approaches)





Thank you for listening!

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