Flight opportunities for Radiation and Plasma Monitors within the SSA programme

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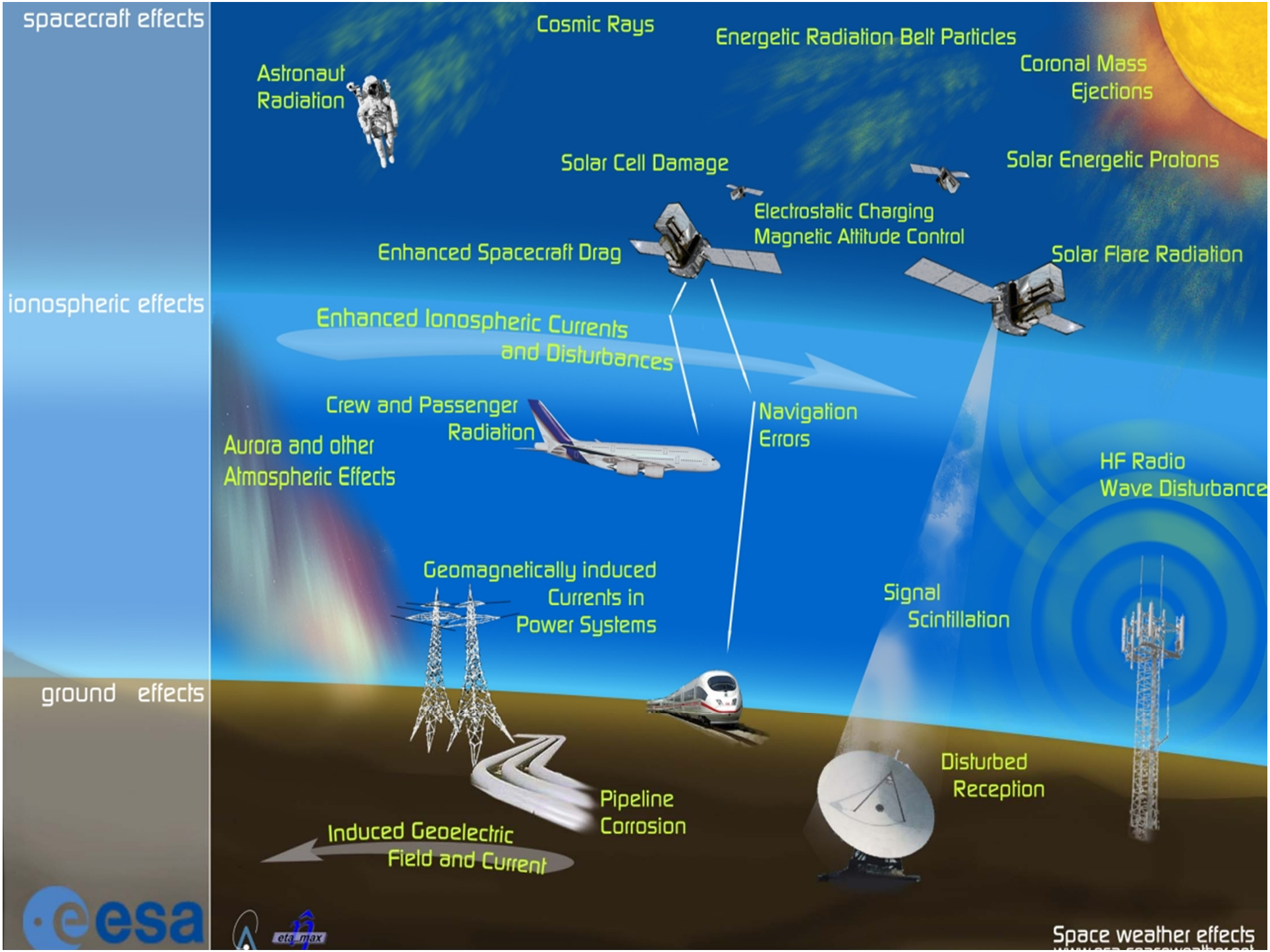
1. SSA programme
2. User needs
3. Measurement needs
4. Opportunities

Space Situational Awareness (SSA) Programme

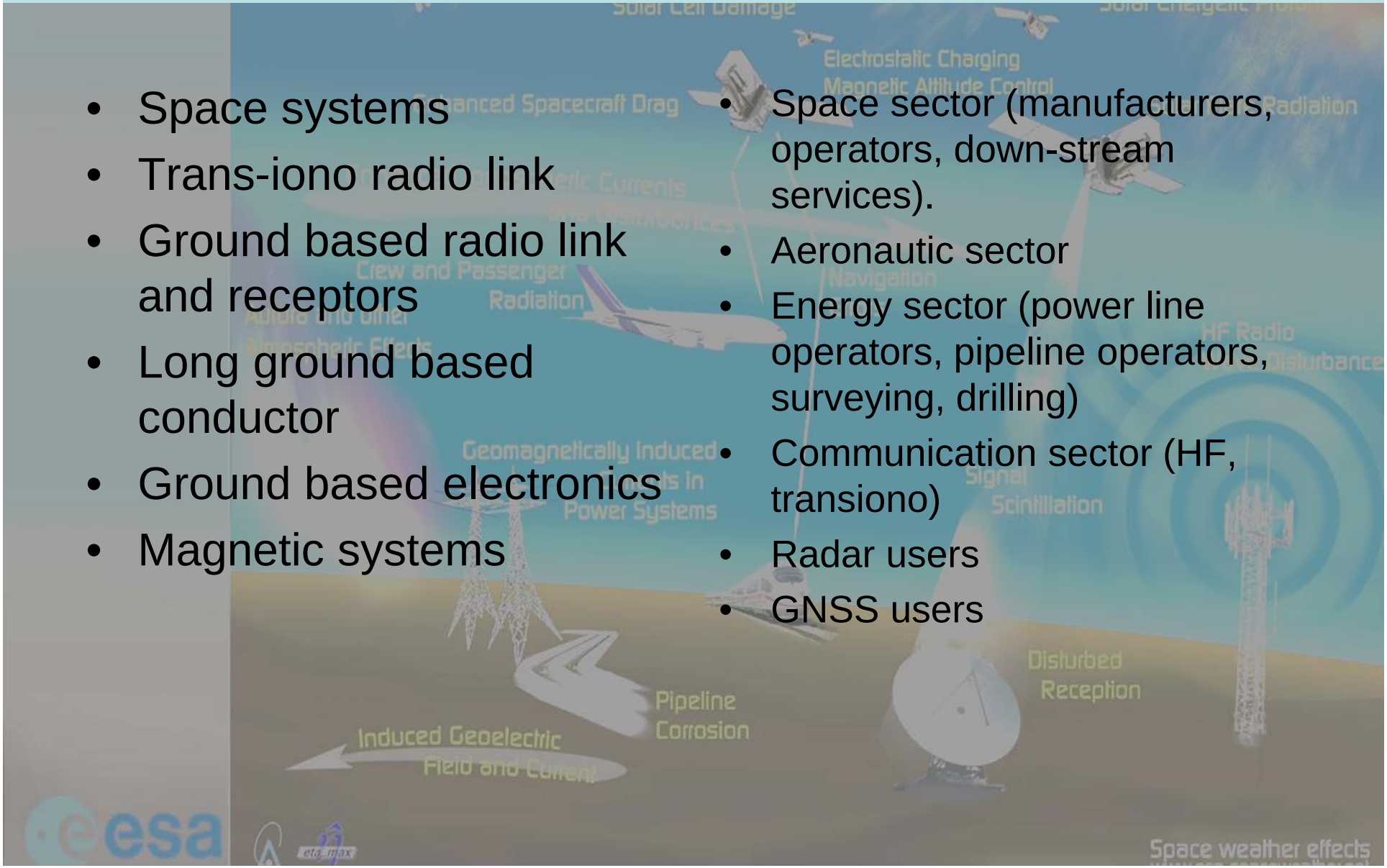
- Programme initiated by Council decision in 2008
  - addresses user needs related to risks prediction and mitigation in the area of orbiting objects, near Earth objects and space weather.
- 2009-2012 Preparatory phase
  - Optional programme with participation from:
  - Definition
  - Prototyping
- 2013-… Next phases
  - Member states participation open


spacecraft effects
ionospheric effects
ground effects
Cosmic Rays
Energetic Radiation Belt Particles
Coronal Mass Ejections
Astronaut Radiation
Solar Cell Damage
Solar Energetic Protons
Electrostatic Charging
Magnetic Attitude Control
Enhanced Spacecraft Drag
Solar Flare Radiation
Enhanced Ionospheric Currents and Disturbances
Crew and Passenger Radiation
Navigation Errors
Aurora and other Atmospheric Effects
HF Radio Wave Disturbance
Geomagnetically induced Currents in Power Systems
Signal Scintillation
Disturbed Reception
Pipeline Corrosion
Induced Geoelectric Field and Current
esa
eta_max
Space weather effects

Systems affected and users

- Space systems
- Trans-iono radio link
- Ground based radio link and receptors
- Long ground based conductor
- Ground based electronics
- Magnetic systems

- Space sector (manufacturers, operators, down-stream services).
- Aeronautic sector
- Energy sector (power line operators, pipeline operators, surveying, drilling)
- Communication sector (HF, transiono)
- Radar users
- GNSS users



Type of services needed

- Information to avoid, protect or support operation taken into account space weather effects.
- Type of information
  - Prediction and specifications
  - Monitoring - delayed or real-time
  - Forecast, nowcast

  of the environment and effects especially of
  - the aerospace vehicle
  - the ionosphere and upper atmosphere
  - the geomagnetic environment in space and on ground

Measurements requirements

- Magnetospheric medium and high energy radiation
- Interplanetary medium and high energy radiation
- Ionosphere and thermosphere density
- Magnetospheric cold, hot plasma and magnetic field
- Upstream solar wind, density, velocity and magnetic field
- Solar disc images from visible to X range
- Solar X and EUV flux
- Ground level magnetic field and first time derivative
- Atmospheric neutrons
- Systems effects

Measurement requirements: example

No.	Identified SWE observables or derived SWE parameters, revised by IET, SAT, SN-II Study Team Dec 1, 2010	Examples of SWE Effects	Identified instrument type	Identified Orbit requirements, preferences and alternatives and orientation for SWE observable and instrument	CRD priority ranking
1a	>1 MeV proton energy spectrum, upper bound 5 MeV, directional resolution of ~20 deg, for 2 pi, 30 sec measurement cadence	Solar cell and surface degradation	**Geo-space and interplanetary high energy proton radiation monitors**	above 600 km, any direction In L1 required spatial resolution shall be 2 pi towards the Sun. GTO, GEO for trapped protons (MEO, HEO, polar LEO) GEO, L1 for solar particles (MEO, HEO, polar LEO) any directed	high
1b	>5 MeV proton energy spectrum, upper bound ~70 MeV, directional resolution of ~20 deg for 2 pi, 30 sec measurement cadence	NIEL and dose			high
1c	>30 MeV proton energy spectrum, upper bound ~400 MeV, directional resolution of ~20 deg for 2 pi, 30 sec measurement cadence	SEEs			high

Current SWE data from EU space H/W

Mission	Solar/solar corona	Solar wind	Plasma/radiation/geomagnetism	Ionosphere/ thermosphere	Comment
SOHO	Coronagraph Solar disk imaging Spectrometer		Interplanetary radiation		**Near real time** **Near end of life**
Picard	Solar disc size				
Proba-2	Solar disc and corona imaging				**1 data downlink per orbit**
Proba-1			Radiation belts		**1 data downlink per orbit** **Near end of life**
GIOVE-A			Radiation belts		**1 data downlink per orbit**
GIOVE-B			Radiation belts		**1 data downlink per orbit**
Rosetta			Interplanetary radiation		**Dormant until 2014**
XMM			Interplanetary and belt's radiations		
Integral			Interplanetary and belt's radiations		
Herschel			Interplanetary radiations		
Planck			Interplanetary radiations		
METOP-A and -B			Radiation belts		**Based on US/NOAA instrument**
Jason-2			Radiation belts		
SAC-C			Radiation belts		
SAC-D			Radiation belts		
Cluster			Hot plasma		**Mainly science mission** **Near end of life**
Champ				Plasma and TEC/ Drag	
GOCE				Drag	
GRACE				**Drag**	

Commonly used SWE data without EU H/W

Mission	Solar/solar corona	Solar wind	Plasma/radiation/ geomagnetism	Comment
ACE		Solar wind density, speed and magnetic field	Interplanetary radiation	**Near real time Near end of life**
Stereo	Solar disc and corona	Interplanetary coronal mass ejections imaging		
GOES satellites	X-ray, proton, electron flux		Radiation belts	**Near real time**
SDO	Solar disc imaging		Radiation belts	**Near real-time**
NPOESS satellites			**Radiation belts and hot plasma**	**1 data downlink per orbit**

Planned mission with SWE EU H/W

Mission	Launch	SWE measurement
MTG	2017	**Radiation belt at GEO**
Metop-SG	2020	**Radiation belts at LEO**
Proba-V	20??	**Radiation belts at LEO**
Galileo FOC	2014 -	**Radiation belts at MEO**
Proba-3	2015 - 2016	**Solar corona (very low priority objective of the mission)**
Taranis	2014	**Radiations at LEO**
Techdemosat	TBA	**Radiations at LEO**
Jason-3	2014	**Ionospheric electron density, hot plasma in LEO**
Solar Orbiter	2017	**Density, speed and magnetic field at 0.3 AU**
Lisa-PF	201?	**Interplanetary radiation and coarse magnetic field measurement**
SWARM	2012	**Geomagnetic field**
BepiColombo	**2014**	**Interplanetary radiation**

SSA on-going analysis

- Architecture of the observation and service systems
- Roadmap for deployment
- Hosted payload design study

Result of AO for SWE instruments

Instrument name	Acronym	Company of prime supplier	Country	Instrument type
Low energy particle detectors				
Low Energy Charged Particle Spectrometers	ELS, PEACE, IPA, ChaPS	MSSL	UK	Low Energy Particle Detector
Multi-Needle Langmuir Probe System	M-NLP	U of Oslo, Dept. of Physics	N	Langmuir Probe
Omni-directional Plasma Analyzer	OPA	LPP; LATMOS	F	Low Energy Particle Detector
Plasma Diagnostic Package	PLEO-PDP	TAS-I	I	Low Energy Particle Detector
Spherical EUV and Plasma Spectrometer + Low Energy Electron Detector	SEPS-LEED	Fraunhofer-Institut IPM; PSI	D, CH	Low Energy Particle Detector
Space Weather Charged Particle Analyser	SW-CPA	MSSL	UK	Low Energy Particle Detector
3-D Solar Wind Monitor	SWM	ESA	TBD	Low Energy Particle Detector + Langmuir Probe
Thermal Ion Retarding Potential Analyzer	TIRPA	LATMOS	F	Low Energy Particle Detector
Thermal Plasma Monitor	TPM	CESR/IRAP	F	Low Energy Particle Detector
Medium and high-energy particle detectors				
3DEES	3DEES	ESA	TBD	Medium Energy Electron Detector
Energetic Proton and Electron Instrument	EPEI	CESR, CNES	F	Medium & High Energy Particle Detector
Energetic Particle Spectrometer	EPS	U of Helsinki, asro-space	FIN	Medium & High Energy Particle Detector
Highly Miniaturised Radiation Monitor	HMRM	RAL	UK	Medium & High Energy Particle Detector
Next Generation Radiation Monitor	NGRM	ESA	TBD	Medium & High Energy Particle Detector
Radiation Monitoring Units	RMU	TAS-I	I	Medium & High Energy Particle Detector 0.5 - 1000 MeV (comprising TID monitor, SEU monitor and charge monitor)
Solar Particle Analyser eXperiment	SPAX	INFN	I	Medium & High Energy Particle Detector
Dust detectors				

Result of AO for SWE instruments

Instrument name	Acronym	Company of prime supplier	Country	Instrument type
Micro-particle detectors				
Advanced Impact Detector Assembly - Entrance Stage	AIDA-ES	etamax space GmbH	D	Dust Particle Trajectory Detector
Advance Impact Detector Assembly Impact Stage	AIDA-IS	etamax space GmbH	D	Dust Particle Calorimeter
Laser-Curtain Particle Trajectory Analyzer	EMI-LPTA	Fraunhofer EMI	D	Dust Particle Trajectory Detector
Meteoroid and Space Debris Detector #3	MDD3	Fraunhofer EMI	D	Dust Particle Detector
Solar Orbiter Dust Analyser	SODA	MPI für Kernphysik	D	Dust Particle Trajectory and Energy Detector
charging detectors				
Internal Discharge Detection and Monitoring	IDDM	TAS-I	I	Surface Charging Detector
Surface Potential Detector	SPD	TAS-I	I	Surface Charging Detector
GNSS receivers				
GNSS Receiver for Atmospheric Sounding - 2nd Generation	GRAS-2	Danish Meteorological Institute + RUAG Space AB	DK, S	GPS/GNSS Receiver
Precise Orbit Determination and TEC-Measurement GNSS-Receiver	PTGR	RUAG Space GmbH	A	GPS/GNSS Receiver
Radio Occultation Sounder for Atmosphere	ROSA	ISA, TAS-I	I	GPS/GNSS Receiver
Magnetometers				
Magnetic Indices Experiment	MAGIE	DTU	DK	3D Vector Magnetometer
Magnetoresistive Magnetometer	MRMAG	Imperial College	UK	3D Vector Magnetometer
Service Oriented Spacecraft Magnetometer Set	SOSMAG	ESA	TBD	3D Vector Magnetometer
SWE-Mag Instrument	SWE-MAG	TU Braunschweig	D	3D Vector Magnetometer
VIS imagers, radiometers and spectrometers				
Heliospheric Imager	HI	RAL, U of Valencia	UK, E	Wide Angle Camera
Wide Angle Coronagraph	WA	ESA	TBD	Wide Angle Coronagraph
(E)UV imagers, radiometers and spectrometers				
UV Flux Monitor	UVFM	PMOD/WRC	CH	UV flux meter
Wide Field Auroral Imager	WFAI	U of Leicester	UK	Wide-field UV Imager
EUV Solar Imager for Operations	ESIO	ESA	B	EUV imager + UV Flux Meter
Solar Lyman Alpha Far Side Monitor	SOLA-FM	IPSL, FMI	F, FIN	Lyman Alpha Imager
X-ray imagers, radiometers and spectrometers				
Compact X-ray Solar Monitor for Operations	CXSMO	ESA	TBD	X-ray Flux Meter
X-Ray Flux Monitor	XFM	U of Helsinki	FIN	X-ray Flux Monitor
X-Ray and Particle Spectrometer	XPS	U of Helsinki, Oxford Instruments, ASRO	FIN	X-ray Spectrometer and High Energy Particle Detector
X-Ray Solar Imager for Operations	XSIO	ESA	TBD	X-ray Imager
Other instrument types				
Active Charging Compensator System	ACCS	TAS-I	I	Electron source
Micro Spatial Tri-axes Accelerometer for Research	MicroSTA	CNES, ONERA/DMPH	F	Accelerometer

Potential EU mission for hosting H/W

Mission	Possible European hosted sensors	Orbit	Launch
Galileo FOC	- 2 spacecraft will have radiation monitors onboard - More satellites could host the same sensor or monitors with equivalent interface (e.g., plasma monitor).	MEO	**2014 -**
Euclid	- Solar X-ray or EUV flux monitor on the unused sunlit side.	L2	**2018**
Lisa-PF	- Magnetometer, Radiation	L1	**201?**
Heinrich-Hertz	- Radiation and hot plasma sensors	GEO	**2016**
EDRS-C (and A)	- NGRM (Next generation radiation monitor) under study	GEO	**2015**
Alphasat next	- Several particle sensors (up to 30 kg)	GEO	**Earliest 2015**
Eurostar next	- Several particle sensors (up to 30 kg)	GEO	**Earliest 2015**
Jason-CS	- Radiation and hot plasma sensors - GNSS receiver could be adapted for ionospheric sounding	LEO	**2017**
MetOp-C	- Radiation and hot plasma sensors - GNSS receiver could be adapted for ionospheric sounding	SSO	**2016 (TBC)**
CSG-1,2	- Radiation and hot plasma sensors - GNSS receiver could be modified for ionospheric sounding - Radiometers, spectrometers or micro-particle sensor	SSO	**2015 and 2016 (two spacecraft)**
Merlin	- Low and medium energy particle sensors - GNSS receiver - Magnetometer	SSO	**2016**
Explorers 7 and 8	- Analysis on hold waiting for the mission selection	SSO	**2019**
Metop-SG	- **Radiation and hot plasma sensors** - **GNSS receiver could be adapted for ionospheric sounding**	**SSO**	**2020**

Non EU missions opportunities

Mission	Possible European hosted sensors	Orbit	Launch
GK-2A, 2B	- Medium energy particle sensors - Surface charging sensors	GEO	**2018 and 2019**
FY-4	- Medium energy particle sensors - Surface charging sensors	GEO	**2018**
FY-3 02	- Low and medium energy particle sensors - GNSS receiver - Magnetometer - Micro-particle detector	LEO	**Not known**
Meteor MP-NP3	- Low and medium energy particle sensors - GNSS receiver - Magnetometer - Micro-particle detector	LEO	**2016**
Cosmic-2	- Radiation belts and hot plasma sensors	LEO	**2015**
Iridium NEXT	- Radiation belts and hot plasma sensors	LEO	**2015** **Not considered at the moment**
DSCOVR	- **Interplanetary radiation sensor**	**LEO**	**2015**

Measurements requiring dedicated missions

Measurement requirements	Type of missions
Solar wind measurement ahead of Earth on Sun-Earth line	**Satellite at L1**
Solar radio observations below ionospheric cut-off	**Satellite at L1 or L2 or highly elliptical orbit**
Auroral activity via auroral imaging and terrestrial radio observations below ionospheric cut-off	**Satellite at L1 or L2 or high inclination highly elliptical orbit**
Nearly continuous solar corona imaging, solar x-ray imaging, solar EUV imaging	**Satellite at L1, or L2 or highly elliptical, or GEO or dawn-dusk SSO.**
Comprehensive near Earth radiation belts and plasma monitoring	**Trans-radiation belts orbit, e.g. GTO**

Kuafu A (at L1), B (2*HEO) may help to cover some of the measurements above.

Conclusion

- The SSA programme offers a real opportunity for federating radiation and plasma monitoring services and related hardware developments.
- Priority 1 activities: Ensure the continuity of the current well established services to European users.
  - Ensuring full exploitation of existing and already planned SWE monitors on European spacecraft and especially Proba-2, METOP-SG, MTG.
  - Ensuring embarkment and data exploitation of particle radiation monitors on future platforms especially on Alphabus next, and EDRS-C for which new agreement should be made.
  - Ensuring embarkment and data exploitation of solar X-ray and EUV radiation monitors on future platforms especially on Alphabus next and/or EUCLID for which new agreement should be made.
  - Ensuring embarkment of radiation monitors on next generation Galileo spacecraft.
  - Ensuring ionospheric measurements capability based on radiation occultation technique on METOP-SG and Jason-CS.
  - Preparing for a solar wind monitoring capability to replace ACE.
  - Preparing a coronagraph imaging mission to replace SOHO and Proba-2.

- Priority 2 activities: Extend the European data source to increase coverage and allow new services.
  - Increasing the number of radiation monitors EMU on Galileo FOC from two to 6 units.
  - Embarking hot plasma monitors on Galileo FOC and Alphabus next.
  - Preparing for a radiation belt monitoring capability on trans-radiation belt orbit (e.g. GTO).
  - Preparing for solar and auroral radio monitoring from space.