Simulation needs for particle instruments

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Outline

-**Overview of particle instruments on board future / Cosmic Vision missions**

-**Processes and effects requesting modeling**

-**Supporting science data on past/current missions**

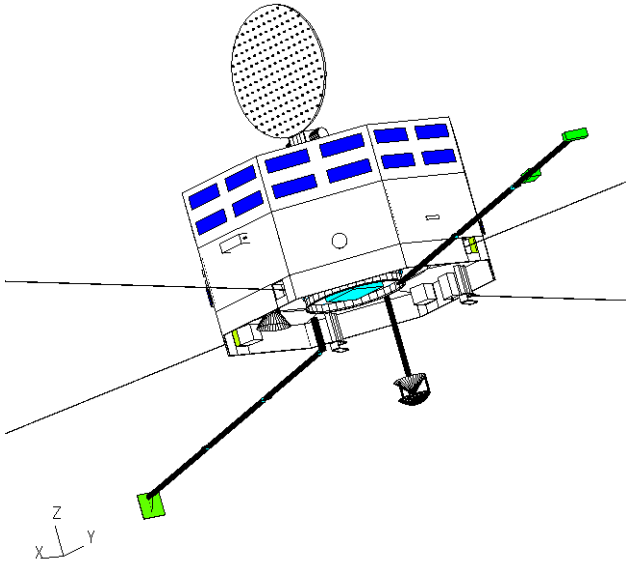
Missions of interest

- Bepi-Colombo
  - MMO
  - MPO
- Solar Orbiter
- EJSM
  - JGO
  - JEO
- Rosetta

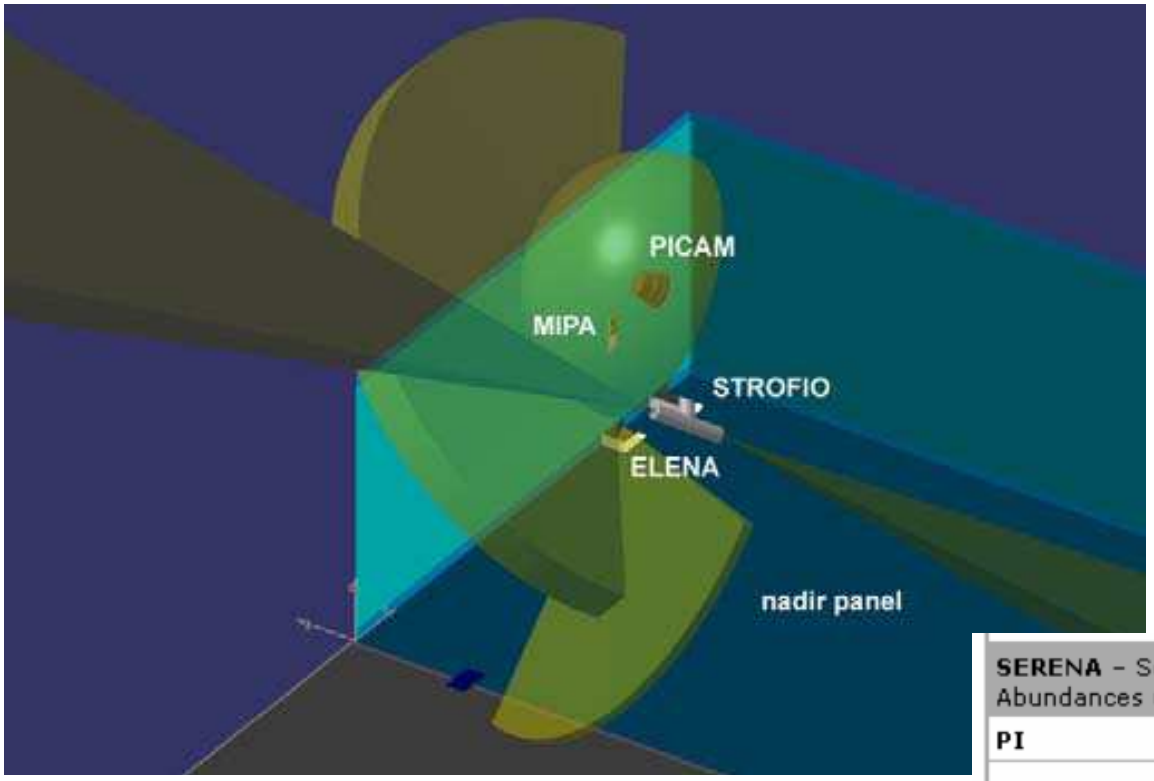
Bepi-Colombo

Mercury Planetary Orbiter

Mercury Magnetospheric Orbiter



SERENA FOV onboard MPO

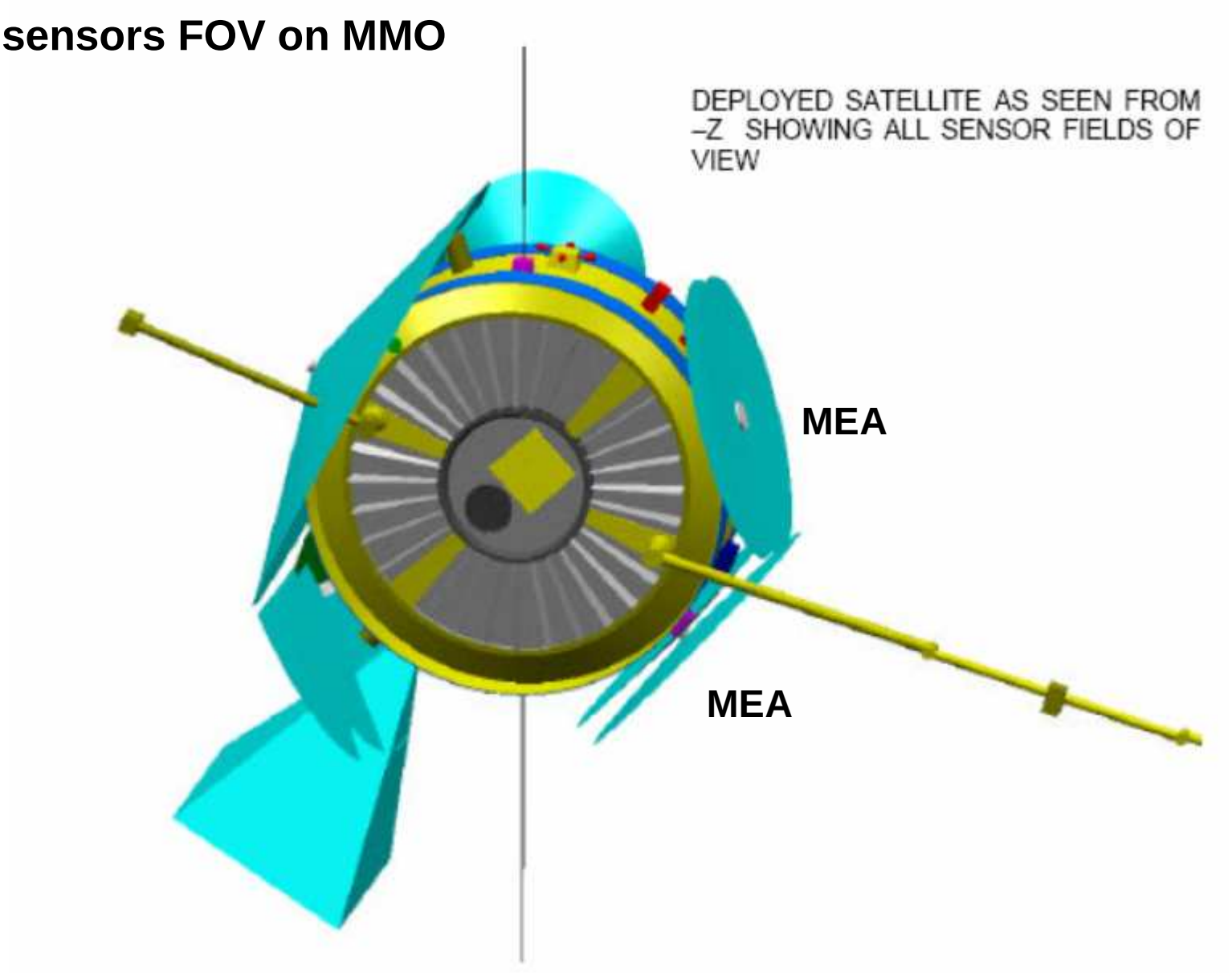


SERENA – Search for Exosphere Refilling and Emitted Neutral Abundances (Neutral and ionised particle analyser)	
PI	**Co-PIs**
S. Orsini CNR-IFSI, Rome Italy	S. A. Livi Johns Hopkins University, Applied Physical Lab., Laurel USA S. Barabash Swedish Inst. of Space Physics (IRF), Kiruna Sweden K. Torkar Space Research Institute, Austrian Academy of Sciences, Graz Austria

SERENA (w/o STROFIO & ELENA) on board MPO

	PICAM	MIPA
Energy range	1 eV–3 keV	10 eV–15 keV
Resolution	$\Delta E/E$~10%	$\Delta E/E$~7%
Mass resolution	$M/\Delta M$>60	$M/\Delta M$ ~5
Type of instrument	all-sky camera for ions	simple ion mass analyzer

Particle sensors FOV on MMO



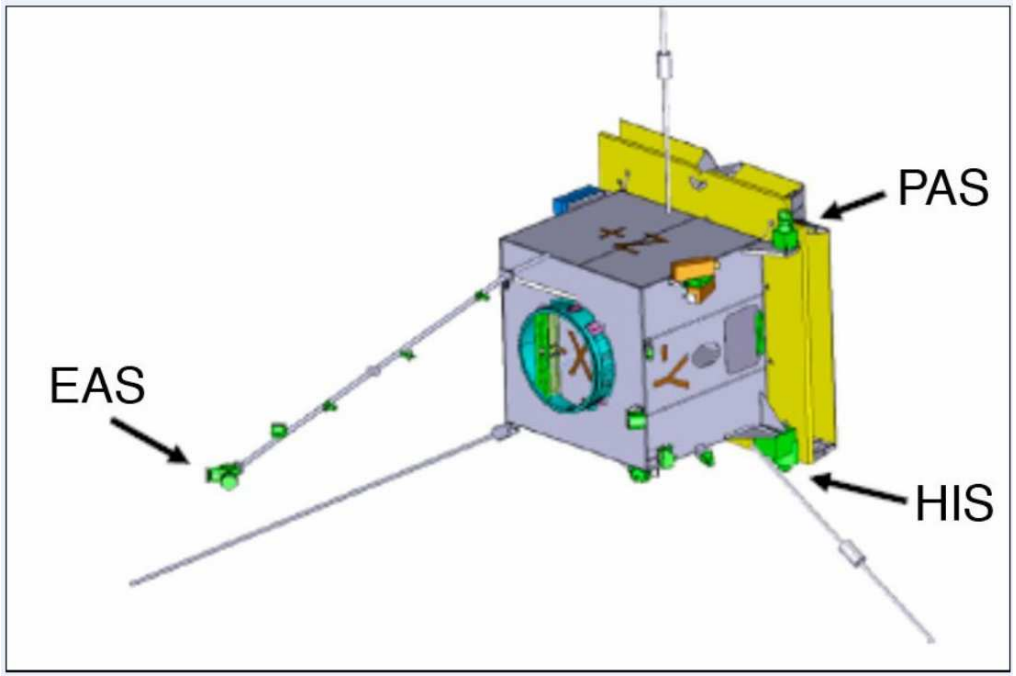
Mercury Plasma Particle Experiment (MPPE, here without ENA) onboard MMO

PI : Y. Saito, ISAS

	MEA	MIA	MSA	HEP-ele	HEP-ion
Energy range	5 eV– 30 keV	5 eV/q-30 keV/q	5 eV/q– 40 keV/q	30–700 keV	30–1500 keV
Resolution	Δ*E*/*E*~10%	Δ*E*/*E*~15% (FWHM, high *g*) Δ*E*/*E*~3% (FWHM, low *g*)	Δ*E*/*E*~10%	Δ*E*/*E*~50%	Δ*E*/*E*~50%
Mass resolution	-	-	m/Δm=15-40 (depends on energy)	-	H, He, C–N–O, Na–MgK–Ca, Fe, electron
Time resolution	1s	-2s / 3D DF for 32 energy steps -16s / 3D DF for 128 energy steps	-2s / 3D DF for 32 energy steps -4s / 3D DF for 64 energy steps	-4s (1 spin) (normal mode) -100 ms (burst mode)	-4s (1 spin) (normal mode) -100 ms (burst mode)
Type of instrument	Toroidal electrostatic analysers (2)	Toroidal electrostatic analyser (solar wind)	Toroidal electrostatic analyser + LEF-TOF mass spectrometer	Spectrometer	Spectrometer

Solar Orbiter

-Non spinning S/C
-Heat shield
-EAS = electron sensor
-PAS & HIS = ion sensors



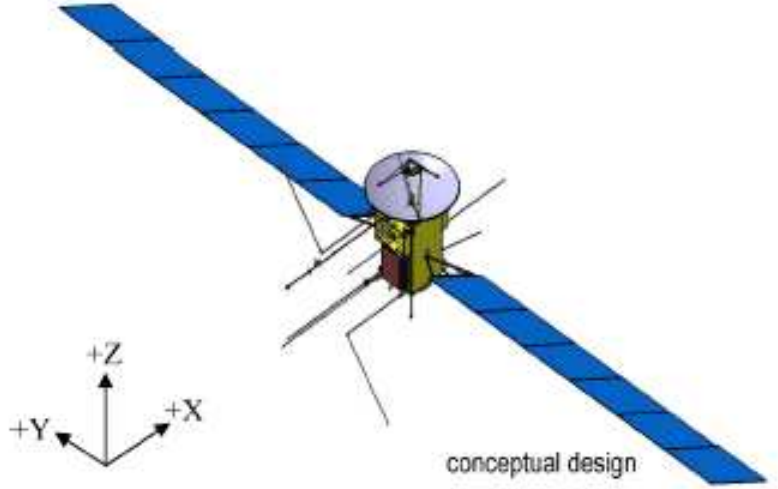
Solar Orbiter / SWA

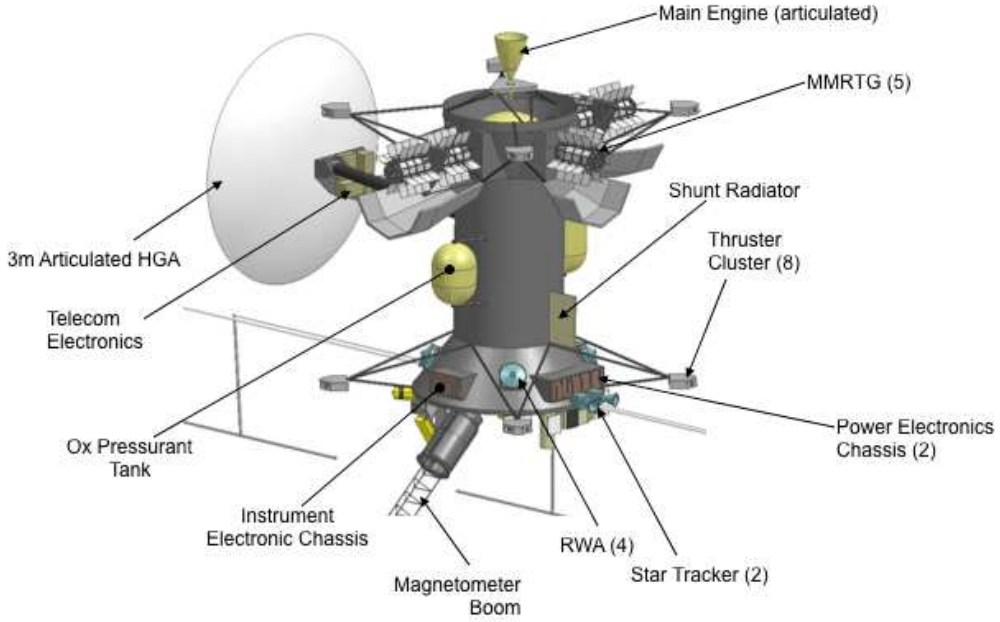
Principal Investigator: Dr. C. Owen, MMSL, UK

	EAS	PAS	HIS
Energy range	~1 eV to ~5 keV	0.2–20 keV/q	0.5–100 keV/q or 0.5–16 keV/q
Resolution	ΔE/E ~10-12%	ΔE/E ~7.5%	ΔE/E ~6%
Mass resolution	-	H, alpha, main solar wind species	2-56 amu/q
Time resolution	-Moments : 3s -3D DF: lower cadence -2D PA: 0.1s (burst)	-3s -0.1s (burst)	-3D DF: 5min -heavy ions (burst):30 s -alpha (burst): 3s
Type of instrument	A pair of top-hat electrostatic analysers	top-hat electrostatic analyser	Electrostaic analyzer module with ion steering + TOF SSD telescope

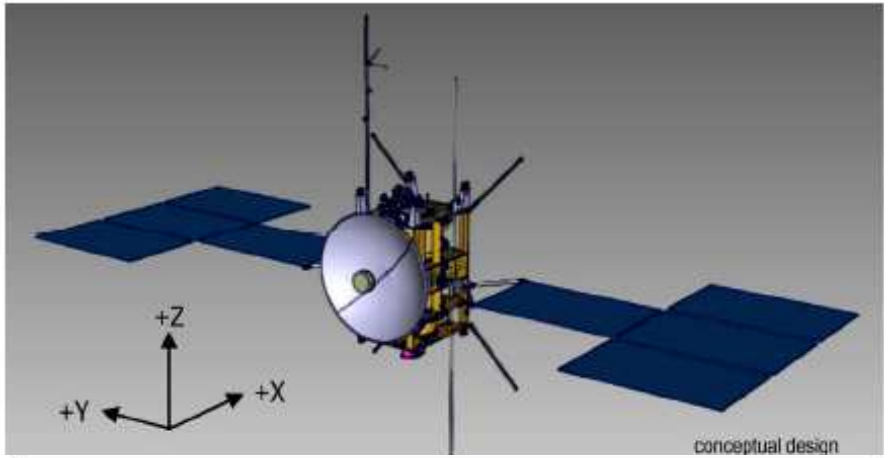
EJSM

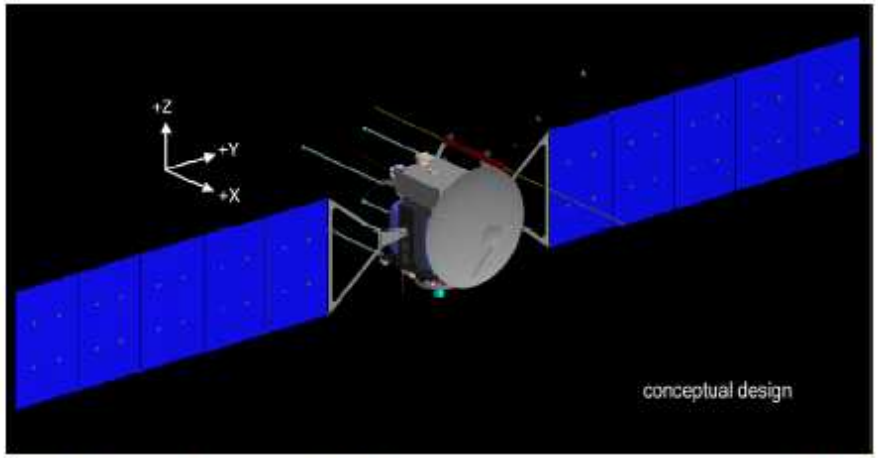
JGO conceptual designs
(solar panels)





JEO conceptual design
(RTGs)





EJSM Plasma Particle Experiment (w/o ENA and INMS) onboard JGO (model payload)

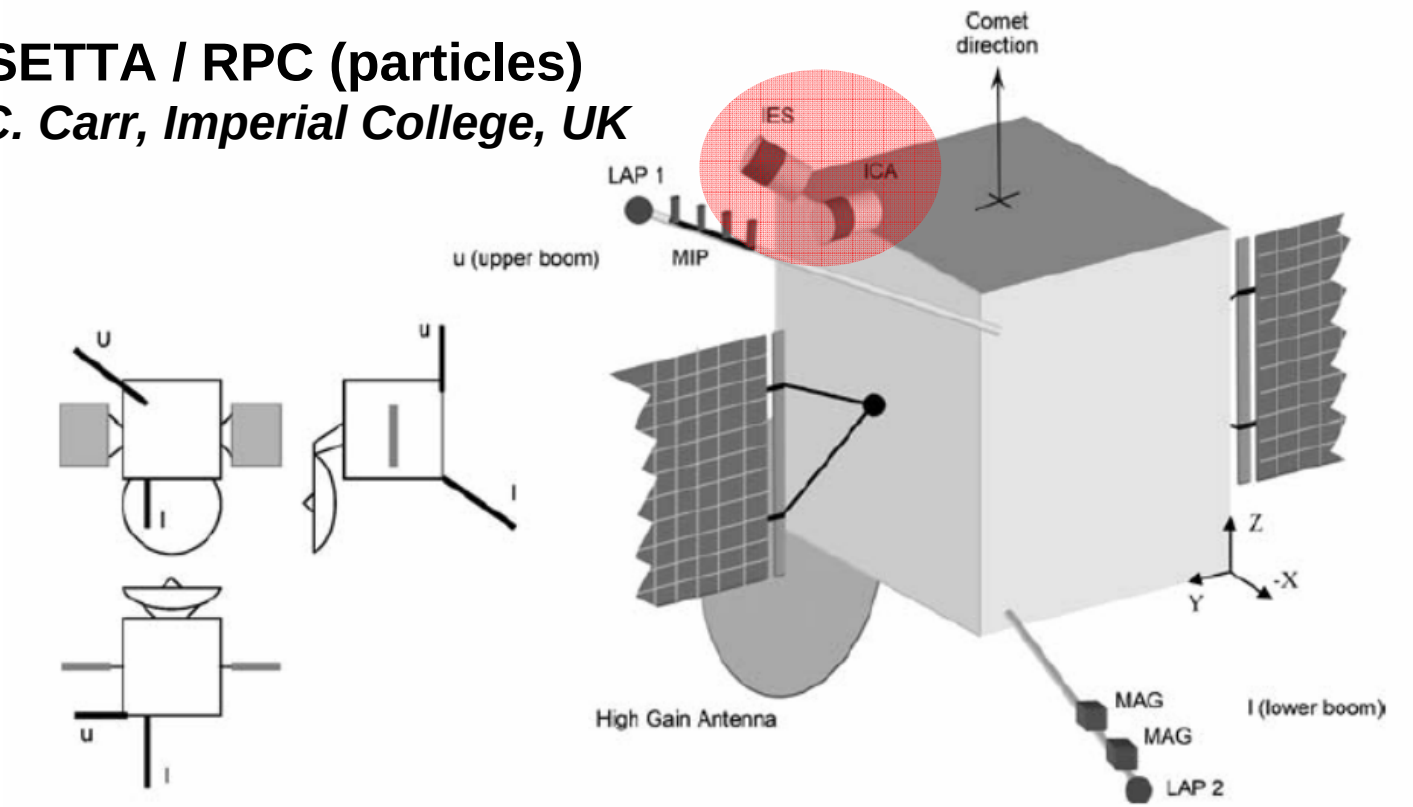
	ELS	HPS	MPS	EPS-ele	EPS-ion
Energy range	1 eV– 20 keV	1 eV/q-30 keV/q	1 eV/q– 10 keV/q	15 keV – 1000 keV	3 keV – 5000 keV
Resolution	Δ*E*/*E*~10%	Δ*E*/*E*~15%	Δ*E*/*E*~10%	Δ*E*/*E*~50%	Δ*E*/*E*~50%
Mass resolution	-	m/Δm<<40	m/Δm>40	-	H, He, C–N–Oxygen, Sulfur-group species
Heritage	Cluster PEACE, ASPERA ELS, Cassini CAPS ELS	Cluster CODIF, ASPERA IMF	BepiColombo MSA, Cassini CAPS IMS	Cluster RAPID, Ulysses, Cassini MIMI	Cluster RAPID, Ulysses, Cassini MIMI
Type of instrument	Top hat analyser	electrostatic cylindrical analyzer + TOF	Top hat analyser + LEF-TOF mass spectrometer	foil-based TOF instrument with solid-state detectors	foil-based TOF instrument with solid-state detectors

EJSM Plasma Particle Experiment onboard JEO (model payload)

	PPI-e-	PPI-ions	PPI-energetic e-	PPI-energetic ions	PPI-high energy e-
Energy range	10 eV–30 keV	10 eV/q-30 keV/q	30 keV–1000 keV	30 keV–10s 000 keV	>2 MeV, >4 MeV, >8 MeV, >16 MeV
Resolution	Δ*E*/*E*>10%	Δ*E*/*E*>10%	Δ*E*/*E*>10%	Δ*E*/*E*>10%	
Instrument heritage	DS1 PEPE MESSENGER FIPS	DS1 PEPE MESSENGER FIPS	New Horizons PEPSSI Juno JEDI	New Horizons PEPSSI Juno JEDI	
Type of instrument	Top hat analyser	Top hat analyser + TOF	Puck analyser	Puck analyser	Omni-directional SSDs

ROSETTA / RPC (particles)

Pi: C. Carr, Imperial College, UK



Instrument	Providing Institute	Key Personnel
Ion Electron Sensor (IES)	Southwest Research Institute San Antonio, Texas, USA	J. L. Burch (PI) R. Goldstein (TM) C. Pollock
Ion Composition Analyser (ICA)	Swedish Institute of Space Physics Kiruna Sweden	R. Lundin (PI) H. Nilsson K. Lundin (TM)

ROSETTA / RPC (particles)

	ICA Ion Composition analyzer	IES Ion and Electron Sensor
Energy range	25 eV/e to 40 kev/e	1 eV/e to 22 keV/e
Resolution	$\Delta E/E$~0.07	$\Delta E/E$~0.04
Mass resolution	H+, He+, He++, O+, O++, CO+2 (plus heavier species)	
Time resolution	3D : 192s	3D : 128s
Type of instrument	electrostatic analyzers + mass spectrograph	2 electrostatic analyzers

ROSETTA / Rosina

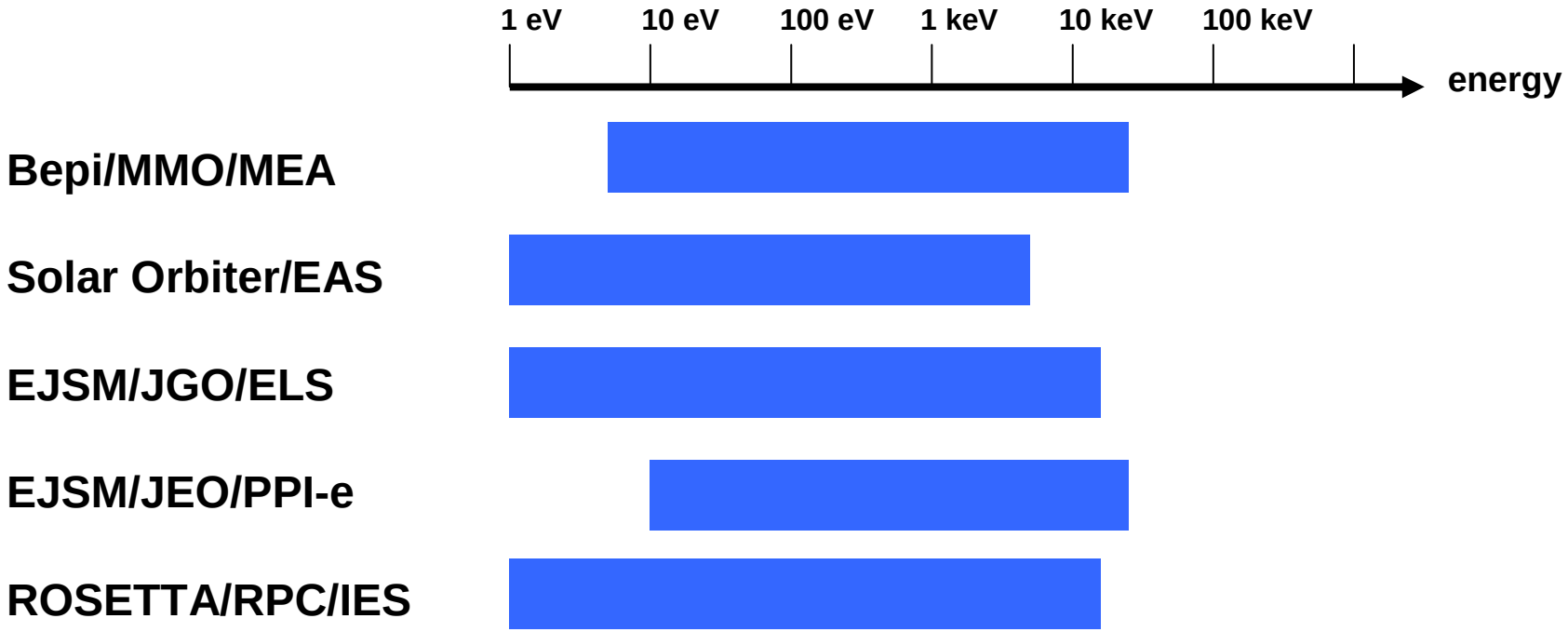
PI : H. Balsiger, Bern University

-two mass spectrometers for neutrals and primary ions
-M/ΔM > 3000
-Time resolution : 4-20s
-Energy range : low energy ions
-Attraction grids (biased +-50V) to favour ion detection
-Preliminary study : *Nyffenegger et al., 2001*

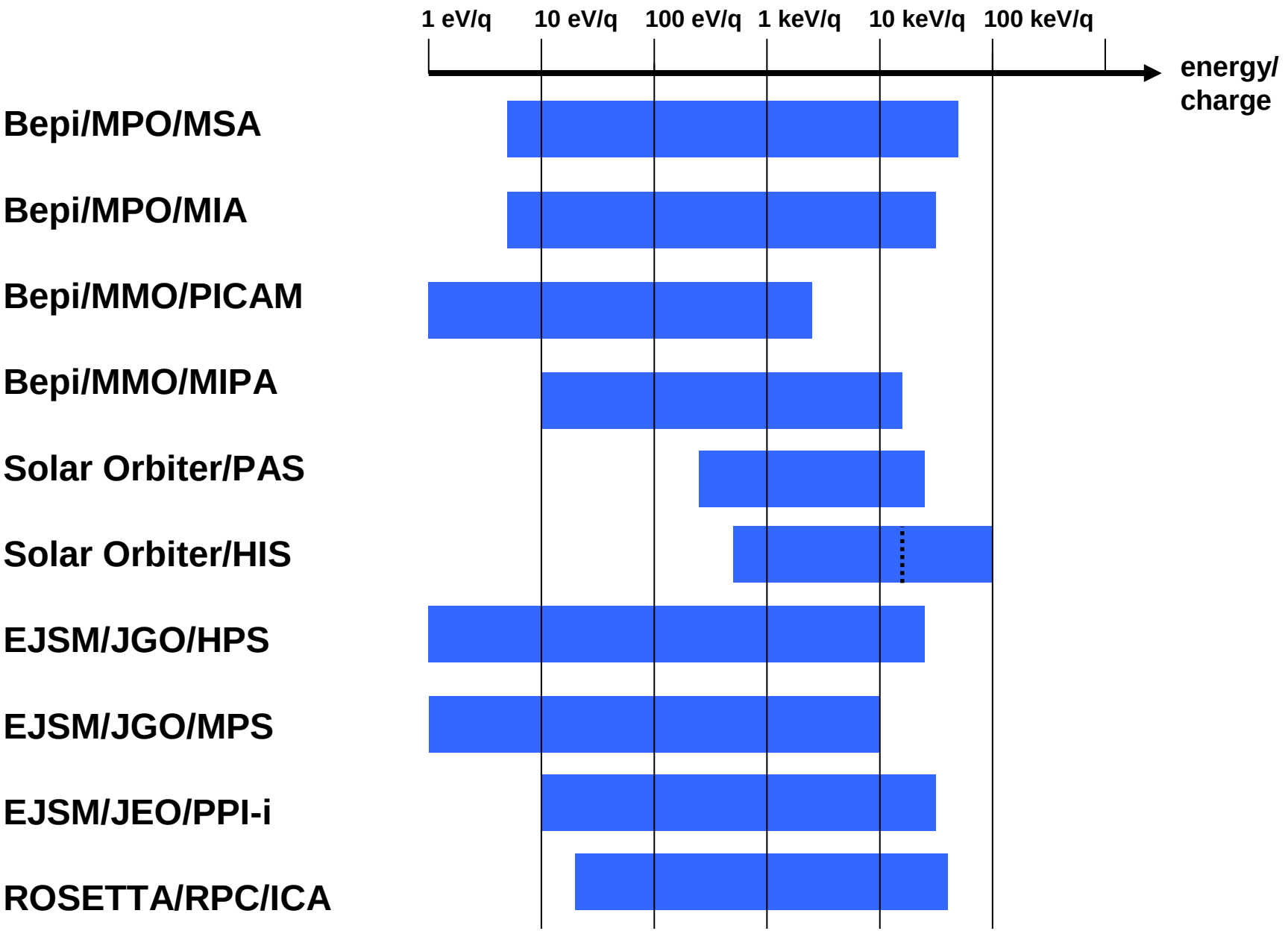
Simulations needs for spacecraft plasma interaction effects on particle instruments

With inputs from M. Wieser (IRF Kiruna), JJ Berthelier (LATMOS), N. André (IRAP)

Overview of thermal electron instruments
-energy range-



Overview of thermal ion instruments
-energy range-



Particle / spacecraft potential effects 1/2

Mission	Detector	Range	Effect	Cause	Parameters for modeling	Accuracy requirement
All	Electron	Thermal energy	Contamination by photo electrons	Photo emission	Distribution function, yield, trajectories (back-tracking)	
All	Electron	Thermal energy	Contamination by secondary electrons	Secondary emission	trajectories (back-tracking)	
All	Ion	Energetic	Contamination of ion measurements / surface alteration	Thruster emission	Thruster modeling	
All	Electron/ion	Thermal energy	Energy offset of ambiant plasma	Spacecraft potential	Material, bias	<1V
All	Electron/ion	Thermal energy	Deviation/distortion of particle trajectory	Spacecraft potential	Material, bias	<1V
Bepi, Rosetta, EJSM/JGO	Ion	Low energy	No or partial measurement when Vsc>0	Spacecraft potential	Material, bias	<1V

Particle / spacecraft potential effects 2/2

Mission	Detector	Range	Effect	Cause	Parameters for modeling	Accuracy requirement
All	Particle	Thermal energy	Ambiant plasma energy/trajectory modification	Active instrumentation (Langmuir probe, radars, potential control device)	Active instrument characteristics	
All	Ion	Low energy	Wake/ram effect	Spacecraft motion		
All			Charge exchange on spacecraft structures	Energetic neutrals generated from ions	Need for particle tracing	
All	Ion		Generation of ghost signals in ion and neutral data / spacecraft potential	Reflection of charged or neutral particles / ionization on spacecraft structures	Need for particle tracing	

instrument / spacecraft design effects

Mission	Detector	Range	Effect	Cause	Parameters for modeling	Accuracy requirement
All	Particle	All energies	Blocking of FOV / shadowing by spacecraft structures	Instrument mounting	Instrument model, localisation, need for particle tracing	
All (especially with large solar panels)	Particle	Thermal energy	Wake / ambiant plasma perturbation	Spacecraft design	Instrument models, localisation	
All, Demeter	Particle ,field	-	Large distance wake	Spacecraft design	Large simulation box (especially towards S/C rear)	
Bepi/MMO	-	-	Large gradient in spacecraft potential / TBD	Rotating spacecraft		
Bepi/MMO			Large potential differences between solar panel elements	Differential surface charging	Mesh	
All	Particle		Secondary emission / particle collection	Wire booms		
	Ion/neutral		Background for neutral gas measurements	Spacecraft outgazing		

Environmental effects

Mission	Detector	Range	Effect	Cause	Parameters for modeling	Accuracy requirement
Solar wind missions	Particle		Peculiar charging characteristics ? / TBD	Non Maxwellian ambiant plasma	Kappa distributions	Kappa=2-6 depending on distance to the Sun
EJSM, Rosetta	Particle		Peculiar charging characteristics ? / TBD	Environment near body	Plasma + radiation characterisation	
Solar wind missions	-		Directionality of solar flux	Finite solar size	Distance to the Sun	
All			Charge build-up on spacecraft surface	Motional electric field		
EJSM, magnetic environment in general	Particle, fields		Wake variation / extent of the sheath (// and ⊥ to B)	Jupiter and Ganymede magnetic fields	Magnetic field models	

Supporting science mission data

in Solar wind, Comets, and Jupiter environments

Solar wind thermal electron/ion data

mission	Electron instrument	Data centres	Ion instrument	Data centres	
Cluster	PEACE	CAA	CIS	CAA	
Themis	ESA-e	SSL, CDPP	ESA-i	SSL, CDPP	
Wind	SWE-e	CDAWeb	SWE-i (faraday cup)	CDAWeb, CDPP	
Wind	3DP/EESA	SSL	3DP/PESA	SSL, CDAWeb	
Imp8	GME (>500keV)	CDAWeb	MIT (faraday cup)	CDAWeb, CDPP	
Ulysses	SWOOPS-e	CDAWeb, CDPP	SWOOPS-i	CDAWeb, CDPP	
STEREO	SWEA	IRAP, CDPP	PLASTIC	UNH, CDPP	
ACE			SWEPAM	CDAWeb, CDPP	

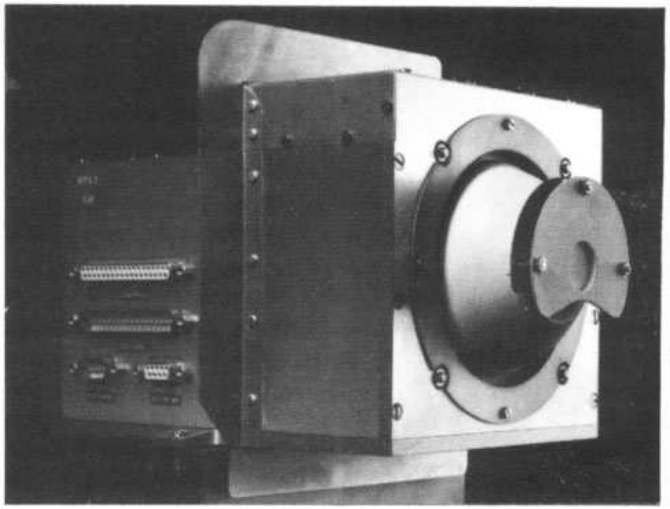
Comet environment data : Giotto

-2 flybys :

- P/Halley march 1986 (mainly around 13th and 14th): RPA1 and RPA2 data (before flyby only).
- P/Grigg-Skjellerup on 10/07/92: only RPA1 data (RPA2 was lost during P/Halley flyby)

Instrument characteristics :
-RPA1: electron spectrometre (0 eV - 30 keV); best resolution = 2s.
-RPA2: ion analyser (1 - 250 uma); best resolution = 3.2s.

-Available at CDPP (IRAP) in the coming months



GIOTTO/RPA1

Availability of Jupiter data

(adapted from N. André/CDPP)

	Pioneer 10&11	Voyager 1&2	Ulysses	Galileo	Cassini-Huygens	New Horizons
Magnetic field	***PDS, avegd***	***PDS, avegd calibrated***	***PDS, avegd calibrated***	***PDS, calibrated***	***PDS, avegd calibrated***	***NaN No MAG***
Ephemeris/ Trajectory	***PDS, Iowa***	***PDS, Iowa***	***PDS, Iowa***	***PDS, Iowa***	***PDS, Iowa***	***PDS, Iowa***
Plasma Cnts/fluxes	***PDS***	***PDS***	***PDS***	***PDS***	***NaN Ask SwRI***	***PDS, fits calibrated***
Plasma moments	***PDS***	***PDS***	***PDS***	***NaN (future)***	***NaN Ask SwRI***	***NaN***
Particle Cnts/fluxes	***PDS, Iowa ONERA (cdf, doc)***	***PDS, FTECS ONERA (cdf, doc)***	***ESA, ONERA (cdf, doc)***	***PDS, ONERA, MPS (Krupp, high res.)***	***PDS, MAPSKP MPS?***	***PDS, fits calibrated***
Radio and Waves	***PDS***	***PDS, Iowa***	***PDS***	***PDS, Iowa***	***LESIA, MAPSKP***	***NaN No RPWS***
Plasma frequency	***NaN***	***PDS?, Iowa***	***QTN (LESIA)***		***NaN Distant flyby***	***NaN No RPWS***

...

Energetic particle detector (EPD)

Principal Investigator: Dr. J. Rodríguez-Pacheco, University of Alcala, Spain

-5 sensors sharing a common DPU for composition, timing, and distribution functions of suprathermal and energetic particles

-SSD telescope + electrostatic deflection + TOF systems

-0.002 MeV to 20 MeV for electrons
-0.003 MeV to 100 MeV for protons
-0.008 MeV/n to 200 MeV/n for heavy ions (species-dependent)