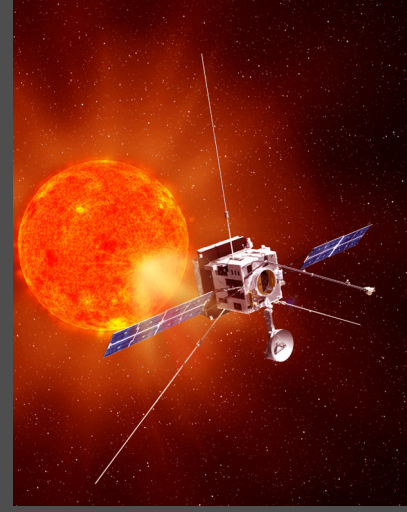
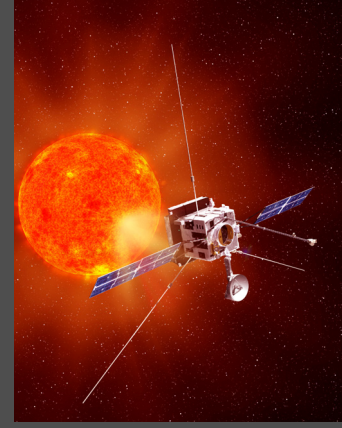


Solar Orbiter Mission (II)

Payload Instruments

Udo Schühle

Mission requirements



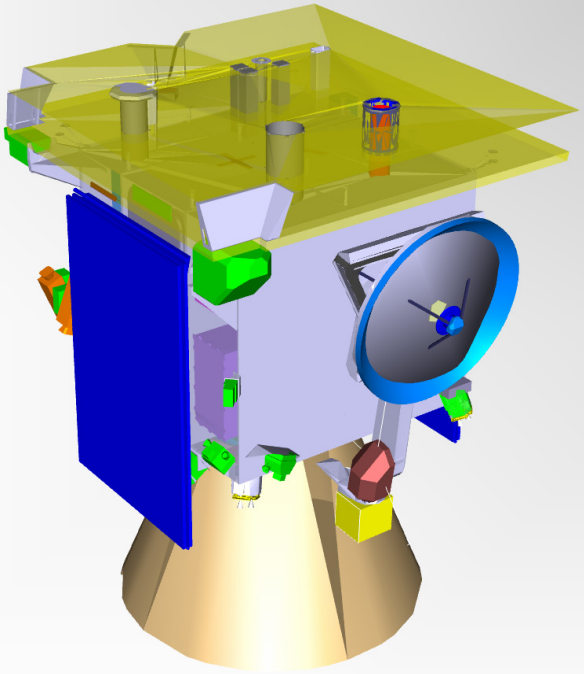
Requirements on the orbit:

1. Go closer to the Sun (within 0.25 AU)
2. Go moderately out of the ecliptic (~ 25°)
3. Have extended periods of near co-rotation
4. Characterize conditions in dependence on latitude, longitude and distance

Requirements on the spacecraft:

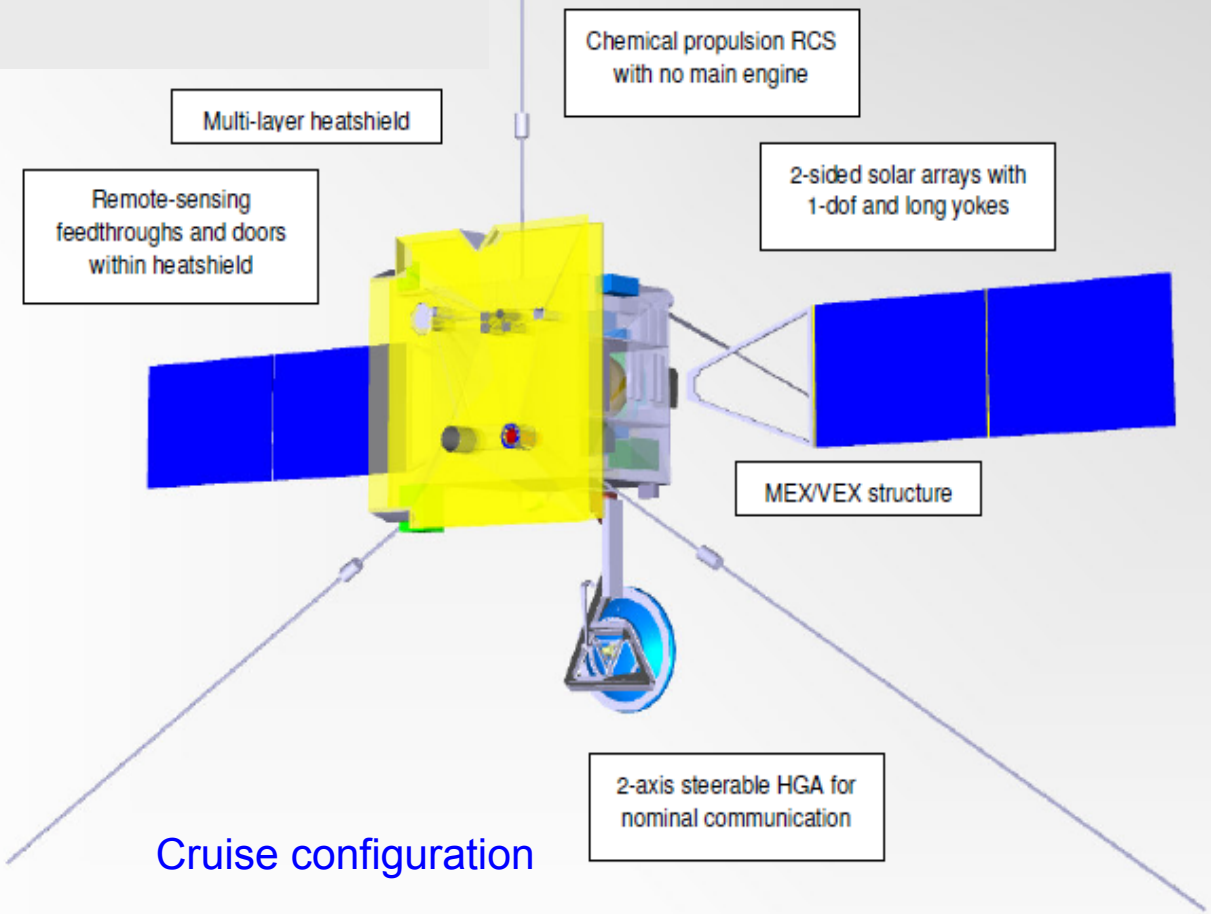
1. Use a three-axis stabilized S/C with sufficient pointing accuracy for imaging and spectroscopy
2. Satisfy electromagnetic cleanliness for plasma wave and magnetic field measurements
3. Enable three ten-days operational periods per orbit near perihelion for close-up views

Spacecraft design



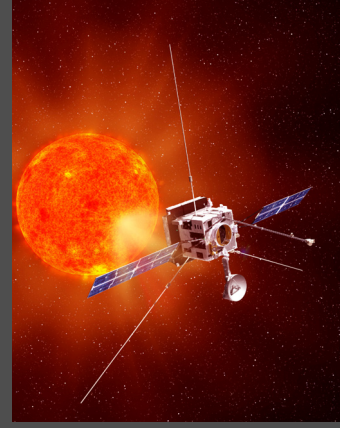
Launch configuration

Reuse of elements from BepiColombo and Express Series



Cruise configuration

Science payload



Instruments have already been selected in a competetive process in response to AOs issued by ESA and NASA.

- Resource-efficient instrumentation (e.g., remote-sensing instruments to be "1-m size, 1 arcsec resolution" class)
- Resource envelopes of all instruments were given in ESA‘s payload definition document
- The selected proposals are ensured being funded by the national European space agencies and NASA
- The 10 PI-led hardware investigations on Solar Orbiter include
  - 6 Remote-sensing solar instruments
  - 4 In-situ measuring heliospheric instruments

Mass 180 kg, power 180 W, telemetry 110 kbps

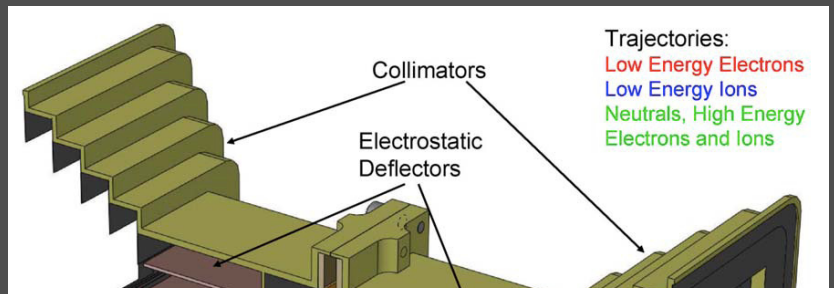
Solar Orbiter Instruments

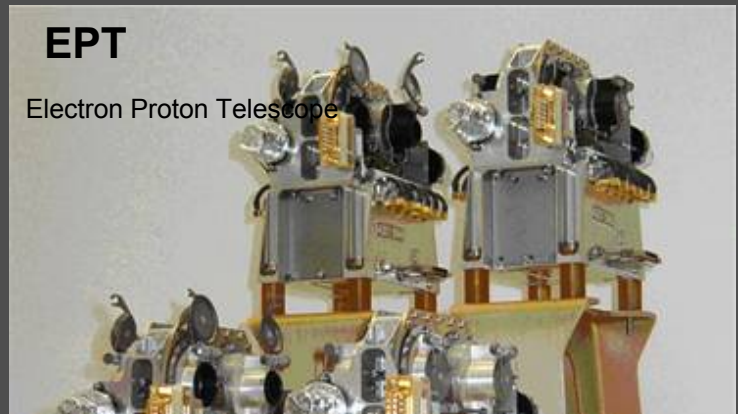
Investigation	Measurements
Solar Wind Analyzer (SWA)	Solar wind ion and electron bulk properties, ion composition (1eV- 5 keV electrons; 0.2 - 100 keV/q ions)
Energetic Particle Detector (EPD)	Composition, timing, and distribution functions of suprathermal and energetic particles (8 keV/n – 200 MeV/n ions; 20-700 keV electrons)
Magnetometer (MAG)	DC vector magnetic fields (0 – 64 Hz)
Radio & Plasma Waves (RPW)	AC electric and magnetic fields (~DC – 20 MHz)
Polarimetric and Helioseismic Imager (PHI)	Vector magnetic field and line-of-sight velocity in the photosphere
EUV Imager (EUI)	Full-disk EUV and high-resolution EUV and Lyman-α imaging of the solar atmosphere
Spectral Imaging of the Coronal Environment (SPICE)	EUV spectroscopy of the solar disk and corona
X-ray Spectrometer Telescope (STIX)	Solar thermal and non-thermal X-ray emission (4 – 150 keV)
Coronagraph (METIS/COR)	Visible, UV and EUV imaging of the solar corona
Heliospheric Imager (SoIOHI)	White-light imaging of the extended corona

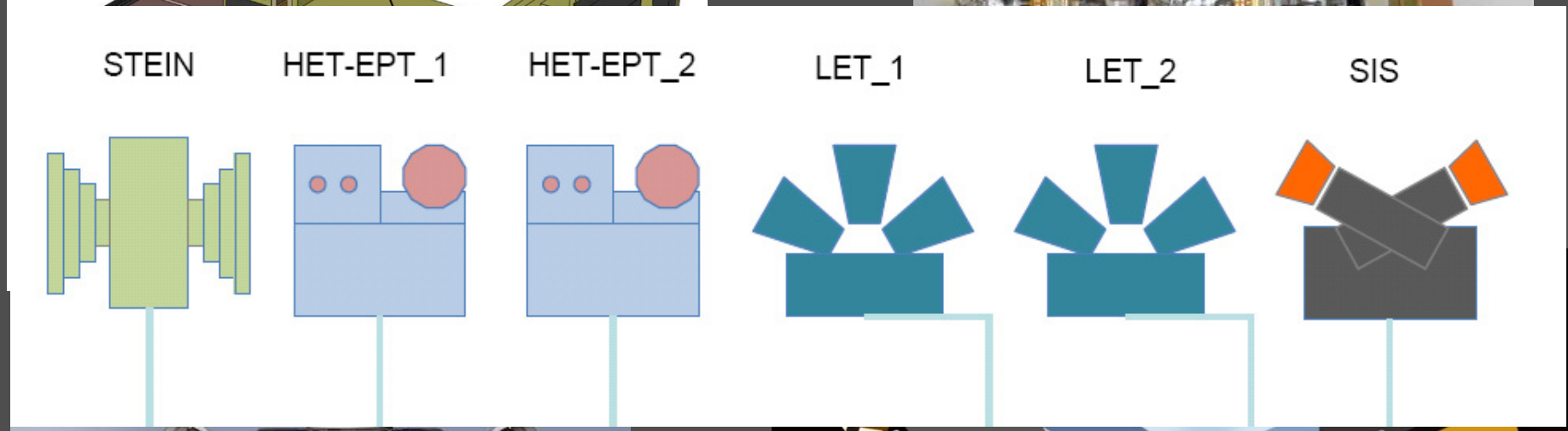
major hardware contributions of MPS

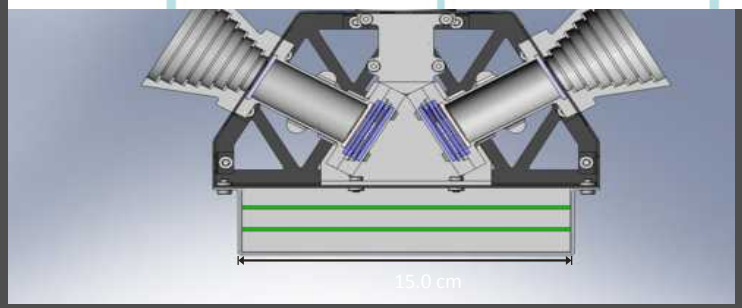
In-situ instruments (I)

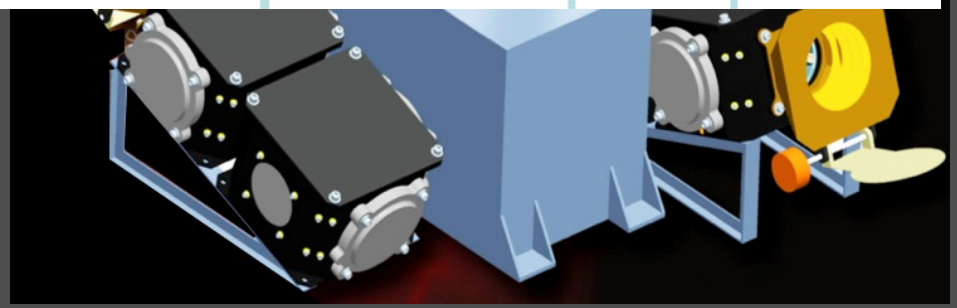
EPD Energetic Particle Detectors



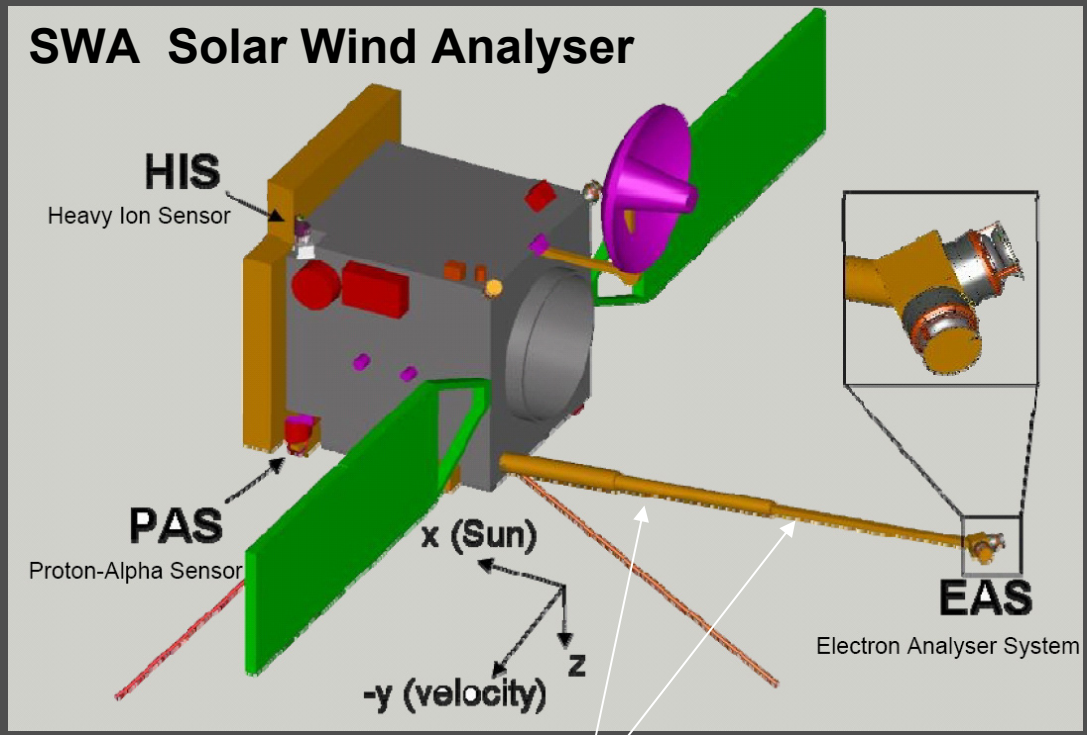






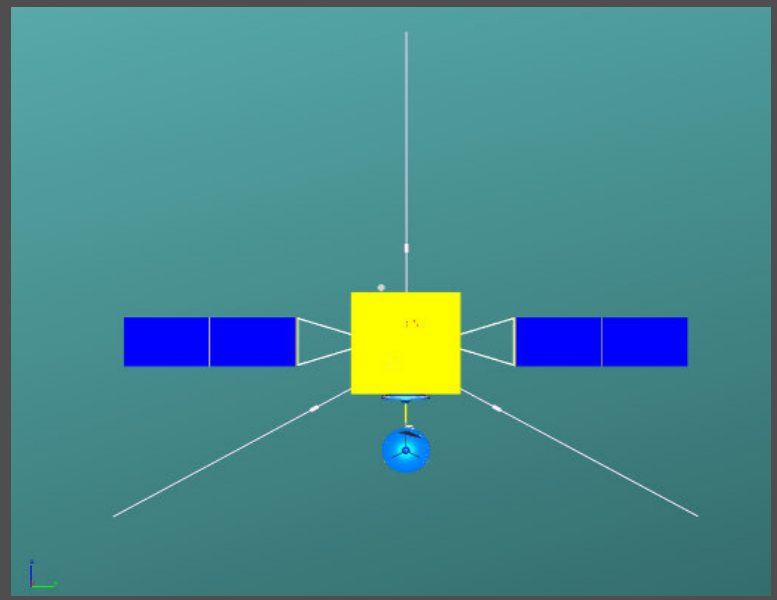


In-situ instruments: (II)

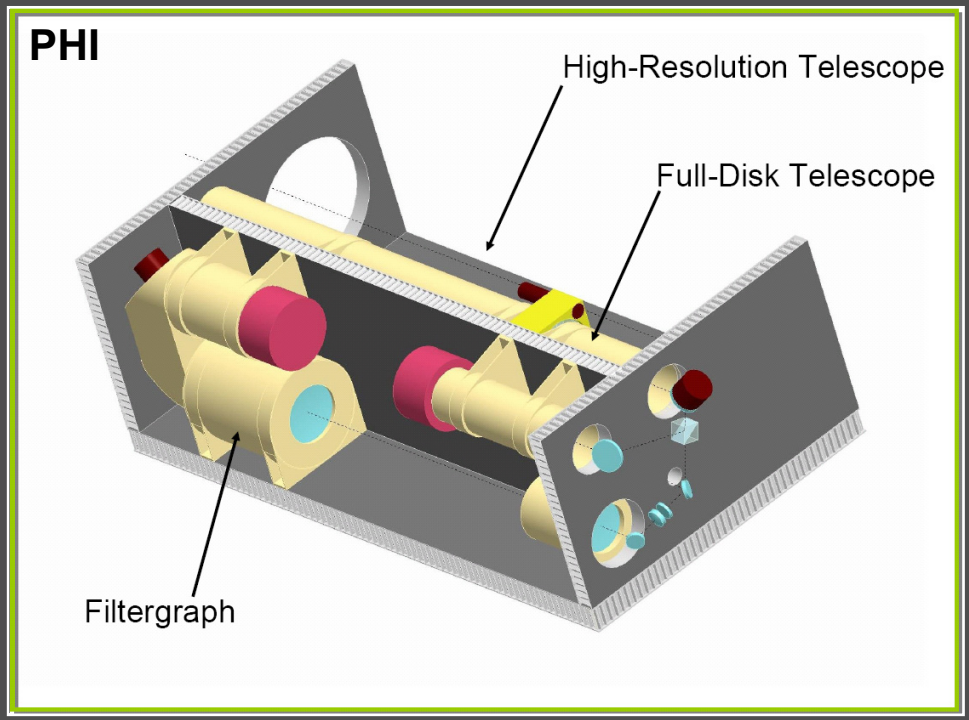


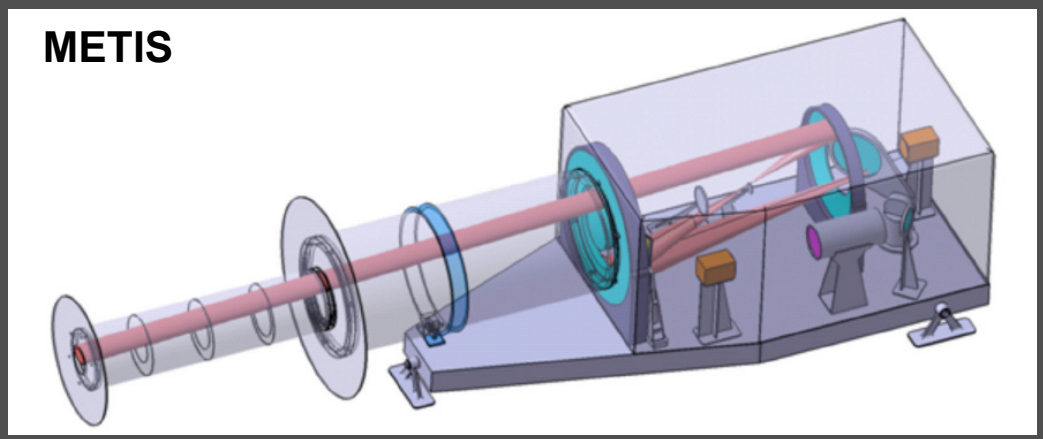
MAG
Magnetometer

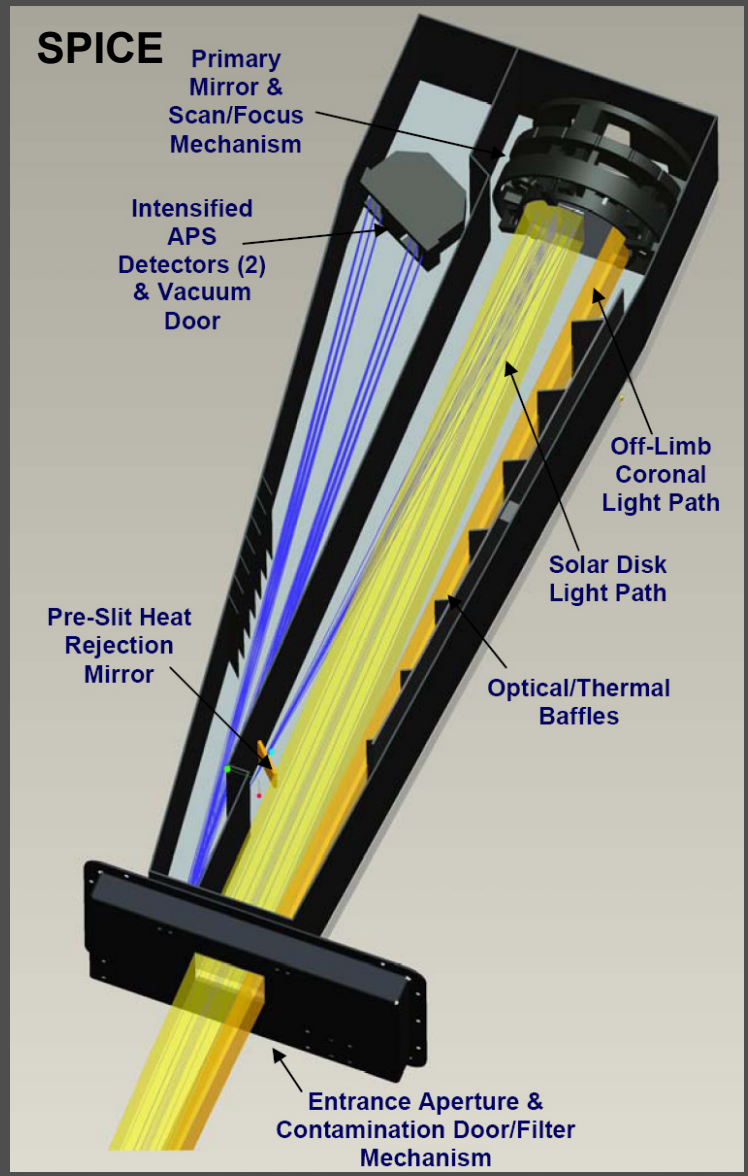
RPW Radio and Plasma Waves



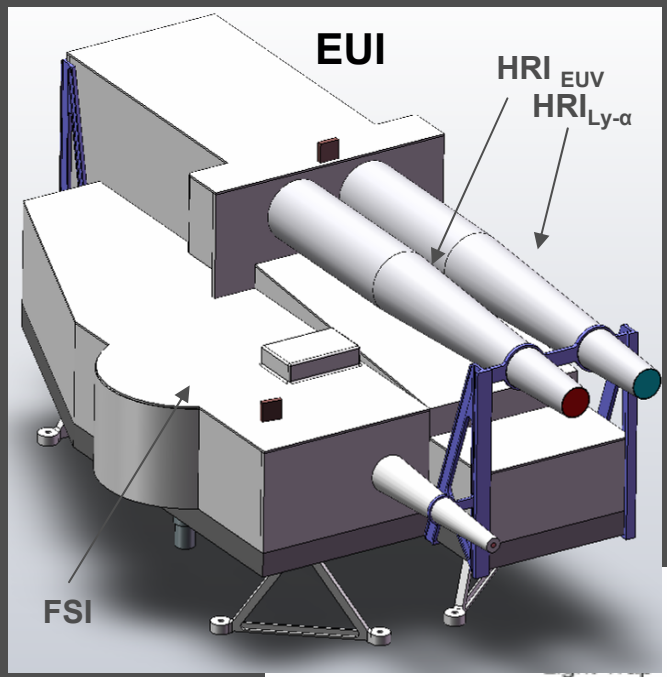
Remote-sensing instruments (I)

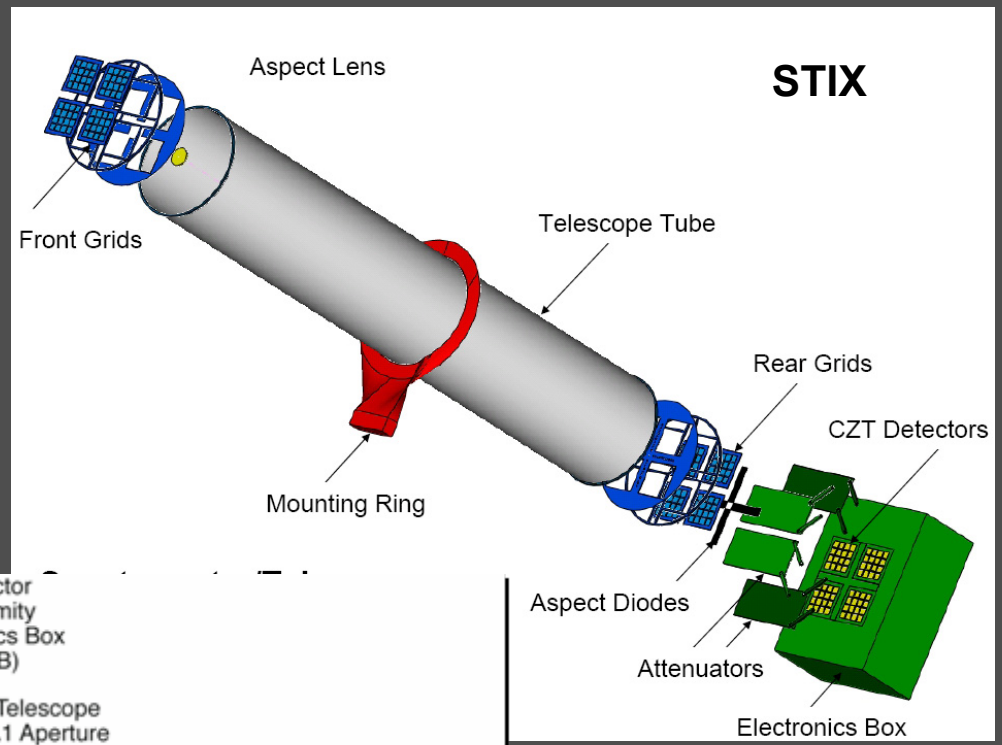


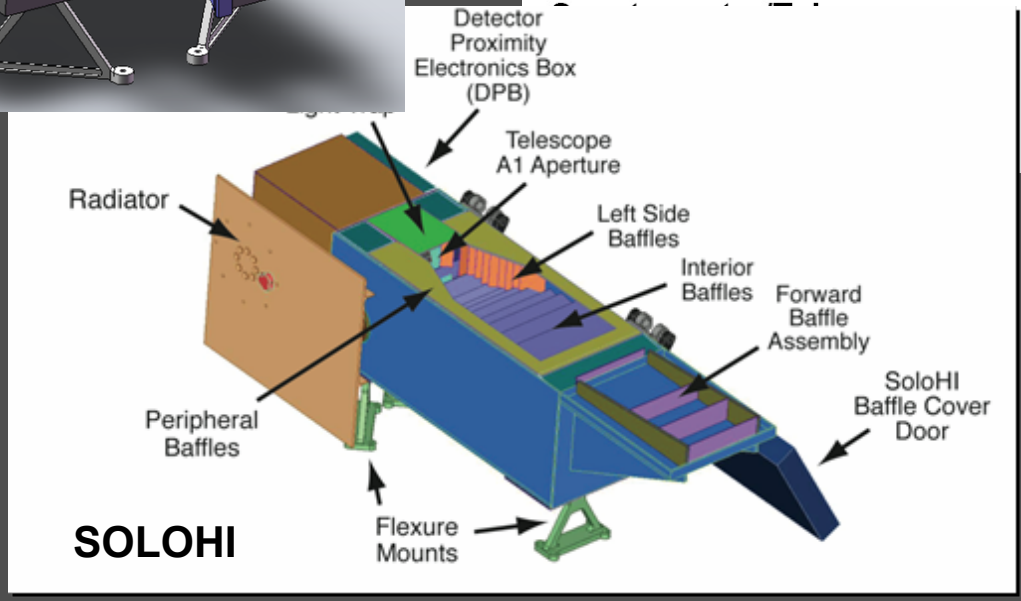




Remote-sensing instruments (II)

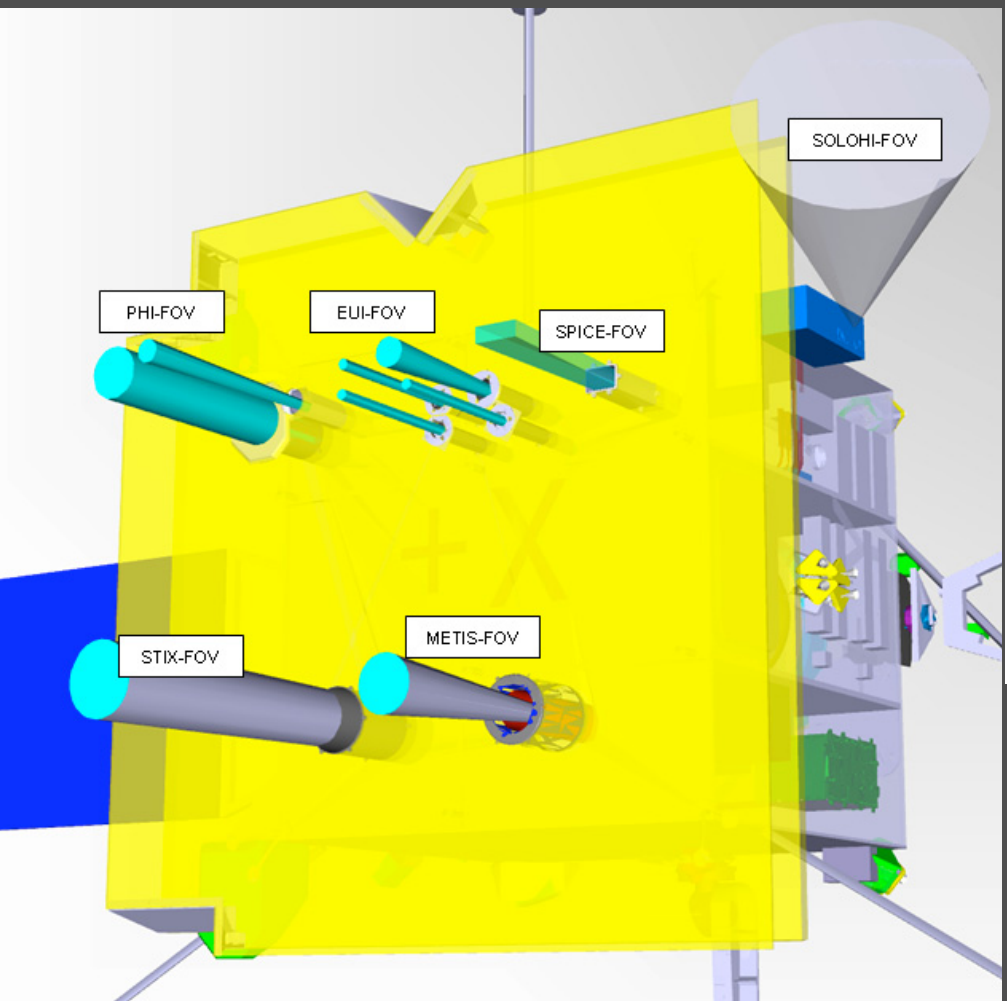


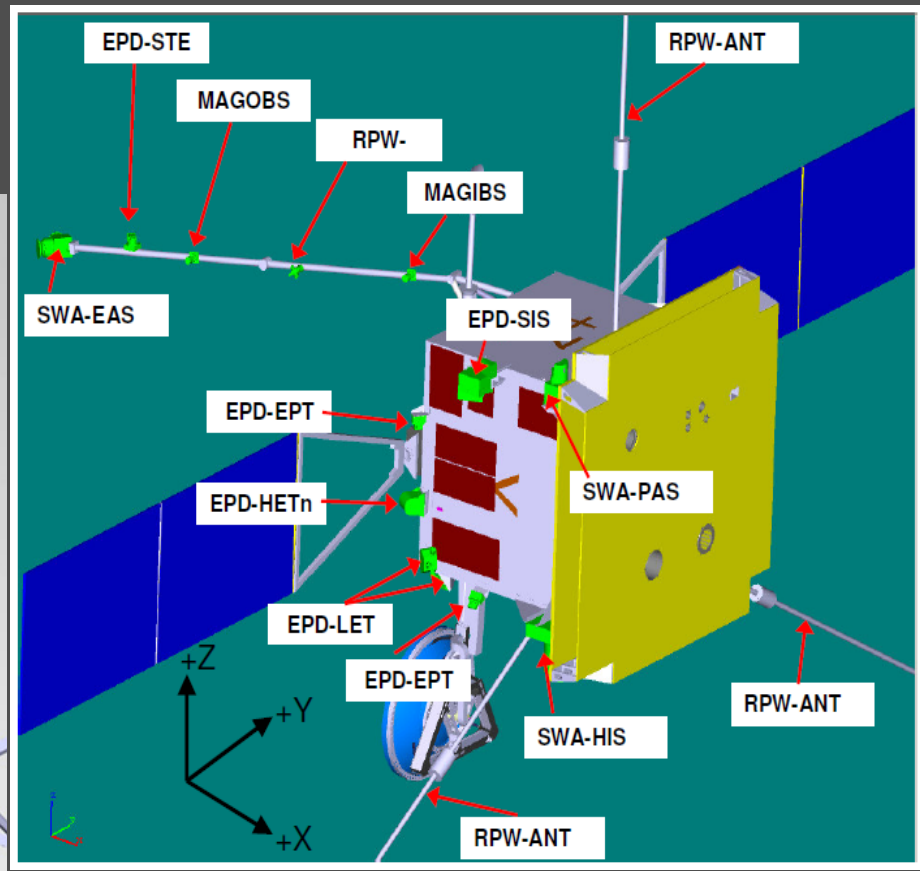




Instruments accommodation

Remote-sensing instrument locations and fields of view





In-situ instrument locations on the spacecraft

Payload resources summary

Investigation	Mass (kg)	Power (W)	Telemetry (kbps)
Solar Wind Analyzer (SWA)	15.9	14.2	14
Energetic Particle Detector (EPD)	13.8	16.1	3.1
Magnetometer (MAG)	2.1	1.9	0.9 (normal) 6.8 (burst mode)
Radio & Plasma Waves (RPW)	13.6	11.5	5
Polarimetric and Helioseismic Imager (PHI)	29.1	31.0	20
EUV Imager (EUI)	18.1	24	20
Spectral Imaging of Coronal Environment (SPICE)	18.4	28.8	17
X-ray Spectrometer Telescope (STIX)	4.4	4.4	0.2
Coronagraph (METIS/COR)	20.6	26.0	10
Heliospheric Imager (SolOHI)	11.2	10.0	20
Total	147	168	110

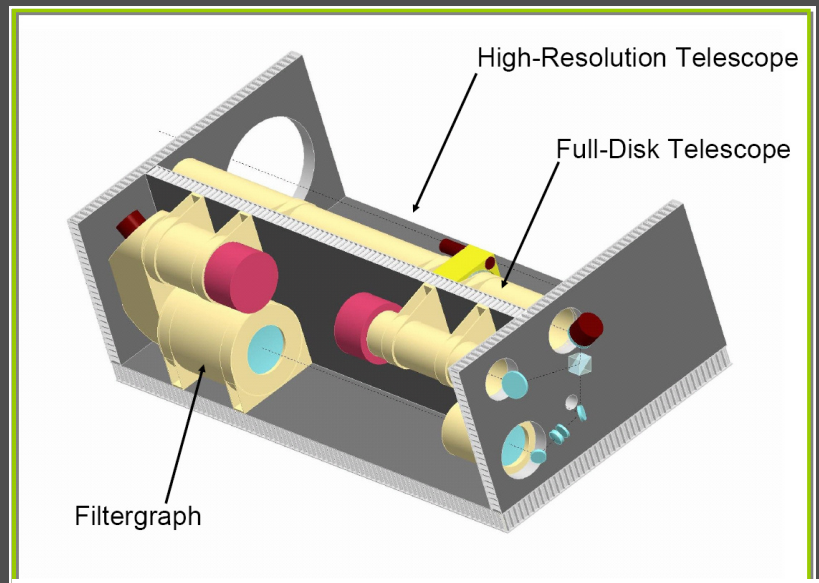
Solar Orbiter Instruments with MPS contributions

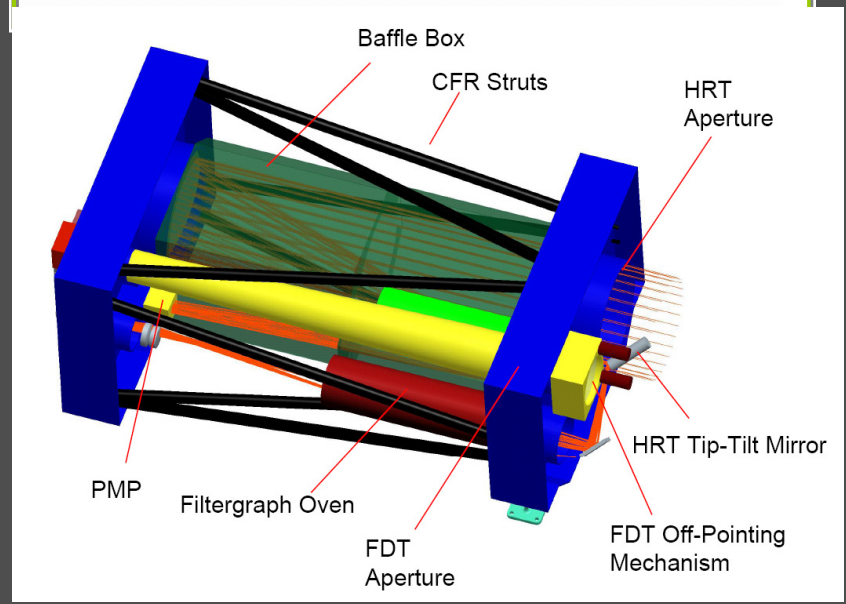
- PHI: Polarimetric and Helioseismic Imager (PI instrument of MPS)
- EUI: Extreme Ultraviolet Imager (co-PI contribution of MPS)
- SPICE: Extreme Ultraviolet imaging Spectrograph (EUS)
- METIS/ICOR: Imaging and Spectroscopy of the Corona

Solar Orbiter Instruments
PHI

PHI – Polarimetric and Helioseismic Imager

PHI will be composed of two telescopes. The off-axis Ritchey-Chrétien High Resolution Telescope (HRT) will image a fraction of the solar disk at a resolution reaching 150 km at perihelion (the same resolution as the Extreme Ultraviolet Imager's high resolution channels will have). The refractor Full Disk Telescope (FDT) will be able to image the full solar disk at all phases of the orbit. It incorporates an off-pointing capability. Each telescope will have its own Polarization Modulation Package (PMP) located early in the optical path in order to minimize polarisation cross-talk effects. Polarimetry at a signal to noise level of 10^3 is baselined for PHI. The HRT and the FDT will sequentially send light to a Fabry-Perot filtergraph system (~ 100 mÅ spectral resolution) and on to a 2048 × 2048 pixel CMOS sensor. PHI will have its own Image Stabilization System (ISS) that will compensate spacecraft jitter or other disturbances.



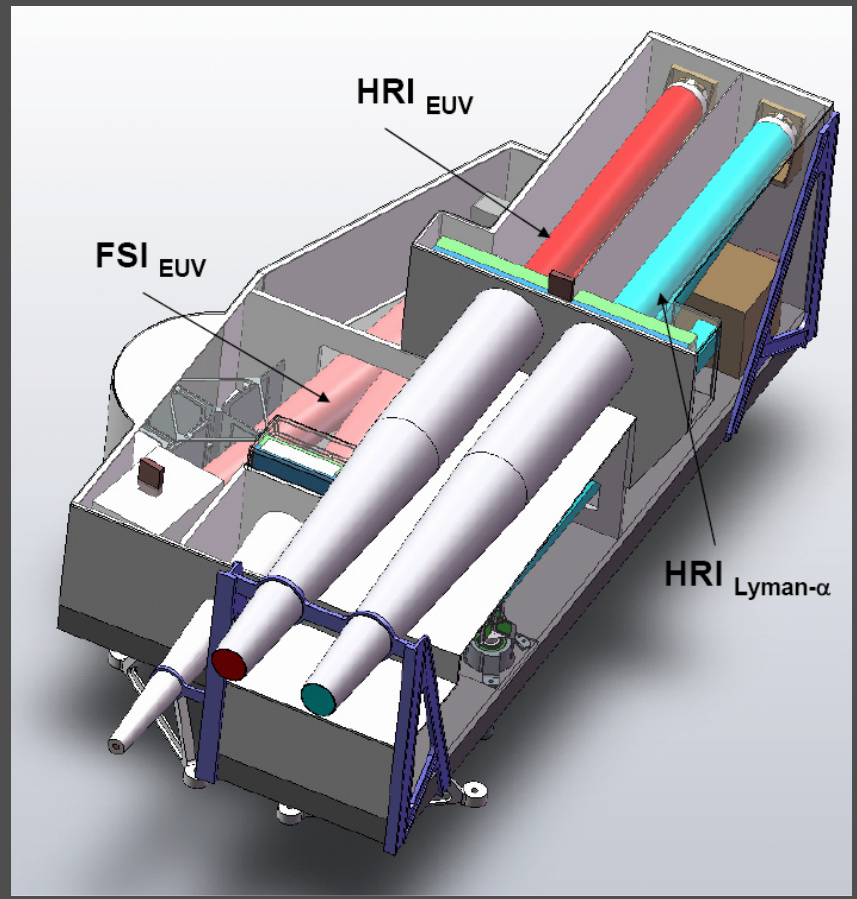


Solar Orbiter Instruments
EUI

EUI – Extreme-Ultraviolet Imager:

The EUI instrument suite is composed of two High Resolution Imagers (HRI), one at Lyman-α 121.6 nm and one dual-band in the extreme UV, alternatively at 17.4 nm and 33.5 nm, respectively named "$HRI_{Ly-\alpha}$" and "HRI_{EUV}", and one dual-band Full-Sun Imager (FSI) working alternatively at the 17.4 nm and 30.4 nm EUV passbands, named "FSI174/304".

In all channels, the image is produced by a two-mirror Gregorien telescope, working in near-normal incidence. The EUV reflectivity of the optical surfaces is obtained with specific EUV multilayer coatings, providing the spectral selection of the units. The spectral selection is complemented with filters rejecting the visible and IR radiation. For the Lyman-α HRI a special "solar-blind" camera is being developed.

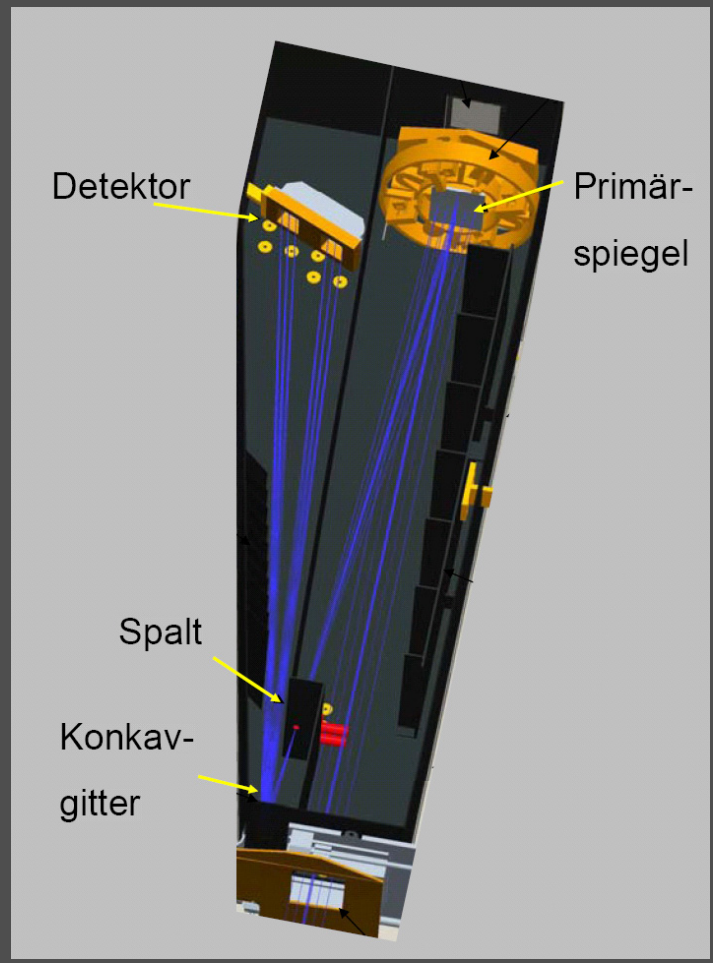


Solar Orbiter Instruments
SPICE

SPICE – Extreme-Ultraviolet Spektrograph:

The SPICE instrument is a high-resolution imaging spectrograph with a movable occulter to observe the solar corona both on the solar disk and off limb out to 3 solar radii. For outer coronal observations the occulter is used to reduce stray light by fully occulting the solar disk.

To optimize throughput, the instrument consists of only two optical elements: a single off-axis parabolic telescope mirror and a toroidal variable line-spaced grating which re-images the spectrally dispersed radiation onto two array detectors. Two spectral passbands are recorded simultaneously with two intensified active pixel sensor (IAPS) detectors. The spectrograph will cover the extreme ultraviolet wavelength bands from 70.2 nm to 79.2 nm and from 97.0 nm to 105.0 nm (and 48.5 nm to 52.5 nm in 2nd order).

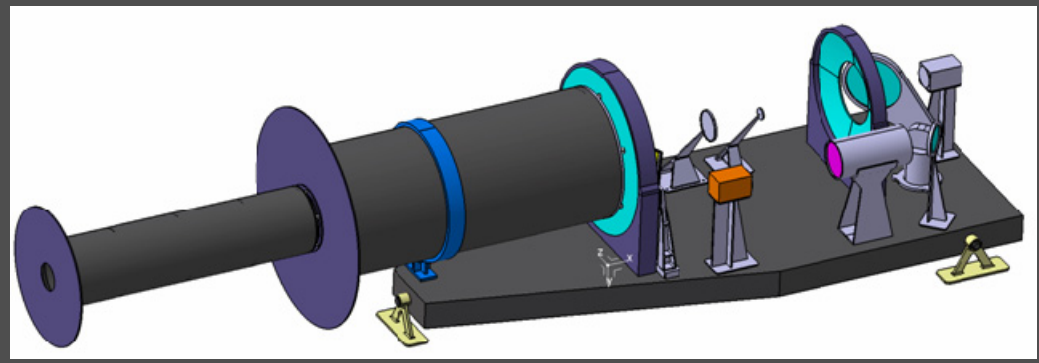


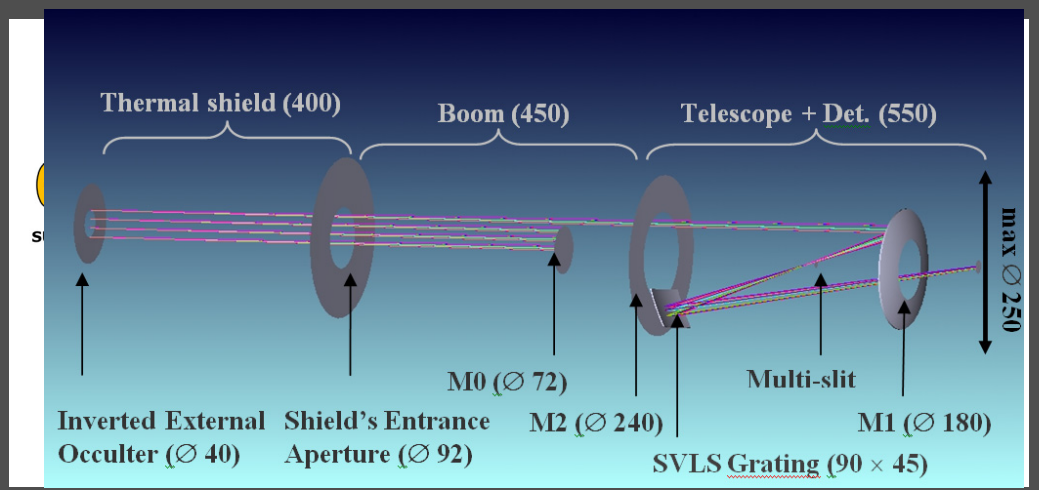
Solar Orbiter Instruments
METIS

METIS - The Multi Element Telescope for Imaging and Spectroscopy:

The METIS instrument is an inverted-occultation coronagraph that will image the solar corona in three different wavelengths (visible light between 450 and 650 nm, and the two Lyman-α lines of hydrogen and helium, H I 121.6 nm and He II 30.4 nm) by a combination of multilayer coatings and spectral bandpass filters. The visible channel also includes a polarimeter assembly to observe the linearly polarized component of the K corona.

Inclusion of spectroscopic capabilities allowing to record spectra of the H I and He II Lyman-α lines simultaneously at three different heights (accomplished by a multiple slit) in a 32° sector of the corona is under design study.





Instruments and Teams

Investigation	Principal Investigator	Collaborating countries	
Solar Wind Analyzer (SWA)	C. Owen, MSSL, UK	UK, I, F, Japan, D, CH, USA	
Energetic Particle Detector (EPD)	J. Rodríguez-Pacheco, Univ. Alcala, E	E, D, FI, GR, CH, F, SL, USA,Korea	
Magnetometer (MAG)	T. Horbury, ICSTM, London, UK	UK, A, I, H, D, F, E, DK, USA	
Radio & Plasma Waves (RPW)	M. Maksimovic, Obs. Meudon, Paris, F	F, SE, CZ, NO, UK, A, D, GR, AU, I, H, FI, Rus, USA	
Polarimetric and Helioseismic Imager (PHI)	S. Solanki, MPS, Katlenburg-Lindau, D	D, E, F, SE, NO, CH, AU, USA	
EUV Imager (EUI)	P. Rochus, CSL, Liege, B	B, UK, F, D, USA	
Spectral Imaging of the Coronal Environment (SPICE)	D. Hassler, SwRI, Boulder, USA	USA, UK, D, F, N	
X-ray Spectrometer Telescope (STIX)	A. Benz, ETH Zurich, CH	CH, PL, D, CZ, IRE, A, UK, F, USA	
Coronagraph (METIS/COR)	E. Antonucci, Univ. of Turin, I	I, UK, F, D, GR, USA	
Heliospheric Imager (SolOHI)	R. Howard, NRL, Washington DC,USA	USA	