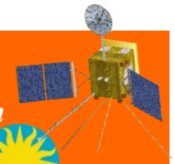
Solar Wind Analyzer-Ions (SWA-I)

Discovering the links between the solar wind and the atmosphere of our Sun



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Summary

We propose the Solar Wind Analyzer-Ions (SWA-I) sensor investigation as part of NASA's contribution to the Solar Orbiter (SO) mission, the first flight element of the joint ESA-NASA HELiophysical Explorers (HELEX) Program. SWA-I is the U.S. portion of the international Solar Wind Analyzer (SWA) instrument suite proposed in Europe by Principal Investigator Dr. C. J. Owen of Mullard Space Science Laboratory, University College London (MSSL/UCL).

Our U.S.-based SWA-I investigation will develop two key ion components: the Proton Alpha Sensor (PAS) and the time-of-flight/solid-state detector (TOF/SSD) telescope of the Heavy Ion Sensor (HIS-TOF). European contributions include an Electron Analyzer System (EAS), the electrostatic analyzer (EA) of HIS (HIS-EA), and a shared Data Processing Unit (DPU).

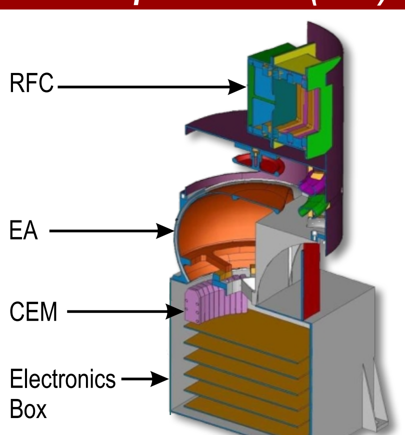
Our unified, coordinated SWA-I investigation centralizes and simplifies management, thereby reducing risks and costs. Our highly experienced science, hardware, and management team guarantees that the SWA-I low risk approach, coupled with large reserves, will fulfill all of the HELEX/SO's extraordinary science goals.

Science Objectives & Traceability to HELEX goals

SWA-I directly addresses all of the HELEX/SO objectives by discovering the fundamental links between the heliosphere and the atmosphere of our Sun.

HELEX/SO Prioritized Objectives	SWA-I Measurement Strategy & Closure
What are the origins of the solar wind streams and of the heliospheric magnetic field?	Measure the three-dimensional distributions of solar wind ions (protons, alphas, and heavies), ion composition, and plasma turbulence in magnetic flux tubes and trace them back to the morphology, structure and variability of their solar sources.
What are the sources, acceleration mechanisms and transport processes of solar energetic particles?	Measure the structure and evolution of shocks, characterize them completely down to kinetic scales and relate the shocks to the properties, composition and evolution of suprathermal ions that seed higher energy solar energetic particles.
How do Coronal Mass Ejections (CMEs) evolve in the inner solar system?	Measure the global structure, composition and evolution of CMEs, identify their initiation mechanisms and determine how they influence the coronal and heliospheric magnetic fields.

Proton Alpha Sensor (PAS)



Rapid Faraday Cup (RFC) makes high cadence (~0.1 s) measurements of bulk solar wind plasma parameters

Electrostatic Analyzer/ Channel Electron Multiplier (EA/CEM) measures the 3D velocity distributions of protons and alpha particles

3D view of the Proton Alpha Sensor (PAS). PAS combines two heritage-based sensor types by means of a simple mechanical interface. PAS has a common thermal protection system, and is mounted on an electronics box that also provides a single interface to the SWA-DPU. PAS will be built entirely in the US.

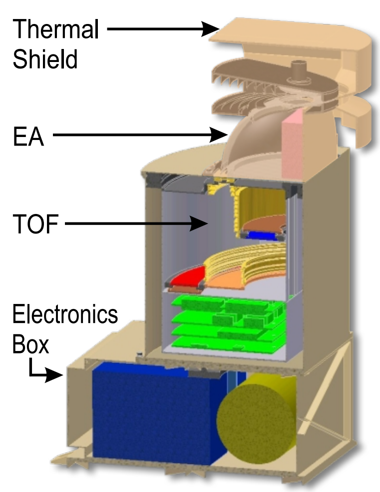
SWA-I Sensor Summary

SWA-I comprises two key ion components: the PAS and HIS-TOF. The SWA-I design, performance and operations are fully optimized and coordinated to provide the best possible solar wind plasma measurements for the SO mission.

The unique capabilities of SWA-I enables breakthrough science by providing the ***fastest ever*** measurements of bulk solar wind parameters and three-dimensional (3D) ion velocity distribution functions (VDFs), as well as the ***first ever*** composition measurements of solar wind and suprathermal ions inside 0.9 AU.

Key Instrument Parameters		PAS	HIS
Species		Protons and alphas	^{4}He, ^{3}He, C-Fe
Energy Range		0.2 - 20 keV/q	0.5 - 100 keV/q
Energy Resolution ΔE/E		5% (5% for 1.5D VDFs <7.5% for 3D VDFs)	<6%
Mass Resolution Δm/m (FWHM)		N/A	~0.2
Field-of-View In-ecliptic Out -of-ecliptic		Sun-pointing -17.5°/+ 47.5° EA: ±22.5°;RFC: ± 30°	Sun-pointing -33°/+ 63° ±17°
Pixel Resolution		5° x 5°	6° x 6°
Geometric-factor/ pixel (cm^2 sr eV/eV)		EA: ~ 4 x 10^{-5} RFC: ~5 cm^2 sr	Variable up to ~2 x 10^{-5}
Time Resolution	SW1 (normal)	3 s for 3D VDFs; 1 s for 1.5D VDFs and bulk proton parameters	300 s for heavy ions 30 s for alphas
	SW2 (burst)	3 s for 3D VDFs; 0.1 s for 1.5D VDFs	30 s for heavy ions 30 s for alphas
	SW3 (burst)	3 s for 3D VDFs; ~0.017 s for flow angles	30 s for heavy ions 3 s for alphas

Heavy Ion Sensor (HIS)

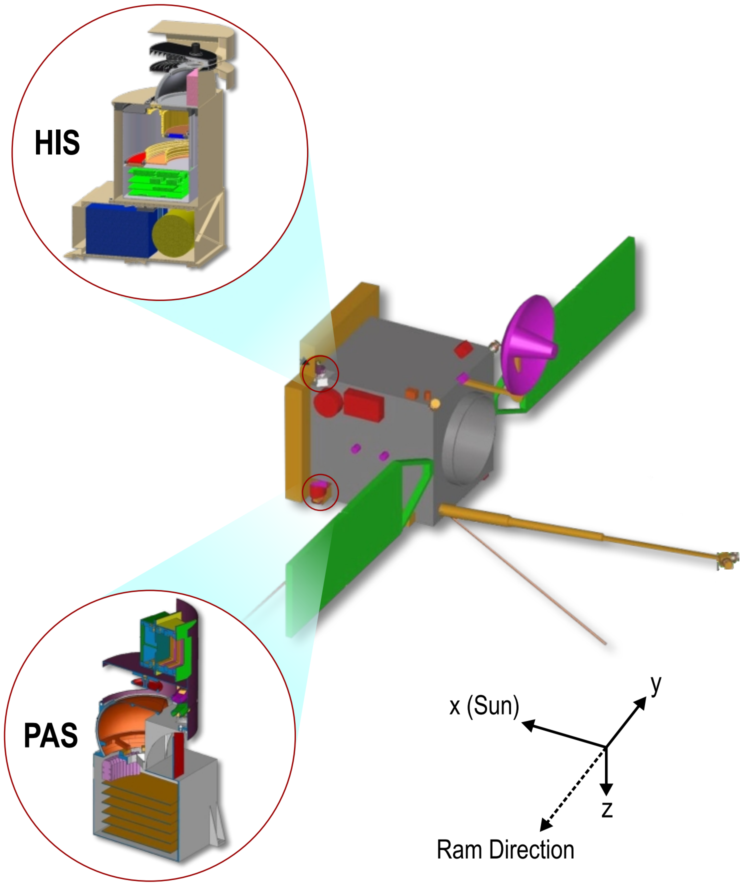


Europe contributes HIS-Electrostatic Analyzer (HIS-EA), which selects alpha particles and heavy ions according to their E/q and elevation angle.

U.S.-based SWA-I contributes HIS-time-of-flight/solid-state-detector (HIS-TOF), which measures the time-of-flight, azimuth, and total energy of solar wind ions.

3D view of the Heavy Ion Sensor (HIS): HIS uses heritage-based design principles to measure the 3D velocity distributions and composition of helium and heavy ions. Like all solar wind ion composition instruments built over the last 20 years, the HIS-EA subsystem will be built in Europe, and the HIS-TOF subsystem will be built in the U.S. These subsystems have a simple well-defined mechanical interface between them.

Accommodation on SO spacecraft



SWA-I sensor components have straightforward, well-defined mechanical, electrical, and thermal interfaces for accommodation on the SO spacecraft.

Resources

SWA Sensor	CBE Mass (kg)	PDD Mass Allocation (kg)	CBE Power (W)	PDD Power Allocation (W)	CBE Telemetry (kbps)	PDD Telemetry Allocation (kbps)
PAS	2.2	3.0	2.6	2.0	2.4	7.0
HIS	6.1	8.0	5.0	7.0	4.3	4.0
Total	**8.3**	**11.0**	**7.6**	**9.0**	**6.7**	**11.0**

Heritage

All subsystems for PAS and HIS-TOF are based on successful space-flight heritage instruments. New technologies are only included if there is no previous solution available or if more advanced technologies can substantially simplify the instrument design. As part of the risk mitigation strategy, we use engineering models to test and validate the electro-optical and functional properties of both sensor components.

Management & Teaming Arrangement

SWA-I will be implemented by world-class institutions with an experienced management team. Our team includes Co-Is/Collaborators of all NASA-funded solar wind plasma and composition ion instruments flown on key heliospheric missions in the last 20 years.

Key US Team Members

Principal Investigator:	Dr. Stefano Livi (SwRI)
Project Manager:	Mr. William Gibson (SwRI)
Lead Co-I (PAS)	Dr. Mihir Desai (SwRI)
Systems Engineer (PAS)	Ms. Tiffany Finley (SwRI)
Instrument Manager (PAS):	Mr. Scott Weidner (SwRI)
Lead Co-I (HIS-TOF):	Prof. Thomas Zurbuchen (UMich)
Systems Engineer (HIS-TOF):	Mr. Robert Lundgren (UMich)
Instrument Manager (HIS-TOF):	Mr. Bruce Block (UMich)
Lead Co-I (Theory & Modeling):	Prof. Nathan Schwadron (SwRI)

U.S. Institutional Members

Southwest Research Institute (SwRI)
PI Institution, Project Management, PAS Lead, PAS-EA/CEM subsystem, PAS electronics, Science Coordination, Theory & Modeling

Smithsonian Astrophysical Observatory
PAS-RFC Lead, PAS Thermal Design, E/PO

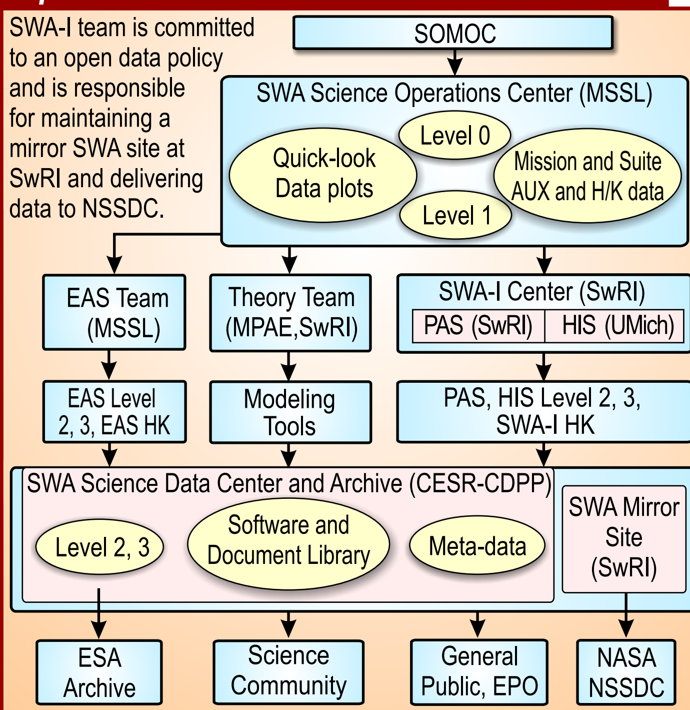
University of Michigan
HIS-TOF Lead and Project Management, HIS-TOF electronics

University of New Hampshire
HIS-TOF/SSD Telescope Lead, SSD electronics

Goddard Space Flight Center
HIS-TOF Low Voltage Power Supply, Thermal Design

Operations & Data Flow

SWA-I team is committed to an open data policy and is responsible for maintaining a mirror SWA site at SwRI and delivering data to NSSDC.



SWA-I Cost (M$) & Schedule Summary

Phase A	Phase B	Phase C/D	Phase E/F
10/08 - 10/09 $ 0.599 RY $ 0.583 FY08 ● **ICR 06/09**	**10/09 - 10/10** $ 8.877 RY $ 8.415 FY08 ● **CR 06/10**	**10/10 - 05/15** $ 18.845 RY $ 16.925 FY08 ● **Deliver STM 03/11** ● **Deliver EQM 12/11** ● **Deliver FM to MSSL 05/12** ● **Suite Integration 02/13-07/13** ● **S/C Integration 07/13 - 11/14** ● **Launch 05/15**	**05/15 - 07/21** $ 7.429 RY $ 5.656 FY08 ● **MODA 08/15 - 07/21**

Phase A-D Cost to NASA: $28.321 M (RY) (includes 30% reserves plus 15.4 weeks of funded schedule reserves)
Total Cost to NASA: $35.750 M (RY)