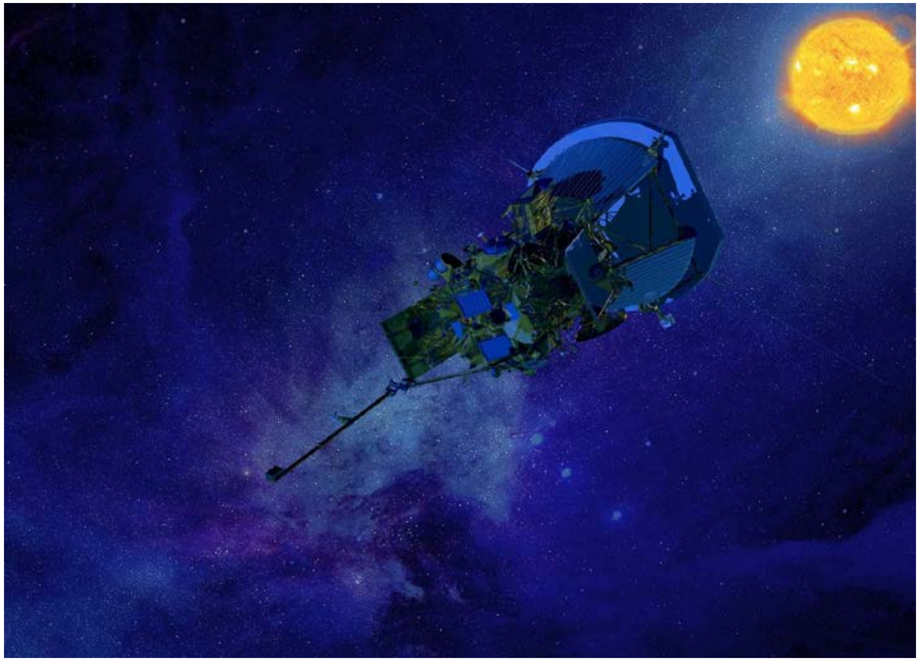
Solar Orbiter and Solar Probe Plus



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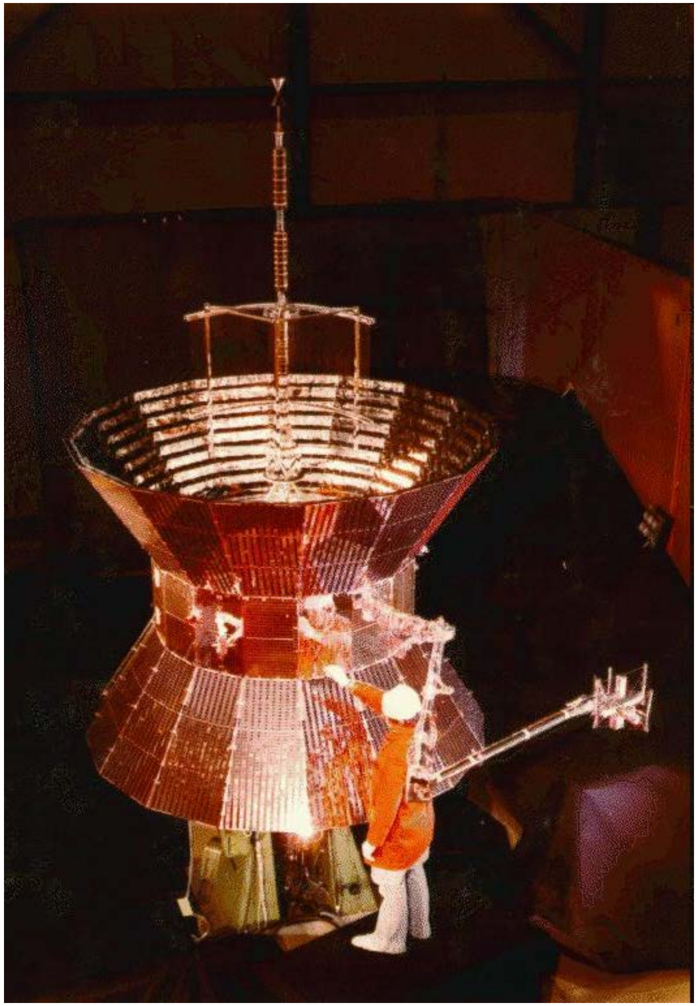
Helios

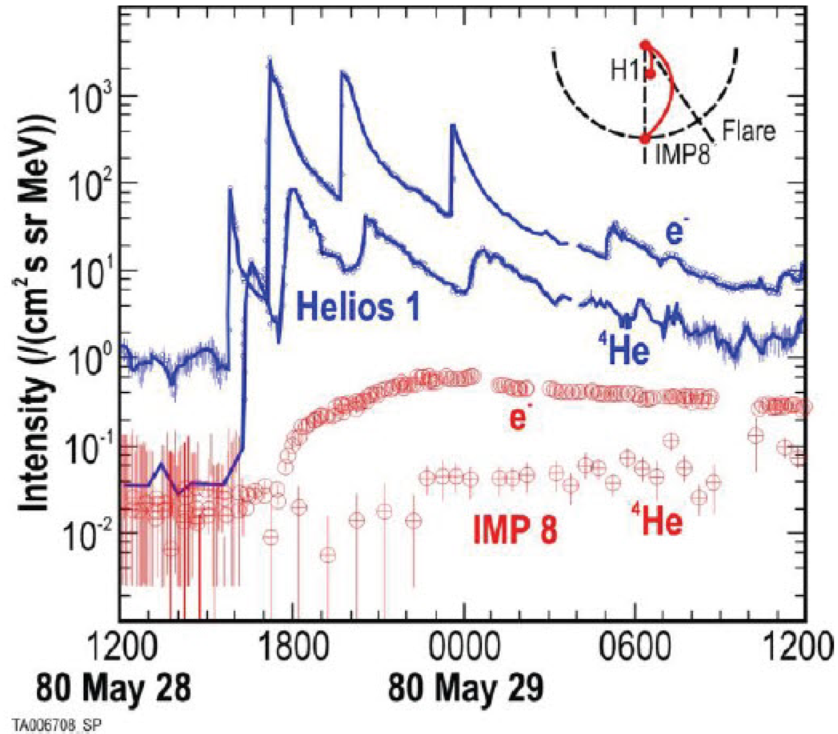
The *Only* Space Physics Mission to the Inner Solar System

- **Helios 1 and Helios 2 were a pair of deep space probes developed by the Federal Republic of Germany (FRG) in a cooperative program with NASA.**
- **Experiments were provided by scientists from both FRG and the U.S. NASA supplied the Titan/Centaur launch vehicle.**
- **Each spacecraft was equipped with two booms and a 32 m electric dipole.**
- **The payload consisted of a fluxgate magnetometer; electric and magnetic wave experiments, which covered various bands in the frequency range 6 Hz to 3 MHz; charged-particle experiments, which covered various energy ranges starting with solar wind thermal energies and extending to 1 GeV; a zodiacal-light experiment; and a micrometeoroid experiment.**
- **The purpose of the mission was to make pioneering measurements of the interplanetary medium from the vicinity of the earth's orbit to 0.3 AU. The spin axis was normal to the ecliptic, and the nominal spin rate was 1 rps. Instrument descriptions written by the experimenters were published in *Raumfahrtforschung* 19/5 (1975).**



Explore the mechanisms that accelerate and transport energetic particles

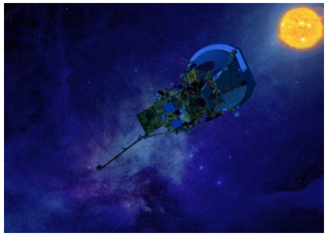
- Understanding solar energetic particle (SEP) acceleration at 1 AU is difficult
  - distance from sources
  - mixing during transport
- Helios showed advantages of near-Sun observations of SEP processes near origin
- SP+ will observe 50-100 ISEP and ≳50 large SEP events inside 0.25 AU
- Enabling detailed studies of
  - flare and CME-shock acceleration
  - seed particle identities
  - the effects of particle transport in the interplanetary medium.



(Wibberenz and Cane 2006)

2-4 MeV He

SCIENCE FOCUS



How Does the Sun Create and Control the Heliosphere?

What drives the solar wind and where does the coronal magnetic field originate from?

How do solar transients drive heliospheric variability?

How do solar eruptions produce energetic particle radiation that fills the heliosphere?

How does the solar dynamo work and drive connections between the Sun and the heliosphere?

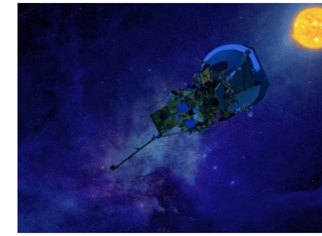
A Mission to Touch the Sun

Why is the solar corona so much hotter than the photosphere?

How is the solar wind accelerated?

How are solar energetic particles generated and transported?

PAYLOAD



In-Situ Instruments		
EPD	Energetic Particle Detector	J. Rodríguez-Pacheco
MAG	Magnetometer	T. Horbury
RPW	Radio & Plasma Waves	M. Maksimovic
SWA	Solar Wind Analyser	C. Owen
Remote-Sensing Instruments		
EUI	Extreme Ultraviolet Imager	P. Rochus
METIS	Coronagraph	E. Antonucci
PHI	Polarimetric & Helioseismic Imager	S. Solanki
SoloHI	Heliospheric Imager	R. Howard
SPICE	Spectral Imaging of the Coronal Environment	European-led facility instrument
STIX	Spectrometer/Telescope for Imaging X-rays	S. Krucker

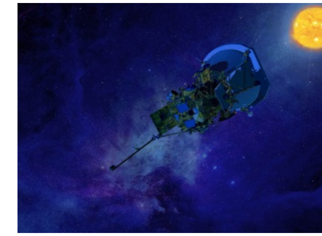
ISIS D. McComas [SwRI]

FIELDS S. Bale [UCB]

SWEAP J. Kasper [Umich]

WISPR R. Howard [NRL]

MISSION SUMMARY



October 2018	LRD	August 2018
Atlas V-411	LV	Delta IV-Heavy
15 km^2/s^2	Launch C3	154 km^2/s^2
3 months [*in situ*] 2+ years [remote sensing]	Cruise Phase	4 months
Multiple EGA & VGA	Gravity Assists	Multiple VGAs
168 days [variable with VGA]	Orbital Period	88 days
62 R_S [0.28 A.U.]	Final Perihelion	9.9 R_S [0.05 A.U.]
$\geq$32°	Final Inclination	Ecliptic [3°]

MISSION PROFILE - VGAs

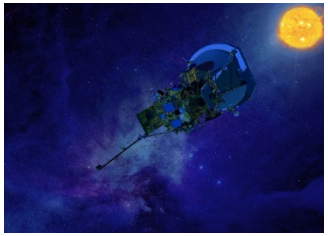


Figure 83: 2018 October Option E – Distance to Sun

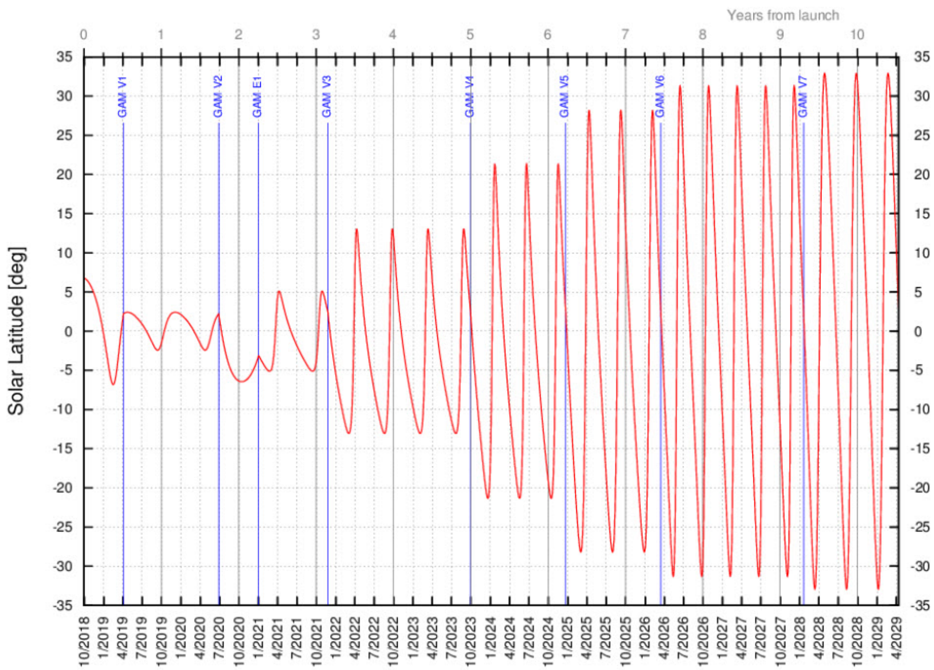
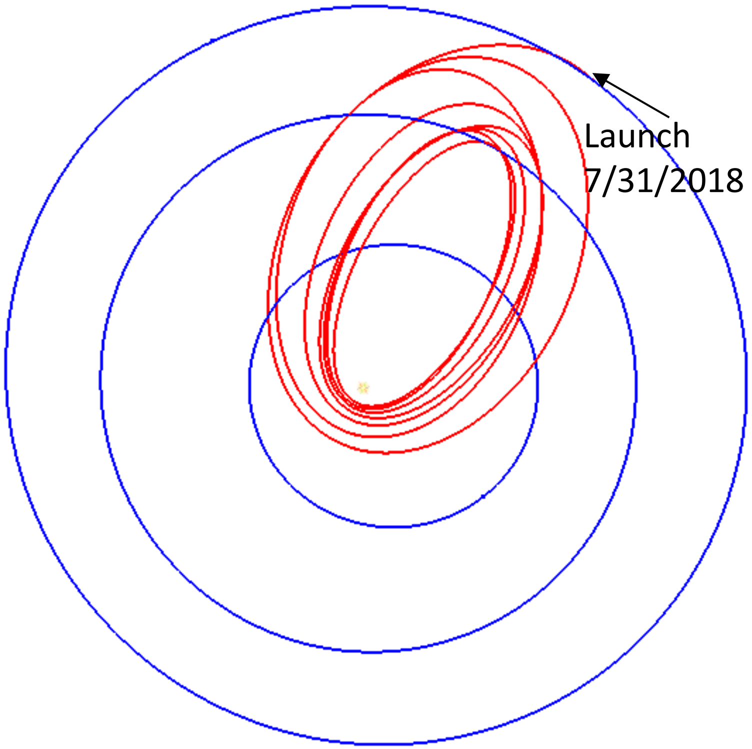


Figure 84: 2018 October Option E –Solar latitude

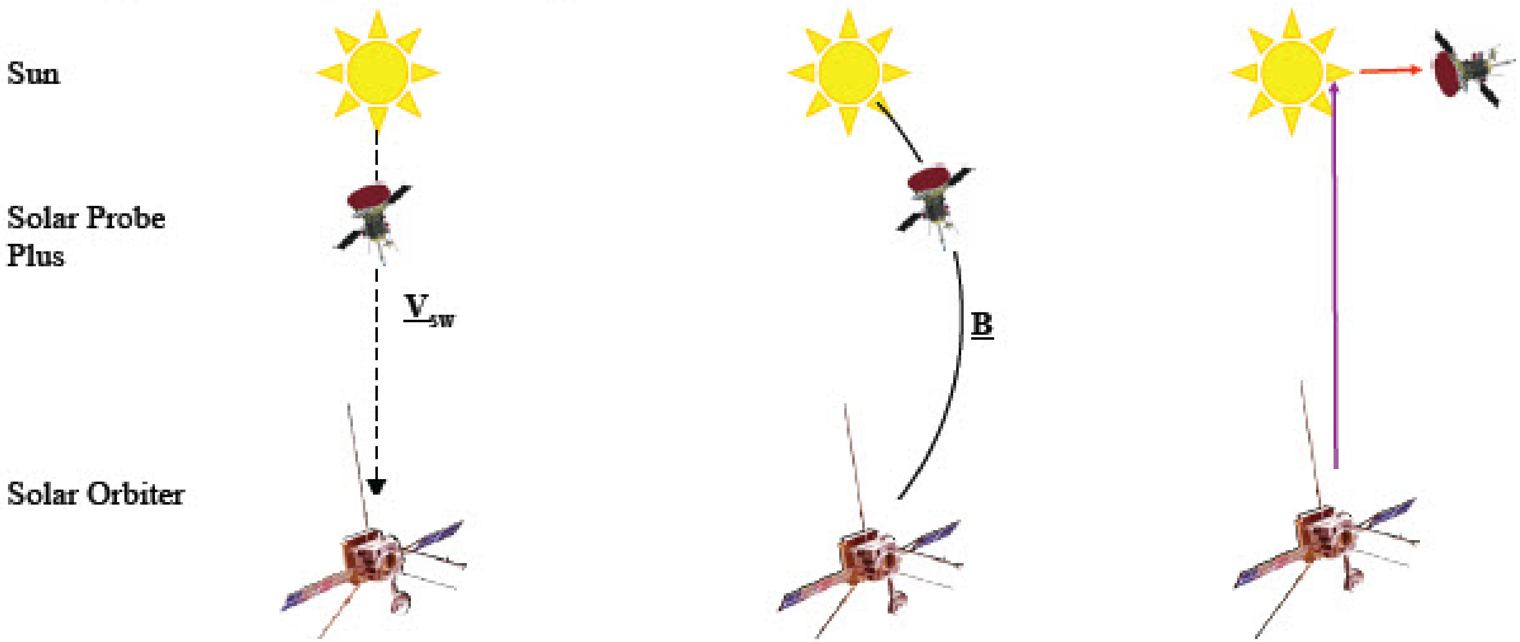


1st Perihelion at 36 R_S 4 months later

First Perihelion <10 Rs in 2024

Joint Observations Solar Orbiter - Solar Probe Plus

Example of alignments/quadratures:



Radial alignments:

SO and SPP observe the same SW plasma

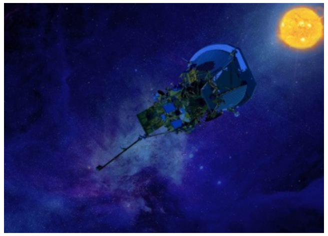
IMF alignments:

SO and SPP connect to the same IMF footpoint

Quadratures:

SO remote-sensing and SPP in-situ @ ≥9.5 Rs

SPP Environmental Trades

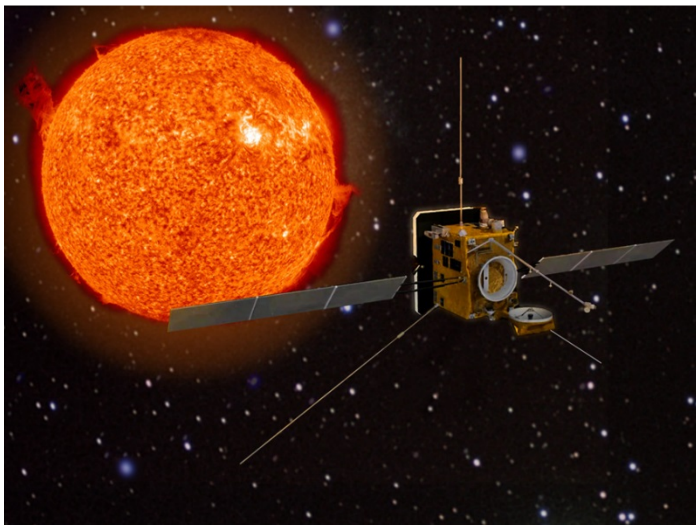


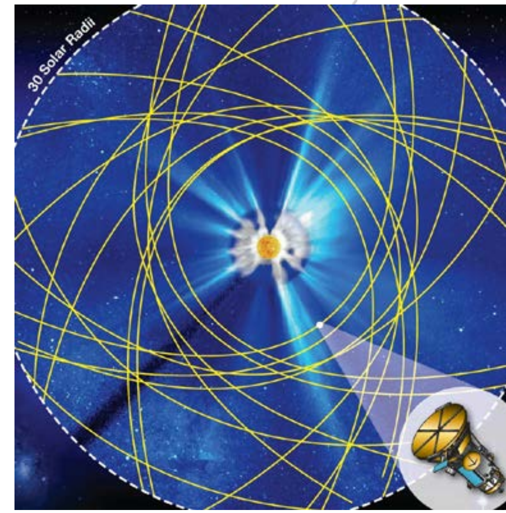
- Thermal protection system (TPS): Mass loss by sublimation & dust impacts
- Solar energetic proton mission-integrated fluences & peak intensity distributions (see D. Lario & R. Decker, Space Weather, 9, S11003, doi:10.1029/2011SW000708, 2011)
- Solar energetic electron mission-integrated fluences & peak intensity distributions
- Solar neutrons
- Solar X-rays and gamma rays
- Solar activity & solar limb sensors
- Dust environment & star trackers
- Distributions of time durations when $j_{SEP} > j_{critical}$ for solar energetic ions and electrons
- Solar electrons & deep dielectric discharge (includes summer intern work)
- Radiant energy and momentum fluxes on solar arrays and solar limb sensors
- Coronal brightness
- Key solar wind parameters
- Spacecraft surface charging (includes work on solar array degradation)
- Observability of Z+ and Z- fluctuations
- Effect of orbit change of min. perihelion 9.50 -> 9.86 R_S on SPP crossing Alfven radius
- Magnetic fields from induced currents in thermal support structure (TSA)
- Solar wind momentum and heat fluxes on SPP surfaces
- Thruster plume neutral constituents & science impacts
- Disturbed magnetic fields in the low coronal

Solar Orbiter and Solar Probe Plus

Solar Orbiter:

+ unique orbit (high inclination)
+ comprehensive payload suite





Solar Probe Plus:

+ unique orbit (min. perihelion <10 R_{Sun})

Questions?

Payload

In-Situ Instruments			
EPD	Energetic Particle Detector	J. Rodríguez- Pachec	Composition, timing and distribution functions of energetic particles
MAG	Magnetometer	T. Horbury	High-precision measurements of the heliospheric magnetic field
RPW	Radio & Plasma Waves	M. Maksimovic	Electromagnetic and electrostatic waves, magnetic and electric fields at high time resolution
SWA	Solar Wind Analyser	C. Owen	Sampling protons, electrons and heavy ions in the solar wind
Remote-Sensing Instruments			
EUI	Extreme Ultraviolet Imager	P. Rochus	High-resolution and full-disk EUV imaging of the on-disk corona
METIS	Coronagraph	E. Antonucci	Visible and UV Imaging of the off-disk corona
PHI	Polarimetric & Helioseismic Imager	S. Solanki	High-resolution vector magnetic field, line-of-sight velocity in photosphere, visible imaging
SoloHI	Heliospheric Imager	R. Howard	Wide-field visible imaging of the solar off-disk corona
SPICE	Spectral Imaging of the Coronal Environment	European-led facility instrument	EUV spectroscopy of the solar disk and near-Sun corona
STIX	Spectrometer/Telescope for Imaging X-rays	S. Krucker	Imaging spectroscopy of solar X-ray emission

SPP Investigations

Investigation	Instruments	Measurements	Principle Investigator
Fields Experiment (FIELDS)	4 Electric Antennas 2 Fluxgate Magnetometers 1 Search Coil Magnetometer (SCM)	Magnetic Field (DC and AC) Electric Field Electric/Mag Wave	Prof. Stuart D. Bale, University of California Space Sciences Laboratory in Berkeley, CA
Integrated Science Investigation of the Sun (ISIS)	High energy Energetic Particle Instrument (EPI-Hi) Low energy Energetic Particle Instrument (EPI-Lo)	Energetic electrons Energetic protons and heavy ions (10s of keV to ~100 MeV)	Dr. David J. McComas, Southwest Research Institute in San Antonio, TX
Solar Wind Electrons Alphas and Protons (SWEAP)	Solar Probe Cup (SPC) 2 Solar Probe ANalyzers (SPAN)	SW Plasma e-, H+, He++ SW velocity, density & temperature	Dr. Justin Kasper, Smithsonian Astrophysical Observatory in Cambridge, MA
Wide-field Imager for Solar PRobe (WISPR)	White light imager	White light measurements of solar wind structures	Dr. Russ Howard, Naval Research Laboratory in Washington, DC
HeliOSPP	Observatory Scientist - Science integration	N/A	Dr. Marco Velli, Jet Propulsion Laboratory, Pasadena, CA