SOLAR PROBE
HUMANITY'S FIRST VISIT TO OUR STAR

Solar Probe
Status Report

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Science and Technology Definition Team - STDT

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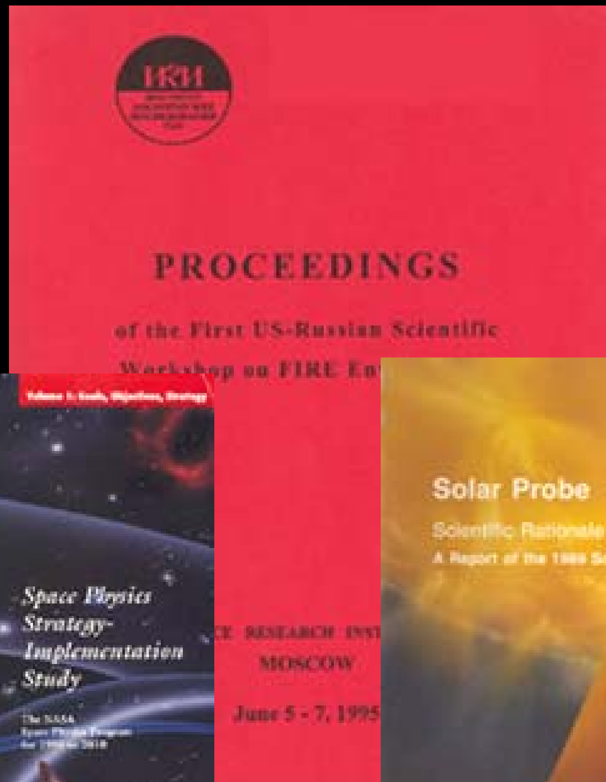
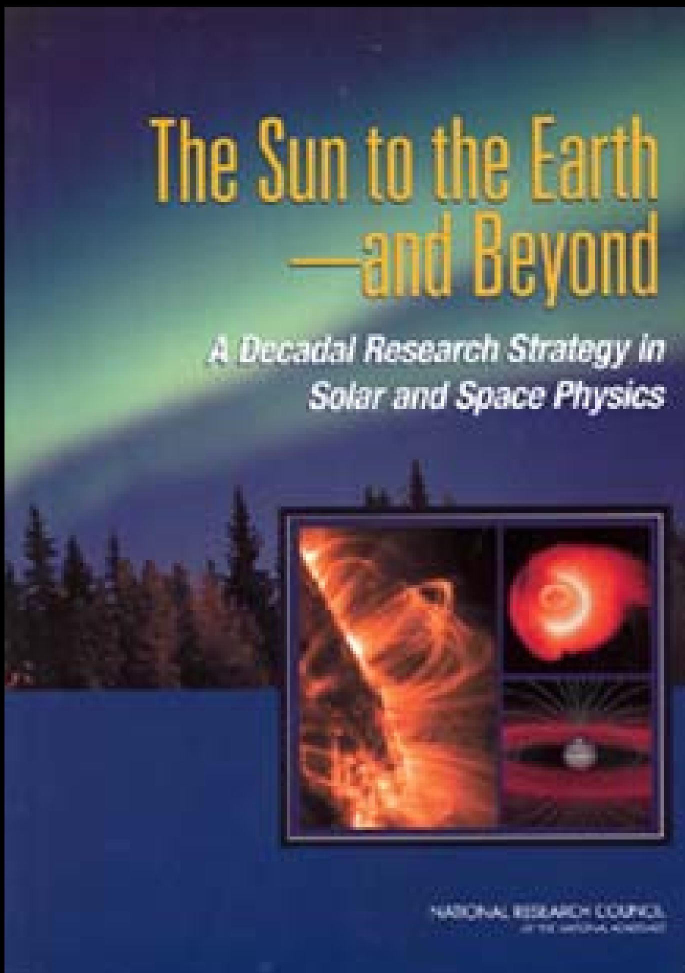
Solar Probe History



New STDT in line of studies dating back to "Simpson's Committee" of the Space Science Board (National Academy of Sciences) (24 October 1958)

Top Priority Science



NRC "Decadal Survey" (Highest Priority Science)

- **"Basic to understanding the genesis of the heliospheric s[illegible]ar wind, which will be provided of the solar wind, which will be provided by the Solar Probe mission. Because of the importance of this objective to the overall understanding of the solar-heliospheric system, as well as to other stellar systems, the Solar Probe should be implemented as soon as possible."**

NASA Sun-Earth Connection "Road map"

- **"The SEC mission roadmap contains some missions that are outside of the typical funding limitations of Solar Terrestrial Probes and Living With a Star mission cost caps. One of these missions is Solar Probe, which is a very high priority mission that accomplishes SEC science that is not possible with any other mission. For this mission and some others, NASA needs to be flexible in determining overall mission cost caps."**

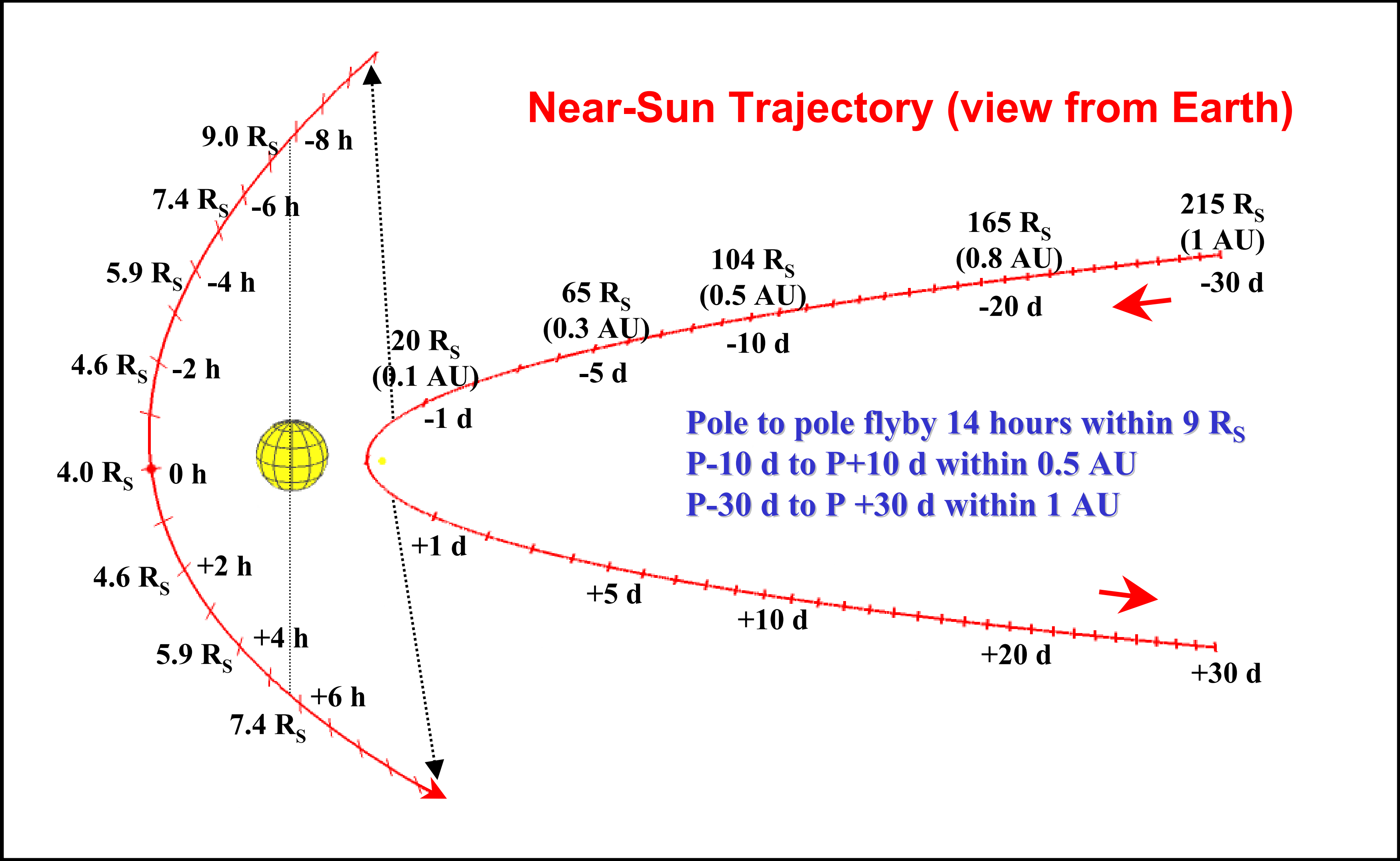
Goals of Current Study

- Demonstrate outstanding and compelling science
  - Review previous studies
  - Incorporate more recent results and theories
- Develop achievable mission concept and plan
  - Maintain focus on critical observations
  - Identify additional science opportunities
  - Prioritize core vs supporting science
- Build consensus in committee and community
- Adapt to evolving political environment

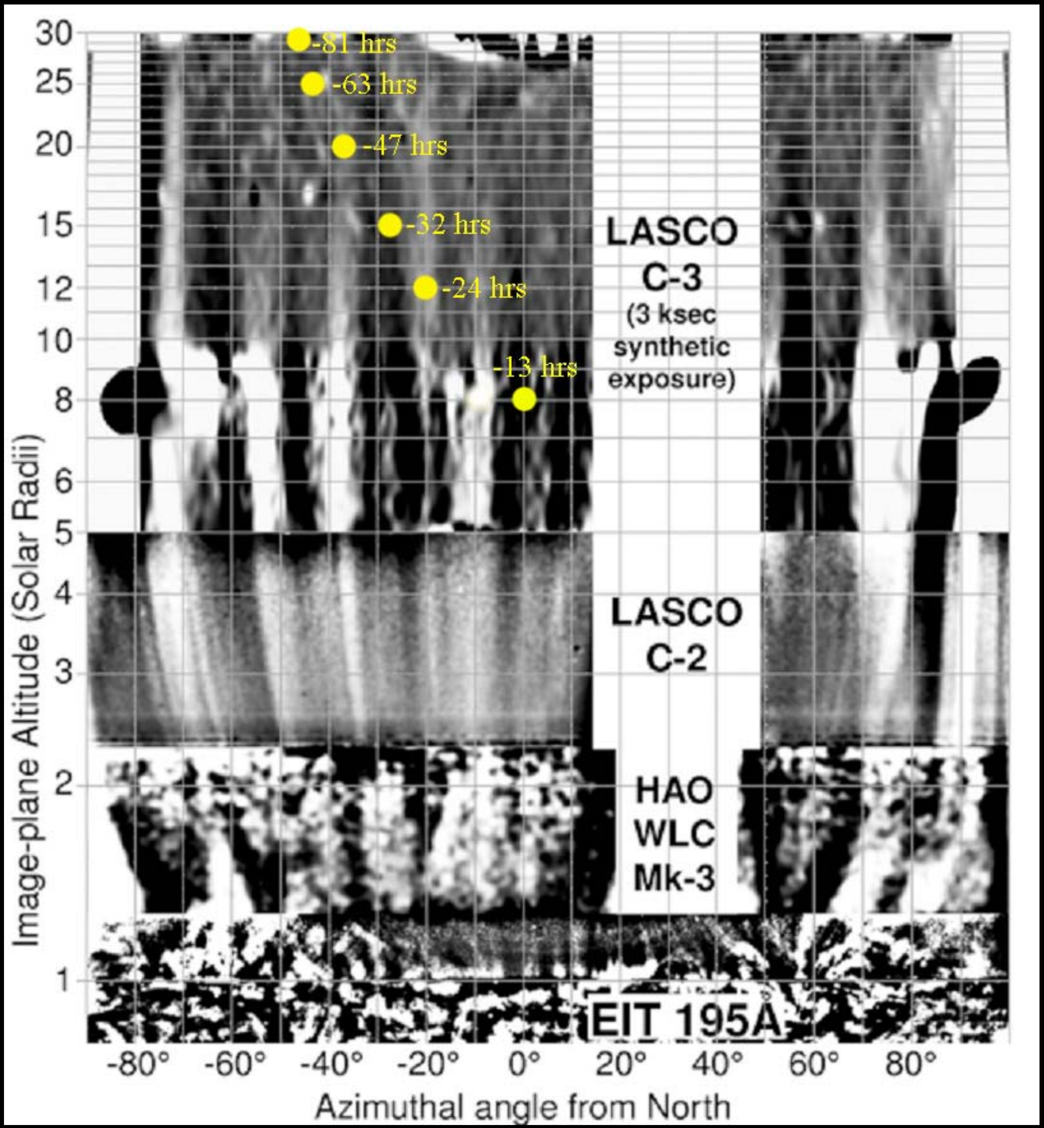
Evolution of Science

Solar Probe '89	Solar Probe '95 (MSM)	Solar Probe '99
Coronal Structure Large-scale structure Time variation Smaller-scale structure **Coronal Heating/Solar Wind Acceleration** Energy transport in lower atmosphere Solar wind acceleration **Plasma Turbulence Within the Coronal Envelope** **Energetic Particle Acceleration, Storage, and Transport** Probing corona w/energetic electrons Origin of suprathermal particles Composition & charge state of suprathermal & energetic particles Large SEP Events Small, Impulsive SEP events Energetic particle storage near Sun Particle propagation in inner heliosphere Nuclear processes in solar atmosphere **Sources, Sinks, & Dynamics of Interplanetary Dust**	Determine the characteristics of the high-speed solar wind plasma within a well-developed coronal hole Determine the characteristics of the plasma, including the source regions of the low-speed solar wind, within the quiet coronal streamer belt Determine the nature and fine-scale structure of source regions of the solar wind and coronal heating processes at the level of the coronal base	Determine acceleration processes and find source regions of the fast and slow solar wind at solar max and solar min. Locate the source and trace the flow of energy that heats the corona Construct 3D coronal density configuration from pole to pole; determine subsurface flow pattern the structure of the polar magnetic field, and its relationship with the overlying corona Identify acceleration mechanisms and locate source regions for energetic particles; determine the role of plasma waves and turbulence in the production of the solar wind and energetic particles

A Solar Flyby Mission



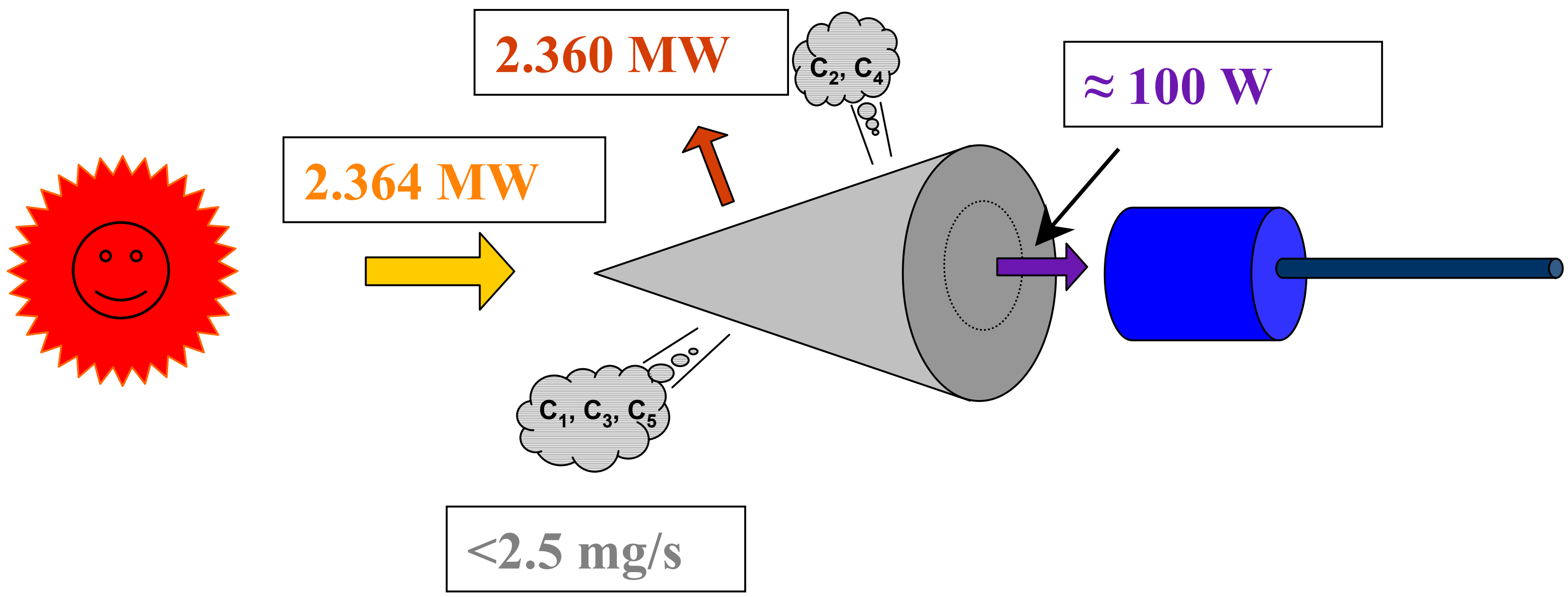
Example: Polar Plumes



At 30 solar radii, Solar Probe is already *embedded* in the polar structures (i.e. polar plumes). Important to *simultaneously connect* in-situ observations of coronal structures through which the S/C is flying with their source regions below.

Solar Probe Thermal Protection System

The Basic Problem



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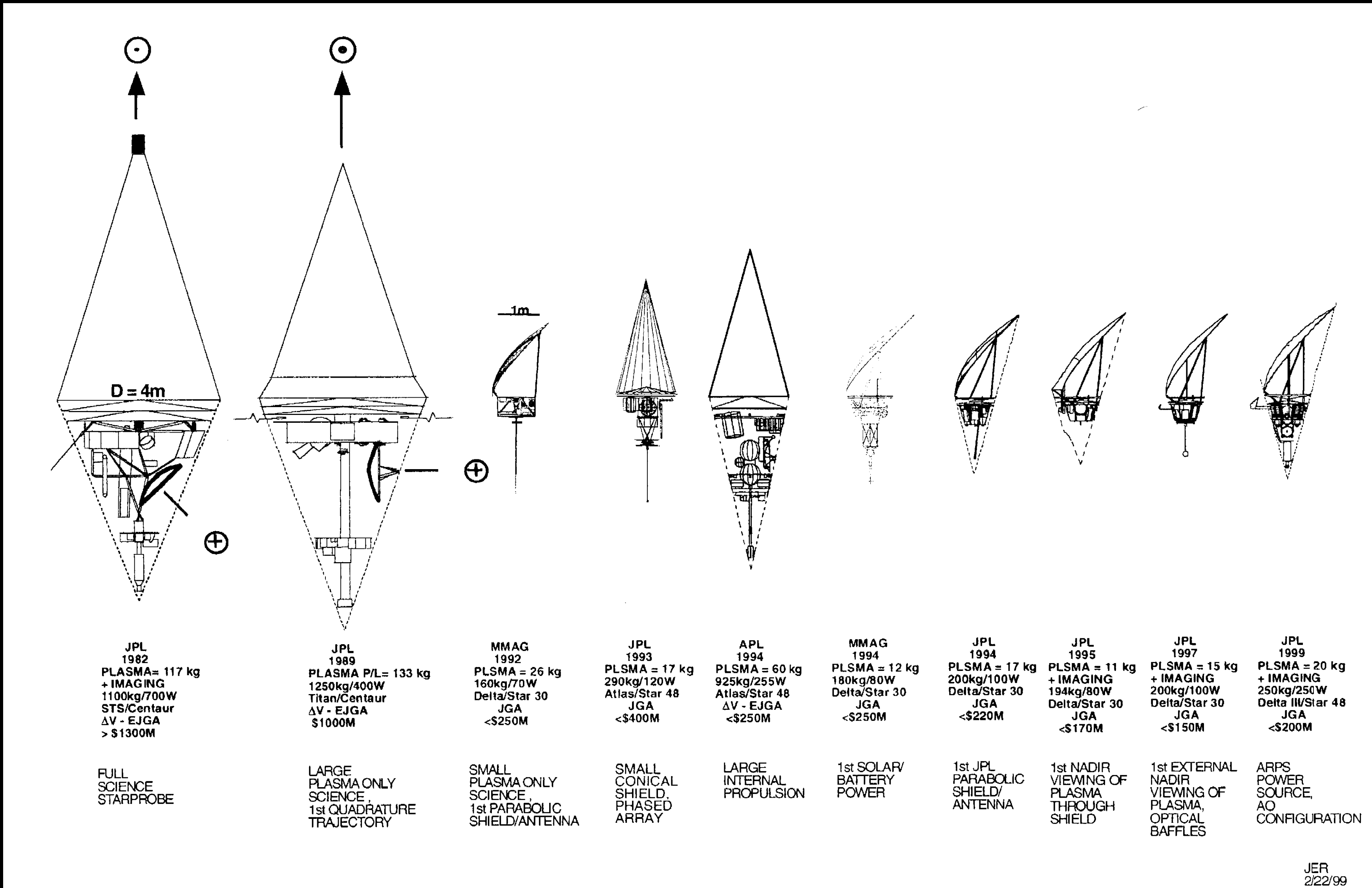
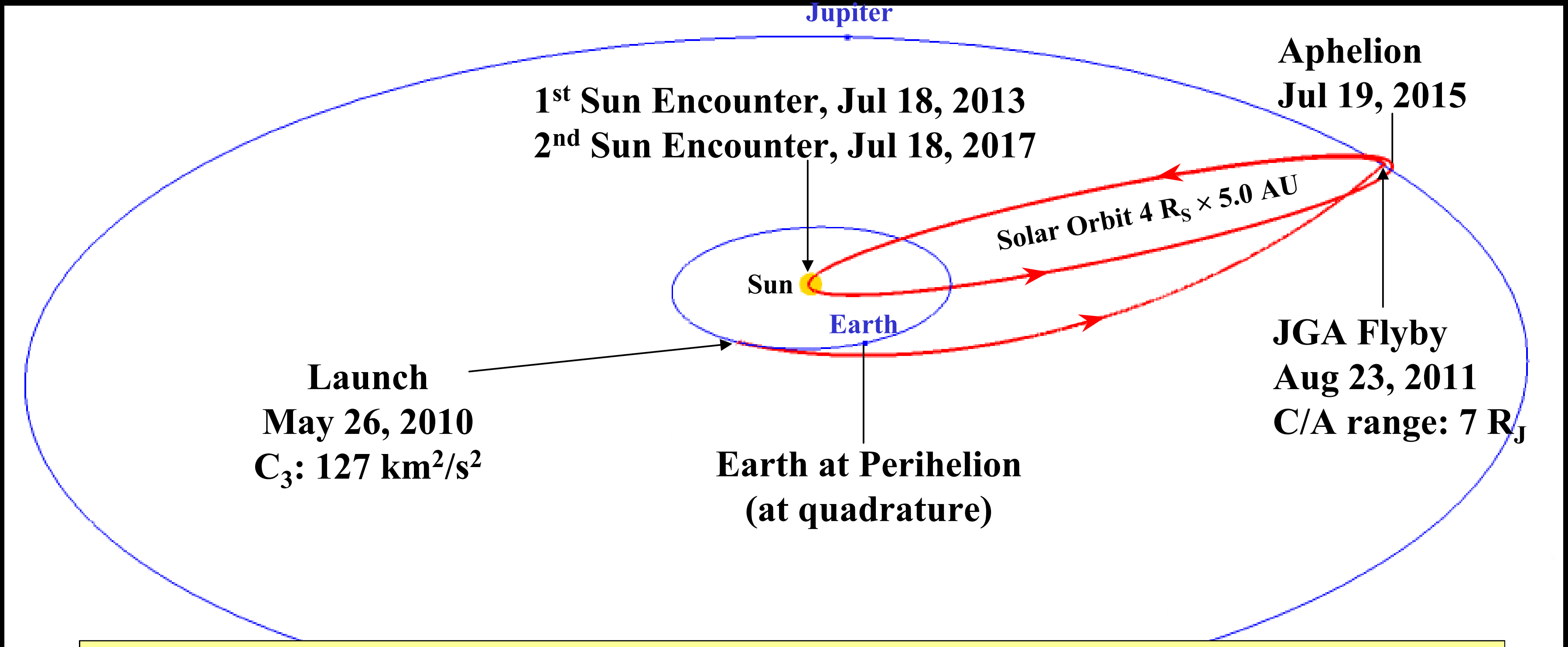
Solar Probe Design Evolution 1982 - 1999



2002 APL Study Movie

2002 APL Study



- Short time of flight to Sun (3.1 years)
- Repeated solar flyby every 4 years – accomplish 2 flybys within 7.1 years and 3 flybys within 11.1 years
- Favorable Earth quadrature at all perihelion passages
- Trajectory adjustment maneuver outside 0.8 AU

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Evolution of Instrumentation

		Starprobe	Solar Probe '89	Solar Probe '95 (MSM)	Solar Probe '99
Payload	In-Situ	Plasma Spectrometer Magnetometers Plasma Wave Sensor Energetic Particle Detector Dust Impact Detector Ion Composition Analyzer	Fast Plasma 3D Ions 3D Electrons Magnetometer Plasma Wave Suprathermal Composition Medium-Energy Particles High-Energy Particles Neutron/γ-Ray Detector Dust Detector	Solar Wind Plasma Analyzer Plasma Wave Instrument Magnetometer Energetic Particle Experiment	Solar Wind Particle & Compostion Spectrometer Energetic Particle Composition Spectrometer Vector Magentometer Plasma Wave Sensor Fast Solar Wind Ion Detector
	Remote Sensing	Visible Magnetograph/ Tachometer EUV Spectroheliograph Soft X-ray Heliograph Coronal Ly-a Spectrometer White-Light Coronagraph/ Magnetograph Coronal EUV Spectrometer	Coronal Spectral Imager	Visible Light Telescope EUV Telescope 2 EUV Pinhole Imager	Visible Magnetograph/ Heliograph XUV Imager 3D Coronagraph Imager
	Other	Drag-free Sensor ("Proof Mass")			
Resources	Mass	117 kg	133.5 kg	8 kg	18.8 kg
	Power	89 W	103 W	8 W	15.5 W
	Data Rate	>20 kbps	70 kbps	.5 kbps	112.4 kbps

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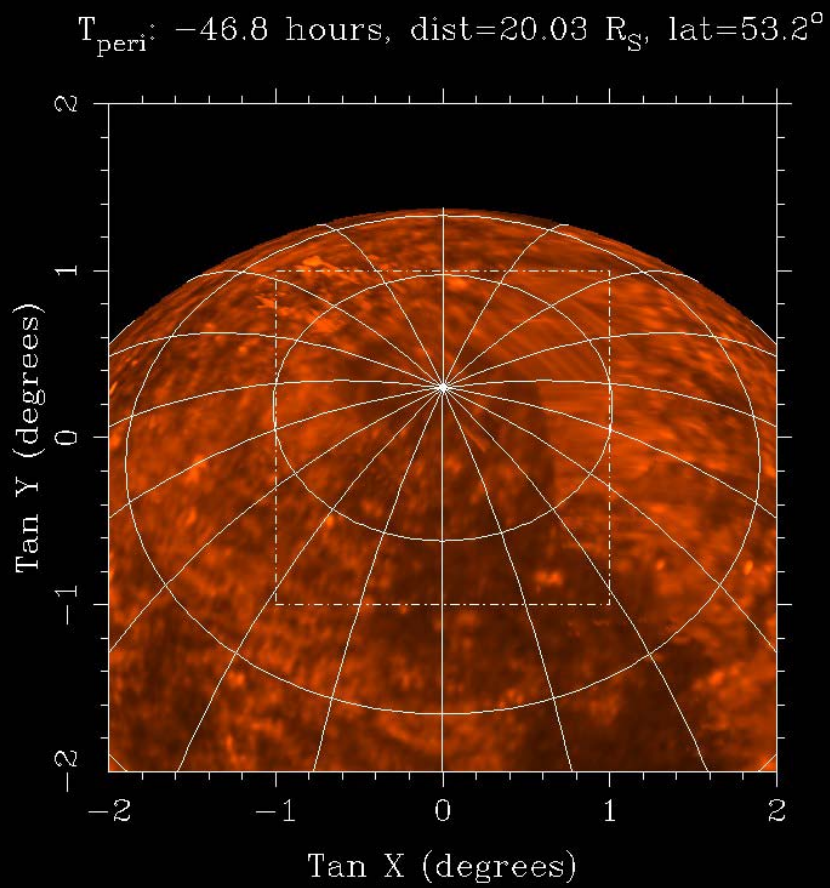
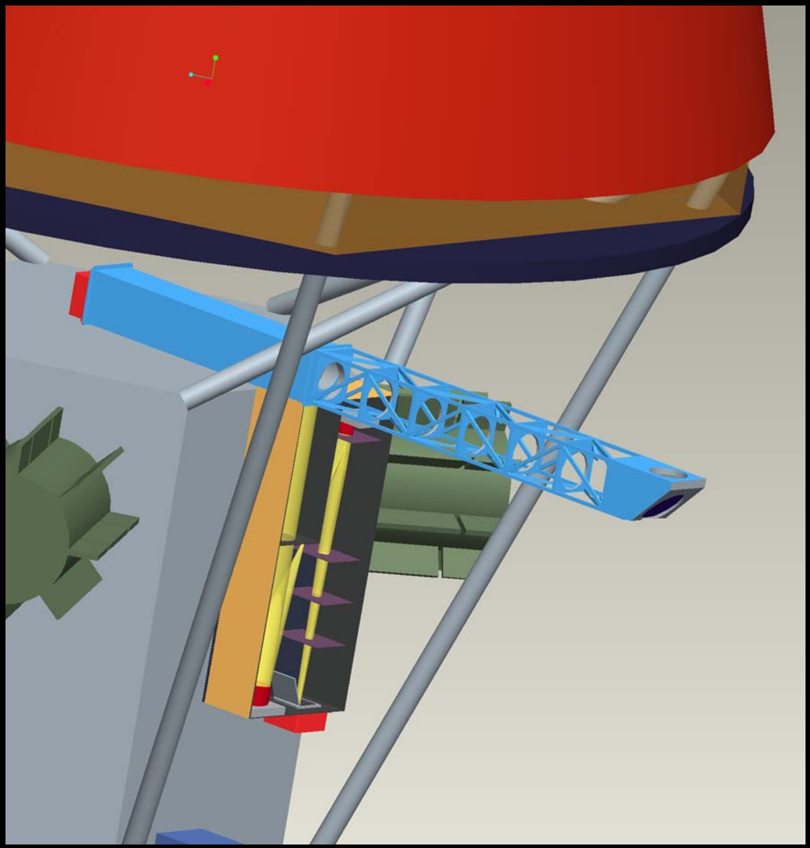
Current Baseline Observations

- Solar Wind Package (SWP)
  - Fast solar wind electrons, protons, and alphas
  - Ion composition
  - Nadir viewing TBD
- Energetic Particles Package (EPP)
  - Suprathermal and energetic particles
  - Solar neutrons, gamma rays and hard x-rays
  - Coronal dust
- Waves and Fields Package (WFP)
  - Magnetic fields
  - Plasma waves
- Remote Sensing Package (RSP)
  - Hemispheric white light
  - Polar imager (EUV & magnetograph channels)

Polar Imager (EUV & Magnetograph)



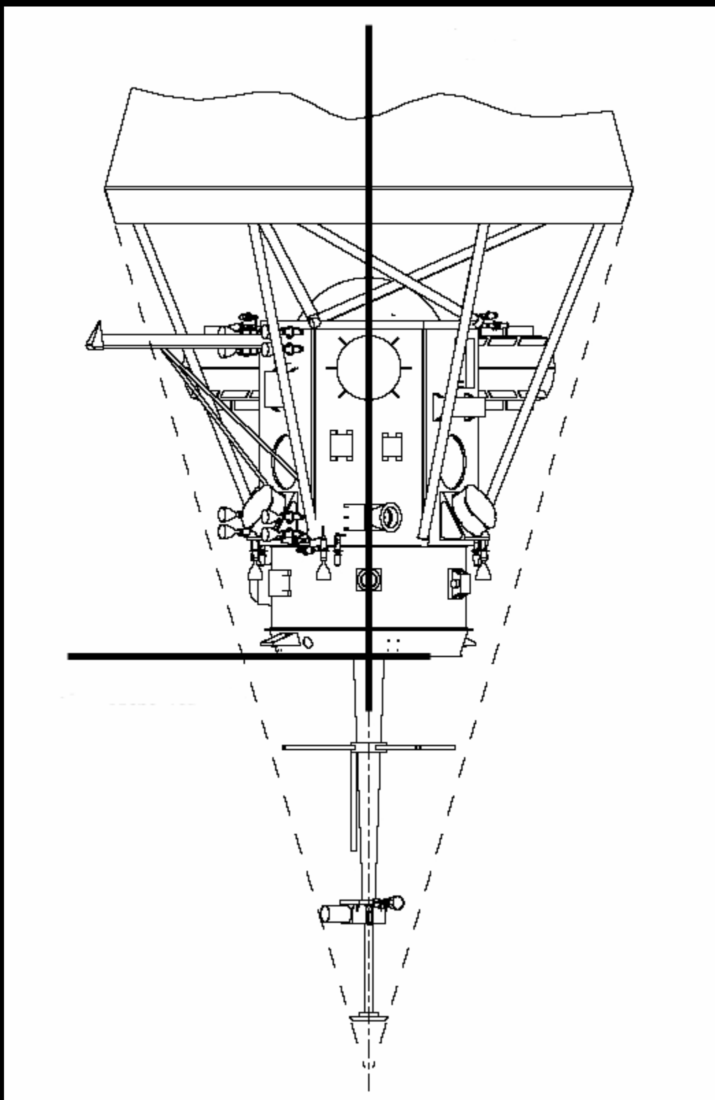


Observations into ~20 Rs with failsafe S/C periscope mirror

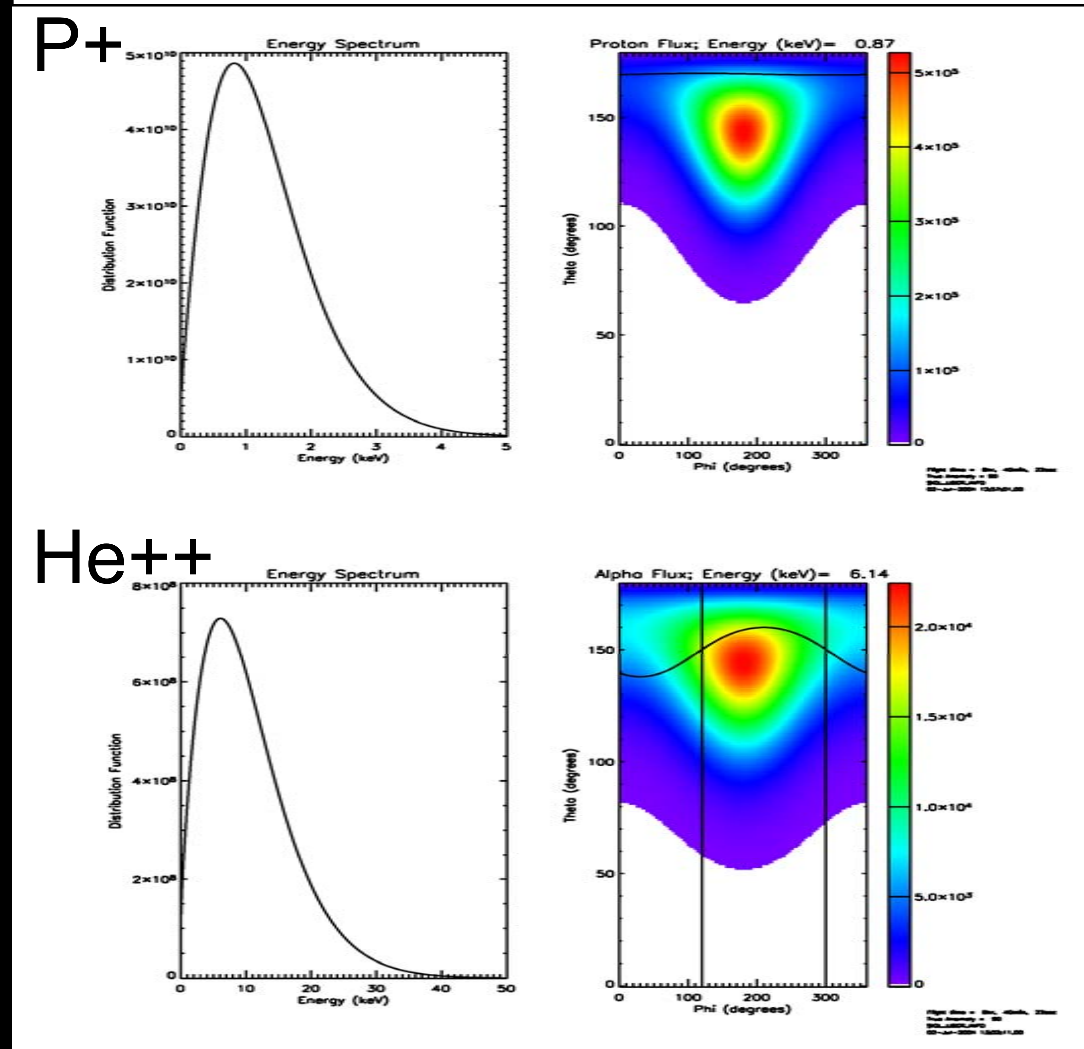
Plasma Viewing (1)

- NV Part of '99 baseline mission requirements
- Very strong driver of S/C requirements
  - Substantial heat load back to S/C
  - Difficult electroptics
  - Strong driver of mission risk
- Any NV appendage must be S/C supplied
- Examining science requirement and effects
- Partially mitigated by aberration & turbulence
- Detailed simulations w/ various BCs

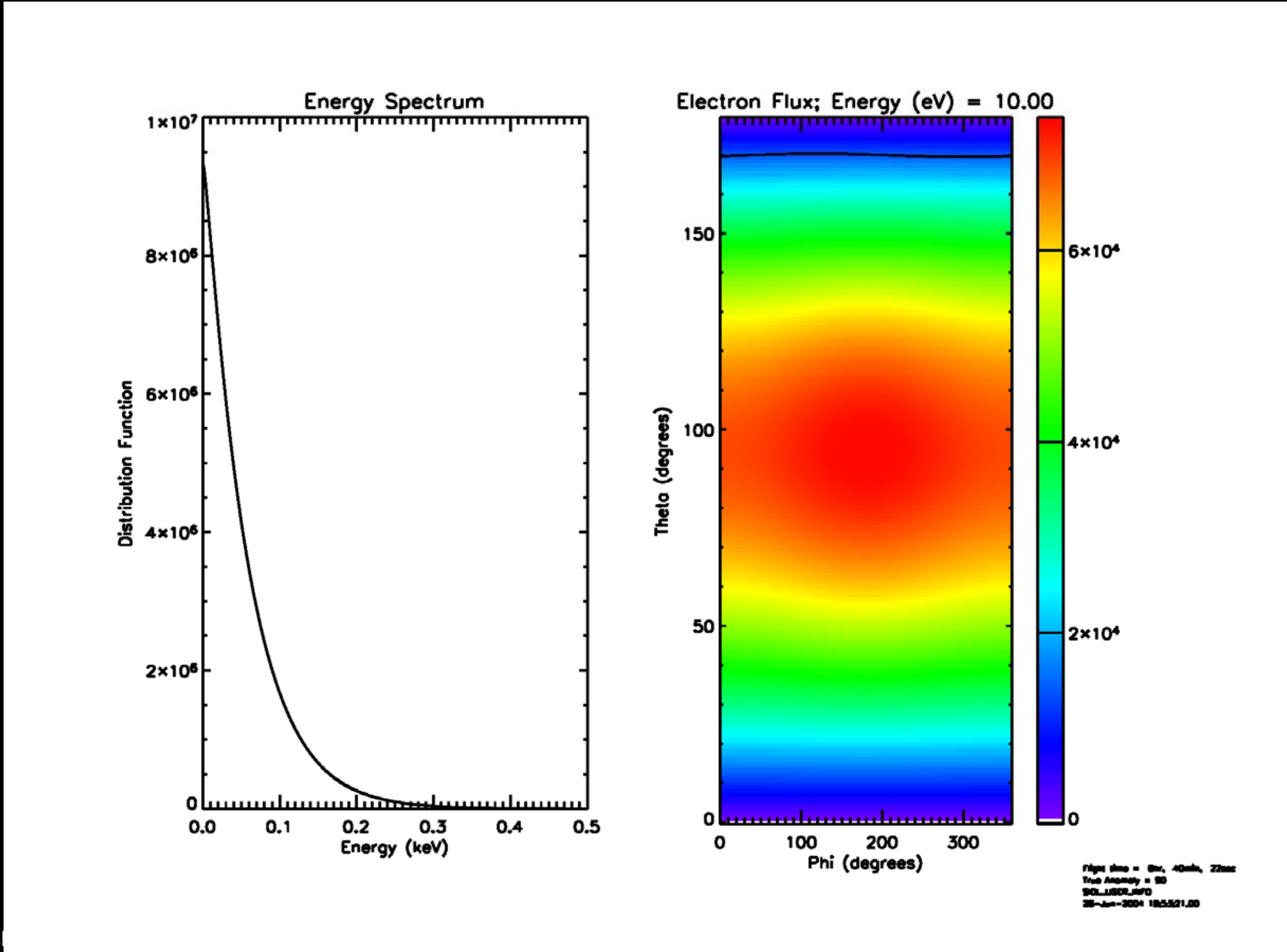
Plasma Viewing (2)



S Polar Pass



S Polar Pass – Electrons



Plasma Viewing (3)

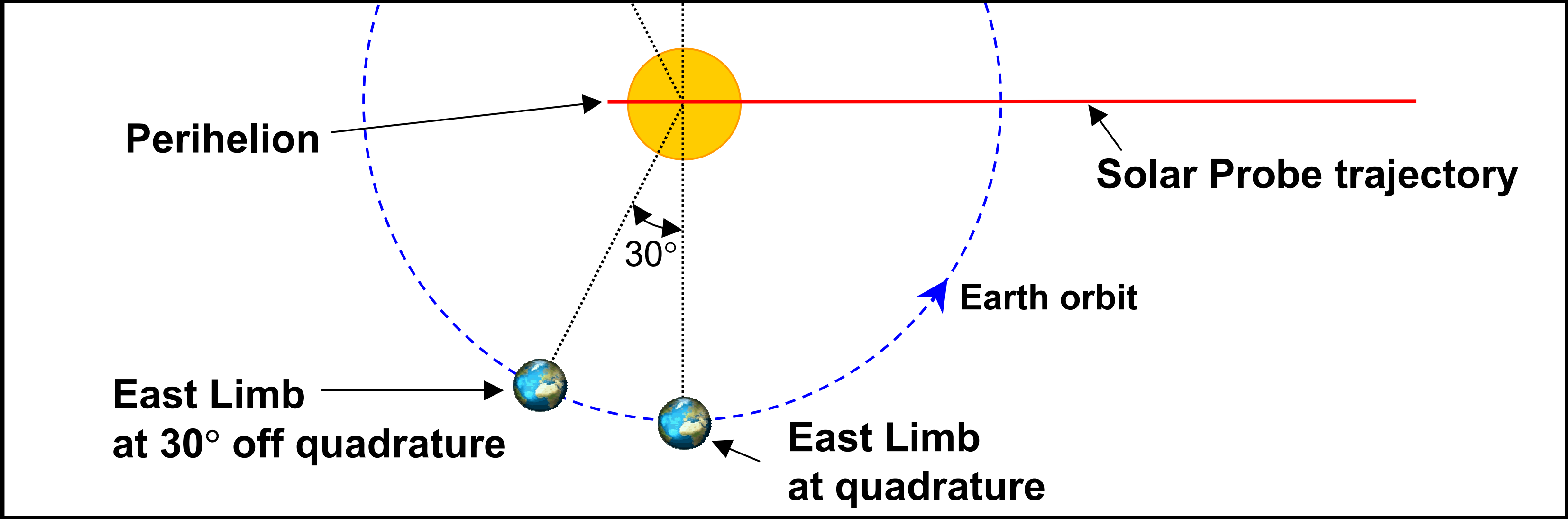
- Nadir viewing not required for electrons
- Continued study of NV requirements for ions
  - Additional simulations
  - More BCs and assumptions
- Study of primary plasma viewing and options
  - Aft axial boom oversubscribed & risky
  - Examining side moving arm to track umbra
- Single pixel NV ion deflector may be needed
  - Engineering team studying resources/risk
- Expect to reach near full consensus of STDT

Coordinated Solar Observations (1)

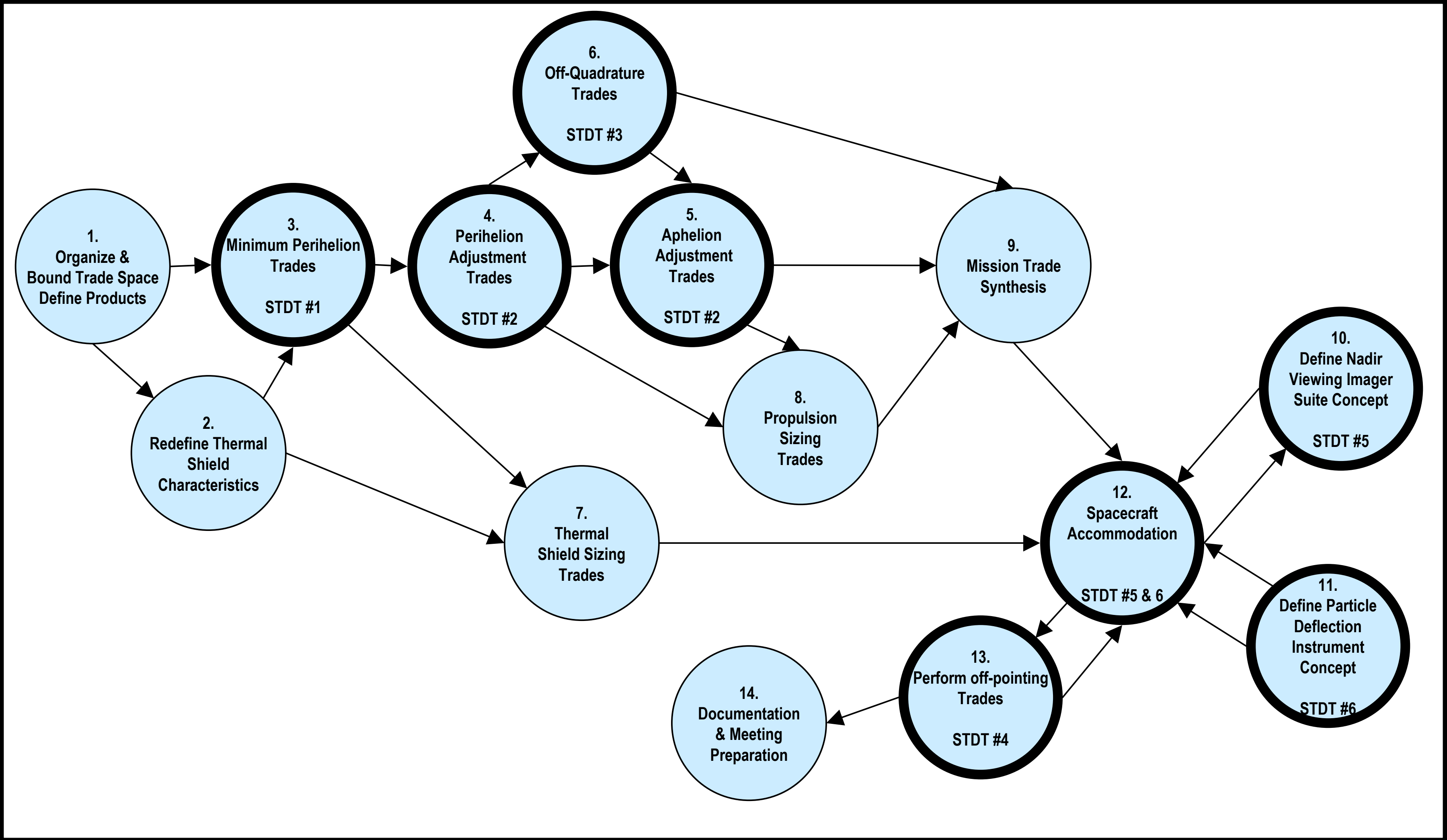
- SP Sun-viewing not possible at perihelion
  - Risk and complexity of high heat load
  - Soda straws not viewing footpoints
- Hemispheric white-light provides context
- Perihelion positioned on disk seen from Earth
  - Full suit of Earth and near-Earth observations
  - Not required but all available should be used
  - Coordinated campaign mode

Coordinated Solar Observations (2)

- Placement ~15 deg from limb optimum
  - Close enough for coronagraphs
  - Adequate surface viewing for other solar observations
  - Real-time communication lost away from quadrature



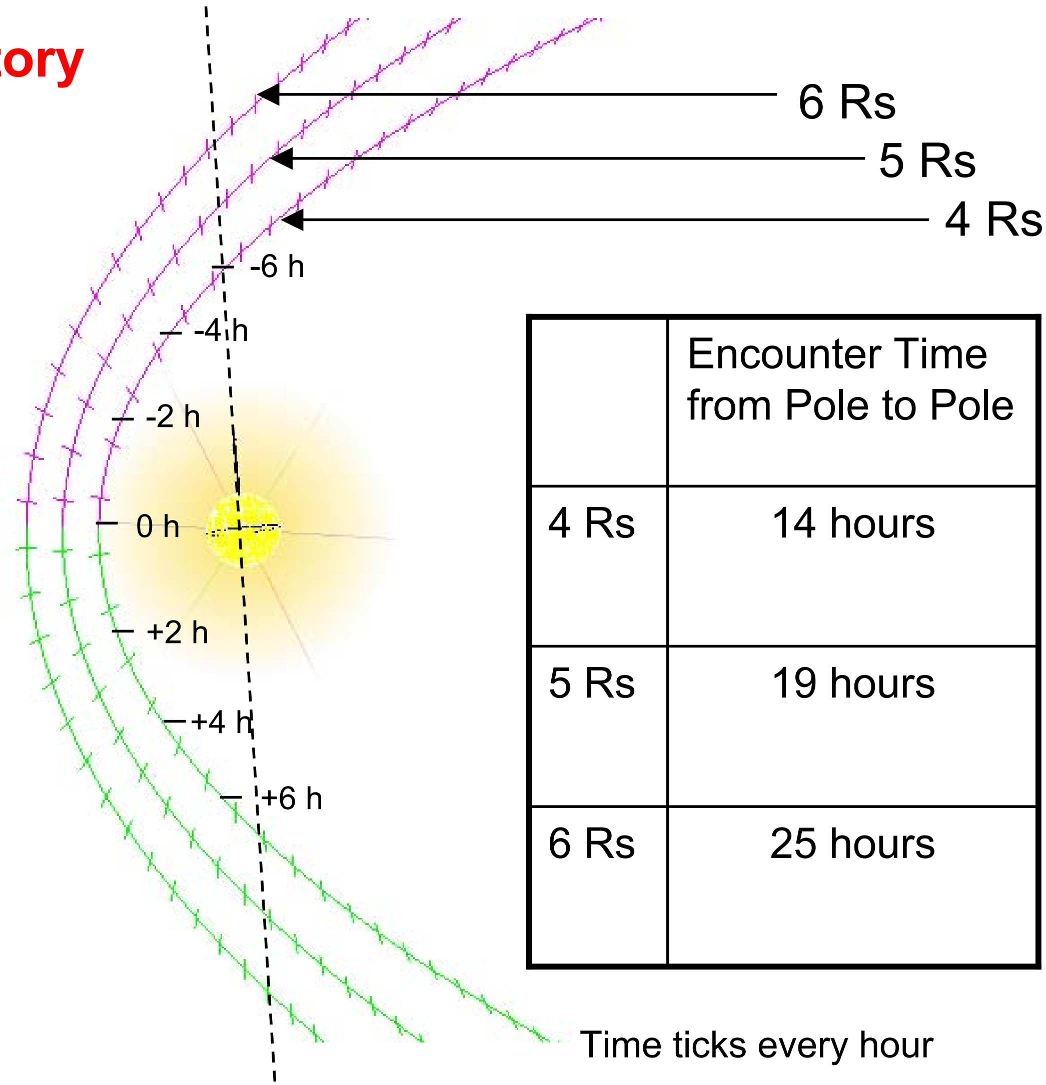
Initial Trade Study Flow



Ongoing Perihelion Study

Near Sun Flyby Trajectory

	Range (Rs)		
	4 Rs	5 Rs	6 Rs
-10 h			10.5
-8 h		9.0	9.2
-6 h	7.4	7.6	8.0
-4 h	5.9	6.4	7.0
-2 h	4.6	5.4	6.3
0 h	4.0	5.0	6.0
+2 h	4.6	5.4	6.3
+4 h	5.9	6.4	7.0
+6 h	7.4	7.6	8.0
+8 h	9.0	9.0	9.2
+10 h		10.4	10.5
+12 h		11.8	11.8
+14 h			13.1



	Encounter Time from Pole to Pole
4 Rs	14 hours
5 Rs	19 hours
6 Rs	25 hours

Time ticks every hour

Launch Oppertunities

Solar Probe Launch Opportunities 2010 - 2018

Launch Opportunity Year/Month	Sun Arrival* Year/Month	C/A Range to Jupiter (R_J)	Initial Orbit Period (yr)	Final Orbit Period (yr)	DSM** at P+20d (m/s)
2010/May	2013/July	7	3.93	4	50
2011/July	2015/August	11.6	4.45	4	270
2012/August	2016/October	11.7	4.51	4	310
2013/September	2017/November	11.9	4.59	4	350
2014/October	2018/December	12	4.65	4	380
2015/November	2019/January	12.3	4.66	4	390
2016/December	2020/February	12.7	4.62	4	370
2018/January	2021/March	12.9	4.55	4	330

*Favorable quadrature at perihelion passage
** Deep Space Maneuver (DSM) for adjusting orbit period

Large ΔV Penalty → Mission Design

- 1st Perihelion ~15 deg off E limb
  – Realtime science data
  – On-disk solar viewing from Earth
- 2nd Perihelion ~20 deg off W limb
  – Store/dump science data (looking at some RT)
  – On-disk solar viewing from earth
- 1-2 additional extended mission Perihelia
  – Store/dump science data
  – Back side perihelia – no viewing from Earth

Additional S/C AIs

- Dust environment and protection
- Largest practical science data volume
- Updated radiation environments
- Thin axial wave antenna extending from axial boom
- Effects of launch, charging, and dust on thermal coatings.

Community Outreach

- Community input & consensus is critical
- Your input is important to us!
  - Science inputs
  - Measurement ideas
  - Anything relevant to Solar Probe
- Contact STDT members who you know
- STDT Website
  http://solarprobe.gsfc.nasa.gov/