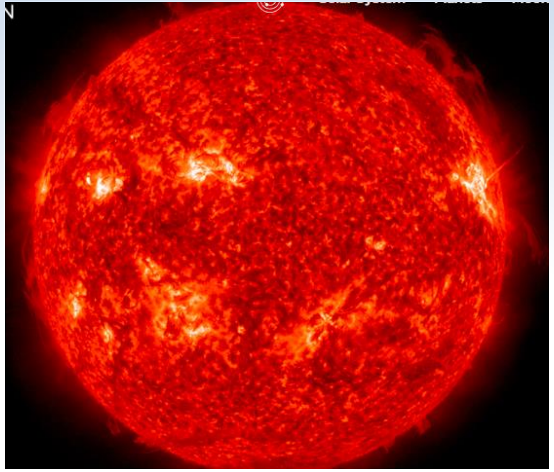


# *Touching* the Sun

Cheki Dorji

(For Space Engineering Seminar, Cho Lab, Kyutech)

2018-12-06

*All images and video clips are taken from NASA media channels unless mentioned otherwise*

# Recognize this person?


https://hypebeast.com/

# Sun – The Beginning and an End

- Formation and Age

  - Formed from a giant, rotating cloud of gas and dust called a solar nebula

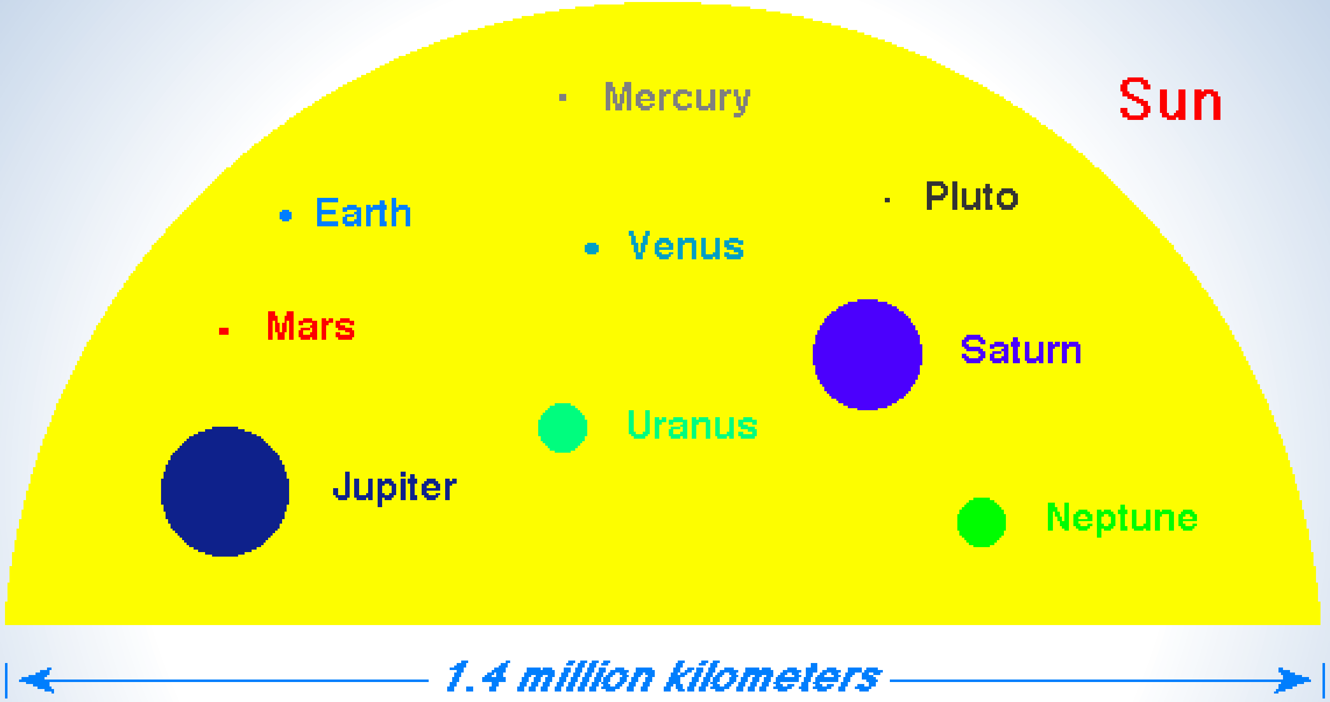
  - About 4.5 billion years ago

Future of Sun

- Swell big enough to engulf Mercury, Venus and even Earth

- 6.5 billion years more

# Size and Mass




The Sun contains more than **99.8%** of the total mass of the Solar System (Jupiter contains most of the rest).

# Gravity and Escape velocity

| Sun | Earth |
| --- | --- |
| **SURFACE GRAVITY** | |
| 274.0 $m/s^2$ | 9.80665 $m/s^2$ |
| **ESCAPE VELOCITY** | |
| 2,223,720 km/h | 40,284 km/h |

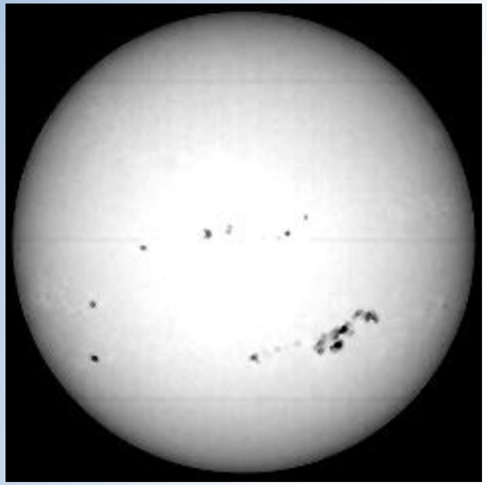
**Chemical composition:**

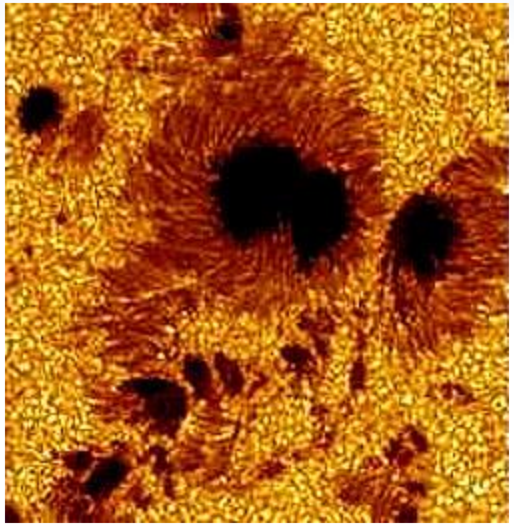
Hydrogen **92.1%**

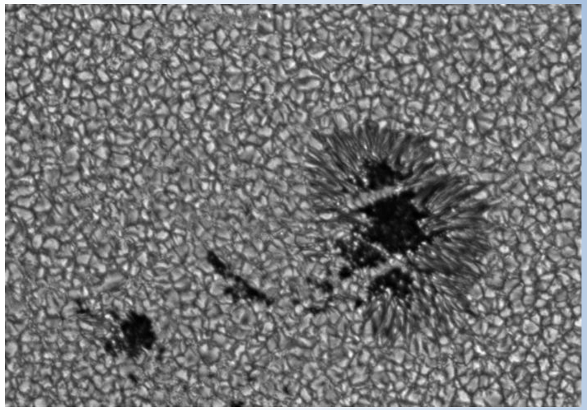
Helium **7.8%**

Rest of the other 90 naturally occurring elements: **0.1%**

# Sunspots







Sunspots appear as dark spots on the surface of the Sun due to concentration of magnetic field flux that inhibit convection. Temperatures in the dark centers of sunspots drop to about 3700 K (compared to 5700 K for the surrounding photosphere). They typically last for several days, although very large ones may live for several weeks.

# Solar Flare

Energetic ejections of particles lasting tens of minutes to hours. Ejected particles appear to trace out magnetic field lines, usually associated with sunspots.

The sun emitted a significant solar flare, peaking at 7:42 a.m. EDT on June 10, 2014. NASA's Solar Dynamics Observatory captured images of the flare.

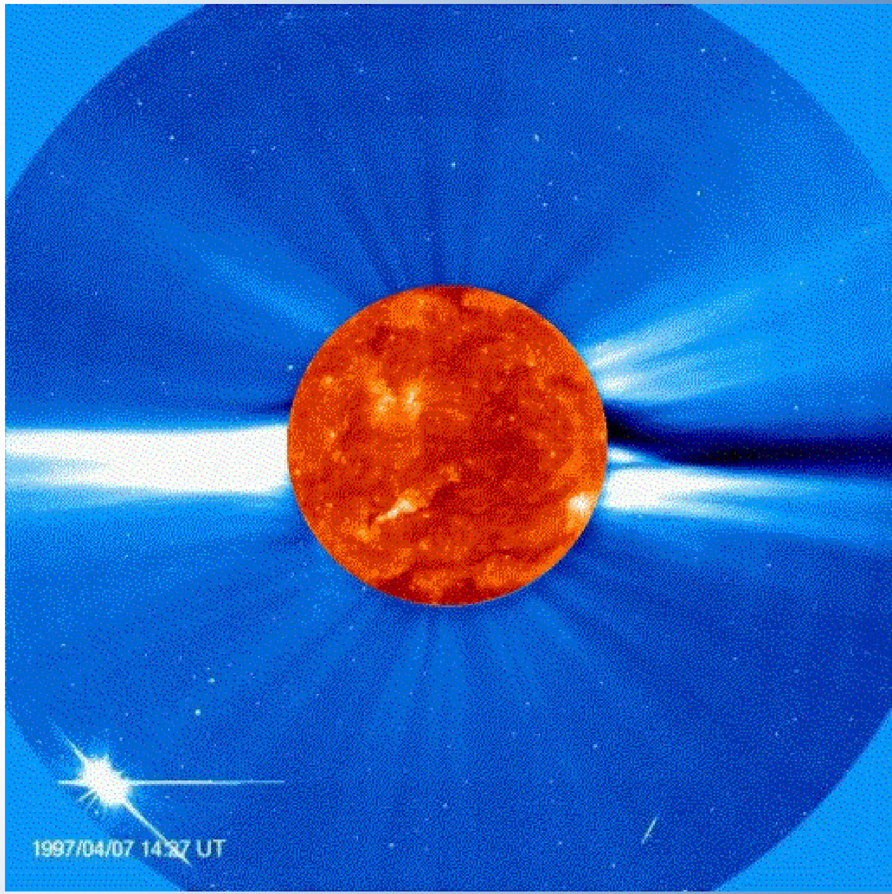
Link to the video:
https://www.youtube.com/watch?v=rRpxs39zn20

# Coronal Mass Ejections (CMEs)

- Coronal mass ejections (CMEs) are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours

- CMEs disrupt the flow of the solar wind and produce disturbances that strike the Earth with sometimes catastrophic results

- They often follow solar flares



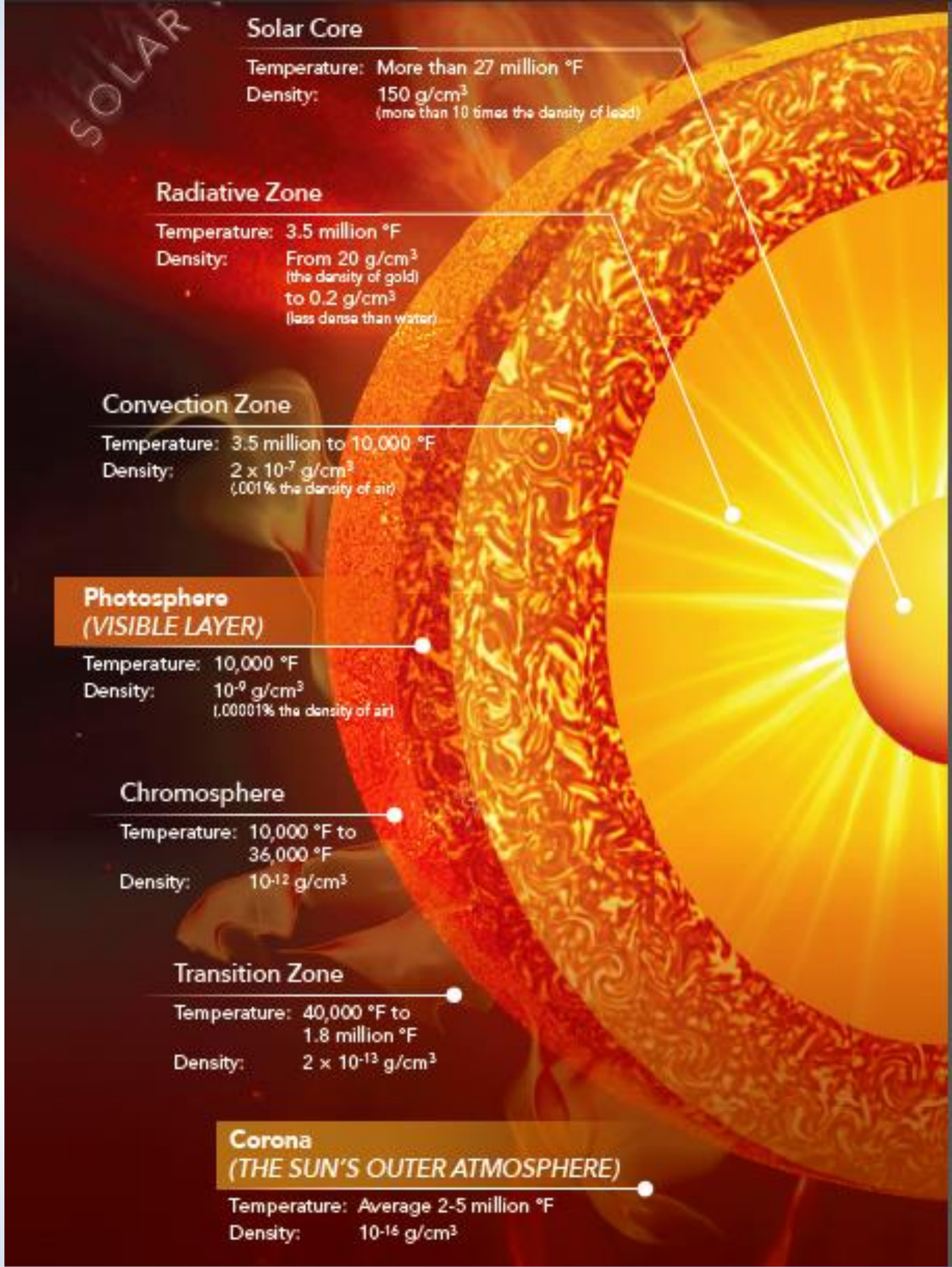
# Solar Wind

- Solar wind is the continuous flow of charged particles (ions, electrons, and neutrons) that comes from the Sun in every direction.
- Solar wind consists of slow and fast components. Slow solar wind is a consequence of the corona’s high temperature. The speed of the solar wind varies from less than 300 km/s (about half a million miles per hour) to over 800 km/s.

# Mystery of the Sun

1\. Why is Solar Wind Continuosly accelerated?

2\. Why is Sun's Corona hotter than the surface of the Sun?



A NASA's Mission
'to touch the Sun'

# Parker Solar Probe Mission

- Named after **Eugene Newman Parker**
- Theorized the theory of Solar Wind in 1950s.

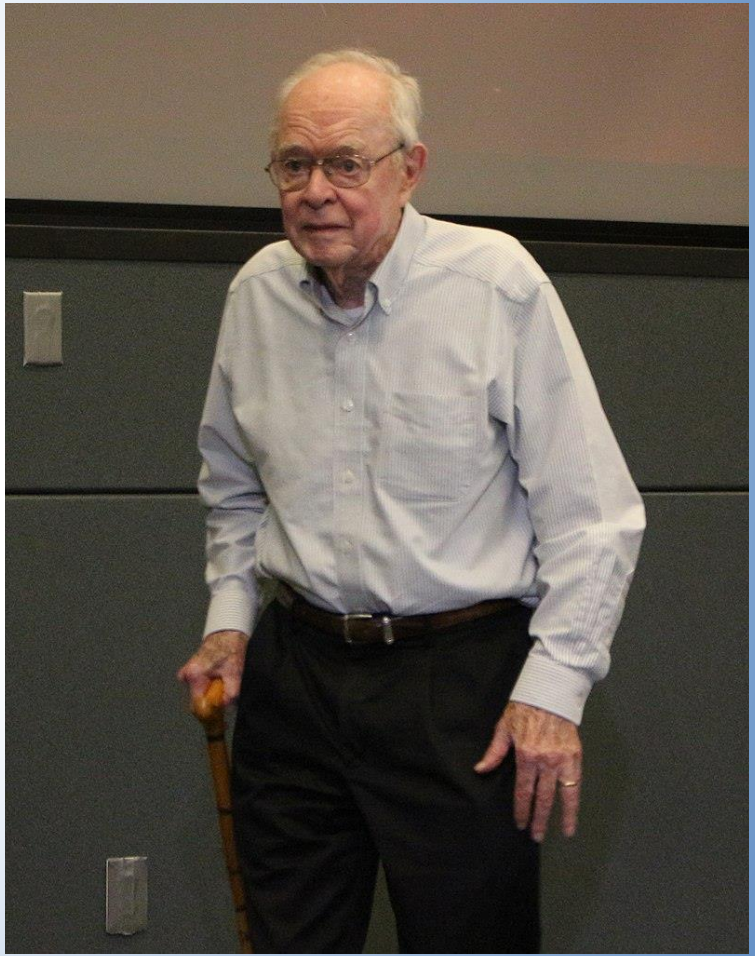
DYNAMICS OF THE INTERPLANETARY GAS AND MAGNETIC FIELDS*

E. N. Parker
Enrico Fermi Institute for Nuclear Studies, University of Chicago
*Received January 2, 1958*

ABSTRACT

We consider the dynamical consequences of Biermann's suggestion that gas is often streaming outward in all directions from the sun with velocities of the order of 500–1500 km/sec. These velocities of 500 km/sec and more and the interplanetary densities of 500 ions/$cm^3$ ($10^{14}$ gm/sec mass loss from the sun) follow from the hydrodynamic equations for a $3 \times 10^{6}$ °K solar corona. It is suggested that the outward-streaming gas draws out the lines of force of the solar magnetic fields so that near the sun the field is very nearly in a radial direction. Plasma instabilities are expected to result in the thick shell of disordered field ($10^{-5}$ gauss) inclosing the inner solar system, whose presence has already been inferred from cosmic-ray observations.

- First time NASA named spacecraft after living individual



Age: 91

https://en.wikipedia.org/wiki/Eugene_Parker

# Parker Solar Probe Mission Objectives

- Trace the flow of energy that heats and accelerates the solar corona and solar wind.
- Determine the structure and dynamics of the plasma and magnetic fields at the sources of the solar wind.
- Explore mechanisms that accelerate and transport energetic particles.

*Understand the Sun better by taking measurements close to it to protect a society that is increasingly dependent on technology from the threats of space weather.*

# Why is Studying Sun Important?

- Understanding the Universe itself - Only star reachable to mankind
- Source of energy for life on Earth
- Disturbances in the solar wind affect space weather
  - Change orbits of satellites
  - Shorten satellite lifetimes
  - Interfere with onboard electronics of spacecraft
  - Threat to Astronauts

# Parker Solar Probe Mission Team

- Institutions Participated in Science Team: 31
  - In the US: 23 Outside the US: 8
  - Educational: 17
  - Non-profit: 5
  - Government labs: 8

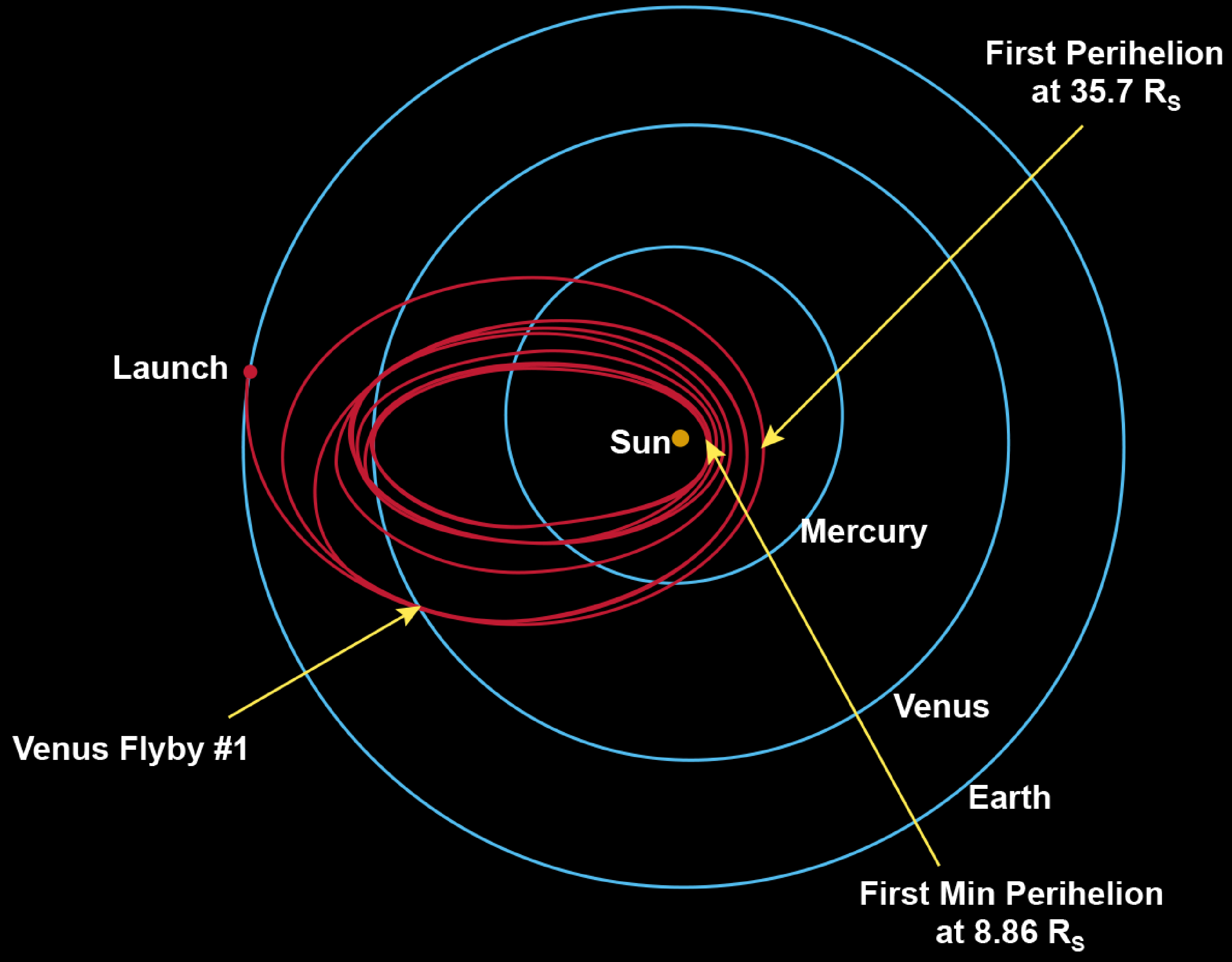
- Science Team Members: 106
  - Principal Investigators and Co-Investigators: 69
  - Additional Scientists: 37

Next generation graduate students and post-docs

# Trajectory and Orbit

| Parameters | Values |
|---|---|
| Life Time | 7 years |
| Orbit Type | Solar Orbit |
| Inclination from Ecliptic Plane | 3.4 |
| Venus gravity assist flybys ($V^7$GA) | 7 |
| Total Orbits | 24 |
| Orbital Period | 168 to 88 days |
| Speed | 192 km/sec |
| Closet Approach/ Perihelion | 8.86 $R_s$ (Solar Radii) |

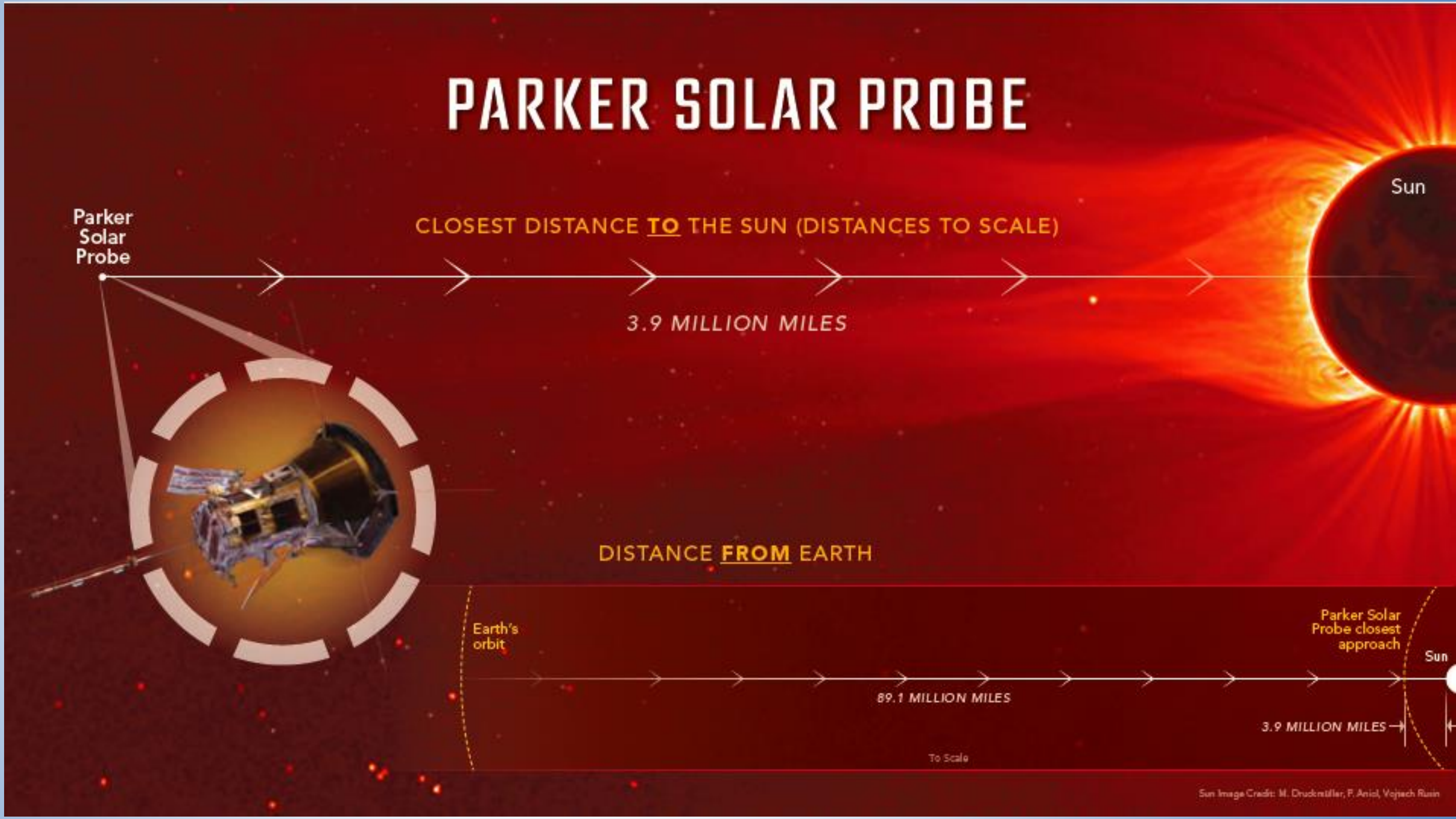
# T R A J E C T O R Y & O R B I T



# TRAJECTORY & ORBIT


Link to the video: https://www.youtube.com/watch?v=cMNQeCWT09A&t=106s

# TRAJECTORY & ORBIT



# MISSION TIMELINE

## 2015

**March:** Critical Design Review (CDR)

## 2016

**May:** System Integration Review

**July:** KDP-D

**July:** Start of Integration and Testing

## 2017

**Begin March 2017:** Instrument Deliveries

**Begin August 2017:** Observatory System Testing

**Fall 2017:** Shipment of Observatory to GSFC

# MISSION TIMELINE

## 2018

- **Spring 2018:** Shipment of Observatory to Cape Canaveral
- **August 12, 2018:** Launch - 3:31 a.m. EDT (7:31 UTC)
- **October 3, 2018:** Venus Flyby #1 - 4:44 a.m. EDT (8:44 UTC)
- **November 5, 2018:** Perihelion #1 - 10:27 p.m. EST (Nov. 6, 2018 at 03:27 UTC)

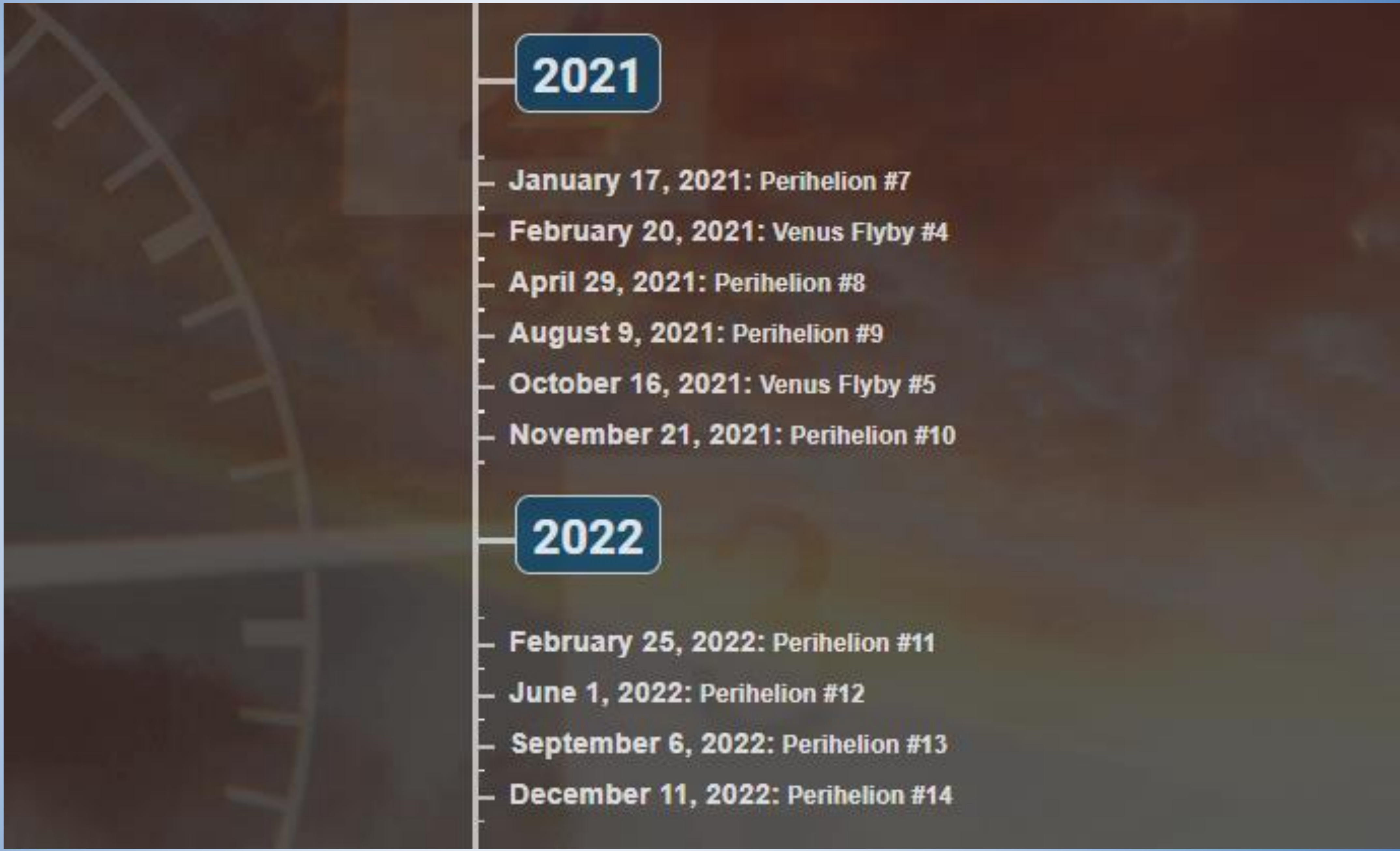
## 2019

- **April 4, 2019:** Perihelion #2
- **September 1, 2019:** Perihelion #3
- **December 26, 2019:** Venus Flyby #2

## 2020

- **January 29, 2020:** Perihelion #4
- **June 7, 2020:** Perihelion #5
- **July 11, 2020:** Venus Flyby #3
- **September 27, 2020:** Perihelion #6

# MISSION TIMELINE



# MISSION TIMELINE

## 2023

- **March 17, 2023:** Perihelion #15
- **June 22, 2023:** Perihelion #16
- **August 21, 2023:** Venus Flyby #6
- **September 27, 2023:** Perihelion #17
- **December 29, 2023:** Perihelion #18

## 2024

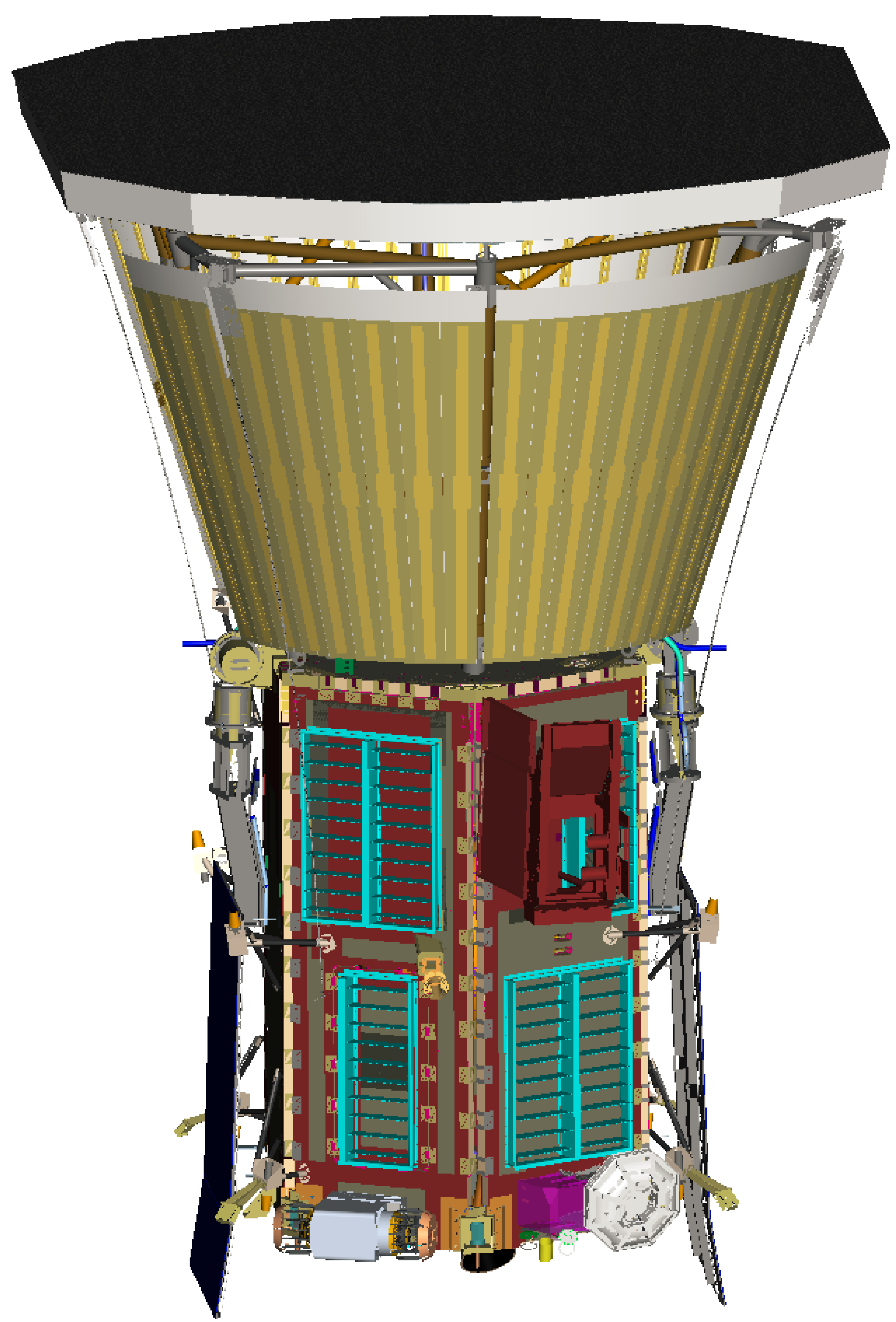
- **March 30, 2024:** Perihelion #19
- **June 30, 2024:** Perihelion #20
- **September 30, 2024:** Perihelion #21
- **November 6, 2024:** Venus Flyby #7 Final Venus Flyby
- **December 24, 2024:** Perihelion #22 First Close Approach

## 2025

- **March 22, 2025:** Perihelion #23
- **June 19, 2025:** Perihelion #24

# Spacecraft Overview

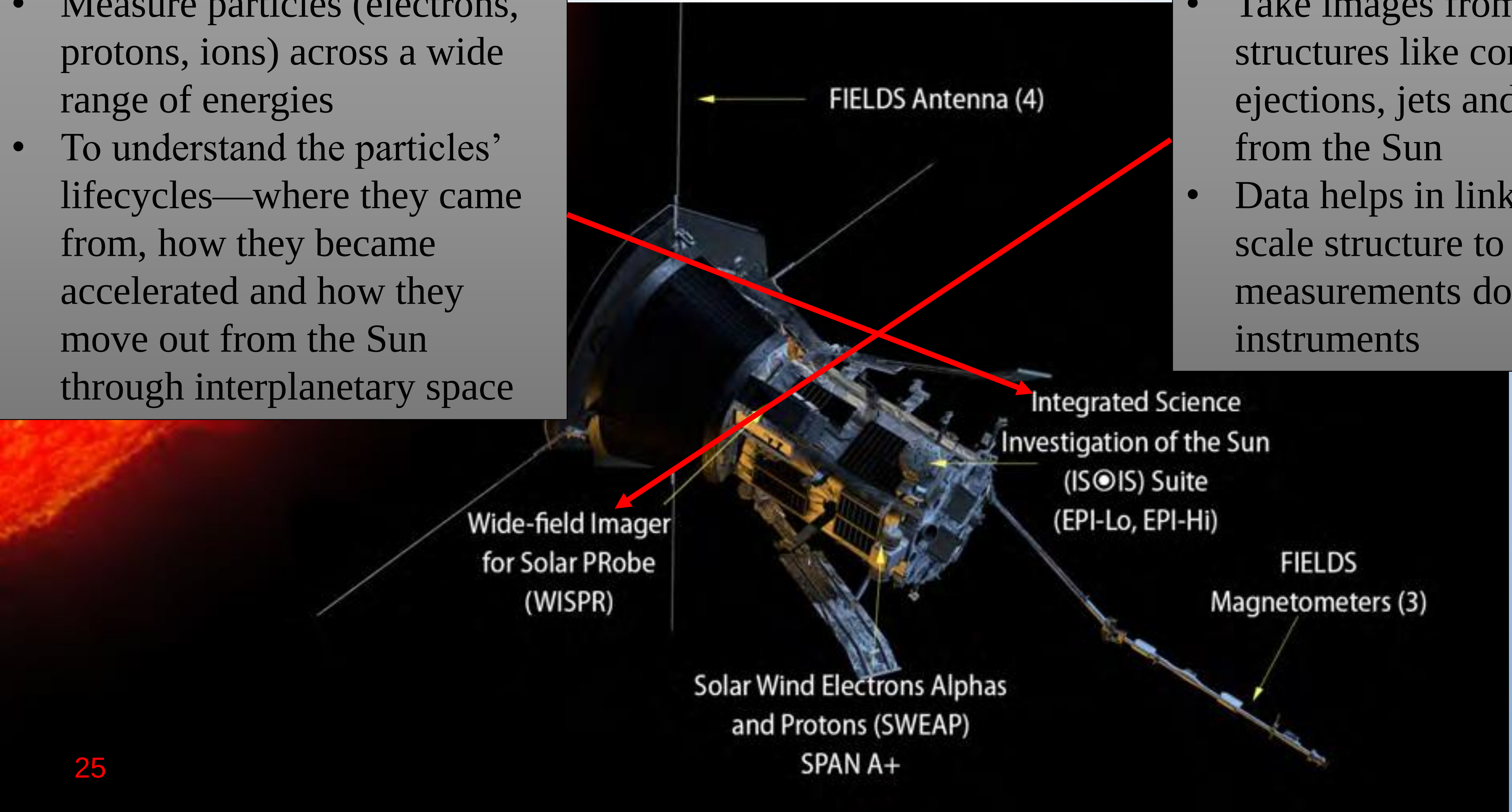
- Mass: 685 kg
- Reference Dimensions:
  - Height: 3 m
  - TPS diameter: 2.3 m
  - Bus system diameter: 1 m
- Bus configuration: Hexagonal
- Propulsion: Monopropellant Hydrazine
- Wheels for attitude control
- Solar Arrays (2): (1.12 X 0.69) m



# Parker Solar Probe: Mission Instruments

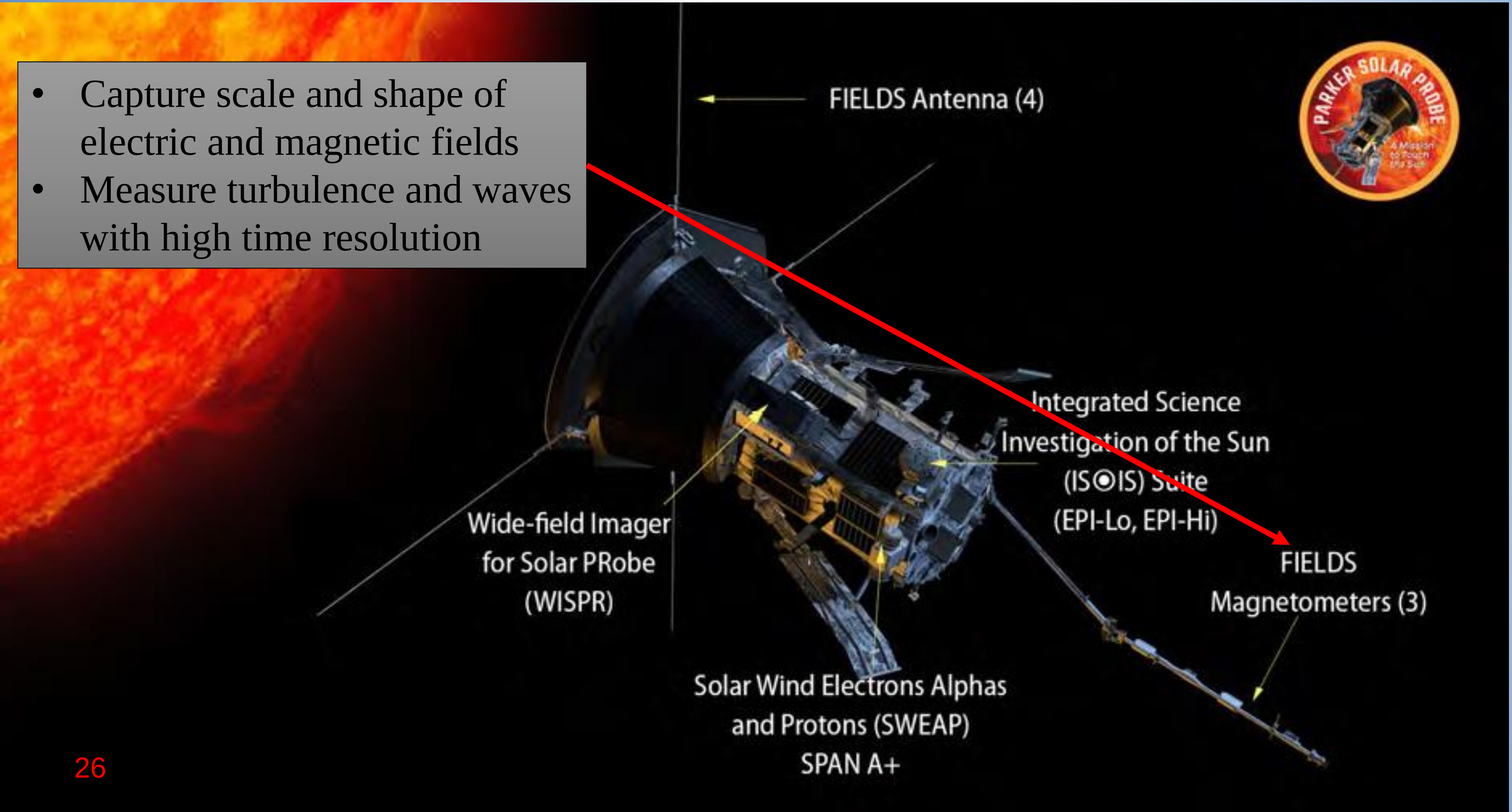
- Measure particles (electrons, protons, ions) across a wide range of energies
- To understand the particles' lifecycles—where they came from, how they became accelerated and how they move out from the Sun through interplanetary space

- Take images from afar of structures like coronal mass ejections, jets and other ejecta from the Sun
- Data helps in linking large-scale structure to detailed measurements done by other 3 instruments

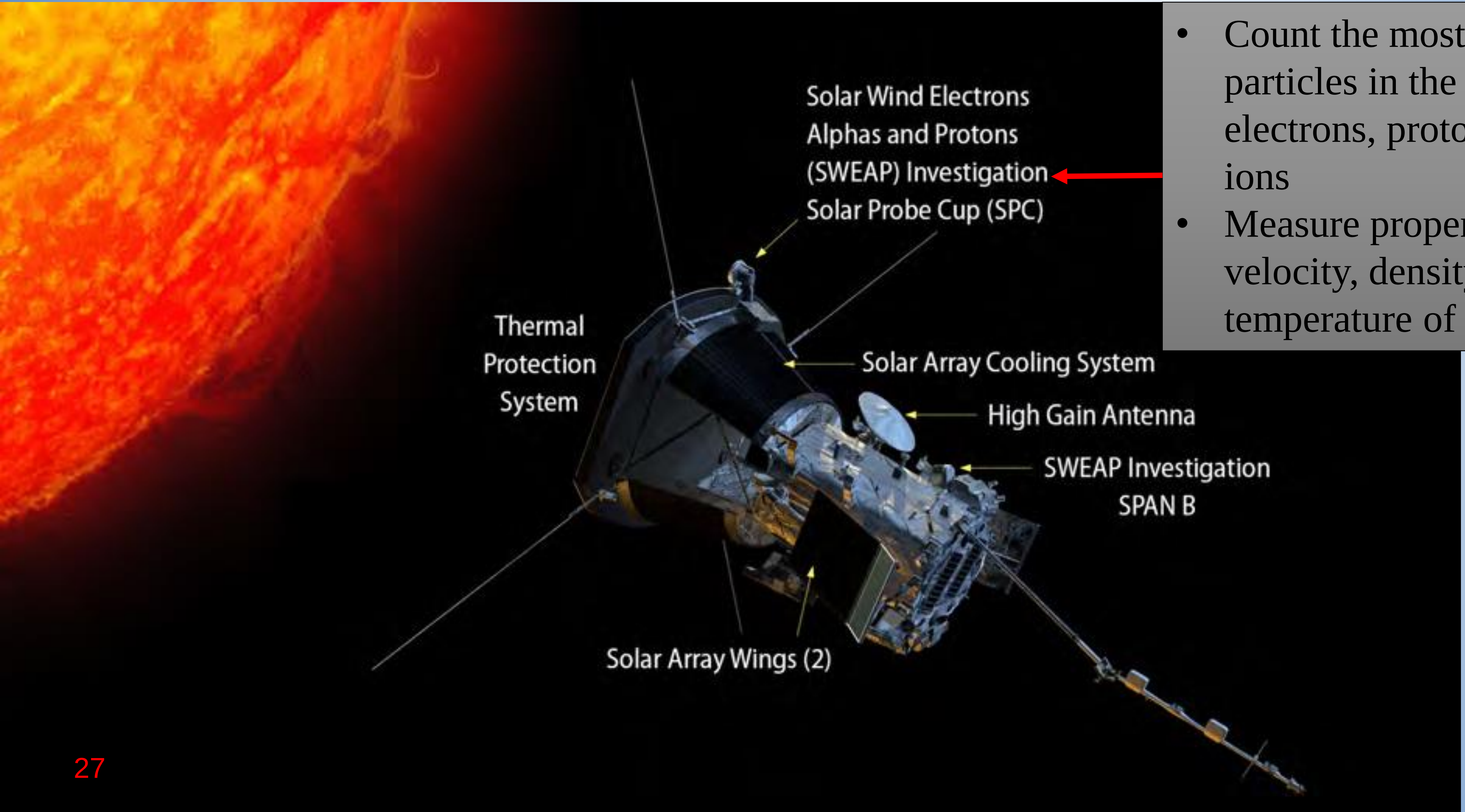


# Parker Solar Probe: Mission Instruments

- Capture scale and shape of electric and magnetic fields
- Measure turbulence and waves with high time resolution

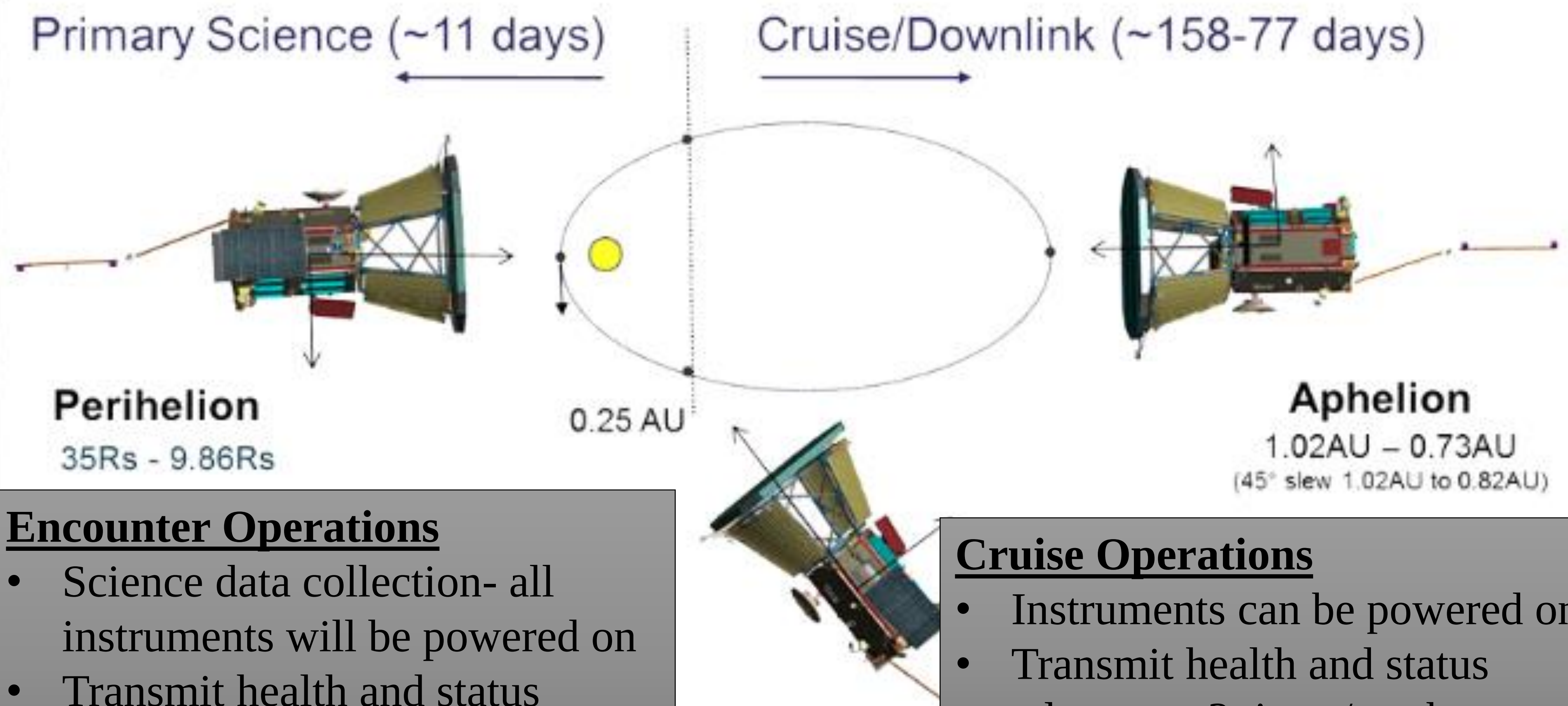


# Parker Solar Probe: Mission Instruments




- Count the most abundant particles in the solar wind—electrons, protons and helium ions
- Measure properties such as velocity, density, and temperature of particles

# CONCEPT OF OPERATION



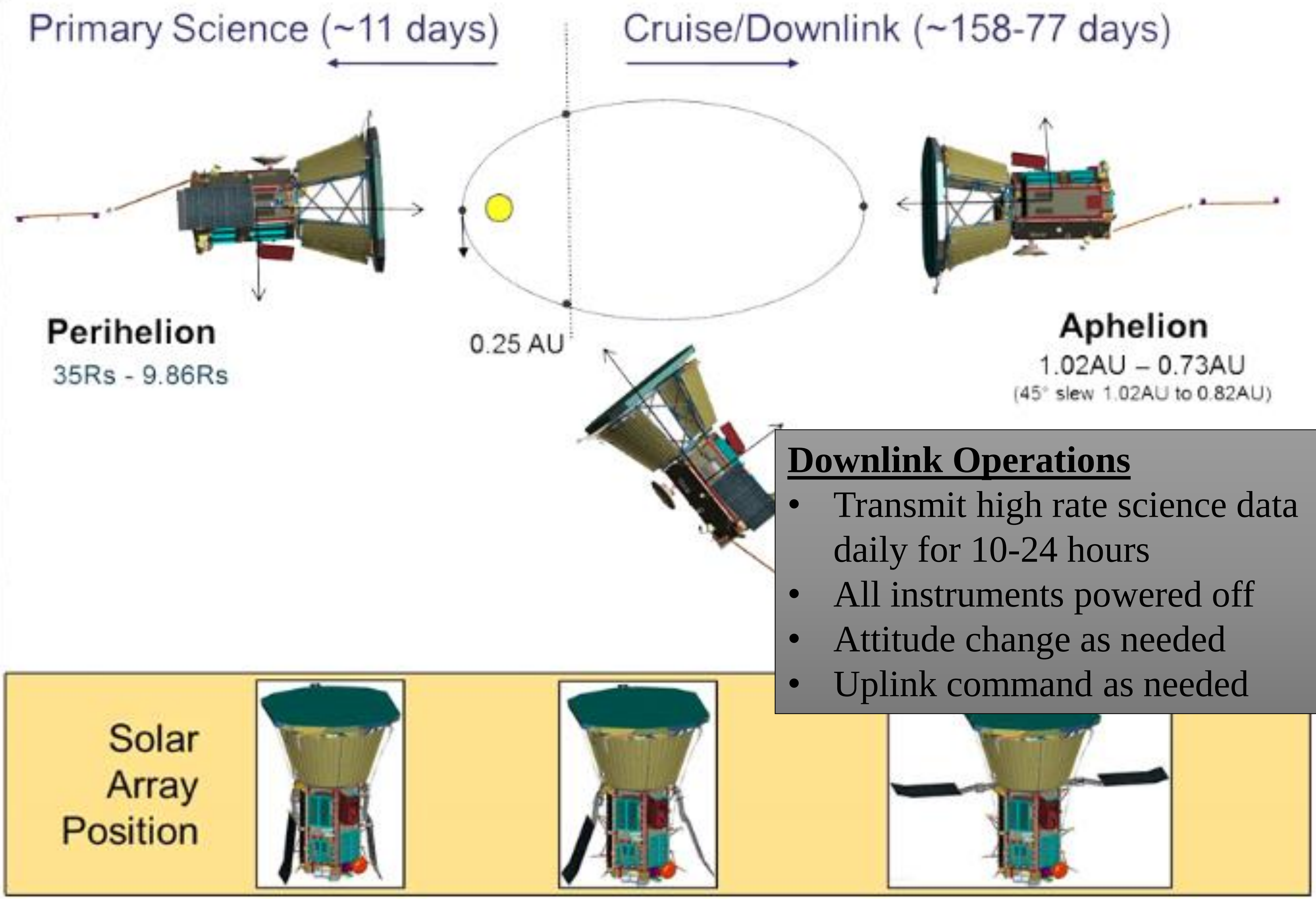

**Encounter Operations**

- Science data collection- all instruments will be powered on
- Transmit health and status beacon: 3 times/week
- Maintain ‘Encounter Attitude’

**Cruise Operations**

- Instruments can be powered on
- Transmit health and status telemetry: 3 times/week
- Attitude change as needed

# CONCEPT OF OPERATION




**Downlink Operations**

- Transmit high rate science data daily for 10-24 hours
- All instruments powered off
- Attitude change as needed
- Uplink command as needed

# Thermal Protection System (TPS)

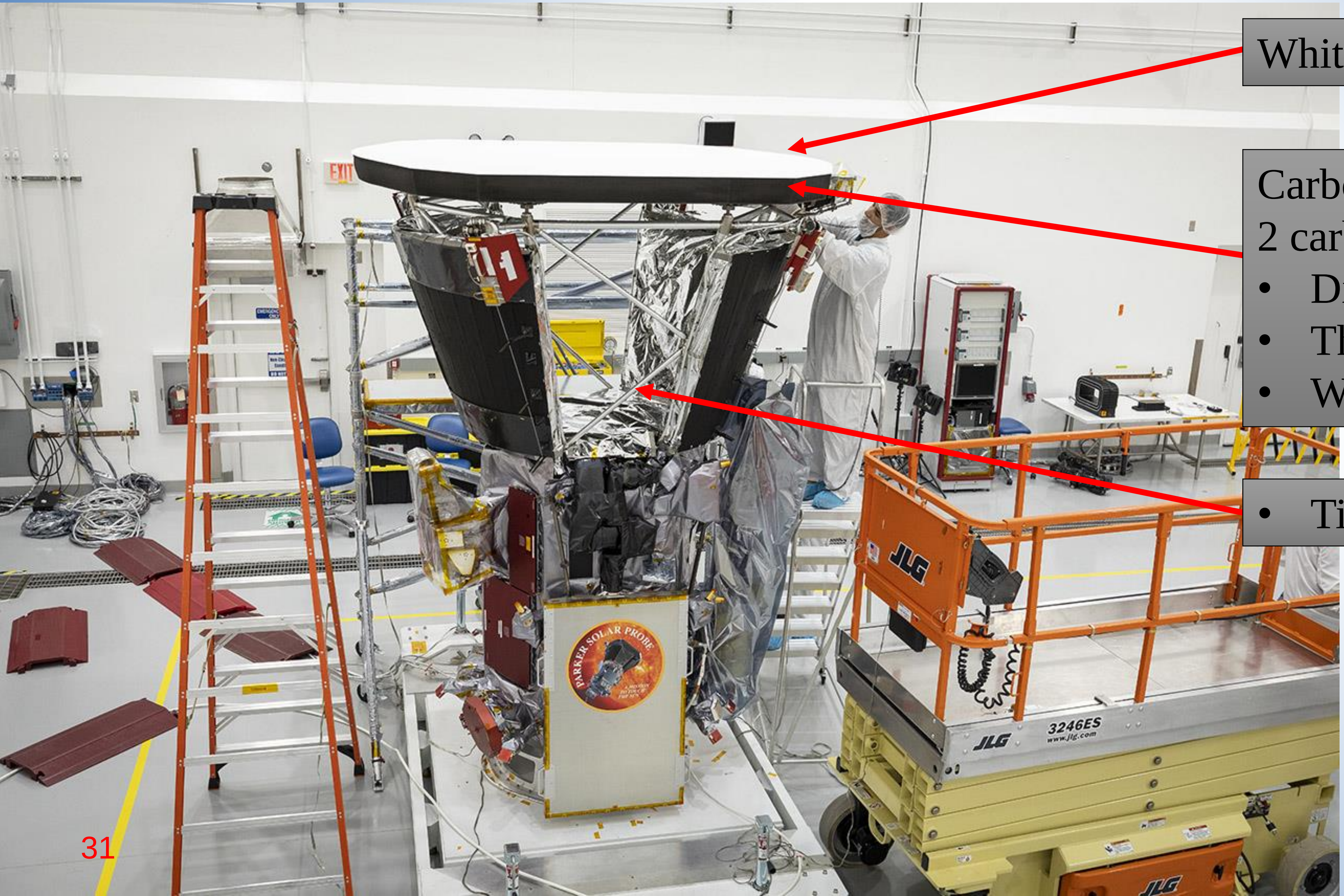
**Why won’t spacecraft melt?**

***High temperatures do not always translate to actually heating another object***

| Temperature | Heat |
|---|---|
| Measures how fast particles are moving | Measures the total amount of energy that particles transfer |

- Corona through which spacecraft travels is very low density
- Spacecraft will travel in around million degrees but spacecraft surface facing Sun will get heated to 1400˚ C only

# Thermal Protection System (TPS)

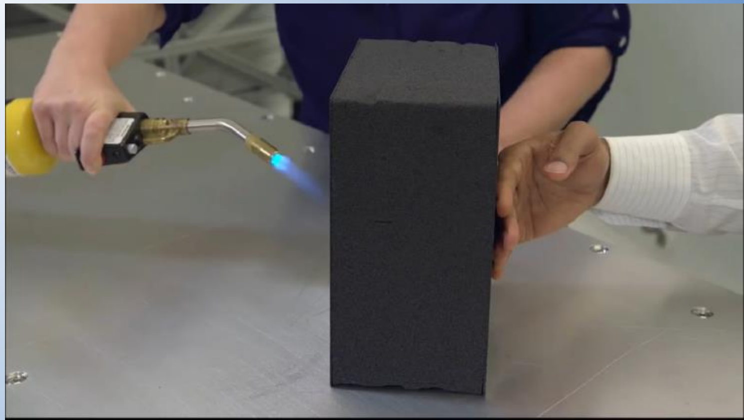



White Ceramic Pain

Carbon foam sandwiched between 2 carbon composite planes

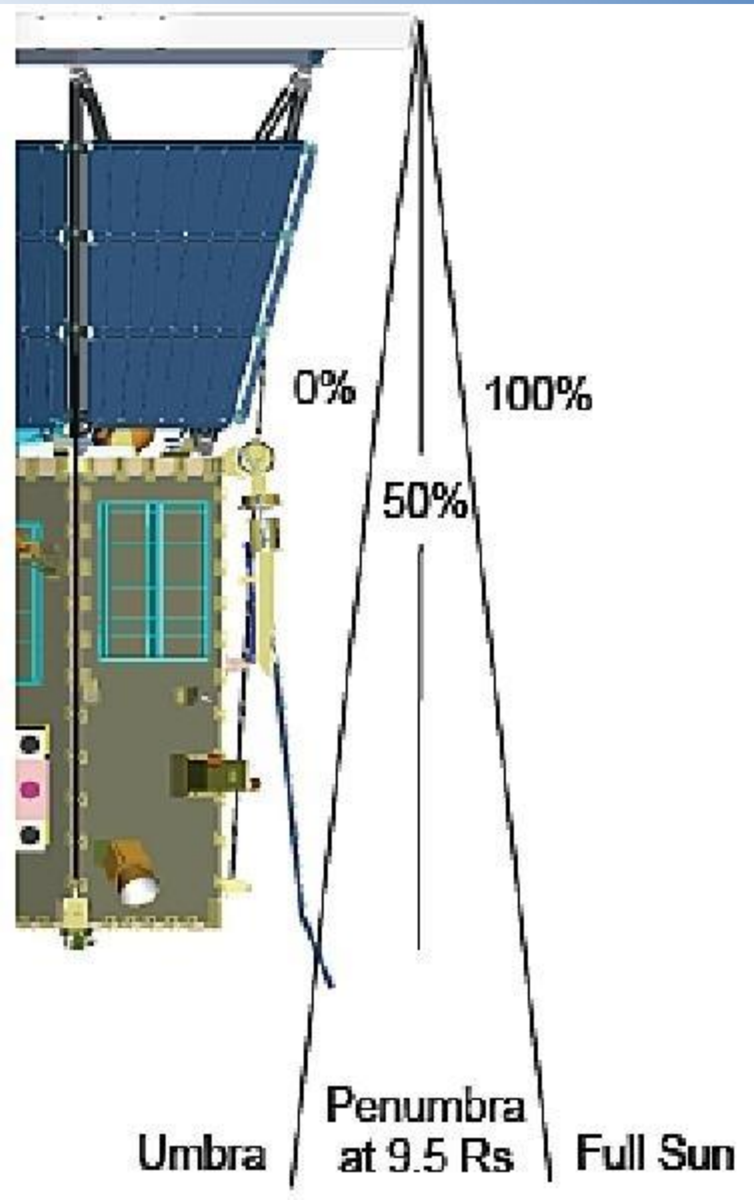
- Diameter: 2.3 m
- Thickness: 11.5 cm
- Weight: 72.5 kg

- Titanium Truss



# Protecting Solar Arrays

- At close approach to the Sun, solar arrays retract behind the heat shield exposing only small area to the Sun
- Radiators
- Coolants: 3.7 L deionized water
- Water pressurized to keep boiling point of water over 125˚ C
- Water warms up behind solar array and cools down at the radiator



# Image of Earth Captured by Spacecraft