Solar Probe Plus Mission Design Overview and Mission Profile

Yanping Guo(1)**, James McAdams**(2)**, Martin Ozimek**(2)**, and Wen-Jong Shyong**(2)
(1)*Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd. Laurel, Maryland, 20723, (240) 228-7541, Yanping.Guo@jhuapl.edu*
(2) *Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd. Laurel, Maryland, 20723*
Jim.McAdams@jhuapl.edu, *Martin.Ozimek@jhuapl.edu*, *Wen-Jong.Shyong@jhuapl.edu*

Keywords: *Solar Probe Plus, Solar Mission, Mission Design, Trajectory Design, Venus Gravity Assist*

ABSTRACT

Although more than a half century has passed since the first manmade satellite launched into space, the sun, along with its near region, still remains unexplored due to technical challenges for a spacecraft to come close to the sun and to survive in the harsh environments there. The closest a spacecraft has ever reached to the sun is in the region of 0.29 AU (62.4 solar radii) by the Helios 2 spacecraft in 1976. In order to more fully understand the nature of the sun and its effects on Earth and on the solar system, data must be collected by a spacecraft inside the region of 10 solar radii (R_S) according to the science community.

Solar Probe Plus (SPP) will be the first mission to encounter the sun and to go deep into the near sun region as close as less than 10 solar radii (R_S) from the sun's center. Four science instruments, SWEAP (solar wind electrons, protons and alpha particles) by Smithsonian Astrophysical Observatory, FIELDS (electric and magnetic fields and waves) by UC Berkeley, WISPR (wide-field visible light imager) by Naval Research Laboratory, and ISIS (energetic particles) by Southwest Research Institute, will be carried onboard the spacecraft to determine the mechanisms that produce fast and slow solar winds, solar coronal heating, and the transport of energetic particles. The SPP mission, designed and managed by the Johns Hopkins University Applied Physics Laboratory (APL) for NASA, is scheduled to launch in 2018. The mission development is well underway and is in Phase B for the preliminary design.

In the current mission design, Solar Probe Plus is scheduled to launch in July or August 2018, over a 20-day period from July 31 through August 19, 2018. The required launch energy (C3) of 154 km^2/s^2 will be supplied by a launch system consisting of an Atlas V 551 launch vehicle and an upper stage under development. The mission trajectory enabling the spacecraft to come within 10 R_S of the sun is a Venus-Venus-Venus-Venus-Venus-Venus-Venus-Gravity-Assist (V^7GA) trajectory, a unique trajectory developed to enable the solar probe mission without a Jupiter gravity assist. An example of the trajectory is shown in Figure 1. After 7 Venus gravity assists, the final solar orbit will have a perihelion distance of 9.86 R_S and an aphelion distance of 0.73 AU, and will be oriented at 3.4° from the ecliptic plane. The time of flight from launch to reach the minimum solar distance will be 6.4 years. The mission design includes three solar passes at the 9.86 R_S and has a total mission duration of 7 years.

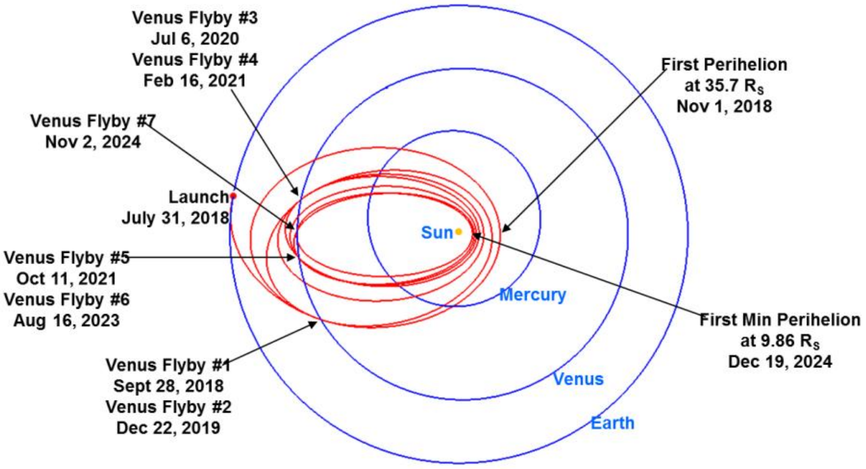

Figure 1. Solar Probe Plus Mission Trajectory

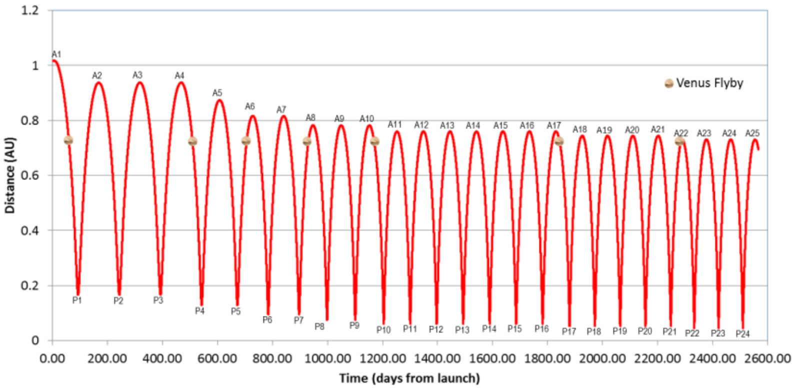

Figure 2. Solar Distance Profile

The solar distance profile (Figure 2) of the mission trajectory shows the distance variation of the spacecraft from the sun over the entire mission. Both aphelion and perihelion distances will be gradually decreased in 7 steps, corresponding to the 7 Venus flybys. The maximum distance from the sun is less than 1.1 AU, which allows for a solar powered spacecraft. The perihelia decrease from 36 R_S to 9.86 R_S. There are 24 solar orbits and multiple solar passes at each of the different perihelia, providing more opportunities for in situ measurements of the science investigations. Total time spent in the near sun regions is critical to the science investigations. For example, the time at less than 20 R_S will be more than 930 hours over the last 17 solar passes. The solar passes will be separated by 3 to 4 months, with 3 to 4 solar passes per year.

Solar conjunction will occur often for this mission due to the nature of this inner solar system trajectory. During the solar conjunction periods, communication with the spacecraft will be significantly degraded or totally unavailable. When the Sun-Earth-Probe (SEP) angle is less than 3°, the X-band communication is assumed to not be available. The Ka-band communication is assumed to be unavailable when the SEP angle is less than 1°. Besides the solar conjunction, the obstruction of the spacecraft's thermal protection system (TPS) on the antennas will also prevent communication with the spacecraft. Communication gaps due to both solar conjunction and TPS obstruction will be identified for each mission orbit. The communication gap information has already been used in navigation tracking simulations and in trajectory maneuver planning.