Solar Orbiter Trajectory Profile and Navigation Challenges

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Keyword : Solar Orbiter, Trajectory Design, Navigation

The Solar Orbiter is an ESA mission in collaboration with NASA that will explore the processes that create and control the heliosphere. In order to understand how the inner solar system works and is driven by the solar activity, it is essential to make in-situ measurements of the solar wind plasma, fields, waves, and energetic particles close enough to the Sun and at large latitudes, and to relate such measurements with the processes on the Sun originating them via simultaneous high-resolution imaging and spectroscopic observations.

The reference trajectory of Solar Orbiter is entirely ballistic and will make use of Earth and Venus gravity-assist flybys repeatedly to change the heliocentric orbit. After launch on a NASA-provided Atlas V and a multi-year cruise phase, Solar Orbiter will reach a Sun range below 0.35 AU and will start the remote sensing observations. A series of gravity-assist flybys in resonance with Venus will gradually increase the orbit inclination with respect to the Sun equator, while maintaining a perihelion as close as 0.28 AU (60 solar radii) from the Sun. By the end of the 10-year mission duration Solar Orbiter will have reached a solar inclination over 33 degrees.

Daily communication is essential to download the huge amounts of science data produced by the instruments on board Solar Orbiter. Maximising the science data return is considered key to the mission and has been one of the goals of the trajectory design. Science data downlink is favoured by phasing the heliocentric orbits such that the aphelion is frequently close to inferior solar conjunction and therefore Solar Orbiter is close enough to the Earth such as to maintain the maximum downlink bit rate for long periods.

The navigation of Solar Orbiter will be based on the use of radiometric measurements from the ESA Deep Space antennas including very precise DDOR measurements from the Cebreros-Malargüe and Cebreros-New Norcia baselines to guarantee an accurate delivery accuracy at the Venus gravity-assist flybys at a nominal minimum altitude of 350 km. 4 trajectory correction manoeuvres (TCM) are planned per gravity-assist to correct errors and perturbations and perform a fine B-plane targeting, plus 1 post-flyby clean-up TCM. Overall more than 45 TCMs are planned for the entire mission.

Being a mission to the inner solar system, Solar Orbiter will be affected by frequent solar conjunctions that will severely disrupt the communications. This will impact the quality of the tracking measurements and the capability of the control centre to perform an accurate orbit determination. Furthermore, the environment and some aspects of the mission design present challenges for the navigation of Solar Orbiter. The modelling of the dynamics will have several contributors that are typically ignored in many other interplanetary missions. In particular non-gravitational force models used by ESOC Flight Dynamics will have to be updated to account among others for the increased perturbations from the solar radiation pressure at close solar ranges and with variable incidence angle of the solar panels, the effect of thermal re-emission by the Sun-shield and the solar panels, and the frequent momentum desaturation manoeuvres that will take place autonomously on-board and foreseeably on an unbalanced thrusters configuration.