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Interstellar Probe: A Mission to Explore the Heliospheric Boundary and Interstellar Medium

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During its evolution, the Sun and its protective magnetic bubble – the heliosphere - has completed nearly twenty revolutions around the Galactic Core. During this “Solar Journey” it has plowed through widely different interstellar environments that have all shaped the system we live in today. The orders-of-magnitude differences in interstellar properties have had dramatic consequences for the penetration of interstellar material and have affected elemental and isotopic abundances, atmospheric evolution and perhaps even conditions for habitability. As far as we know, only some 60, 000 years ago, the Sun entered what we call the Local Interstellar Cloud (LIC), and in less than 1,900 years the Sun will be entering a very different interstellar environment that will continue to shape its evolution and fate.

The Interstellar Probe is a pragmatic mission with a possible launch already in the next decade that would explore the heliospheric boundary and how it interacts with the Very Local Interstellar Medium (VLISM) to understand the current state along this Solar Journey and, ultimately understand where our home came from, and where we are going. During its 50-year nominal design life, it would go far beyond where the Voyager missions have gone, out to about 400 astronomical units (au) and likely survive out to 1000 au. Therefore, the Interstellar Probe mission would represent humanity’s first explicit step in to the galaxy and become NASA's boldest step in space exploration.

When the Voyager missions traversed the heliospheric boundary with their very limited payload it became clear that we are faced with a whole new regime of space physics that is not only decisive for our own heliosphere, but also for understanding the physics of other astrospheres as well. Today we still do not understand the force that is upholding the magnetic shell (the heliosheath) around our heliosphere, or the mechanisms that shield the solar system from galactic cosmic rays, and many other mysteries. Once beyond where the furthest Voyager spacecraft will cease operations (likely at ~170 au), Interstellar Probe would step in to the unknown, traverse the hydrogen wall and the complex magnetic topology at the very edge of the Sun’s sphere of influence, and then directly sample for the first time the interstellar material that has made all of us. There, measurements of the unperturbed gas, plasma, and fields would allow accurate determination of the current state of the LIC and how it affects the global heliosphere. Measurements of unshielded interstellar dust and galactic cosmic rays would provide unprecedented information on stellar and galactic evolution. The physical processes that occur as the solar wind and magnetic field interact with VLISM would also provide the only directly measurable prototypes for understanding the astrospheres surrounding other stars that control the atmospheres and habitability of their exoplanets. All this newly acquired knowledge would then enable an understanding of the current state of the heliosphere and the VLISM, and how they interact, which ultimately can be used to extrapolate the understanding of our system back to the past and into the future.

At the same time, the outward trajectory is a natural opportunity for exploring one of the ~4,000 Kuiper Belt Objects or ~130 dwarf planets similar to and beyond Pluto and determine the large-scale structure of the circum-solar dust disk to provide the ground truth for planetary system formation in general. Once beyond the obscuring dust, the infrared sky would open a window to early galaxy formation.

An Interstellar Probe has been discussed and studied since 1960, but the stumbling block has always been propulsion. Now this hurdle has been overcome by the availability of new and larger launch vehicles. An international team of scientists and experts are now in the final year of a NASA-funded study led by The Johns Hopkins University Applied Physics Laboratory (APL) to develop pragmatic example mission concepts for Interstellar Probe with a nominal design lifetime of 50 years. Together with the Space Launch System (SLS) Program Office at NASA's Marshall Space Flight Center, the team has analyzed dozens of launch configurations and demonstrated that asymptotic speeds in excess of 7.5 au per year can be achieved using existing or near-term propulsion stages with a powered or passive Jupiter Gravity Assist (JGA). These speeds are more than twice that of the fastest escaping man-made spacecraft to date, which is Voyager 1 currently at 3.59 au/year. Launching near the nose direction of the heliosphere, Interstellar Probe would therefore reach the Termination Shock (TS) in less than 12 years and cross the Heliopause into the VLISM after about 16 years from launch.

In this presentation we provide an overview and update of the study, the science mission concept, the compelling discoveries that await, and the associated example science payload, measurements and operations ensuring a historic data return that would push the boundaries of space exploration by going where no one has gone before.

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