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Interstellar Probe: Highway to the stars

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Abstract

The quest for reaching the interstellar medium beyond the solar system is almost as old as the Space Age itself. While spacecraft have pushed further and further from the Sun and our knowledge both of our own stellar system and others has increased exponentially in the intervening years, the ultimate scientific imperative for a fast, properly instrumented, scientific spacecraft has remained intact. The primary issues have been "How far? How fast? How to implement?" As technical input to the next "decadal survey" for heliophysics NASA has tasked the Johns Hopkins Applied Physics Laboratory (JHU/APL) to provide a detailed look at various implementation scenarios and possibilities for such a mission, which could be launched during the time period of the next decadal survey for NASA's Heliophysics Division, nominally the years 2023 – 2032. This work is and remains one of many pre-decisional tools for providing potential implementation options for an Interstellar Probe, which NASA and/or the to-be-assembled decadal survey panel may elect to draw upon directly or indirectly at their discretion with no endorsement herein implied.

1. Introduction

The scientific goal of probing the outer heliosphere and nearby interstellar medium beyond is almost as old as NASA itself, cf. the "Outer Solar System Probe" of Committee 8 - Physics of Fields and Particles in Space of the Space Science Board of the National Academy of Sciences (the "Simpson Committee" [1]). With the evolution of NASA's science program and our knowledge of the heliosphere driven by the Pioneer 10 and 11 and Voyager 1 and 2 missions to date, the call for a dedicated probe to the near interstellar medium has evolved but nonetheless persisted as a scientific priority [2-6].

1.1 Background

There are three threads of work running though previous Interstellar Probe studies:

1) The notional goal of a mission to escape rapidly from the solar system
2) The engineering means
3) Mission studies, including both measurements and instrumentation

With respect to point 1), the earliest analysis was the *gedanken* experiment of Oberth who noted that the most rapid escape would be enabled by (1) using a propulsive maneuver at a great distance from the Sun to cancel the orbital angular momentum and thus enable it to fall into the near vicinity of the Sun, followed by (2) a larger propulsive maneuver at perihelion. In 1929, he showed that such a set of maneuvers would provide the most rapid escape for a given propulsive capability [7].

At the time of the 1960 "Simpson Committee" report, there were no technical details discussed (other than a somewhat protracted discussion of a need for very sensitive magnetometers but with no numbers mentioned). Gradually, more studies pulled in other engineering concepts including a variety of in-space, low-thrust approaches. From 1960 to the present almost 20 approaches have been studied [8] with flyout distances of 100 to 1000 AU with nominal asymptotic heliospheric speeds of ~5 AU/yr to ~125 AU/yr. The question has always been how to achieve such speeds for a scientifically compelling probe.

To enable such a mission in the near term, recent work has concentrated on using ballistic approaches, combining large launch vehicles with multiple upper stages and/or deep space maneuvers [8-10].

2. Ongoing Work

Potential science questions for such a mission include both *in situ* and remote sensing of heliospheric structures, potential planetary targets in the Kuiper Belt, accessing astrophysical objects obscured within our heliosphere by zodiacal dust, and studying our own inner solar system from afar to compare and contrast with the growing population of exoplanets [11].

Work required to support potential implementation of such a mission includes a refinement of science targets and how those can be enabled by measurement approaches and techniques, more detailed studies of near-term science instruments implied by these, communications requirements, and detailed implementation architectures to enable a mission requirement of up to 50 years of spacecraft and mission lifetime.

3. Summary and Conclusions

The ranking and study of particular mission concepts and approaches for implementation is the proper function of the various decadal surveys chartered by NASA's Science Mission Directorate for its various discipline divisions. To serve that process, robust studies of various mission options and implementations have their role as part of the input to those studies. With the multi-decadal debates and discussion about an "Interstellar Probe," pre-decisional, technical work can help such studies with assessing the extent of readiness of these various implementations for the time period to be covered by the upcoming decadal surveys.

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