The Andromeda Study: Some Design Solutions for Project Starshot

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Abstract

This paper discusses some aspects of Project Starshot that were considered during a design study conducted by the Initiative for Interstellar studies in early 2016. Key aspects include the design for an in-space laser beaming infrastructure, power generation for the probe, and a trade-off between optical and radio-frequency communication. The baseline objectives were to design a fly-by mission to Alpha Centauri with a total mission duration of 25 to 50 years travelling at a cruise speed between 0.1c and 0.2c. We propose a space-based beaming infrastructure based on a segmented lens system as suggested by Landis [1]. Our proposed design for a 0.1c cruise velocity and a 23 gram probe comprises ten graphene based lenses of around 200 m in diameter spaced equidistant from Earth out to a distance of roughly 2 AU. The total mass of the lens system is around 10 tons (about one ton per lens). The laser beam power is 112 MW. A 5 grams probe could be accelerated to 0.2c by this infrastructure. In consideration of the power supply for the probe we have identified several options that are either relying on power sources external or internal to the spacecraft: radio-isotope generator (Americium-241-based), alphavoltaics [2], betavoltaics [2], nuclear D-cell battery [3], radioisotope thermophotovoltaics [4], ultrathin and lightweight organic solar cell (power generation close to star), and microbal fuel cells, power beaming, electromagnetic tether [5], residual stellar luminosity, fluctuations in the galactic magnetic field, capture galactic cosmic rays, protons, and electrons. Based on rough calculations, we conclude that either a nuclear power option, power beaming, or an electromagnetic tether are likely feasible. One of the key technologies on which feasibility of Project Starshot depends is to send back reasonable amounts of data from the target star system. We compare optical and radiofrequency communication options. For achieving a 4kbit/s data rate between the probe and Earth (500m diameter receiver), 1W power and a 100m transmitter antenna would be required. A similar data rate could be achieved with a 1W, 0.1m diameter laser link, which is the option of choice. Pointing requirements will be very challenging but could be alleviated by a constellation of space-based receiver antennas that are distributed within the Solar System. An operationally more difficult option is the use of a gravitational lens. Based on the exploring options for key technologies for a laser-powered gram-sized interstellar probe, we conclude that there is at least one technology option for each of the considered areas that could make such a mission feasible in the next decades. This paper is submitted for the day 2 session Sails and Beams.

References:

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