BRIDGE TO THE STARS: A MISSION CONCEPT TO AN INTERSTELLAR OBJECT

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Introduction: The study of exoplanets has revealed an astounding diversity of planetary systems. Studying these systems is essential to improving our understanding of planetary formation processes, as well as extent life in the universe. Unfortunately, humanity can only observe limited aspects of exoplanetary systems by telescope, and the significant distances between stars means it would take millennia to reach them for in-situ study. But what if we could study exoplanet material up-close without having to travel light years? Interstellar objects (ISOs) allow for close-up observation of the building blocks or fragments of exoplanetary systems [1], and two ISOs have now been discovered: volatile poor 1I/'Oumuamua [2] and volatile rich 2I/Borisov [3]. We propose a mission concept (Bridge) to flyby a yet-to-be discovered ISO as it passes through our own solar system. Designed as a New Frontiers-class mission during the National Aeronautics and Space Administration's (NASA) 31st Planetary Science Summer Seminar [4], Bridge would provide a unique opportunity to gain insight into physical, chemical, and biological differences between our solar systems and others as well as the exchange of planetary materials between them, which addresses the Building New Worlds and Planetary Habitats themes in the Planetary Science Decadal Survey [5].

Science goals & objectives: Bridge has two science goals: (1) determine whether prebiotic chemical ingredients can be transported between stellar systems and the interstellar medium, and (2) determine if interstellar objects form via the same processes as objects within our solar system. To address the first goal, Bridge would determine whether the ISO contains prebiotic ingredients by looking for spectral signatures from CH, N_2, polycyclic aromatic hydrocarbons, and tholins. To address the second goal, Bridge would determine whether the ISO formed in an environment chemically similar to our own solar system by comparing its elemental abundances, isotope ratios, and relative abundances of noble gases to those of other solar system objects and presolar grains (e.g. [6]). Bridge would also look for the presence of ices, the molar abundances of minerals, and the morphological properties of the ISO to 10 m resolution in order to determine if the ISO is similar to any objects in our own solar system.

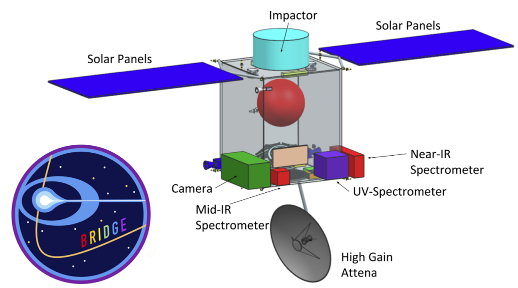

Figure 1: *Bridge spacecraft conceptual design including all instruments.*

Instrument	Heritage	Mass	Power	Spec range
Vis Camera	LORRI	25 kg	15 W	.35- .85 μm
NIR pt. spec	OVIRS	17.7 kg	10 W	1-4 μm
Mid-IR pt. spec	OTES	23 kg	15 W	5-15 μm
UV/Vis pt. spec	IUVS	25 kg	10 W	.2- .6 μm
Impactor	Dp.Imp.	250 kg	Battery	NA

Table 1: *Bridge baseline science payload.*

Science payload: Bridge's instrument payload can address the aforementioned science goals and objectives regardless of the specific properties of the target ISO. Bridge utilizes a remote sensing suite consisting of a mid-infrared spectrometer, a near infrared spectrometer, an ultraviolet/visible spectrometer, and a visible light camera. Bridge also employs a battery-powered guided impactor, based on the impactor from Deep Impact [7], to expose the ISO's interior material. Table 1 lists the instruments and their properties. The high relative encounter velocities of our mission preclude direct in-situ sampling. All instruments in our selected payload are based on previously flown instruments.

Mission design: Bridge is designed to flyby a yet-to-be discovered ISO. Multiple telescopic survey facilities exist that scout the sky for Near-Earth Objects, comets, and possible ISOs. It is estimated that ≈ 0.2 ISO detections should occur per year, and when future survey telescopes such as the Large Synoptic Survey Telescope become operational, the number of ISO detections should improve to ≈ 1 per year [8]. Bridge is designed to wait in storage on Earth until a suitable ISO is detected.

Bridge requires three criteria to be satisfied for a successful ISO flyby: (1) the ISO must pass through the ecliptic plane at a distance between 0.7 and 2.0 AU from the Sun (green region in Figure 2), (2) the relative encounter velocity must be less than 70 km/s, and (3) the total launch C_3 is less than 60 km^2/s^2 for the intercept maneuver, which is achievable given the mass of Bridge and an Atlas V 431 launch vehicle. With these criteria, Bridge could encounter 65% of ISOs whose orbital characteristics are predicted by [1]. Figure 2 illustrates a hypothetical encounter with 1I/'Oumuamua that meets all the aforementioned criteria.

In a 70 km/s flyby scenario, the impactor would be released approximately eight hours before the main spacecraft achieved its closest approach. Fifteen minutes later the main spacecraft would perform a deflection maneuver, steering it to a safe closest approach distance of 8000 km. Thirty seconds prior to impact, the IR spectrometer and visible camera would observe the surface composition. The visible camera would capture a video at the time of the impact, at which point the UV spectrometer would image the ejecta plume flash. Following the impact, the spectrometers would continue to take measurements of the plume. All critical science data would be transmitted before the spacecraft's closest approach to the ISO ninety seconds after impact. The complete encounter timeline is shown in Figure 3.

To enable the Bridge concept, several technological advancements and policy changes must occur. This includes: improved ground detection capabilities of small bodies, infrastructure to store a spacecraft in a launch-ready state, rapid launch response, and the opportunity to propose a mission that requires these capabilities. Improved detection (e.g. LSST [9]) and rapid launch ca-

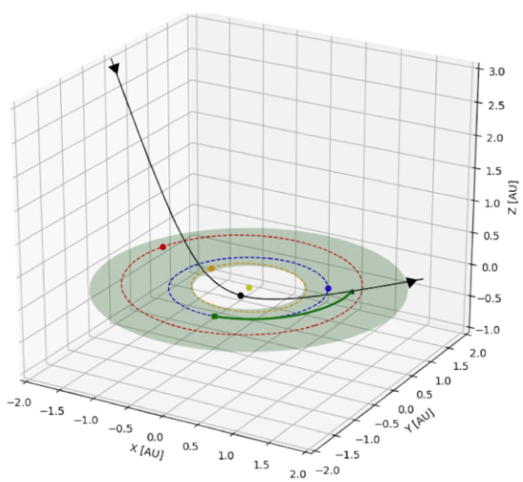

Figure 2: *Example mission trajectory to 1I/'Oumuamua had Bridge been launched on 6/27/2017 and intercepted on 10/22/2017. The solid black line is 1I/'Oumuamua, and the solid green line is the Bridge spacecraft. Total flight time would have been 116.85 days, and resulted in a relative intercept velocity of 55.97 km/s.*

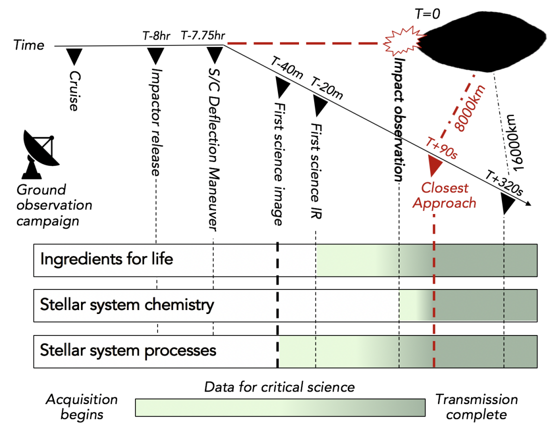

Figure 3: *Timeline of Bridge ISO encounter.*

pabilities will likely exist in the near future; however, to make missions like Bridge a reality, the planetary science community must advocate for language explicitly permitting mission architectures that include storage and rapid launch in future NASA New Frontiers, Discovery, and SIMPLEx Announcements of Opportunity.

Conclusion: Exploring material from an exoplanetary system is an excellent scientific opportunity. The most feasible way to accomplish this is to intercept an interstellar object as it passes through our solar system. Such a mission would address numerous high-priority science goals and questions in planetary science and astrophysics, from the formation of solar systems to the development of life. Bridge demonstrates a mission concept point design that is feasible under the NASA New Frontiers cost cap; however, the unique and ephemeral nature of ISOs will require specific changes to future NASA Announcements of Opportunity to enable long-term spacecraft storage and rapid launch response. As the next Decadal Survey in Planetary Sciences approaches, the collective advocacy of the scientific community will be required to make this mission a reality.

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