National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Starshade Scenario Options Analysis for Large IR /O/UV Observatory

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Co-Investigators: Dmitry Savransky (Cornell University)

Objectives: Create new capabilities in the simulation of starshade-based exoplanet imaging missions by expanding the starshade-specific modeling capabilities of EXOSIMS, an open-source codebase for exoplanet mission simulation.

- model starshade refueling
- model multiple starshades operating with one telescope
- model starshades that change separation distance (and thereby change their wavelength range)
- simulate starshades optimized for UV (because UV coronagraphs have not been proven to be feasible)
- explore new observation scheduling algorithms capable of taking advantage of these starshade operations concepts

Background: The Astro 2020 decadal survey recommended as a top priority the maturation of a "large (~6 m aperture) infrared/optical/ultraviolet space telescope … to search for biosignatures from a robust number of about ~25 habitable zone [exo]planets." While the recommendation was agnostic as to the nature of the starlight suppression system to be utilized, the survey mentioned only coronagraphs, putting starshades at a perceived disadvantage. As JPL has made significant effort in starshade maturation via the S5 program and strategic RTDs, it is highly desirable to demonstrate the competitiveness of starshades for Habitable Worlds Observatory, which requires updated simulation tools, operations concepts, and challenging assumptions made in previous work that predicted a degradation of starshade science yield beyond the 4-5 m telescope scale.

Significance/Benefits to JPL and NASA: . The extent of JPL's participation in HWO will be seeded in the architecture trades likely to occur in FY24-26. The current suite of EXOSIMS updates are geared for starshades to remain a viable and exciting in the architecture trade space in FY25. The timing of Co-I Savransky's sabbatical provided an ideal opportunity for collaboration with Rus Knight and others at JPL with expertise in mission scheduling optimization. These tool updates and analyses are a critical path to ensuring that JPL's interest in starshades and the JPL-developed segmented primary mirrors enabled by starshades are assessed fairly and accurately when technology roadmaps are developed and technology development investments are made by NASA headquarters through SATs and directed funds. Additionally, these updates also help position EXOSIMS as a mission development tool through Phase A, and the JPL-Cornell collaboration as a leader of mission science performance modeling for the next astrophysics flagship.

Approach and Results:

EXOSIMS' wavelength range was expanded from 400-1000 nm to 200 nm-2500 nm. EXOSIMS's new stellar flux handling system utilizes template spectra.

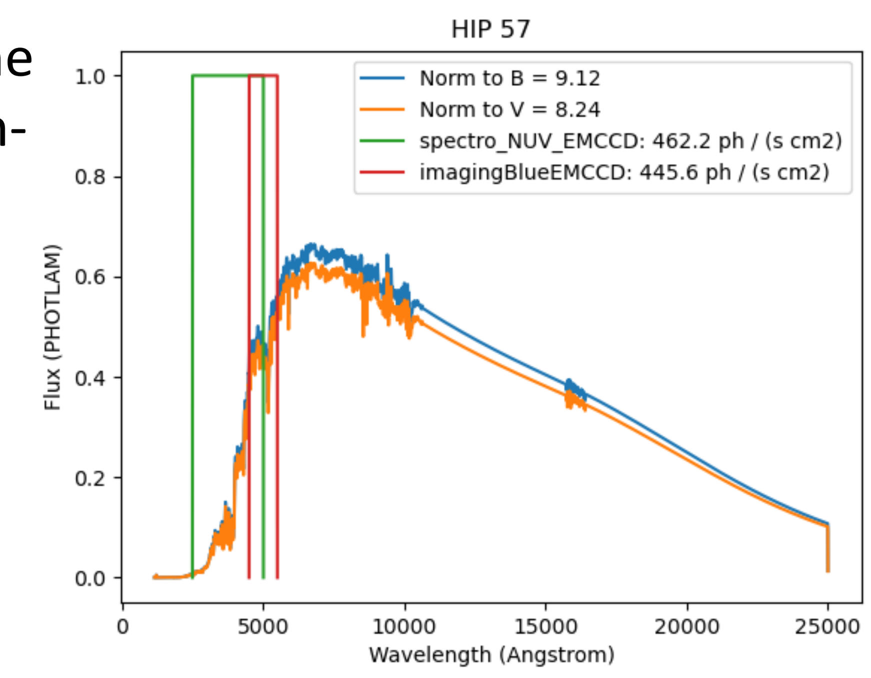

Figure 1. EXOSIMS's new stellar flux handling system for target HIP 57: the two curves represent renormalizations of a template spectrum for the star to cataloged B- and V-band apparent magnitudes, which are used to find the stellar flux in each observing band.

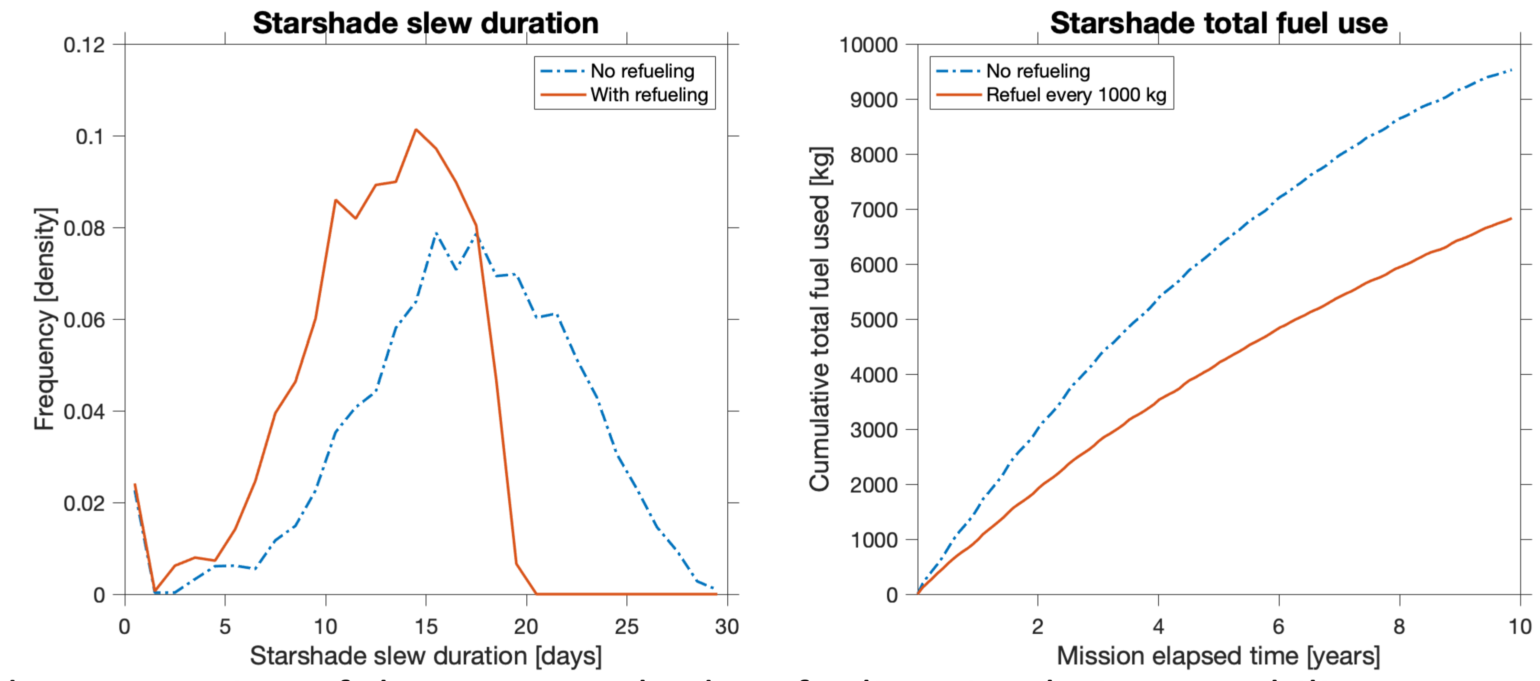

Figure 2. A demonstration of the new starshade refueling simulation capability. In an observing scenario with a very large number of required starshade slews, refueling every 1000 kg shortens the average retargeting slew duration from 16.9 days to 12.6 days (*left*) and reduces the total fuel consumed from 9500 kg to 6800 kg (*right*). From Morgan et al. (2023).

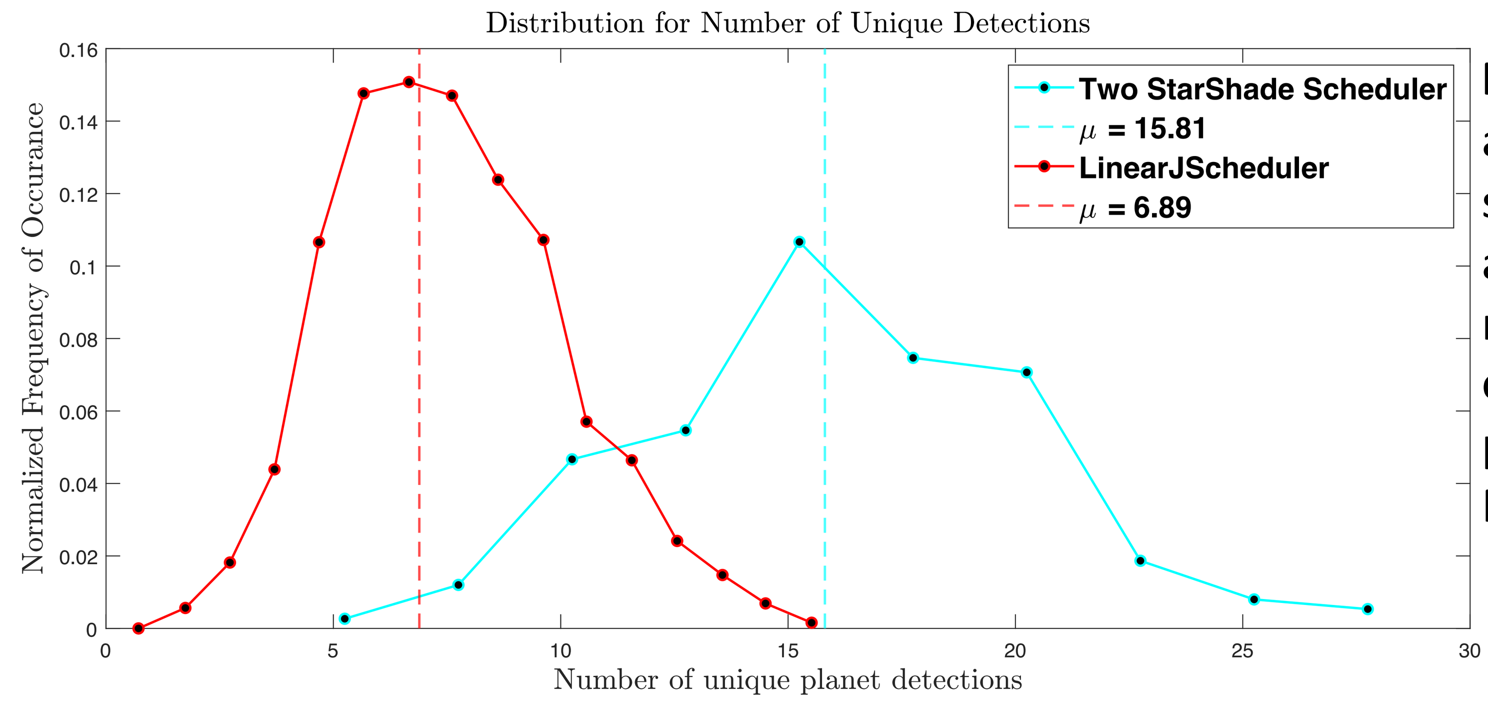

Figure 3. Comparison of a new, two-starshade scheduler result against a prior single starshade result for an equivalent observatory and mission profile (Soto et al. 2019). From Kelkar (2023).

A new observation scheduling methodology, based on graph planning techniques, developed during the co-Is sabbatical visit to JPL, showed that EXOSIM's scheduler came within 5% of the theoretical maximum yield.

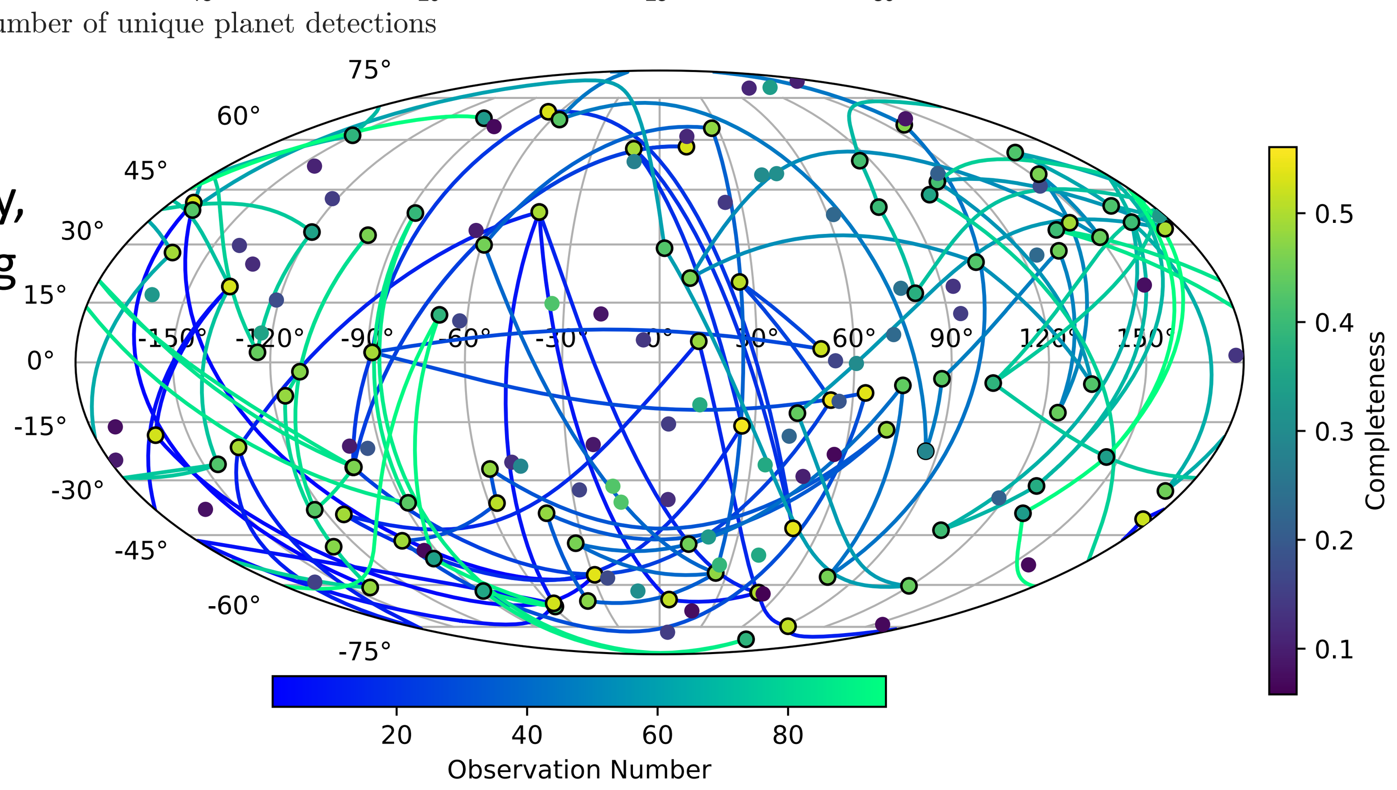

Figure 4. Mission schedule for 1 year of observations with a 6 m unobscured aperture telescope and 3.25 days of overhead time per observation. Points are stars in the target list, with color scale representing their single visit completeness. The path corresponds to the highest summed completeness node in a graph expanded using an iterative pruning depth of k = 2. Segments of the line are shaded with a color scale representing the order of the observation in the path. Points not connected by lines (and without black edges) were not selected for observation. From Savransky et al. (2023).

Publications:

[A] Dmitry Savransky, Russell Knight, Michael Turmon, Corey Spohn, Rhonda Morgan, Mario Damiano, Grace Genszler, and Jackson Kulik, "Quantifying the impacts of schedulability on science yield of exoplanet imaging missions," Proc. SPIE, 2023

[B] Rhonda Morgan, Dmiry Savransky, Mario Damiano, Doug Lisman, Bertrand Mennesson, Eric E. Mamajek, Tyler D. Robinson, and Michael Turmon, "Exo-Earth yield of a 6 m space telescope in the near-infrared," Proc. SPIE 2023.

[C] Sachin Sunil Kelkar, "Observation Scheduling for Exoplanet Imaging Mission With Two Starshades," MS Thesis, Cornell University, 2023.

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