National Aeronautics and Space Administration

FY25 Strategic University Research Partnership (SURP)

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

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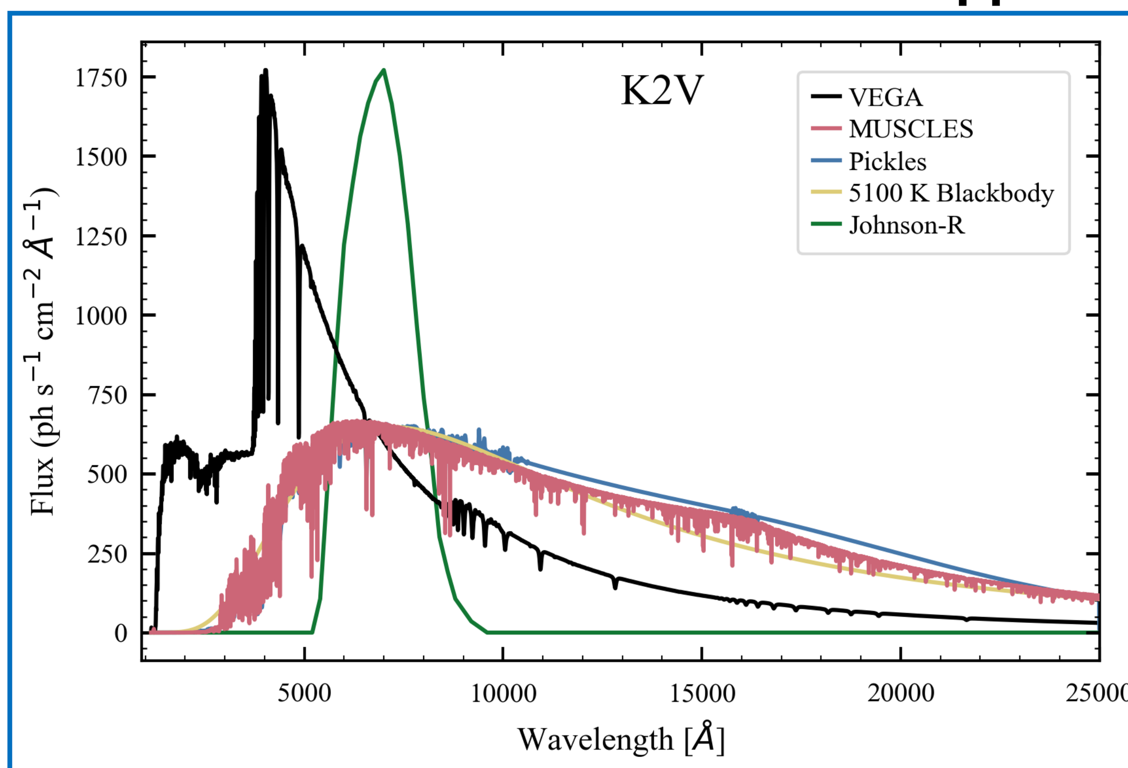
Objectives: Create new capabilities in the simulation of starshade-based exoplanet imaging missions by expanding the starshade-specific modeling capabilities of EXOSIMS, an open-source codebase for exoplanet mission simulation.

- 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 complementary value 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. This can be accomplished with targeted enhancements and extensions to the EXOSIMS software framework—a modular, open-source codebase for exoplanet imaging space mission simulation.

Significance/Benefits to JPL and NASA: The extent of JPL’s participation in HWO will be seeded in the architecture trades occurring in FY25-26. The current suite of EXOSIMS updates are geared for starshades to remain viable and exciting in the architecture trade space in FY26. These updates 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. The collaboration led to a successful ADSPS ROSES proposal which will further support these efforts over the next year. Additionally, these tool updates and analyses are also a critical path to ensuring that JPL’s interest in starshades and the segmented primary mirrors well-matched to starshades are assessed fairly and accurately when technology roadmaps are developed and technology development investments are made through SATs and directed funds.

Approach and Results:



EXOSIMS uses stellar spectral template model libraries to calculate stellar flux from the NUV to NIR. The MUSCLES observational spectra [1] were added to the library, increasing fidelity of NUV spectra.

Figure 1. Example MUSCLES spectrum compared with the Pickles spectrum for the same spectral type as well as an equivalent effective temperature blackbody spectrum, all normalized to the same magnitude in R band.

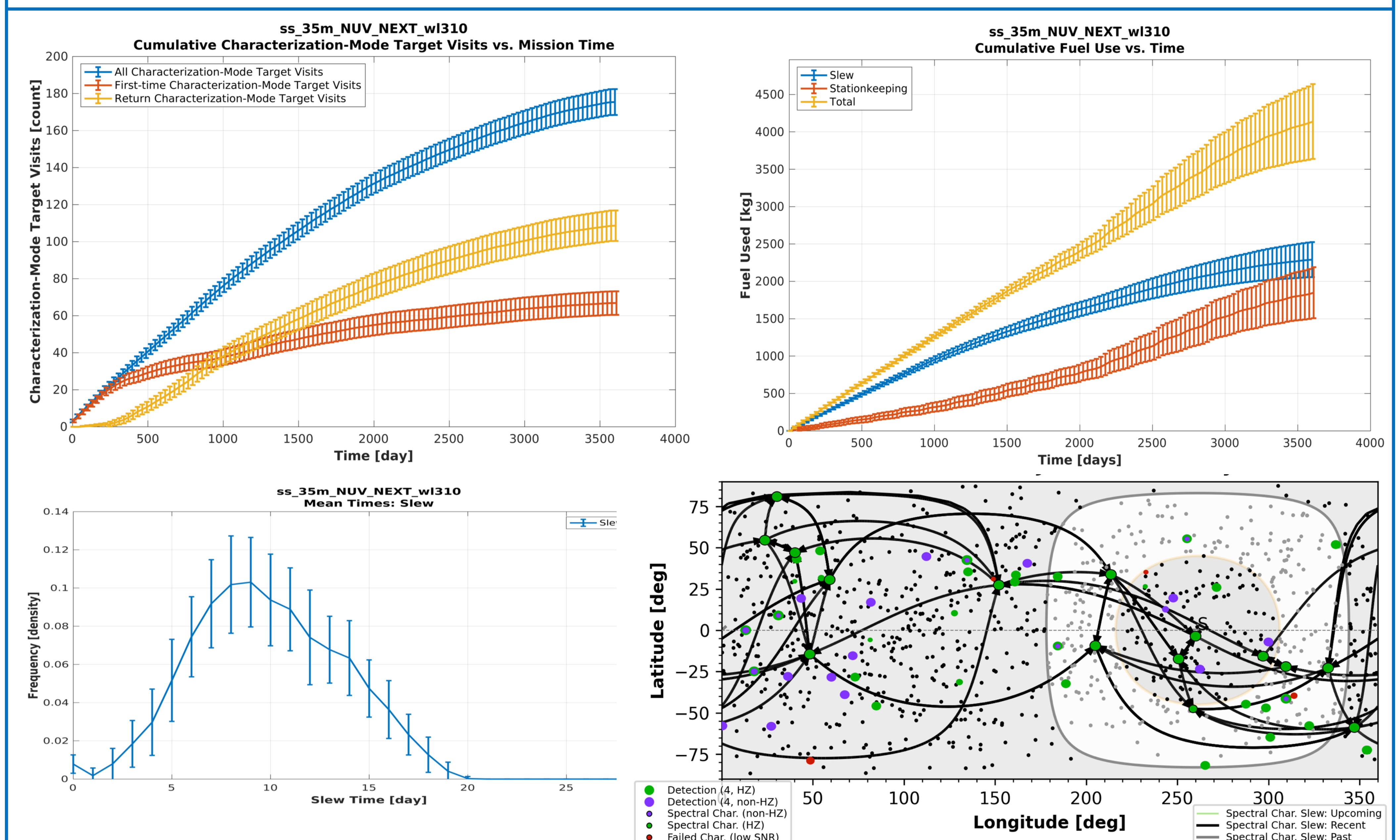
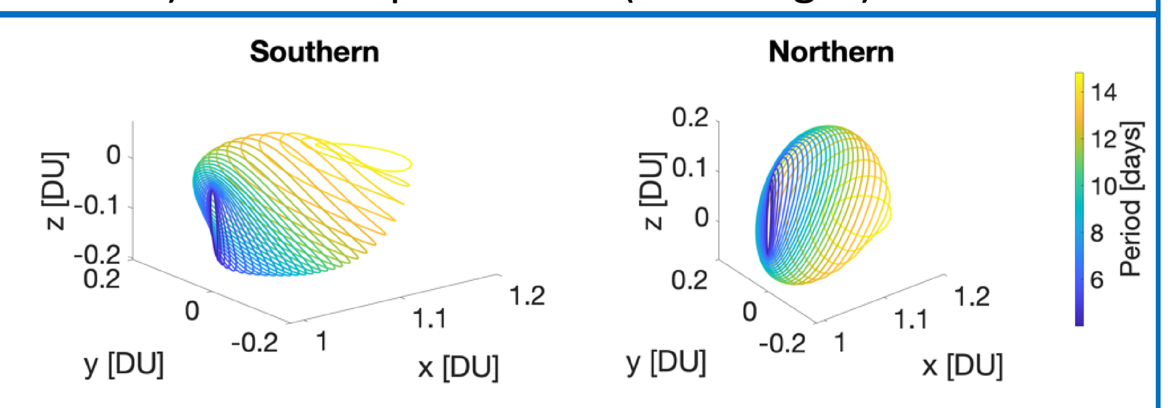


Figure 2. This SURP enabled study of the NUV starshade for HWO. The 35m design [1] can make 180 spectral observations (upper left) without refueling and using 4000 kg of fuel (upper right) with an average slew duration of 9 days (lower left) and multiple revisits (lower right).

Figure 3. Samples of southern and northern halo orbits, generated directly by code being integrated into the EXOSIMS base package [B], to expand EXOSIMS’s ability to generate and use a broader variety of starshade and telescope orbits.



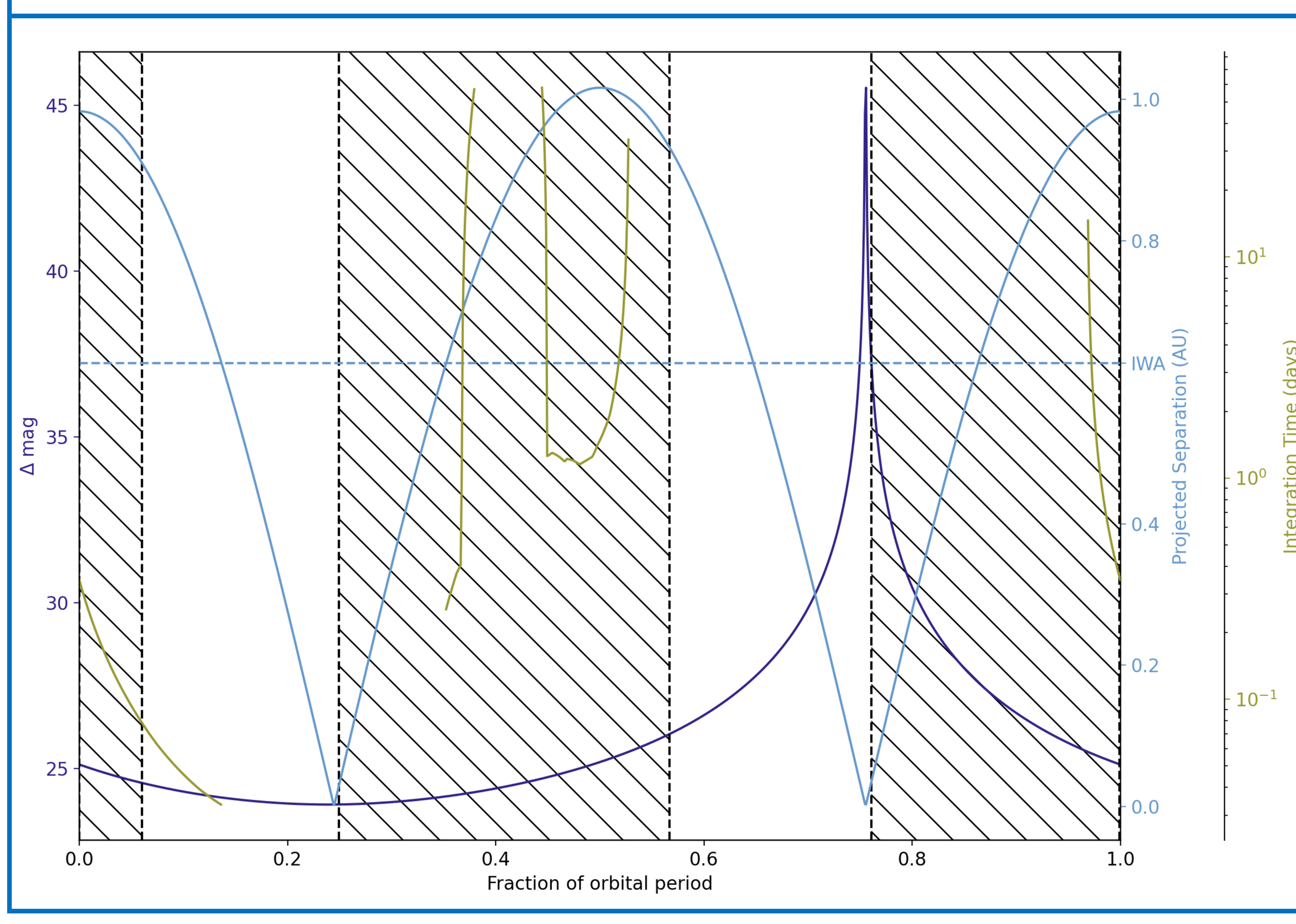


Figure 4. The three curves show the Δ magnitude, projected separation, and integration time to observe an Earth-twin in orbit about HIP 25278 (tier-A star on the ExEP HWO Stars list). Integration time curve (green) discontinuities indicate photometric and/or obscurational non-observability. Taking local zodi variations into account, planet is observable 28% of an orbit. Further accounting for observatory keepout (modeled on Roman’s field of regard), this further decreases to 7.5%.

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References: [1] France, K., et al., "The MUSCLES Treasury Survey. I. Motivation and Overview", 2016, The Astrophysical Journal, 820, 89

Publications:

[A] Savransky, D., Morgan, R., Turmon, M., Tokadjian, A., Damiano, M. (2025) “The effects of scheduling constraints on exoplanet imaging science yield", Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, 13627-42

[B] Genszler, G., Savransky, D., Soto, G. J. (2025) “Surveying orbits in cislunar space for telescope-starshade observatories,” Acta Astronautica, DOI: 10.1016/j.actaastro.2025.08.043

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