



Jet Propulsion Laboratory
California Institute of Technology

Starshade Science and Industry Partnership

Telecon #8

NASA Exoplanet Exploration Program

Renyu Hu

August 20, 2020

Telecon Agenda

- S5 and SIP Updates - **Renyu Hu**
- Stray Light in Starshade Exoplanet Imaging – **Doug Lisman**
- Comments/Discussion by TSWG Chair, Open Floor for Discussion

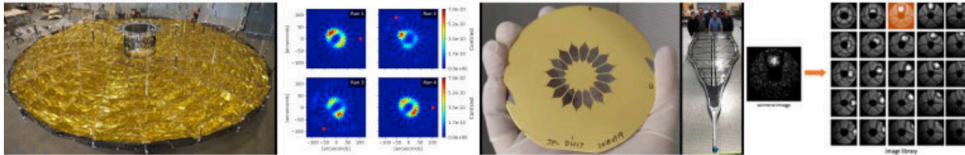
Motivation for Starshade Science and Industry Partnership

The purpose of the Starshade SIP is to maximize the technology readiness level of starshades to enable potential future exoplanet science missions.

- Starshades (or External Occulters) are **one of the starlight suppression technologies** for high contrast imaging of exoplanets and are baselined for large- and probe-class mission concept studies funded by the NASA Astrophysics Division for submission to the Astro2020 Decadal Survey.
- The Astrophysics Division authorized the Exoplanet Exploration Program (ExEP) to **execute a directed technology development activity** to advance starshades to Technology Readiness Level (TRL) 5.
- The Starshade **Technology Development Activity to TRL5, or S5**, follows an approved **Technology Development Plan** with technology milestones that respond to documented mission performance requirements.
- The ExEP recognizes that robust and impactful technology maturation requires **ongoing consideration** of new technology approaches and new mission concept drivers.



Starshade Technology Development



The Exoplanet Exploration Program Charter identifies one of the Program’s critical functions to be to “...manage exoplanet-related technology initiatives, including the management of specifically directed technology activities, facilitation of a coordinated NASA Astrophysics technology identification/prioritization process, oversight of competitively-selected technology activities, and certification of technology milestones and or Technology Readiness Levels (TRLs).”¹

A key method in the pursuit of these goals and objectives is the direct imaging of planets around other stars. Directly sampling the light from an exoplanet separately from that of its host star facilitates measurement of its size, orbit, albedo, and ground and atmospheric spectra, which provide clues to its habitability, and potentially could provide signatures of the presence of life itself. However, direct observation of small, rocky planets like Earth close enough to their host stars to harbor liquid water is very difficult due to the extreme faintness of the exoplanet relative to the very nearby star. The starlight must be suppressed, either interferometrically or by an occulter, to allow exoplanet detection. Occulters that are internal to the telescope are referred to as coronagraphs. Occulters that are external to the telescope are referred to as starshades.

Starshade Technology Development Activity (S5) Documents

- [Starshade Technology Development Plan](#)
- [Level 1 Technology Milestones – Summary Table](#)

Milestone #1

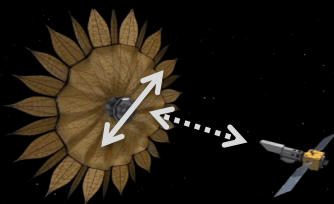
- [1A Report - Narrowband Optical Contrast Performance](#)
- [1B Report - Broadband Optical Contrast Performance](#)
- [ExoTAC Review of #1A, #1B](#)

Milestone #3

- [Report- Demonstration of Solar Glint Lobe Scatter Performance](#) ***NEW**

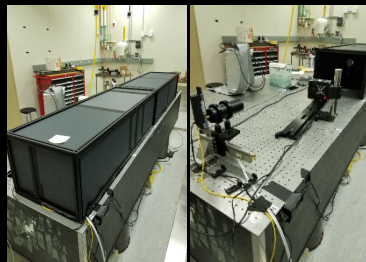
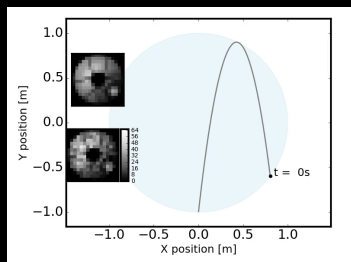
Starshade Technology Development Activity

Formation Flying



+/- 30 cm sensing accuracy
+/- 1 m control

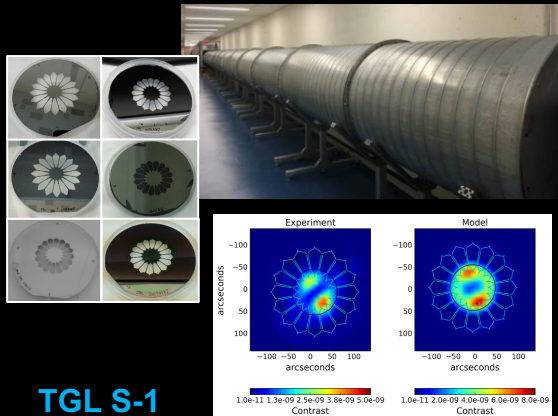
Testbed validated model of sensing accuracy; simulated control performance under flight-like conditions.



TGL S-3

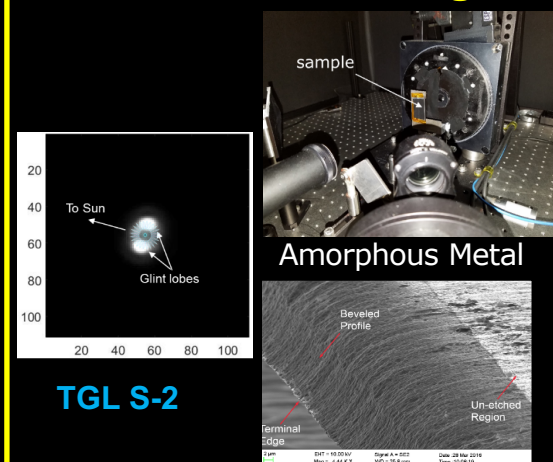
Starlight Suppression

Subscale demonstration of $1e-10$ contrast at both narrow and broadband; optical model validation to 25% accuracy.



TGL S-1

Scattered Sunlight



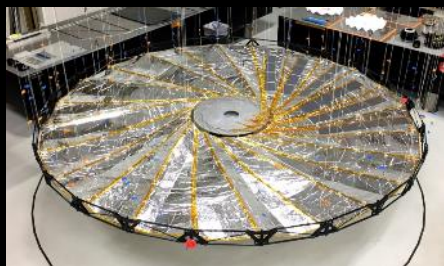
TGL S-2

Scatterometer measurements of half-scale petal edge segments show scattered sunlight less than Vmag 25 in image simulations.

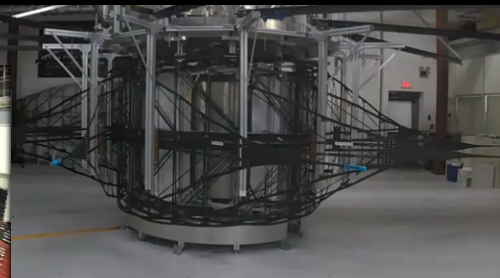
Petal Shape and Position Accuracy Petal Shape and Position Stability

Fabricate petals shape to a pre-launch accuracy of +/- 70um and demonstrate by analysis an on-orbit shape stability of +/- 80um

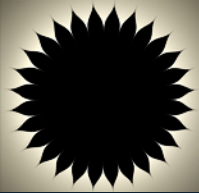
Perform petal deployment to a position accuracy of +/- 300um and demonstrate by analysis an on-orbit position stability to +/- 200 um



TGL S-4 TGL S-5



TGL S-# is the ExEP Technology Gap List reference number



S5 Technology Milestones Scorecard

Complete June 2020



Complete June 2023

Starlight Suppression



Scattered Sunlight



Formation Flying



Critical Features

All Features

Shape Accuracy



Shape Stability



Starshade SIP – Terms of Reference

Starshade Science and Industry Partnership – Terms of Reference 5/30/2019

A. Background

Starshades (or External Occulters) are one of the starlight suppression technologies for high contrast imaging of exoplanets and are baselined for large- and probe-class mission concept studies¹ funded by the NASA Astrophysics Division for submission to the Astro2020 Decadal Survey. Recently the Astrophysics Division authorized the Exoplanet Exploration Program (ExEP) to execute a directed technology development activity to advance starshades to Technology Readiness Level (TRL) 5 to enable potential future exoplanet science missions. The Starshade Technology Development Activity to TRL5, or S5, follows an approved Technology Development Plan² with technology milestones that respond to documented mission performance requirements. The ExEP recognizes that robust and impactful technology maturation requires ongoing consideration of new technology approaches and new mission concept drivers. Therefore the ExEP charters the Starshade Science and Industry Partnership (SIP). The purpose of the Starshade SIP is to maximize the technology readiness level of starshades to enable potential future exoplanet science missions.

B. Expected Outcomes

Expected outcomes of the Starshade SIP are to:

1. Identify solutions to challenges and risks faced by the S5 development activity;
2. Propose new approaches, techniques, and research beyond planned S5 activities that can maximize starshade technology readiness;
3. Document new mission concept drivers for starshade technology performance requirements;
4. Maintain alignment between S5 technology development activities and future mission needs;
5. Facilitate groups of investigators to communicate research, new technology, and new mission concepts across disciplinary, organizational, and geographic boundaries;
6. Enable continued participation of the community in NASA's starshade technology development activities.

C. Participation

The Starshade SIP is open to all participants from NASA, industry, academia, and any organization or individual with research, technology, or science capabilities and

¹ <https://science.nasa.gov/astrophysics/2020-decadal-survey-planning>

² <https://exoplanets.nasa.gov/exep/technology/starshade/>

contributions in starshade-related technology. *Ex officio* participants in the SIP include S5 project staff, ExEP Chief Technologists and Chief Scientists, and the Exoplanet Technical Assessment Committee (ExoTAC)³ chaired by Dr. Alan Boss. Non-US participation is welcome. Export-controlled topics, if any, will be covered in a separate forum.

The Starshade SIP will be managed by the ExEP Manager (Dr. Gary Blackwood) and supported by the ExEP Scientist for Starshade Technology (Dr. Renyu Hu).

To maximize participation of small businesses and academia in the Starshade SIP within limited program funds the following opportunities are planned:

1. Up to three set aside contracts for small business to be announced on FedBizOps by the Jet Propulsion Laboratory.
2. A Technology and Science Working Group (TSWG) of approximately 8 members solicited through a NASA *Dear Colleague* letter. Travel expenses will be reimbursed to TSWG members.
3. Up to four graduate students and/or post-docs will be selected by the TSWG to attend and present at Starshade SIP events. Travel expenses will be reimbursed for these students.

D. Work Structure and Timeframe:

The Starshade SIP will convene periodically by telecon (approximately bimonthly) and biannually in face-to-face Starshade SIP forums facilitated for remote participation. Small-business awardees and TSWG members, when selected, are expected to participate in the Starshade SIP telecons and forums. Agendas for telecons and Forums will include status from the S5 Project and presentations from Starshade SIP participants recommended by the TSWG.

Timeline:

- Dec 2018: SIP informational telecon
- Jan 2019: Request for Proposal for cost-sharing contracts
- Feb 2019: *Dear Colleague* letter for the Technology and Science and Working Group
- Jun 2019: Award of small business contracts; announce TSWG membership
- Aug 2019: Starshade SIP forum #1
- Feb 2019: Starshade SIP forum #2
- July 2020: Starshade SIP forum #3
- Nov 2020: Starshade SIP forum #4

The Starshade SIP, TSWG, and contracts will conclude in December 2020 and may be renewed pending the outcome of the Astro2020 Decadal Survey.

E. Reporting

The Starshade SIP Manager, The ExEP Scientist for Starshade Technology, and the TSWG will prepare a report summarizing each forum. Annually the SIP Chair and TSWG will provide a briefing to the NASA Astrophysics Division.

Expected Outcomes of the Starshade SIP

1. Identify **solutions to challenges** faced by the S5 development activity;
2. Propose **new approaches, techniques, and research** beyond planned S5 activities that can maximize starshade technology readiness;
3. Document **new mission concept drivers** for starshade technology performance requirements;
4. **Maintain alignment** between S5 technology development activities and future mission needs;
5. **Facilitate** groups of investigators to communicate research, new technology, and new mission concepts across disciplinary, organizational, and geographic boundaries;
6. Enable **continued participation** of the community in NASA's starshade technology development activities.

Status Since February Forum

- Progress in milestones
 - Achievements of Milestones 5A (shape stability of petal after deployment cycles), 7A (thermal stability of longeron and node subassemblies), 7C (deployment accuracy of the inner disk), and 8A (on-orbit thermal stability of longeron and node subassemblies)
 - Milestone 6A (on-orbit thermal stability of petal) to be reviewed by Exo-TAC
 - Milestones 5B, 6B, 7B, 7D, 8B in progress
 - Milestone 2 in progress: S5 is investigating the vector diffraction effects as part of its work towards meeting milestone 2
- Progress in stray light analyses
 - S5 is conducting a comprehensive stray light analysis that includes micrometeoroid damage, bright-body and Milky Way reflection, fluorescence, secondary reflection, etc
 - S5 is conducting a trade regarding the black starshade coating, considering specular/diffuse reflection and fluorescence, in response to TSWG recommendations
- JATIS special issue on starshade
 - Submission closed on July 31
 - S5 submissions on reassessment of noise budget, SISTER image simulation tool, optical edge coating experiments, and mechanical analyses

SIP Activities Replanned

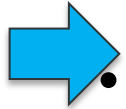
- SIP Forums #3 and #4 will be replaced by a series of SIP telecons
 - Topics from TSWG recommendations and other SIP activities
 - 10am PT on the third or fourth Thursday of each month
- Preliminary agenda of SIP telecons
 - Aug: Stray light analyses. Starshade data challenge announcement
 - Sep: Mechanical milestones
 - Oct: Presentations from ATA and Zecoat
 - Nov: Effects of binary companions and other astrophysical backgrounds
 - Dec: Presentations from Tendeg and Opterus
 - Will be keen on including student and postdoc presentations
- New starshade data challenge
 - Build upon the *Roman* Exoplanet Imaging Data Challenge:
<https://www.exoplanetdatachallenge.com/timeline-data>
 - Focus on imaging and spectroscopy of small planets
 - Probe sensitivity on instrument performance parameters

Starshade Data Challenge

- Recommendation by TSWG
 - “Document a flow down of requirements from science to key performance parameters based on synthetic images”
 - “Produce a plan for the starshade data challenge”
 - “Pursue updates of SISTER software including all relevant interference effects (eg., stray light, defects, stability)”
- Objectives of the Data Challenge
 - Validate requirements from science to key performance parameters
 - Quantify the accuracy of calibration of solar glint and exozodiacal light
 - Prepare science community for analyzing starshade exoplanet observations
- S5 will simulate images for the data challenge
 - The simulated images will include effects of optical edge coating, exozodiacal disk, formation flying variability, and slit/prism spectroscopy
- 2 teams will be selected by proposals
 - RFP to be released by the end of September. Proposals due one month after RFP release
 - \$50K per subcontract, with the period of performance Jan – Aug 2021

Telecon Agenda

- S5 and SIP Updates - **Renyu Hu**



- Stray Light in Starshade Exoplanet Imaging – **Doug Lisman**
- Comments/Discussion by TSWG Chair, Open Floor for Discussion

Closing

Future telecon topics

- **Starshade SIP mailing list:** Follow instructions at <https://exoplanets.nasa.gov/exep/technology/starshade/>
- Suggest telecon topics and student & postdoc presentations to:
 - Gary Blackwood and Renyu Hu
 - Simone D'Amico, Chair of TSWG
- Open the floor for further discussion



Jet Propulsion Laboratory
California Institute of Technology

Acknowledgements

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Program Office – Key Participants

NASA Exoplanet Exploration Program (ExEP)

Science and Industry Partnership

- **Gary Blackwood**, NASA ExEP Manager, Starshade SIP Chair
- **Renyu Hu**, ExEP Scientist for Starshade Technology

Starshade Technology Development Activity (S5)

- **Kendra Short**, NASA ExEP Deputy Manager
- **Phil Willems**, Manager of S5, LBTI Project Manager

NASA Headquarters Leadership

Astrophysics Division

- **Shahid Habib**, Program Executive for ExEP
- **Douglas Hudgins**, Program Scientist for ExEP
- **Mario Perez**, Division Technology Lead
- **Jeff Volosin**, Deputy Division Director
- **Paul Hertz**, Division Director