Jet Propulsion Laboratory
California Institute of Technology

Starshade Exoplanet Data Challenge

Telecon #3

NASA Exoplanet Exploration Program

Renyu Hu

June 16, 2021

CL # 21-2798

Telecon Agenda

- Introduction – **Renyu Hu**
- Overview of Data Release 3 – **Stuart Shaklan**
- Preliminary Analysis of Data Releases 1 and 2 – **Participating Teams**
- Open Floor for Discussion

Starshade Science and Industry Partnership

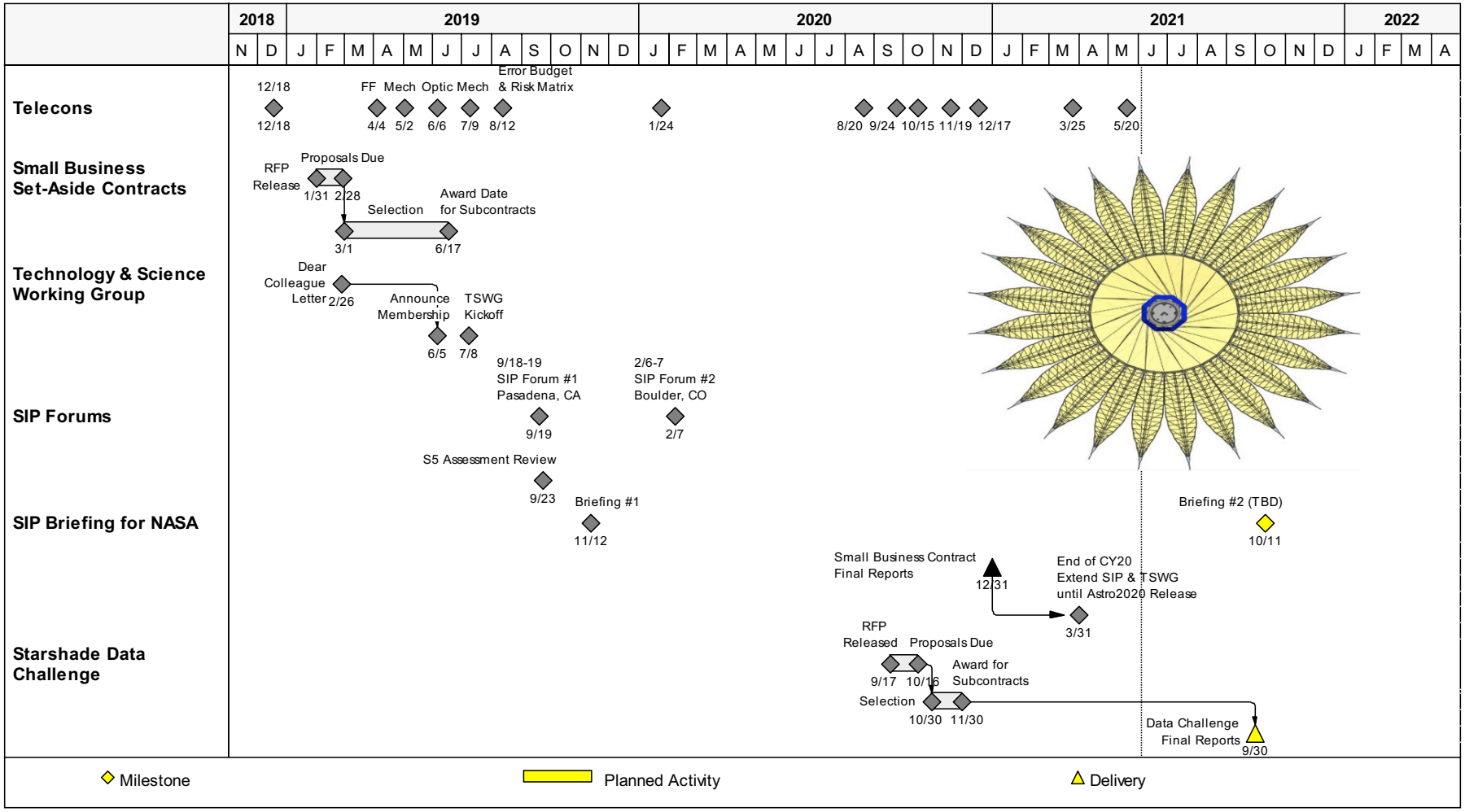
The purpose of the Starshade SIP is to maximize the technology readiness level of starshades to enable potential future exoplanet science missions.

- 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 Science and Industry Parnership (SIP)

Tier 2 Schedule

6/4/2021



Starshade Exoplanet Data Challenge

- Recommended by the Technology and Science Working Group
  - "Document a flow down of requirements from science to key performance parameters based on synthetic images"
  - "Produce a plan for the starshade data challenge"
- Objectives
  - 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
- Two teams have been selected from submitted responses to a JPL Request for Proposals
  - **Mississippi State University**, Mississippi State, MS. The Principal Investigator is Dr. Angelle Tanner
  - **Quartus Engineering Incorporated**, El Segundo, CA. The Principal Investigator is Brian Dunne
- The data challenge is open to the the general astronomy and exoplanet community

Starshade Exoplanet Data Challenge

- Data Release 1
  - Kick-off telecon on January 27
  - Selected broadband scenarios, 30 images, and calibration files

- Data Release 2
  - Telecon #2 on April 7
  - All broadband scenarios, total of 1440 images
  - Starshade Rendezvous with Roman, 425-552 nm and 615-800 nm
  - Nominal and a “worse” starshade (10x contrast, 2x solar glint)
  - Smooth exozodiacal dust density and resonant cloud structures
  - Broadband Reference documentation as a “live document”

  https://docs.google.com/document/d/1bsDX5wIIDidiLt_7wmAkJ-g5SBQ74WNjdgQW3twrtI0/edit

- Publications related to the data challenge in JATIS
  - Overall design and rationale
  - (Theoretical) noise budget of starshade exoplanet imaging
  - SISTER

Starshade Exoplanet Data Challenge

- Data Release 3
  - Slit-prism spectroscopy of Starshade Rendezvous with Roman in 615 – 800 nm (4 images)
    - Tau Ceti, with 2 slit location/orientation
    - Sigma Draconis with 30- or 80-degree system inclination, each with one slit location/orientation
  - IFS spectroscopy of HabEx in 400 – 1000 nm (3 images)
    - Tau Ceti
    - Sigma Draconis with 30- or 80-degree system inclination
  - Correspond to selected broadband images in Release 2, but with 13-fold longer integration times
  - Post-dispersion detector images are provided. Dispersion curves and star spectroscopy exposures (i.e., without the starshade) are also provided for calibration
  - For Roman, the slit overlaps with one or more planets and may include exozodi contributions
  - For HabEx, the simulations assume the same astrophysical scenes and integration times as Roman for comparison
  - Spectroscopy reference documentation as a “live document”

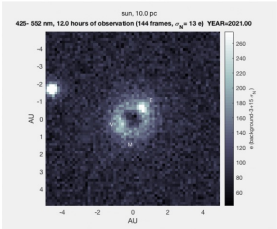
https://docs.google.com/document/d/1bsDX5wIIDidiLt_7wmAkJ-g5SBQ74WNjdgQW3twrtI0/edit

https://exoplanets.nasa.gov/exep/technology/starshade-data-challenge/

Starshade Exoplanet Data Challenge

A key recommendation that emerged from Starshade Science and Industry Partnership (SIP) meetings and discussions is to produce a flow down of requirements from science to key performance parameters based on synthetic images via a data challenge. Responding to the community recommendation, the Starshade Technology Development Activity to TRL5 (S5) is now developing and conducting a Starshade Exoplanet Data Challenge.

The Starshade Exoplanet Data Challenge seeks to quantify the required accuracy of noisy background calibration to detect planets and exozodiacal disks and extract their spectra from synthetic images. The synthetic images simultaneously include multiple sources of background and noise including residual starlight, solar glint, other stray light sources, exozodiacal light, detector noise, as well as variability resulting from starshade's motion in formation flight and telescope's jitter. Many of these terms are specific to starshade observations, and the interplay of these terms of background and noise can be revealed and evaluated with the analyses on synthetic images.



Example synthetic images of starshade-assisted imaging of a hypothetical solar system at 10 parsec.

The images will be generated with the Starshade Imaging Simulation Toolkit for Exoplanet Reconnaissance (SISTER), which takes into account the full 2-dimensional nature of the astrophysical scene and the spatial variation of the Point Spread Function (PSF) due to the optical diffraction from the starshade. Astrophysical and observational scenarios will be selected to represent key science objectives of the well-studied starshade mission concepts including Roman Starshade Rendezvous and HabEx.

Two participating teams have been selected from submitted responses to a JPL Request for Proposals (RFP). The participating teams are tasked to develop image-processing algorithms to test the ability to retrieve faint exoplanet signals from the synthetic images and quantify the precision needed for background calibration. With the simulated images of slit-prism spectroscopy for Roman and the data cubes of integral field spectroscopy for HabEx, the algorithm could also attempt to extract the planets' spectra. Results from the analyses will help determine the detection limit of planets vis-a-vis instrument parameters and indicate how well image processing can subtract the background to the photon-noise limit.

Upcoming Starshade Exoplanet Data Challenge Telecon

- June 16, 2021 from 1-2pm PT
- Join Webex Meeting ID: 199 543 6799 PW: planets

Announcement and Telecon Presentations

- Selection of Starshade Exoplanet Data Challenge subcontracts
- **06-16-21 Telecon #3**
- **04-07-21 Telecon #2**
  - Introduction, Renyu Hu
  - Broadband Imaging Simulations for Starshade Rendezvous, Sergi Hildebrandt
  - Approach and Release 1 Results, Brian Dunne
- **01-27-21 Kick Off Telecon #1**
  - Welcome, Renyu Hu
  - Overview of Starshade Tech Development to TRL5, Phil Willems
  - Starshade Image Simulations, Sergi Hildebrandt
  - Timeline and Logistics, Renyu Hu

Objectives of Spectroscopy Data Analysis

- Extract planetary spectra
  - Planet-star flux ratio as a function of wavelength

- Key questions
  - Can planetary spectra be extracted from with slit-prism spectroscopy and IFS spectroscopy?
  - Can backgrounds be calibrated to the photon-noise limit?
  - Are planets and exozodiacal dust contributions separable in spectroscopy?
  - How does the slit location and orientation impact spectral extraction?
  - Can exozodi disk spectra be measured?

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Open Discussion

- Questions?

Closing

- Studies to conclude with final presentations and reports in September

- Data releases and presentations are posted at

https://exoplanets.nasa.gov/exep/technology/starshade-data-challenge/

- Future announcements will be made to the Starshade SIP mailing list

- A dedicated Slack channel for data challenge participants

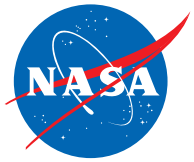
E-mail:

mario.damiano@jpl.nasa.gov

slack channel:

Starshade Data Challenge

starshadedata-ett3036.slack.com



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Disclaimer

The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

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Science and Industry Partnership

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

Starshade Technology Development Activity (S5)

- **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