Starshade Science and Industry Partnership
Forum #2 – Welcome and Introduction

Dr. Gary Blackwood
Manager, NASA Exoplanet Exploration Program
Jet Propulsion Laboratory, California Institute of Technology

February 6, 2020
Boulder, Colorado
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.
Exoplanet Roadmap

Technology:
- Ultrastable Structures
- Advanced Detectors
- Starshade Technology
- Coronagraphs
- Segmented Mirrors

Missions:
- Hubble
- TESS
- Spitzer
- Webb
- Kepler

Science:
- Exoplanet Populations
- Detect Atmospheres
- Atmospheric Chemistry
- Nearest Exoplanets
- Exoplanet Diversity
- Exozodiacal Dust
- Direct Imaging
- Direct Imaging
- Exoplanet Characterization

Timeline:
- Today
- 2020s
- 2025s
- 2030s
- 2035 & Beyond
- Pending Decadal Survey

Potential Missions:
- Starshade Rendezvous
- Luvoir
- Habex
Starshade Science and Industry Partnership

SIP

- Technology and Science Working Group (TSWG)
- SIP Industry Subcontracts

Starshade Technology Development Activity (S5)
Starshade SIP – Terms of Reference
https://exoplanets.nasa.gov/exep/technology/starshade/

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 studies 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) 6 to enable potential future exoplanet science missions. The Starshade Technology Development Activity to TRL 5, or SS, 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. 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 SS development activity;
2. Propose new approaches, techniques, and research beyond planned SS activities that can maximize starshade technology readiness;
3. Document new mission concept drivers for starshade technology performance requirements;
4. Maintain alignment between SS 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 contributions in starshade-related technology. Ex officio participants in the SIP include SS project staff, ExEP Chief Technologists and Chief Scientists, and the Exoplanet Technical Assessment Committee (ExTAC)2 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. Romy Iida).

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 SS 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 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.

1 https://science.nasa.gov/astrophysics/2020-decadal-survey-planning
2 https://exoplanets.nasa.gov/exep/technology/starshade/
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.
# Technology and Science Working Group

**Congratulations and Welcome!**

<table>
<thead>
<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Institution</th>
<th>Title</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seager</td>
<td>Sara</td>
<td>Massachusetts Institute of Technology</td>
<td>Professor</td>
<td><a href="mailto:seager@mit.edu">seager@mit.edu</a></td>
</tr>
<tr>
<td>Turnbull</td>
<td>Margaret</td>
<td>SETI Institute</td>
<td>Principal Investigator</td>
<td><a href="mailto:turnbull.maggie@gmail.com">turnbull.maggie@gmail.com</a></td>
</tr>
<tr>
<td>Arenberg</td>
<td>Jon</td>
<td>Northrop Grumman Aerospace Systems</td>
<td>Chief Engineer</td>
<td><a href="mailto:jon.arenberg@ngc.com">jon.arenberg@ngc.com</a></td>
</tr>
<tr>
<td>d'Amico **</td>
<td>Simone</td>
<td>Stanford University</td>
<td>Assistant Professor</td>
<td><a href="mailto:damicos@stanford.edu">damicos@stanford.edu</a></td>
</tr>
<tr>
<td>Harness</td>
<td>Anthony</td>
<td>Princeton University</td>
<td>Postdoc</td>
<td><a href="mailto:anthony.harness@princeton.edu">anthony.harness@princeton.edu</a></td>
</tr>
<tr>
<td>Mather</td>
<td>John</td>
<td>NASA Goddard Spaceflight Center</td>
<td>Senior Project Scientist</td>
<td><a href="mailto:john.c.mather@nasa.gov">john.c.mather@nasa.gov</a></td>
</tr>
<tr>
<td>Romero-Wolf</td>
<td>Andrew</td>
<td>NASA Jet Propulsion Laboratory</td>
<td>Technologist</td>
<td><a href="mailto:Andrew.Romero-Wolf@jpl.nasa.gov">Andrew.Romero-Wolf@jpl.nasa.gov</a></td>
</tr>
<tr>
<td>Witkowski</td>
<td>Allen</td>
<td>Katabasis Engineering</td>
<td>Owner</td>
<td><a href="mailto:al.witkowski@katabasisengineering.com">al.witkowski@katabasisengineering.com</a></td>
</tr>
<tr>
<td>Stahl</td>
<td>Phil</td>
<td>NASA Marshall Space Flight Center</td>
<td>Senior Engineer</td>
<td><a href="mailto:h.philip.stahl@nasa.gov">h.philip.stahl@nasa.gov</a></td>
</tr>
<tr>
<td>Jensen-Clem</td>
<td>Becky</td>
<td>UC Berkeley</td>
<td>Post Doc</td>
<td><a href="mailto:rjensenclem@berkeley.edu">rjensenclem@berkeley.edu</a></td>
</tr>
</tbody>
</table>

** Chair

---

**Note:** The table above lists the members of the Technology and Science Working Group along with their institutions, titles, and email addresses. The table is structured to provide clear information about each individual's role within the group. The asterisk indicates the chairperson of the group.
Technology and Science Working Group

• Context:
  – TSWG is a steering group for the SIP
  – The SIP will help S5 achieve its milestones, and, help NASA understand if S5 has the right milestones

• TSWG members will:
  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. Document findings in annual Starshade SIP reports to NASA APD

• The TSWG will select up to four graduate students and postdocs to attend and present at each SIP forum (travel expenses reimbursed), starting with forum #2
Small Business Subcontracts

• **Zecoat Corporation**, Torrance CA. Zecoat will evaluate, optimize, and test performance of a specular black coating on the starshade edges to minimize solar glint.

• **Opterus Research and Development Inc.**, Fort Collins CO. Opterus will evaluate creep behavior of composite material resins through test and analysis.

• **Tendeg, LLC**, Louisville CO. Tendeg will perform analysis and test of petal and PLUS deployments and petal deformations under stowage loads.

• **ATA Engineering, Inc.**, San Diego CA. ATA will evaluate multiple structural analysis methodologies and software and assess the benefits of the approaches using petal deployment and position error as case studies.
Highlights Since our Last Meeting

• Starshade Technology Project (aka S5) met several milestones
• Briefings to NASA Astrophysics Division: the SIP recommendations, and Remote Occulter
• Mission concepts completed (HabEx, Rendezvous Probe)
• WFIRST – starshade accommodation, held DPMC, next: APMC
• Starshade briefings to the National Academies
• Starshade briefings at the AAS splinter session on technology and at the ExoPAG (mDOT, mission yields)
• Small business teams active – presentations, tours at this meeting
• TSWG active – four student/post docs selected to present today
  – Mario Damiano (JPL)
  – Mengya Hu (Princeton)
  – Adam Koenig (Stanford)
  – Gabriel Soto (Cornell)
### Starshade Science and Industry Partnership

<table>
<thead>
<tr>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telecons</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Small Business Set-Aside Contracts</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1/31 RFP Released</td>
<td>2/28 Proposals Due</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Technology &amp; Science Working Group (TSWG)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SiP Forums</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SiP Briefing for NASA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Milestone**
- **Planned Activity**
- **Delivery**
NASA Exoplanet Exploration Program

Space Missions and Concept Studies
- Kepler K2
- Large- and Probe-Scale Mission Concepts

Supporting Research & Technology
- Coronagraph
- Starshade

Key Sustaining Research
- NN-EXPLORE
- Keck Observatory
- High Resolution Imaging
- Coronagraph Technology Development
- Starshade Technology Development (S5)

Technology Development

Exoplanet Communications
- Archives, Tools, Sagan Program, Professional Engagement

NASA Exoplanet Science Institute (NExScI)
Acknowledgements
ExEP Contributors to the Starshade SIP

- Douglas Hudgins – ExEP Program Scientist, NASA HQ
- Renyu Hu – Starshade Scientist
- Kendra Short – ExEP Deputy Manager
- Ray Lemus – Program Business Administration Manager
- Phil Willems – S5 Manager
- Doug Lisman – S5 Lead System Engineer
- Stuart Shaklan – S5 Lead Optical Engineer
- David Webb – S5 Lead Mechanical Engineer
- Manan Arya - Inner Disk Subsystem Lead
- Flora Mechentel - Optical Edge Lead
- Jade Smith – Program Schedule Analyst
- Jennifer Gregory – Program Administrator
## Agenda

<table>
<thead>
<tr>
<th>Agenda Item - Day 1 Feb 6</th>
<th>Presenter</th>
<th>Start</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction and overview</td>
<td>Gary Blackwood</td>
<td>8:00</td>
<td>0:10</td>
</tr>
<tr>
<td>Welcome from the TSWG chair</td>
<td>Simone D’Amico</td>
<td>8:10</td>
<td>0:10</td>
</tr>
<tr>
<td><strong>Session 1: SS Updates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair: Phil Williams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SS programmatic and technical status and assessment of TSWG recommendations</td>
<td>Phil Williams</td>
<td>8:20</td>
<td>0:30</td>
</tr>
<tr>
<td>Report on TSWG recommendation: Vector diffraction and milestone #1</td>
<td>Stuart Shkalen</td>
<td>8:50</td>
<td>0:30</td>
</tr>
<tr>
<td>Report on TSWG recommendation: Edge scatter, milestone #3, and beyond</td>
<td>Stuart Shkalen</td>
<td>9:20</td>
<td>0:30</td>
</tr>
<tr>
<td><strong>Break</strong></td>
<td></td>
<td>9:50</td>
<td>0:20</td>
</tr>
<tr>
<td>Report on TSWG recommendation: Reflected bright body and other sources of straylight</td>
<td>Doug Usman</td>
<td>10:10</td>
<td>0:30</td>
</tr>
<tr>
<td>straylight analysis: sunlight scattering off out-of-plane petal deformations</td>
<td>Glenn Sellars</td>
<td>10:40</td>
<td>0:20</td>
</tr>
<tr>
<td>Report on mechanical milestones</td>
<td>Manish Arya</td>
<td>11:00</td>
<td>0:30</td>
</tr>
<tr>
<td><strong>Discussion 1</strong></td>
<td></td>
<td>11:30</td>
<td>0:20</td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
<td>12:00</td>
<td>1:30</td>
</tr>
<tr>
<td><strong>Session 2: Industry Partners Updates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair: Kendra Short</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATA</td>
<td>Laura Hoffman</td>
<td>13:30</td>
<td>0:30</td>
</tr>
<tr>
<td>Opterus</td>
<td>Patrick Rodriguez, Thomas Murphy</td>
<td>14:00</td>
<td>0:30</td>
</tr>
<tr>
<td>Zecosat</td>
<td>David Sheikht</td>
<td>14:30</td>
<td>0:30</td>
</tr>
<tr>
<td><strong>Break</strong></td>
<td></td>
<td>15:00</td>
<td>0:30</td>
</tr>
<tr>
<td><strong>Session 3: Student and Postdoc Presentations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair: Jon Arenberg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exoplanetary characterization through reflection spectroscopy</td>
<td>Mario Campano (IPOL)</td>
<td>15:30</td>
<td>0:25</td>
</tr>
<tr>
<td>The search for another Earth using space telescopes with starshades: realistic image simulation and signal detection</td>
<td>Mengya Hu (Princeton)</td>
<td>15:55</td>
<td>0:25</td>
</tr>
<tr>
<td>Enabling starshade missions in Earth orbit through optimal formation design</td>
<td>Adam Koenig (Stanford)</td>
<td>16:20</td>
<td>0:25</td>
</tr>
<tr>
<td>Fuel cost heuristics for starshade slews and station-keeping in exoplanet imaging mission simulations</td>
<td>Gabriel Soto (Cornell)</td>
<td>16:45</td>
<td>0:25</td>
</tr>
<tr>
<td><strong>Discussion 2</strong></td>
<td></td>
<td>17:10</td>
<td>0:20</td>
</tr>
<tr>
<td>TSWG Meet and Discuss</td>
<td></td>
<td>17:30</td>
<td>0:30</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Agenda Item - Day 2 Feb 7</th>
<th>Presenter</th>
<th>Start</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>What we have learned from Day 1 and the objectives for Day 2</td>
<td>Ranju Hu</td>
<td>8:00</td>
<td>0:10</td>
</tr>
<tr>
<td><strong>Session 4: Technology and Science Working Group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair: Simone D’Amico</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formation flying with Princeton testbed</td>
<td>Anthony Harness</td>
<td>8:10</td>
<td>0:20</td>
</tr>
<tr>
<td>SISTER Imaging Simulation Tool</td>
<td>Stuart Shaklan</td>
<td>8:30</td>
<td>0:20</td>
</tr>
<tr>
<td>Data Challenges</td>
<td>Maggie Turnbull, Simone D’Amico, Anthony Harness</td>
<td>8:50</td>
<td>0:40</td>
</tr>
<tr>
<td><strong>Break</strong></td>
<td></td>
<td>9:30</td>
<td>0:20</td>
</tr>
<tr>
<td>Planet characterization and discoveries by GAIA and the impact on starshade missions</td>
<td>Tim Brandt (remote)</td>
<td>9:50</td>
<td>0:20</td>
</tr>
<tr>
<td>Progress and Challenges of Earth-Orbiting Starshades</td>
<td>John Mather</td>
<td>10:10</td>
<td>0:20</td>
</tr>
<tr>
<td>What Science Can Do To Improve the Design of a Ruggish Exo-Planet Mission: NG Perspective</td>
<td>Jon Arenberg</td>
<td>10:30</td>
<td>0:20</td>
</tr>
<tr>
<td>JFAST Special Issue</td>
<td>Jon Arenberg</td>
<td>10:50</td>
<td>0:10</td>
</tr>
<tr>
<td><strong>Discussion 3</strong></td>
<td></td>
<td>11:00</td>
<td>0:20</td>
</tr>
<tr>
<td>Summary and Next Steps</td>
<td>Gary Blackwood</td>
<td>11:20</td>
<td>0:10</td>
</tr>
<tr>
<td>Lunch and a short drive</td>
<td></td>
<td>11:30</td>
<td>1:30</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>Agenda Item - Day 2 Feb 7</th>
<th>Presenter</th>
<th>Start</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Session 5: Starshade Testing Facility at Tendeg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chair: David Webb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starshade Testing Facility at Tendeg</td>
<td>Mark Thomson</td>
<td>13:00</td>
<td>1:30</td>
</tr>
</tbody>
</table>

---

| End | | 14:30 |
Other Meeting Logistics

• Jennifer Gregory – Meeting Logistics
  – Will be posting slides to website when released

• Important Logistics:
  – Refreshments
  – Restrooms
  – Lunch
  – Optional Group Dinner tonight
Acknowledgements

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration. © 2019 All rights reserved.
Program Office – Key Participants
NASA Exoplanet Exploration Program (ExEP)

Science and Industry Partnership
• Gary Blackwood, NASA ExEP Manager, Starshade SIP Chair
• Yuriy Tsurkan, Subcontract Manager
• 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
Contact Information
Starshade Science and Industry Partnership

• **Gary Blackwood**, NASA ExEP Manager, Starshade SIP Chair
  – Gary.blackwood@jpl.nasa.gov
  – W: 818 354 6263
  – M: 818 458 0507

• **Yuriy Tsurkan**, Subcontract Manager
  – Yuriy.Tsurkan@jpl.nasa.gov
  – W: 818 393-8052
  – M: 747 261-8928

• **Renyu Hu**, ExEP Starshade Scientist
  – Renyu.Hu@jpl.nasa.gov
  – W: 818 354 6090
  – M: 818 281-9459

• **Kendra Short**, S5 acting Manager, NASA ExEP Deputy Manager
  – Kendra.Short@jpl.nasa.gov
  – W: 818 354 9286
  – M: 818 634 3918
NASA Headquarters Leadership

Astrophysics Division

• Shahid Habib, Program Executive for ExEP
• Douglas Hudgins, Program Scientist for ExEP
• Martin Still, Deputy Program Scientist for ExEP
• Nasser Barghouty, Division Technology Lead
• Jeff Volosin, Deputy Division Director
• Paul Hertz, Division Director