Starshade Technology Development

Dr. John K. Ziemer

Starshade Technology Development Manager

NASA Exoplanet Exploration Program

Starshade Technology Workshop

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Starshade to TRL 5

Introduction to S5

Direction from NASA Astrophysics Division:

- Develop starshade technology to discover Earth-like planets in habitable zones around Sun-like stars for future space telescope missions

- Reach a technology readiness level of 5 (component and/or breadboard validation in relevant environment)

- Deliver a TRL-5 Development Plan by end of 2017; key decision point based on this plan will determine if this activity continues

Starting Points

- Focused starshade technology development activity approved in March 2016
  - TDEM activity and funding consolidated
  - Approved for a planning phase through end of FY17; execution phase conditional upon approval from APD Director
  - Currently planning 2017, which depends on final NASA budget from Congress, APD allocation, and this workshop
- Regardless of budget, first year focuses on planning and conducting trades, highest priority first
- Exo-S rendezvous study is our point of departure, but baseline will be updated as WFIRST Rendezvous and HabEx and LUVOIR concepts mature
- NASA will make no decision on conducting a starshade mission until after the 2020 Decadal Survey

Keys to Our Success

- We must be ready for 2020 Astrophysics Decadal (submission sometime in early 2019)
  - Technologies need to be mature enough to enable starshades to be in the trade space for possible WFIRST Rendezvous and future large telescope missions
  - Complete near-term milestone of an approved TRL 5 Plan
  - Technical progress in prioritized areas, meeting milestones on time with some early successes
- Our Models
  - We will reach higher TRLs based on meeting error budget requirements developed through validated performance models (optical diffraction and scattering, mechanical, thermal, etc.)
  - Ground based tests must focus on validating performance models and error budget as well as demonstrations of meeting requirements that are derived from the error budget
- Independent reviews of our plan and technical progress

Near-Term Plans

- Use this workshop to inform community and collect technology gaps, risks, key performance parameters, and trades for prioritization to plan work in FY17
- Starting with the body of technology material that has already been produced, we will ask: is it complete, prioritization correct, and do we have the solution space mapped out?
- Use follow-on workshops (technology topic specific) in late February, March, and April to plan out how TRL 5 will be reached and kick-off high priority trade analysis that needs to be complete by end of FY17
- Update engineering baseline design in August 2017
- Preliminary Technology Plan by Sept 2017
- Final reviewed plan delivered to APD Director by end of CY17 (TBC based on final budget)

Analysis Group, Peer Reviewers, and ExoTAC

- S5 will be putting out a public call to form an analysis group consisting of 5-6 exoplanet scientists and engineers in early 2017
  - Will help keep the science case current, guide the trade studies, and ensure consistency
  - Will provide the best analysis possible heading into peer and independent reviews
  - Will be a direct link to the exoplanet community
- Positions on the analysis group will be funded to conduct analysis and recommend future directions for S5

- S5 will convene separate, independent peer reviews of technical material prior to formal program reviews

- ExoTAC is a review board convened by ExEP Manager and APD to formally evaluate the technology plan and future milestone achievements prior to delivery to APD

S5 Activity Process Loops
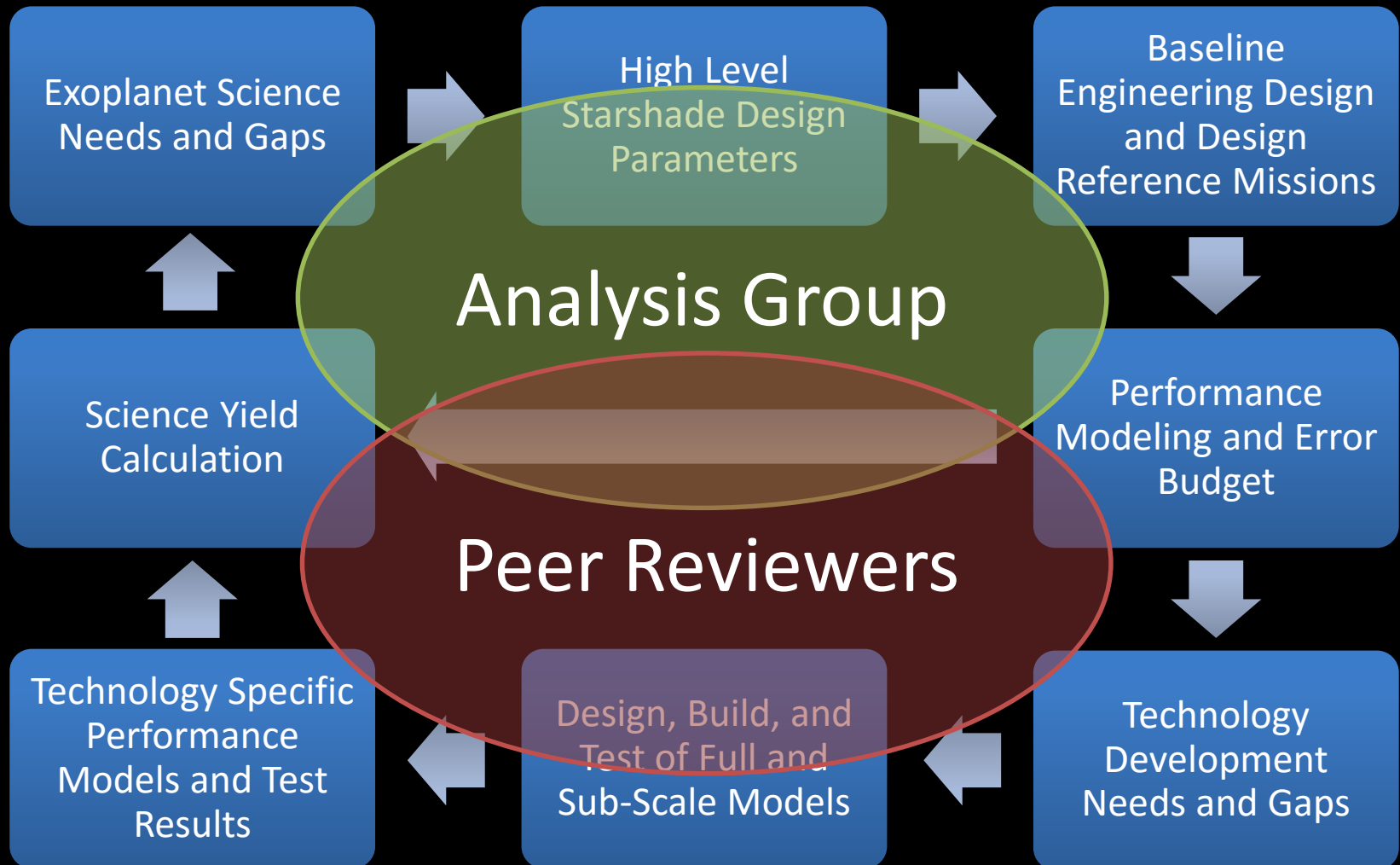
The Three Key Technology Areas for a Starshade

(1) Starlight Suppression

Suppressing scatted light off petal edges from off-axis Sunlight (S-1)

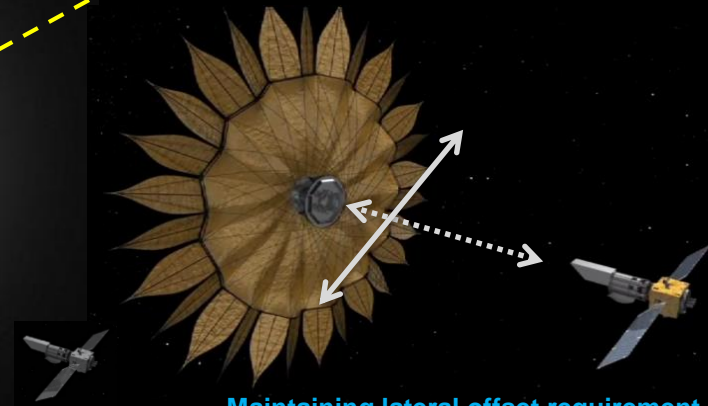**Suppressing diffracted light from on-axis starlight and optical modeling (S-2)**

(2) Formation Sensing and Control

Maintaining lateral offset requirement between the spacecraft (S-3)

(3) Deployment Accuracy and Shape Stability

Fabricating the petals to high accuracy (S-4)

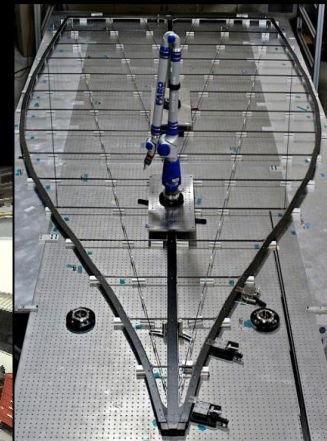**Positioning the petals to high accuracy, blocking on-axis starlight, maintaining overall shape on a highly stable structure (S-5)**

S-# corresponds to ExEP Starshade Technology Gap number (http://exoplanets.nasa.gov/exep/technology/gap-lists)

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Example of Key TRL-5 Requirements:
Quantified performance needs tied to Error Budgets, Vetted Gap Lists, Exo-S

Technology Area	Key Performance Tolerances (3σ)	Proposed End-State Fidelity (TRL-5+)			Tested in Relevant Environment; Designed to Meet Life Rqmt	Performance Verification	Model Validation
		Fit	Form	Function			
Deployment Accuracy and Shape Stability	**Petal Shape and Stability**						
	In-plane envelope: ± 100 μm	High fidelity, full-scale	High-fidelity prototype	Required performance demonstrated	Deploy and thermal cycles	Measure shape after deployment and thermal cycles	CTE, CME, creep
					Temperature and humidity	Measure shape with optical shield at temp.	Shape vs. applied loads
					Stowed strain	Predict on-orbit petal shape with all errors	Shape vs. temperature
	Petal Deployment Accuracy						
	In-plane envelope: ± 1 mm	High fidelity, half-scale inner disk; scaling issues understood	High-fidelity prototype	Required performance demonstrated with critical interfaces	0-gravity and vacuum	Measure position after deployment cycles in air with negligible air drag and imperfect gravity comp.	CTE, CME, creep
					Temperature and humidity	Measure position with optical shield at temp.	Shape vs. applied loads
					Stowed strain	Analyze on-orbit petal shape with all errors	Shape vs. temperature
Formation Sensing and Control	**Bearing Angle Sensing and Control**						
	Sensing: ± 1 mas Control (modeling): ± 1 m	Medium fidelity, using small-scale starshade; scaling issues	Medium-fidelity prototype	Basic functionality demonstrated	Large separation distance	Measure angular offsets with brassboard guide camera (coronagraph instrument) that simulates PSFs and fluxes from beacon and star	PSFs bearing angle vs. signal
Contrast	**Scattered Sunlight**						
	Edge radius x reflectivity: ≤ 10 μm-%	High fidelity, full-scale petal with full-scale optical edges	High-fidelity prototype	Required performance demonstrated with critical interfaces	Same as for petal shape	Measure petal level scatter after environment tests at discrete angles	Scatter vs. sun angle Scatter vs. dust
					Sun angle	Measure coupon level scatter after environment tests at all sun angles	
					Dust in launch fairing	Analyze effect for on-orbit solar glint	
	Starlight Suppression						
	Test at a flight-like Fresnel: Contrast (test) $< 10^{-9}$ (traceable to 10^{-10} system performance with validated model)	Medium fidelity, small-scale starshade; scaling issues understood	Medium-fidelity prototype	Basic functionality demonstrated	Space	Measure image plane contrast between 500-850 nm	Optical performance, sensitivity to perturbations

(to be concurred by a TAC at the end of Starshade Technology Formulation)

Starshade Technology Workshop

- Goal:
    - Provide a forum for the broad community of starshade stakeholders to offer input and influence the formulation of a starshade technology development plan (STDP) that would guide technology maturation and investments under the activity.

- Desired Outcome:
    - Use community inputs to inform the planning for the remainder of FY17 tasks, including follow-on focused workshops, identifying technology gaps, risks, key performance parameters, and trades.

- Method:
    - Provide program-level information to community along with technology progress, needs, and opportunities with ample discussion periods
    - Use break-out groups in each major technology area to asses current gaps and needs for TRL 5, opportunities for reaching TRL 5, and identifying key trades

Thank You

- You are key to making this workshop useful
- We want your ideas to be heard
- Proceedings will be public
- Workshop will provide the basis for a recommendation to Paul Hertz on how S5 will proceed this year to complete our trades and technology plan
  - Updates, if needed, to technology gap list
  - Process for establishing TRL 5 milestones
  - Prioritization of trades and analysis