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California Institute of Technology

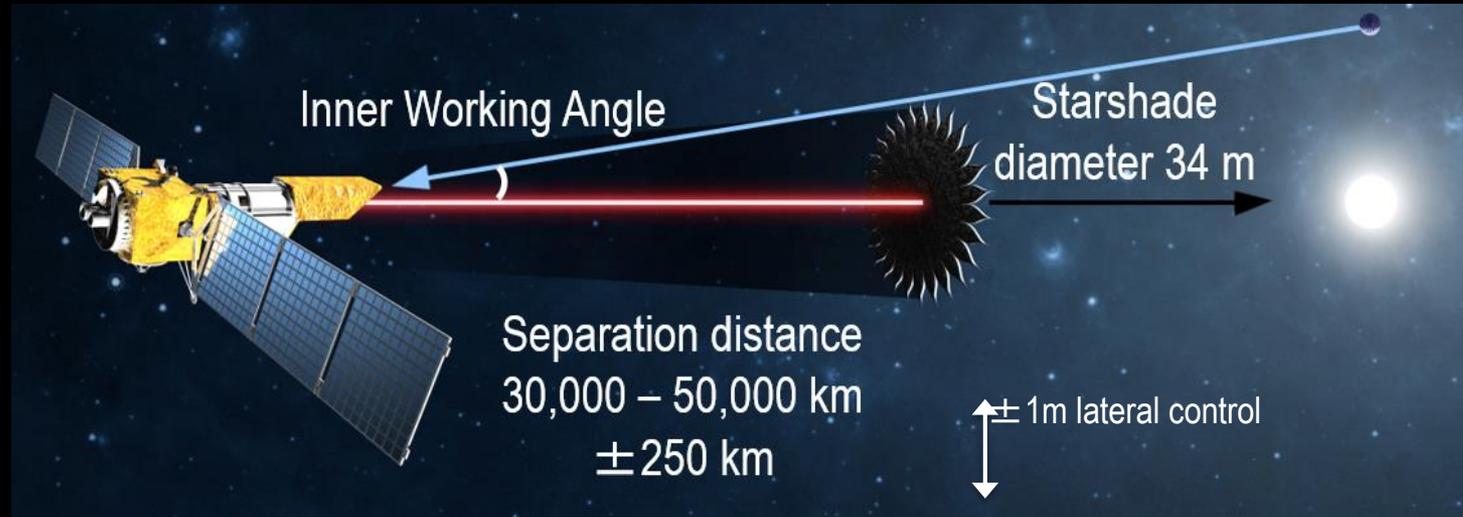
Introduction to NASA Starshade Development Activities

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

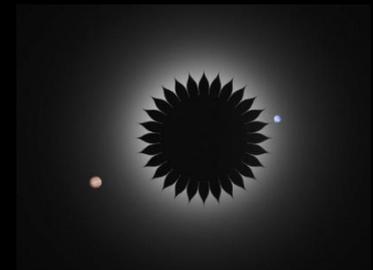
January 06, 2017

Starshade Development for Direct Imaging of Exoplanets
Grapevine, TX

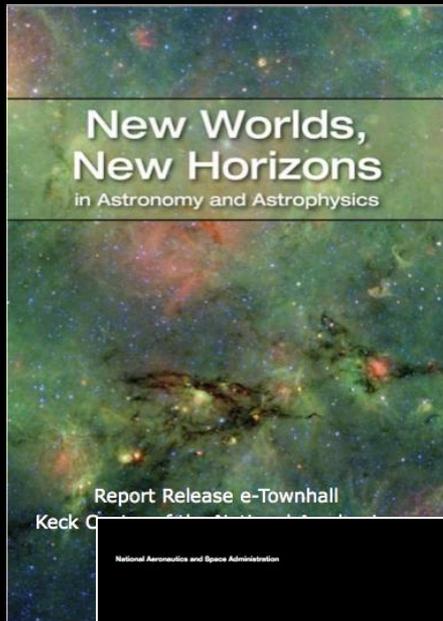
Why is NASA interested in Starshades?



- One of two technologies for high-contrast imaging of earth-sized planets in habitable zones of sun-like stars
- Provides small inner working angle, high throughput
- Different technology challenges to coronagraph
- Complementary to coronagraph
- Provides access to Earth-sized planets in habitable zones of sun-like stars for small apertures

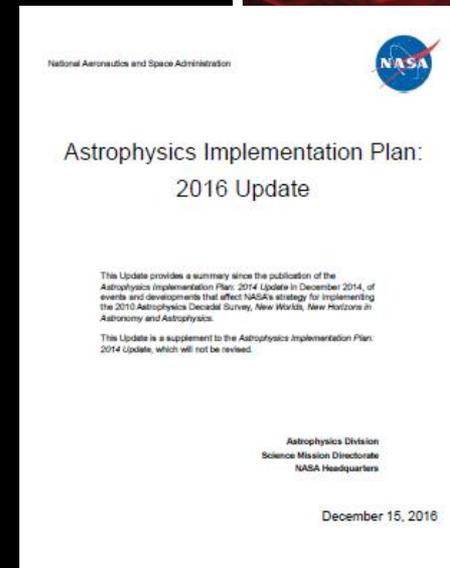
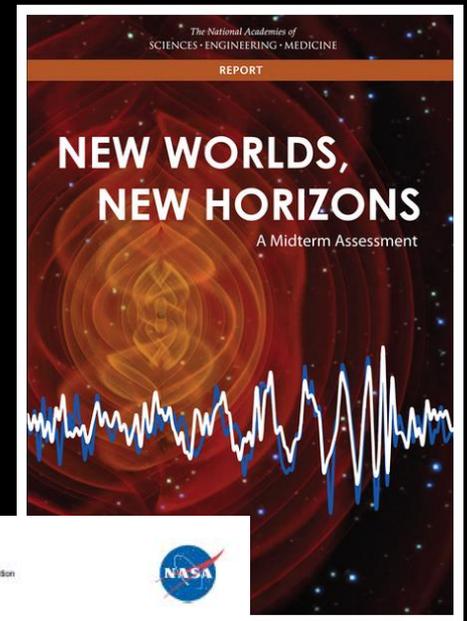


Astrophysics Division: Driving Documents



Results of NWNH:

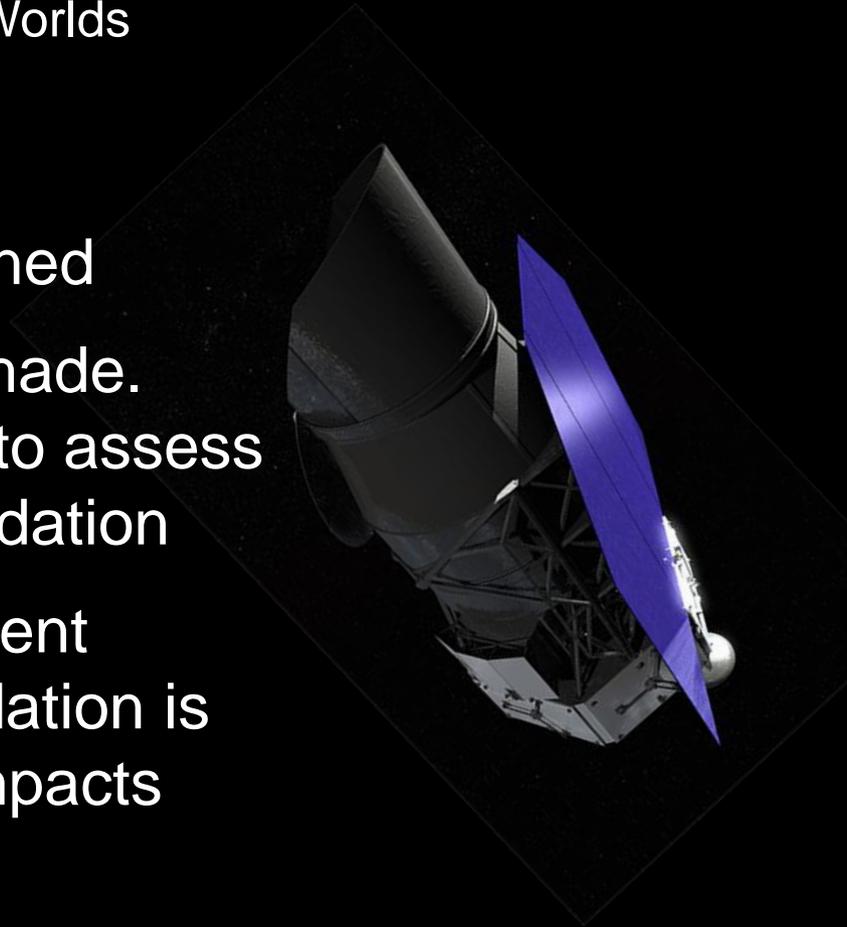
- WFIRST is top large-scale recommended activity
- NWNH technology program is top medium-scale recommended activity



WFIRST

Dark Energy, Infrared Astrophysics, Alien Worlds

- WFIRST in Formulation Phase
- Coronagraph Instrument baselined
- WFIRST does not have a starshade. Project received APD direction to assess impacts of starshade accommodation
- Preliminary starshade assessment indicates spacecraft accommodation is feasible: technical, cost, risk impacts considered
- NASA will make decision following SRR/MDR on whether to continue starshade compatibility



Why is Starshade Technology Urgent Now?

- Decadal Large Mission Studies (HabEx, LUVOIR) are considering starshades and the science they enable
- Possibility for “Rendezvous at L2” of Starshade with WFIRST
 - Would require 2020 Decadal Survey endorsement of a probe-scale mission
- In all cases: Be ready and inform the 2020 Astrophysics Decadal Survey with mature technology (at TRL5 or close to it) for DS consideration

NASA Exoplanet Exploration Program

Astrophysics Division, NASA Science Mission Directorate

Purpose described in 2014 NASA Science Plan

1. Discover planets around other stars
2. Characterize their properties
3. Identify candidates that could harbor life

ExEP serves the science community and NASA by implementing NASA's space science vision for exoplanets

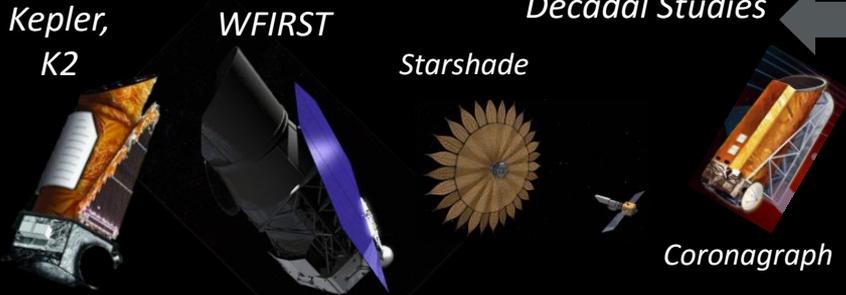
Exploring a galaxy of worlds while inspiring our own

<http://exoplanets.jpl.nasa.gov>

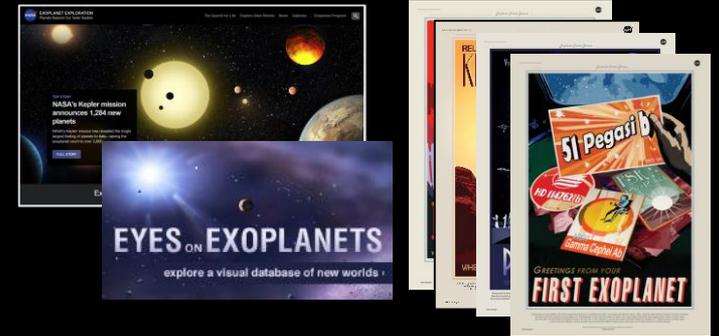


NASA Exoplanet Exploration Program

Space Missions and Mission Studies



Public Communications



Supporting Research & Technology

Key Sustaining Research



Large Binocular Telescope Interferometer

Keck Single Aperture Imaging and RV



NN-EXPLORE

Technology Development



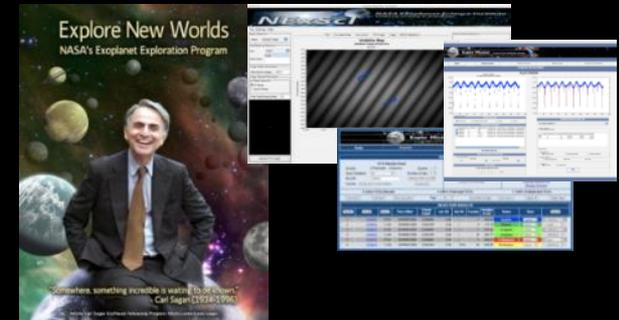
Coronagraph Masks

High-Contrast Imaging



Deployable Starshades

NASA Exoplanet Science Institute



Archives, Tools, Sagan Fellowships, Professional Engagement

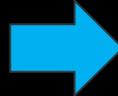
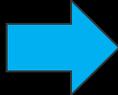
Starshade Developments since 2015

- **3 / 2015:** Final report from [Exo-S Probe-Scale Study](#). Developed concept for (34m) starshade standalone mission and introduced concept for [WFIRST Starshade Rendezvous](#) (34m)
- **1 / 2016:** Charter of the [Starshade Readiness Working Group](#)
- **2 / 2016:** Final Report of the [Exo-S Extended Study](#). Larger (40m) and smaller (26m) starshade sizes for WFIRST
- **3 / 2016:** [Starshade Technology Development Activity](#) created to deliver TRL5
- **4 / 2016:** [Decadal large mission studies](#) chartered: HabEx and LUVOIR considering starshades
- **6 / 2016:** APD directs WFIRST to assess impacts of [starshade accommodation](#)
- **12 / 2016:** First Starshade Technology community workshop
- **12 / 2016:** Interim starshade accommodation assessment by Project

Strategic Astrophysics Technology - TDEM

Reports for completed and active TDEMs: <https://exoplanets.nasa.gov/technology/>
Reviewed and approved by ExoTAC, Alan Boss (chair)

- TDEMs pending final reports (by year of ROSES call in December):
 - 2010
 - (Bierden) Environmental Testing of MEMs DMs
 - (Helmbrecht) Environmental Testing of MEMs DMs
 - 2012
 - (Kasdin) Optical and Mechanical Verification of External Occulter
 - 2013
 - (Bendek) Enhanced Direct Imaging with Astrometric Mass
 - (Cash) Development of Formation Flying Sensors
 - 2014
 - (Bolcar) Next Generation Visible Nulling
 - (Serabyn) Broadband Vector Vortex Coronagraph
 - 2015
 - (Breckinridge) Polarization in Coronagraphs

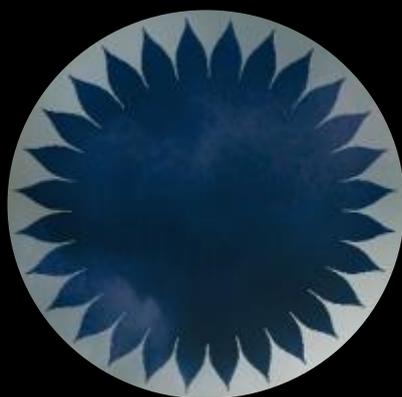


Starshade Technology – Plan Forward

- Plan in FY17, Execute during FY18-20
(conditional upon APD Director's authorization to proceed)
- Next steps:
 - Informed by the recent December workshop, recommend FY17 investments to APD Director
 - APD Director makes the decision
 - Present FY18-20 plan to APD Director by end of 2017

Session Presentations

- 2:00 PM Introduction to NASA Starshade Development Activities
 - ([Gary Blackwood](#), JPL)
- 2:10 PM Starshade-enabled Exoplanet Science for the 20s and 30s
 - ([Margaret Turnbull](#), SETI Institute)
- 2:30 PM The Engineering Strategy to Demonstrate Technical Readiness
 - ([Charley Noecker](#) and [Gary Blackwood](#), JPL)
- 3:00 PM Next Steps in Starshade Technology Development
 - ([John Ziemer](#), JPL)
- 3:20 PM Accommodation of Starshade Readiness on WFIRST
 - ([Dominic Benford](#), NASA HQ)





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