



Technology Selection and Prioritization Process for the ExEP 2018 Technology Gap List

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ExoPAG 16

Mountain View, CA

18 June 2017



Program Technology Updates Since Last ExoPAG

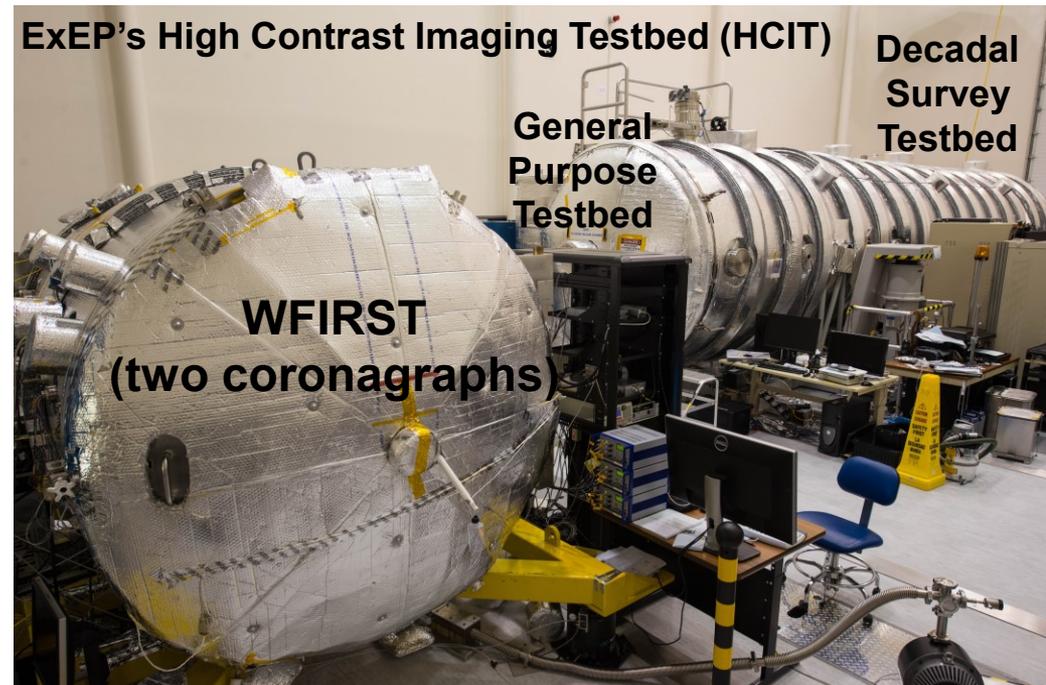


Exoplanet Exploration Program

1. TDEM update

<https://exoplanets.nasa.gov/exep/technology/TDEM-awards/>

- TDEM-15 Breckinridge: SOW developed and Milestone Whitepaper approved by ExoTAC
- TDEM-10 Bierden: MEMs DMs pre-environmental characterization completed and shipped for environmental testing at GSFC
- TDEM-14 Serabyn: Vector Coronagraph demonstration in HCIT starting in July (10^{-9} contrast goal at $3 \lambda/D$, 10% band with charge-4 and charge-6 masks)



2. Decadal Survey Testbed

- Program Office is upgrading one of the High-Contrast Imaging Testbeds to enable future users to perform coronagraph demonstrations at the 10^{-10} contrast level
 - Peer Review of testbed design and goals for Phase 1 conducted
 - 1st light for unobscured demo scheduled for Feb 2018, completion by end FY18
 - Phase II: Segmented on-axis demonstration scheduled to start in October 2018



Program Technology Updates Since Last ExoPAG



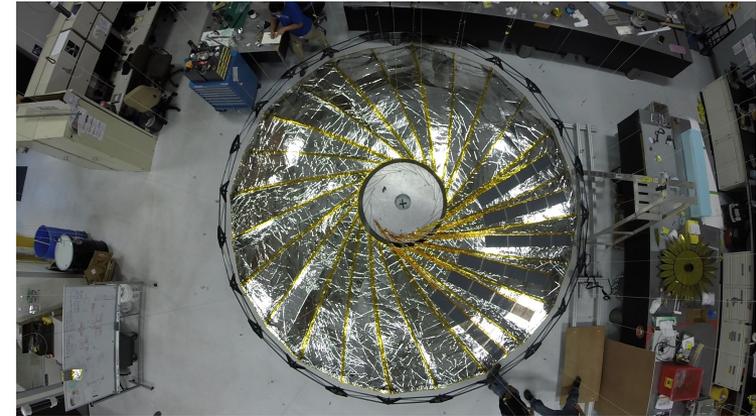
Exoplanet Exploration Program

3. TRL assessments for large mission STDTs

- Worked with other APD program offices and Aerospace to assess Technology Readiness Level (TRL) of technology needs of LUVOIR, HabEx, OST, and Lynx.

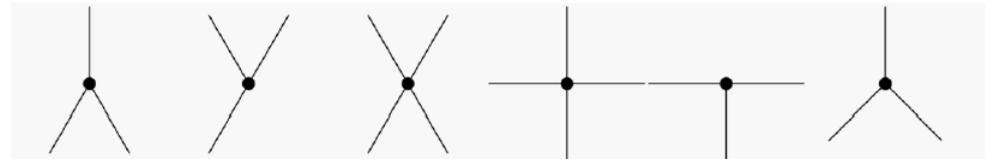
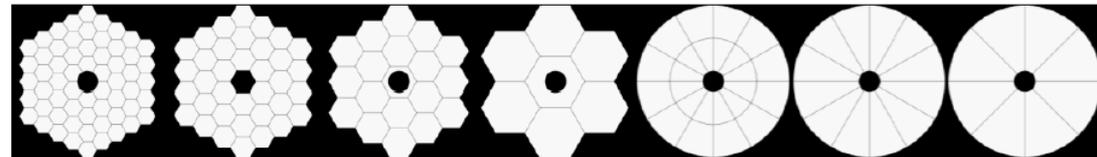
4. Starshade

- Paul Hertz directed the WFIRST mission to continue studying starshade compatibility
- Two workshops at JPL: Starshade Scattered Sunlight Control, Starshade Mechanical Architecture



5. Segmented Coronagraph Design & Analysis study

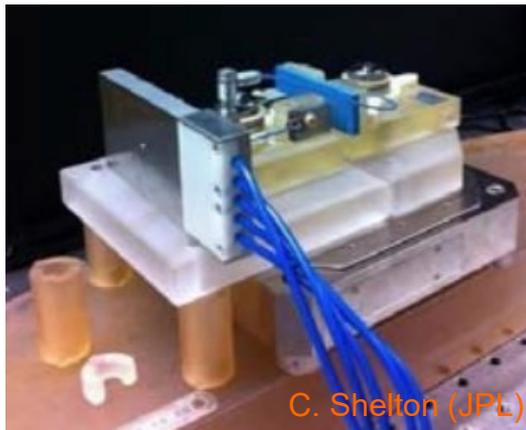
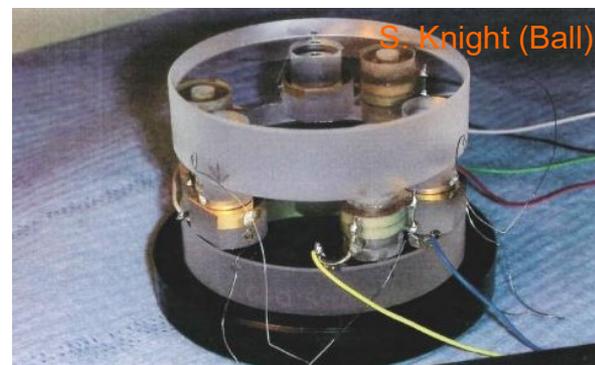
- APLC design is most successful so far with apertures under consideration;
- APLC robustness against design tolerances being evaluated; Vortex being optimized for finite star size and on-axis secondary; PIAACMC considered for longer-wavelength use.
- Next design round to include realistic errors (e.g. segment phase errors and SFE)



6. ExEP Technology Colloquium Series continues

https://exoplanets.nasa.gov/exep/technology/tech_colloquium/

- Mirror segment edge-sensing technology, colloidal microthrusters, MEMS DMs



7. Annual Technology Selection and Prioritization Process starts now!

Exoplanet

MISSIONS

First high-contrast coronagraph in space; starshade accommodation under study

JWST

WFIRST

TESS

PLATO

Kepler

CHEOPS

Gaia

New Worlds Telescope

NASA Jet Propulsion Laboratory
California Institute of Technology

EXOPLANET EXPLORATION PROGRAM Technology Plan Appendix 2017

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JPL Document No: 1513240

ESA/European
Missions

2020 Decadal Survey Mission Concept Studies

- ❖ Origins Space Telescope
- ❖ HabEx Imaging Mission
- ❖ LUVOR Surveyor
- ❖ Lynx

Probe Studies with Exoplanet focus

- ❖ WFIRST/Starshade Rendezvous (S. Seager)
- ❖ Radial Velocity Instrument (P. Plavchan)



Technology Gaps Selection Criteria



Exoplanet Exploration Program

- 1. Technology gaps considered for tracking and development by the ExEP must support APD exoplanet science missions as:**
 - defined by the needs of the 2010 Decadal Survey as described in the Astrophysics Implementation Plan;
 - directed through the Science Mission Directorate;
 - selected through open competition; or
 - described in the APD 30-year roadmap.

- 2. The subset of these gaps that enables or enhances exoplanet science are selected and prioritized onto the ExEP Technology Gap List**
 - Technologies that address these gaps are the ones prioritized for development and considered for resource allocation
 - The list is published in the annual Technology Plan Appendix
 - Some of these technologies may be funded outside of the ExEP



Technology Selection and Prioritization Process

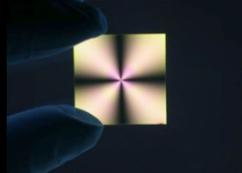


Exoplanet Exploration Program

ID	Activity	
1	Technology needs input window opens	06/18/17
	email ExoPAGannounce: Technology Gap Lists, input forms, process explanation	06/09/17
	presentation at June ExoPAG	06/18/17
2	Technology window closes	08/28/17
3	Technology Gap Selection and Prioritization Criteria Review by APD Program Offices	08/25/17
4	Selection and Prioritization Criteria Review by ExoTAC	09/05/17
5	Technology Gap Assessment Review by APD Program Offices	09/18/17
6	Technology Gap Assessment Review by ExoTAC	10/02/17
7	Technology Gap Lists inform TDEM Amendment	mid-Nov
8	Technology Amendment released through NSPIRES	mid-Dec
9	ExEP Technology Plan Appendix updated and released	12/01/17
	Presentation at January ExoPAG	01/06/18
10	TDEM Proposal Deadline	03/15/18
11	TDEM Awards Selected	Aug 2018

The Enabling Coronagraph/Telescope Technology Needs

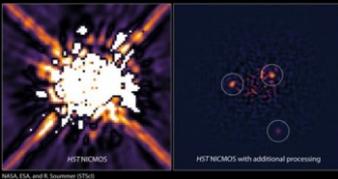
Contrast



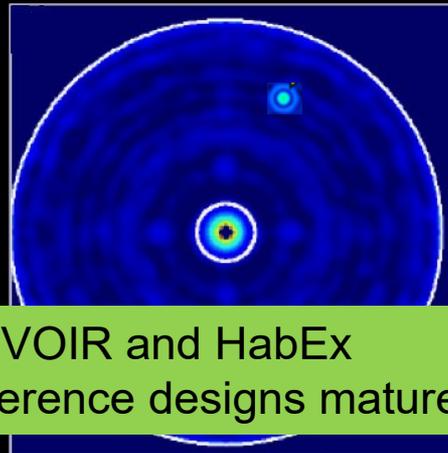
CG-2: Coronagraph Demonstrations and Modeling



CG-3: Deformable mirrors

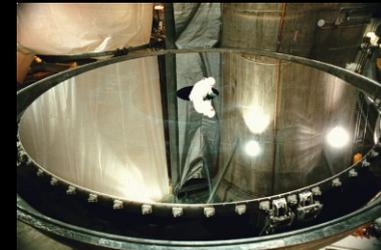


CG-4: Image post-processing



LUVOIR and HabEx reference designs mature

Angular Resolution



CG-1: Large monolith mirrors



CG-1: Segmented mirrors

Contrast Stability



WFIRST Milestone 9 achieved



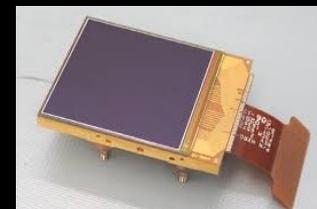
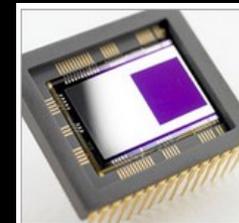
CG-5: Wavefront sensing and control



CG-7: Telescope vibration sensing and control

CG-6: Segment phasing and rigid body sensing and control

Detection Sensitivity



Ultra-low noise visible (CG-8) and infrared (CG-9) detectors

The Enhancing Coronagraph/Telescope Technology Needs

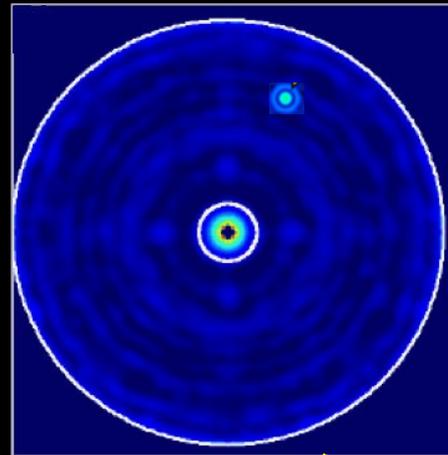
Contrast



CG-11 Mid Infrared Spectral Coronagraph



CG-10 UV/Vis/NIR mirror coatings

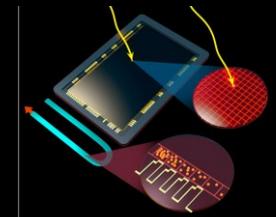


Mission Efficiency



M-1: Ultra-high precision Radial Velocity

Detection Sensitivity



Ultra-low noise UV detectors (CG-12)

Starshade Technology Needs

Starlight Suppression



S-1: Controlling Scattered Sunlight



Princeton optical demo reaches $3e-8$ contrast; work continues



S-2: Starlight Suppression and Model Validation

5 m optical shield prototype built and deployed

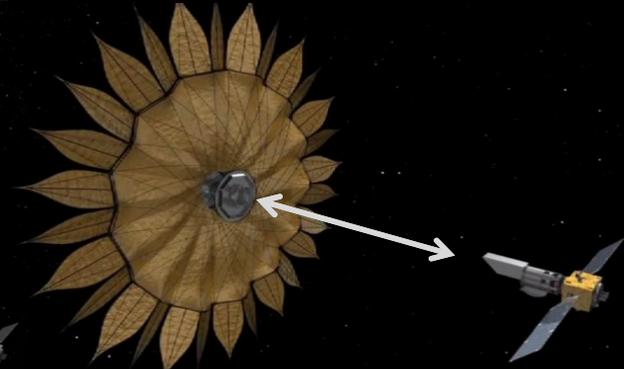


S-5: Petal Positioning Accuracy and Opaque Structure

Starshade Rendezvous Probe Study selected



Formation Sensing and Control



S-3: Lateral Formation Sensing

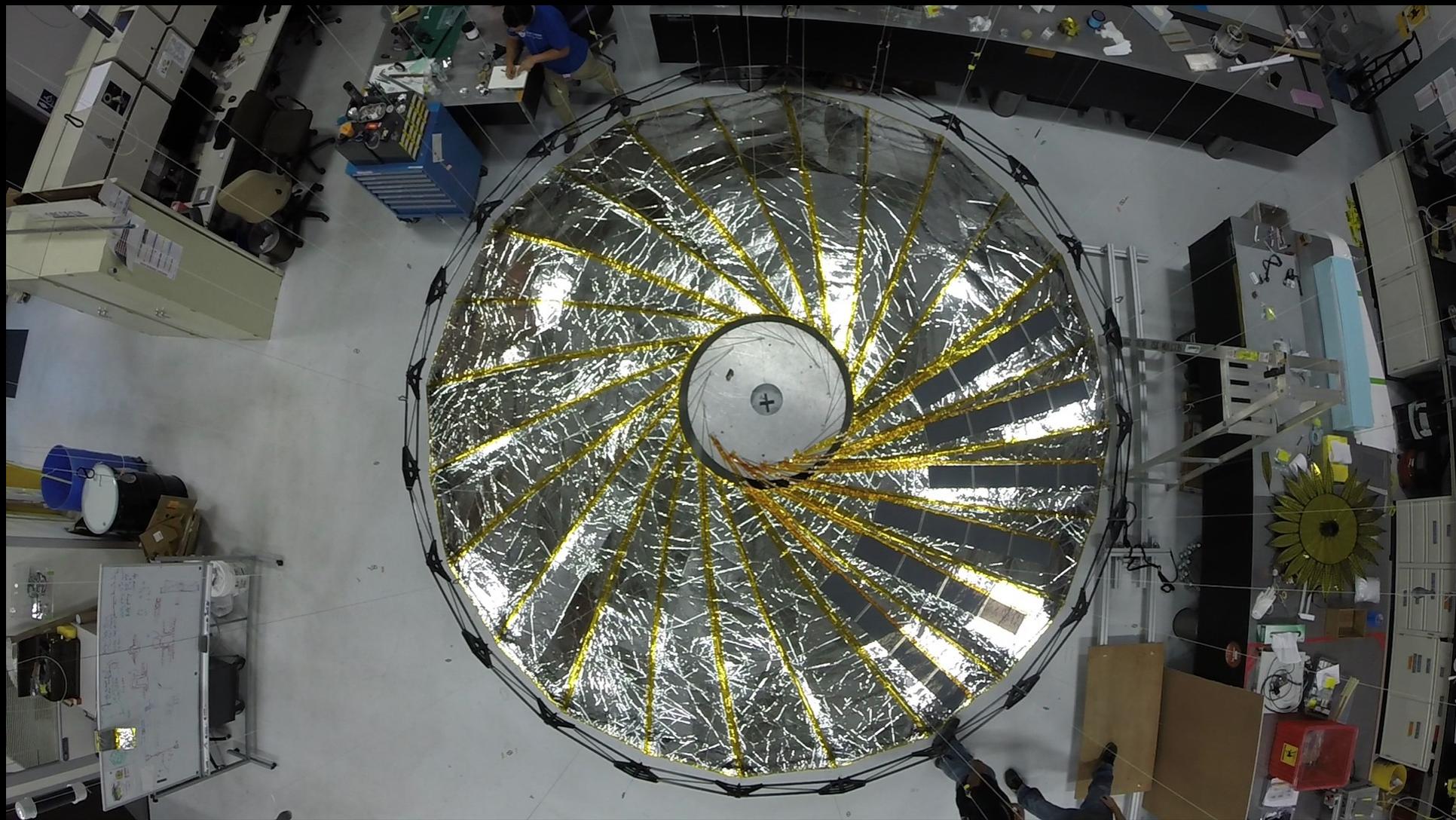
Deployment Accuracy and Shape Stability

SBIR-1 awarded to Tenedeg for deployment motor



NGAS studying alternative deployment approach

5m Starshade Optical Shield Prototype

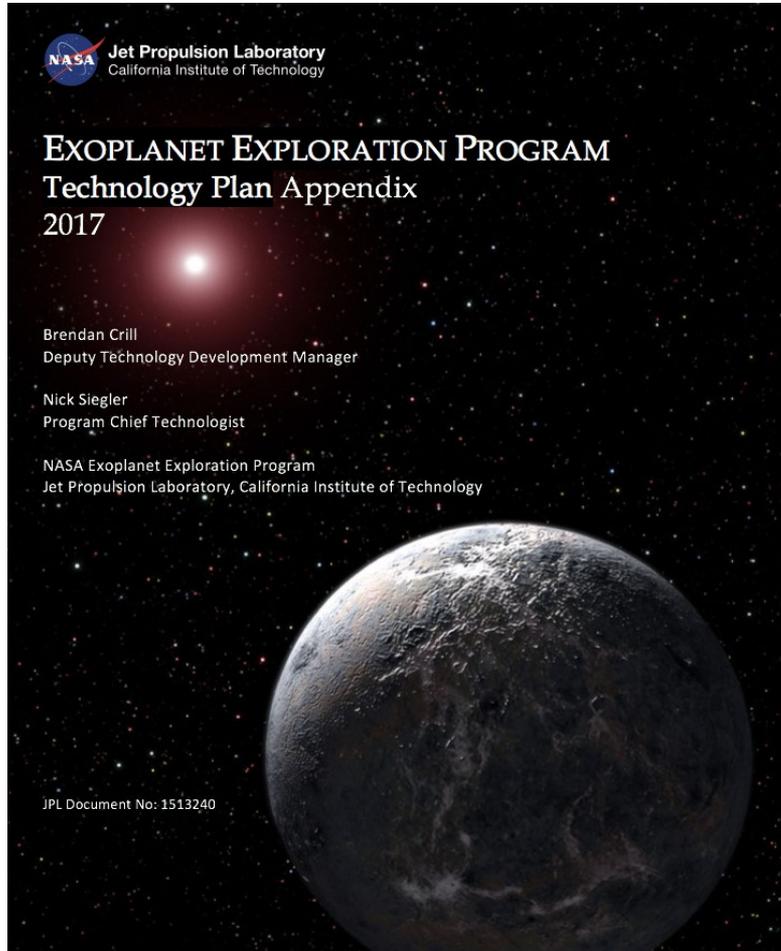




ExEP Technology Plan Appendix



Exoplanet Exploration Program



Next update: January 2018

Gap ID	Gap Title
S-2	Starlight Suppression and Model Validation
S-1	Control Edge-Scattered Sunlight
S-3	Lateral Formation Flying Sensing
S-4	Petal Shape
S-5	SS Deployment and Shape Stability
CG-1	Large Aperture Mirrors
CG-2	Coronagraph Architecture
CG-6	Mirror Figure / Segment Phasing, Sensing & Control
CG-7	Telescope Vibration Control
CG-9	NIR Ultra-Low Noise Detector
CG-3	Wavefront Sensing and Control
CG-5	Deformable Mirrors
CG-8	Visible Ultra-Low Noise Detector
M-1	Extreme Precision Radial Velocity
CG-4	Post-Data Processing
CG-10	UV/NIR/Vis mirror coatings
CG-11	Mid-IR Spectral Coronagraph
CG-12	UV Ultra-low noise detector

Enabling Technology

Enhancing Technology

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



Did we miss anything?



Additional Slides



2017 ExEP Technology Gap List



Exoplanet Exploration Program

Prioritized List

Gap ID	Gap Title	Impact	Urgency	Trend	Total
	Weight:	10	10	5	
S-2	Starlight Suppression and Model Validation	4	4	2	90
S-1	Control Edge-Scattered Sunlight	4	4	2	90
S-3	Lateral Formation Flying Sensing	4	4	2	90
S-4	Petal Shape	4	4	2	90
S-5	SS Deployment and Shape Stability	4	4	2	90
CG-1	Large Aperture Mirrors	4	3	3	85
CG-2	Coronagraph Architecture	4	3	3	85
CG-6	Mirror Figure / Segment Phasing, Sensing & Control	4	3	3	85
CG-7	Telescope Vibration Control	4	3	3	85
CG-9	NIR Ultra-Low Noise Detector	4	3	3	85
CG-3	Wavefront Sensing and Control	4	3	2	80
CG-5	Deformable Mirrors	4	3	2	80
CG-8	Visible Ultra-Low Noise Detector	4	3	2	80
M-1	Extreme Precision Radial Velocity	3	3	3	75
CG-4	Post-Data Processing	4	2	2	70
CG-10	UV/NIR/Vis mirror coatings	3	3	2	70
CG-11	Mid-IR Spectral Coronagraph	2	3	3	65
CG-12	UV Ultra-low noise detector	2	3	2	60

Enabling Technology
Enhancing Technology
Watch List

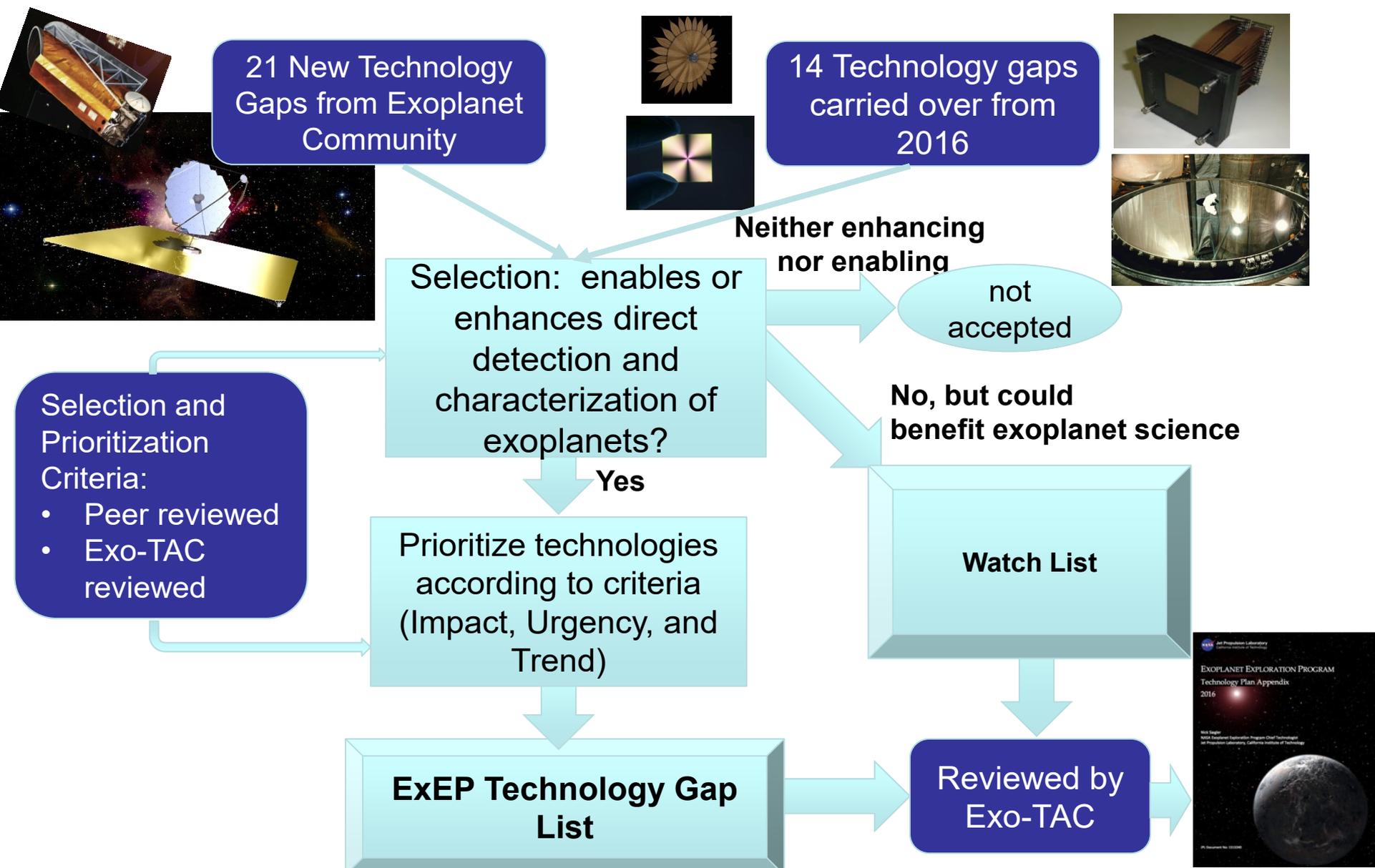
Watch List

Sub-Kelvin Coolers
Advanced Cryocooler
Mid-IR Ultra-low Noise Detector
Astrometry



Technology Selection and Prioritization Process

Exoplanet Exploration Program





2017 Prioritization Criteria



Exoplanet Exploration Program

Impact (weight: 10)	4: Critical technology - required to meet mission concept objectives; without this technology, applicable missions would not launch
	3: Highly desirable - not mission-critical, but provides major benefits in enhanced science capability, reduced critical resources need, and/or reduced mission risks; without it, missions may launch, but science or implementation would be compromised
	2: Desirable - not required for mission success, but offers significant science or implementation benefits; if technology is available, would almost certainly be implemented in missions
	1: Minor science impact or implementation improvements; if technology is available would be considered for implementation in missions

Urgency (weight: 10)	4: reduced risk needed for missions currently in pre-formulation or formulation.
	3: In time for the Decadal Survey (2019); not necessarily at some TRL but reduced risk by 2019.
	2: Earliest projected launch date < 15 yr (< 2030)
	1: Earliest projected launch date > 15 yr (> 2030)

Trend (weight: 5)	4: (a) no ongoing current efforts, or (b) little or no funding allocated
	3: (a) others are working towards it but little results or their performance goals are very far from the need, (b) funding unclear, or (c) time frame not clear
	2: (a) others are working towards it with encouraging results or their performance goals will fall short from the need, (b) funding may be unclear, or (c) time frame not clear
	1: (a) others are actively working towards it with encouraging results or their performance goals are close to need, (b) it's sufficiently funded, and (c) time frame clear and on time

Footnote: to be deemed “ready,” the technology is available to NASA at TRL 6 by the earliest possible Preliminary Design Review (PDR) of a mission; or at TRL 5 by the start of Phase A