NASA's Exoplanet Exploration Program (ExEP): Technology Selection, Prioritization, and Investment

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19 October 2017

Outline

Request:

The APAC requests a joint presentation from the three program Chief Technologists that addresses the strategic technology gaps in each subject area, the progress that is being made to close these gaps, and the chief impediments to closing these gaps in a timely manner.

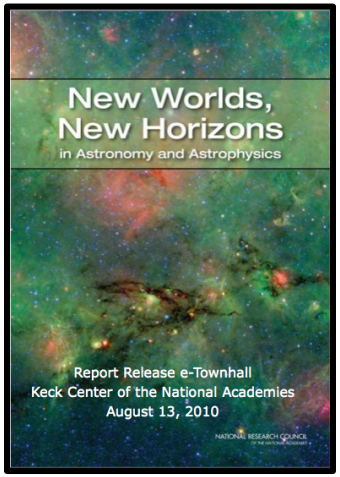
Outline:

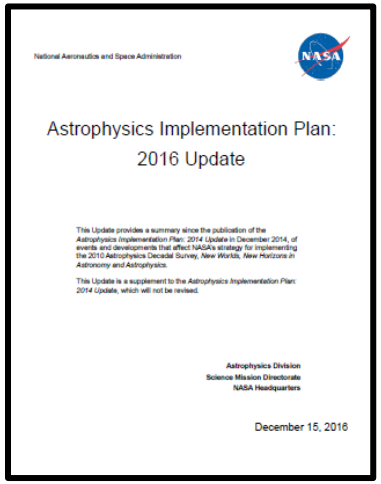
- **Overview of the Exoplanet Exploration Program's Technology Selection and Prioritization Process**
- **Investments in ExEP Technologies**

ExEP's Technology Focus

- **The driving ExEP science goals are to:**
  1. Discover planets around other stars
  2. Characterize their properties
  3. Identify candidates that could harbor life

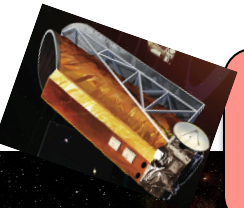
- **As recommended in the 2010 Astrophysics Decadal Survey and planned in NASA's Astrophysics Implementation Plan, the ExEP develops technologies that will enable the direct imaging and characterization of exoplanets in the habitable zone of Sun-like stars.**

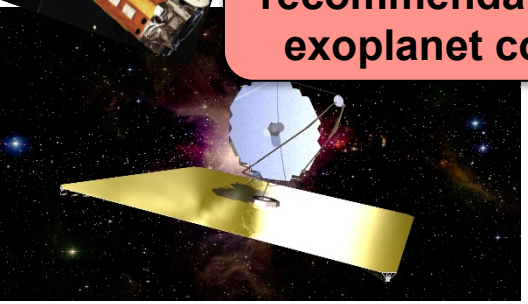


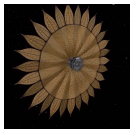


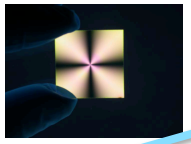
ExEP Technology Selection and Prioritization Process

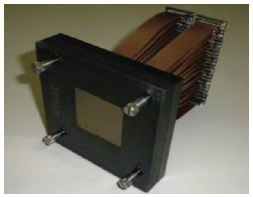
Exoplanet Exploration Program

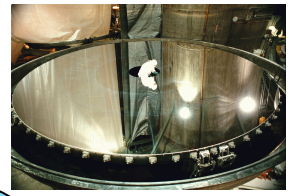












New technology recommendations from exoplanet community

Technologies carried over from previous year

Selection Criteria: Enables or enhances direct detection and/or characterization of exoplanets?

No

Not accepted

No, but could still benefit exoplanet science

Watch List

Yes

Accepted and Prioritized: (Impact, Urgency, and Trend)

Reviewed by (1) APD Program Offices and (2) Exo-TAC

Informs SAT/ TDEM Call

ExEP Technology List

Reviewed by Exo-TAC

Program Offices Coordination

- **COR/PCOS/ExE Program technologists coordinate during the prioritization cycle by reviewing each other's work and sitting on peer review boards.**

- **The three programs work together to determine which program is best suited to advance a particular technology**
  - For example, sometimes a technology submitted to COR is entirely driven by exoplanet science needs, and passed to ExEP

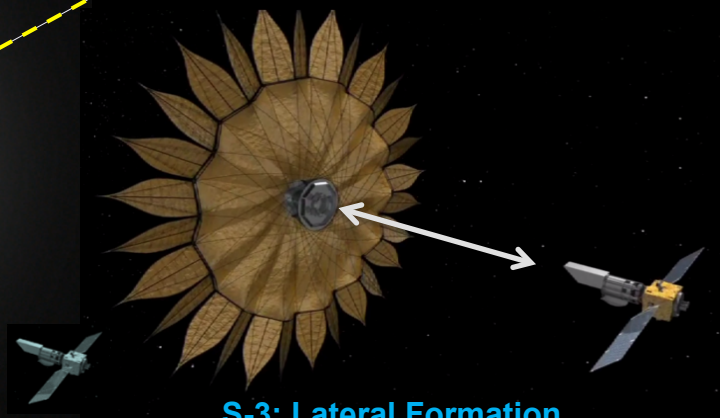
Starshade Technology Gaps

Starlight Suppression

S-1: Controlling Scattered Sunlight

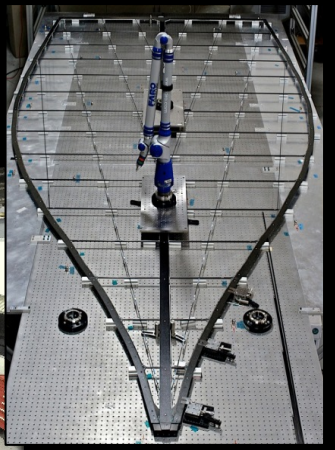
S-2: Starlight Suppression and Model Validation

Formation Flying



S-3: Lateral Formation Sensing

Deployment Accuracy and Shape Stability

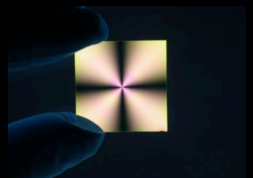


S-4: Petal Shape And Stability

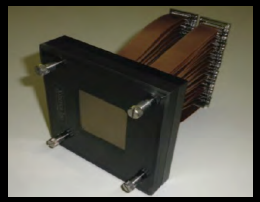
S-5: Petal Positioning Accuracy and Opaque Structure

V-NIR Coronagraph/Telescope Technology Gaps

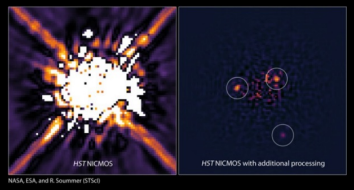
Contrast



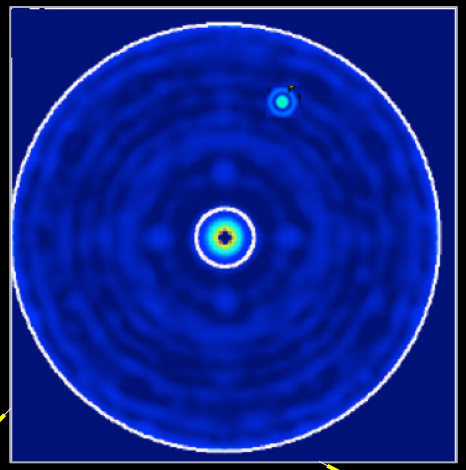
CG-2: Coronagraph Demonstrations and Modeling



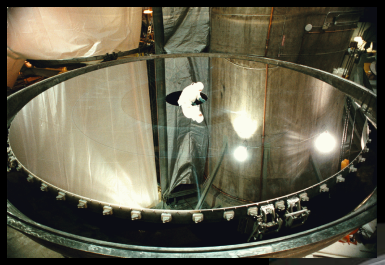
CG-3: Deformable mirrors



CG-4: Image post-processing



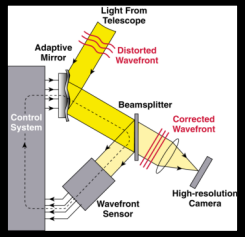
Angular Resolution



CG-1: Large monolith mirrors

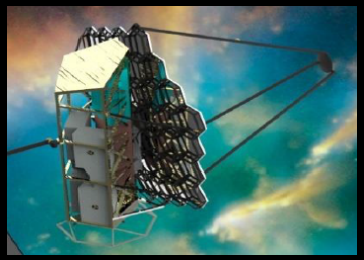
CG-1: Segmented mirrors

Contrast Stability



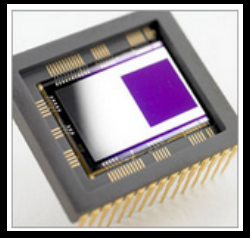
CG-5: Wavefront sensing and control

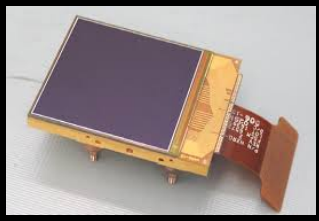
CG-6: Segment phasing and rigid body sensing and control



CG-7: Telescope vibration sensing and control

Detection Sensitivity





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

Investments in ExEP Technologies (2017)

Exoplanet Exploration Program

ID	Technology
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	Starshade Deployment and Shape Stability
CG-1	Large Aperture Mirrors
CG-2	Coronagraph Architecture
CG-6	Mirror Figure / Segment Phasing, Sensing and 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

✓ SAT / APRA

✓ directed

✓ mission or mission concept

funded to TRL 5 *

funded to TRL 5 * for some mission architectures

* for an exo-Earth imaging mission

Additional Slides

Technology Selection and Prioritization Process Schedule

ID	Activity	2017
1	Technology needs input window opens	June 1
	email ExoPAG announce: Technology Gap Lists, input forms, process explanation	
	presentation at June ExoPAG	
2	Technology window closes	Aug 30
3	Technology Selection and Prioritization Criteria Review by APD Program Offices	Aug 30
4	Selection and Prioritization Criteria Review by ExoTAC	Sep 15
5	Technology List Assessment Review by APD Program Offices	Sep 30
6	Technology List Assessment Review by ExoTAC	Oct 15
7	Technology Lists inform TDEM Amendment	mid-Nov
8	Technology Amendment released through NSPIRES	mid-Dec
9	ExEP Technology Plan Appendix updated and released	Dec 15
	Presentation at January ExoPAG	Jan 15
10	TDEM Proposal Deadline	Mar +1 yr
11	TDEM Awards Selected	Aug +1 yr

ExEP's Technology Prioritization Criteria

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

Technology Needs of Decadal Survey Concept Studies

Mission Concept	TRL 2 Gaps	TRL 3 Gaps	TRL 4+ Gaps	Total # Gaps	Gaps advanced by SAT/ directed
HabEx	0	6	6	12	12
LUVOIR	1	4	4	9	7
Lynx	1	3	1	5	4
OST (*)	1	1	3	5	2

- **HabEx Gaps:** mirror coatings, starshade starlight suppression, starshade controlling scattered sunlight, starshade lateral formation sensing, starshade petal position accuracy, starshade petal shape and stability, *telescope vibration control*, deformable mirrors, **visible detectors**, *large aperture primary mirror*, **wavefront sensing and control**, ***coronagraph optics and architecture***
- **LUVOIR Gaps:** closed-loop segment phasing, *vibration isolation*, ***wavefront sensing and control***, *mirror segments*, ***high-contrast segmented-aperture coronagraphy***, deformable mirrors, near Infrared detectors, **visible detectors**, mirror coatings
- **Lynx Gaps:** high-resolution lightweight X-ray optics, non-deforming X-ray reflecting coatings, megapixel X-ray imaging detectors, **large-format, high resolution X-ray detectors**, X-ray grating arrays
- **OST Gaps:** far-IR (FIR) detectors, cryogenic readouts for large-format FIR detectors, warm readout electronics for large-format FIR detectors, sub-K Coolers, cryogenic FIR mirror segments
  (*) note that OST's science case is developing and the distribution of TRLs may need updating

  - Green: technologies being advanced through SAT or directed development,
  - **Bold**: technologies being advanced by WFIRST or ATHENA
  - *Italics*: technologies being worked on through the STDT's design studies

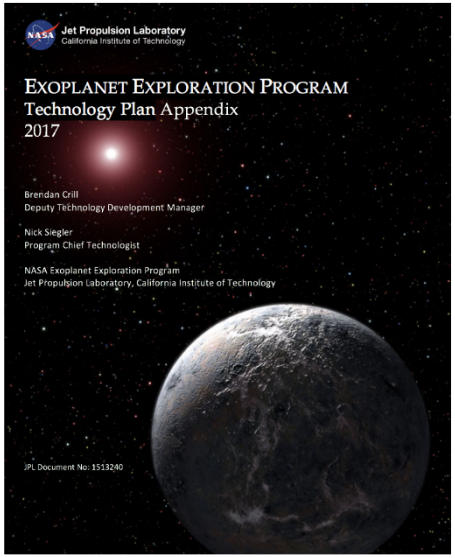
Investment Details in ExEP Technologies (2017)

S-2	Starlight Suppression and Model Validation	Starshade technology development activity
S-1	Control Edge-Scattered Sunlight	Starshade technology development activity
S-3	Lateral Formation Flying Sensing	Starshade technology development activity, WFIRST
S-4	Petal Shape	Starshade technology development activity
S-5	SS Deployment and Shape Stability	Starshade technology development activity
CG-1	Large Aperture Mirrors	SAT awards; HabEx/LUVOIR work, APD plans a telescope systems-level study, pending adequate appropriation
CG-2	Coronagraph Architecture	WFIRST. TDEM awards (Vortex,PIAACMC,HLC,polarization), ExEP's High Contrast Imaging Testbed & Decadal Survey Testbed
CG-6	Mirror Figure / Segment Phasing, Sensing & Control	HabEx/LUVOIR work; part of systems-level study
CG-7	Telescope Vibration Control	HabEx/LUVOIR work ; part of systems-level study
CG-9	NIR Ultra-Low Noise Detector	Solicited in SAT/TCOR-16, HabEx and LUVOIR are OK with SOA; APRA
CG-3	Wavefront Sensing and Control	WFIRST, HabEx/LUVOIR work
CG-5	Deformable Mirrors	WFIRST, TDEM
CG-8	Visible Ultra-Low Noise Detector	WFIRST
M-1	Extreme Precision Radial Velocity	NN-EXPLORE; ADAP, ATP opportunities for data analysis / stellar jitter theory
CG-4	Post-Data Processing	WFIRST
CG-10	UV/NIR/Vis mirror coatings	SAT/TCOR awards, part of systems-level study
CG-11	Mid-IR Spectral Coronagraph	To be split: 1. mid-IR detectors (SAT/TCOR), 2. cryogenic DMs, and 3. coronagraph architecture
CG-12	UV Ultra-low noise detector	SAT / TCOR awards

2017 Prioritized Technology List

Exoplanet Exploration Program

ID	Technology	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

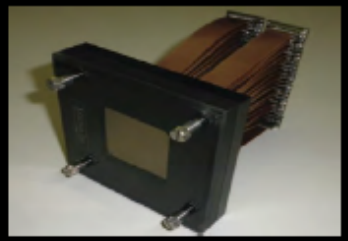


https://exoplanets.nasa.gov/exep/technology

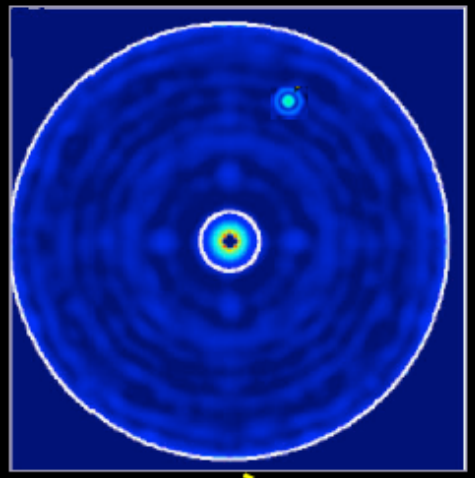
Mid-IR Coronagraph/Telescope Technology Gaps

Contrast

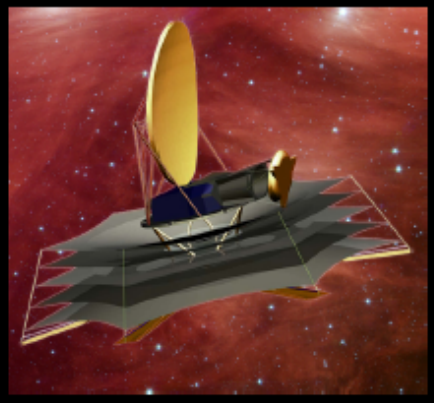
CG-15: Mid Infrared Coronagraph Optics and Architecture



CG-16: Cryogenic Deformable Mirror

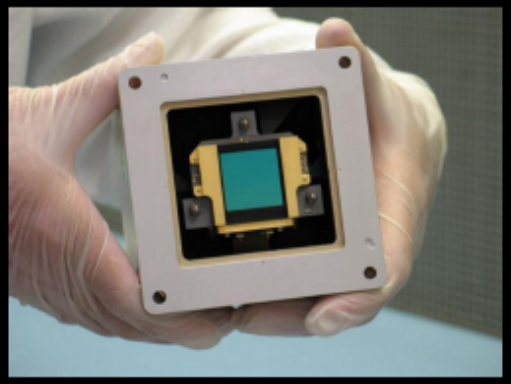


Angular Resolution



CG-14: Mid-IR Large Aperture Telescopes

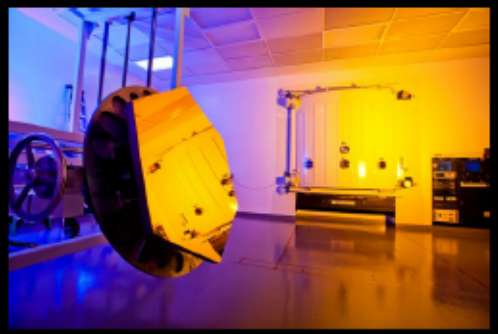
Detection Sensitivity



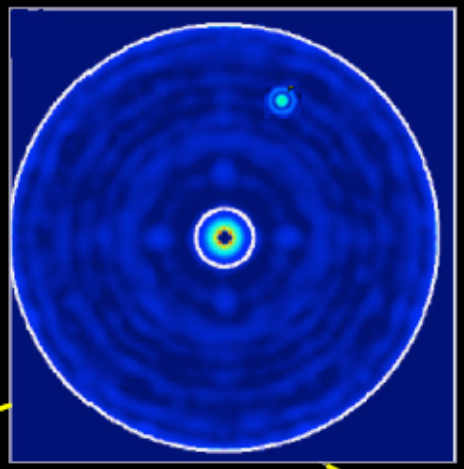
CG-13: Ultra-stable low noise Mid-IR detectors

Other Technology Gaps

Contrast



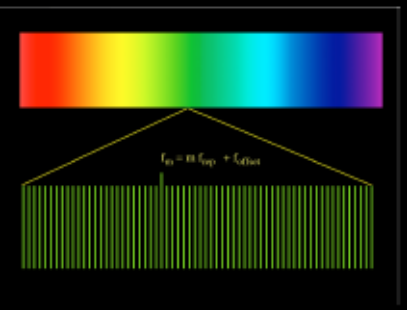
CG-10 UV/Vis/NIR mirror coatings



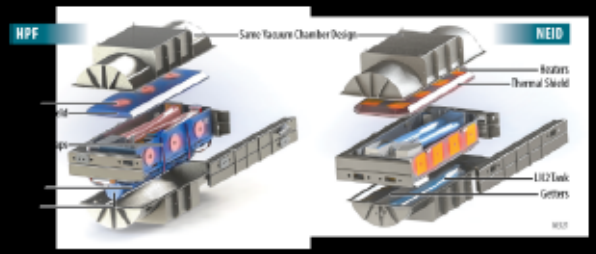
Tangential Stellar Motion Sensitivity

M-3: Astrometry

Radial Stellar Motion Sensitivity

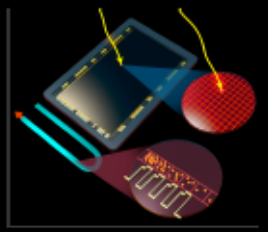


M-2: Laser Frequency Combs for Space-based EPRV



M-1: Ground-based Ultra-high precision Radial Velociity

Detection Sensitivity



CG-12: Ultra-low noise UV detectors