Exo-C coronagraph probe mission study

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Technology provides science opportunity

- Precisi
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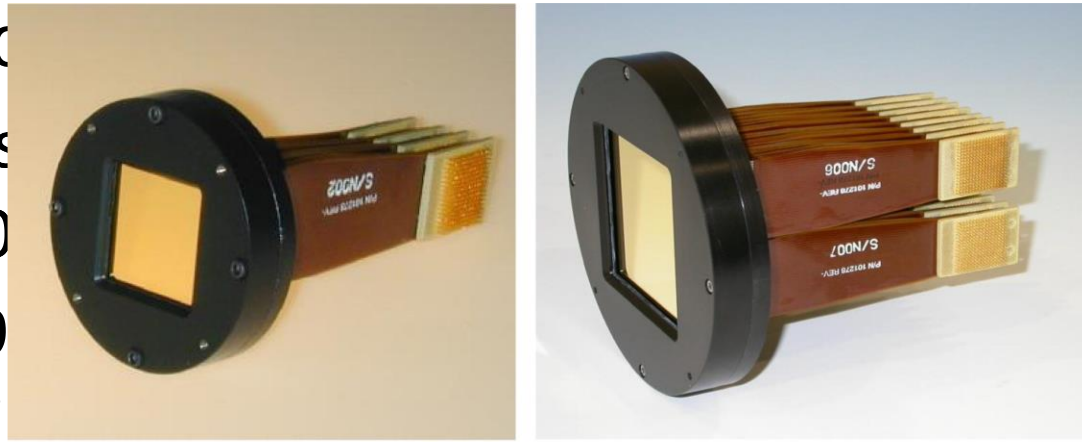
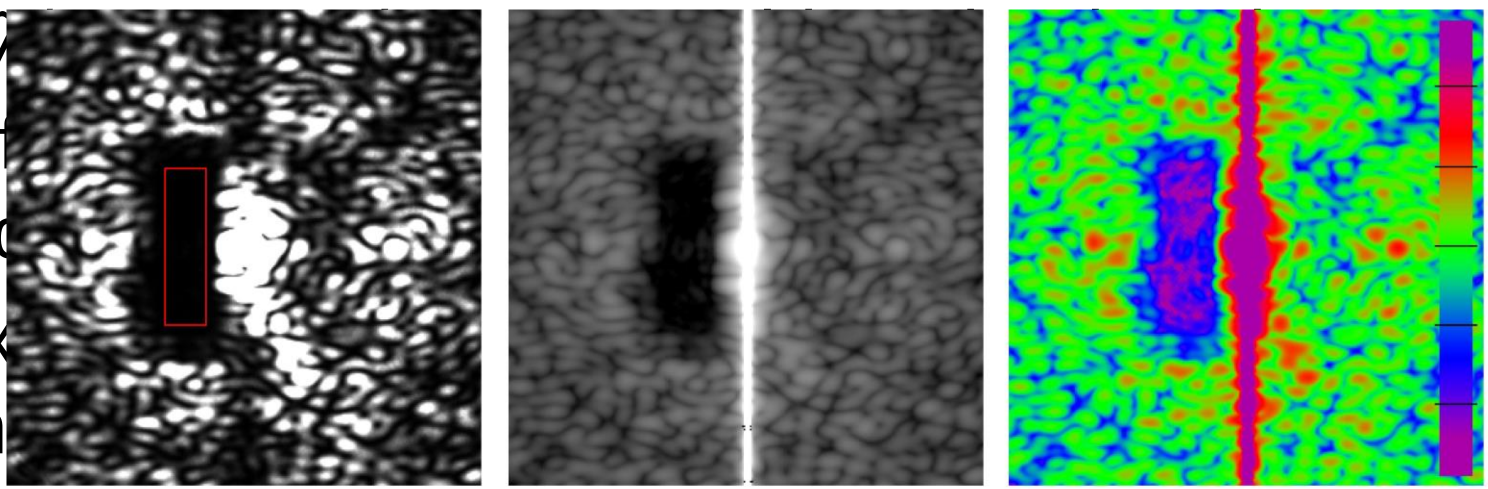
  - in 19 ecision and stabi



Single-module DM (32x32 mm, 1024 actuators)   Four-module DM (64x64 mm, 4096 actuators)

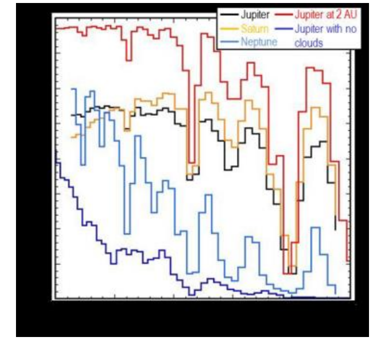
- Laboratory demonstrations of 10^{-9} contrast at 4 λ
- Ef te
- Ex im < $1B, technical readiness by 2017? APTA backup.

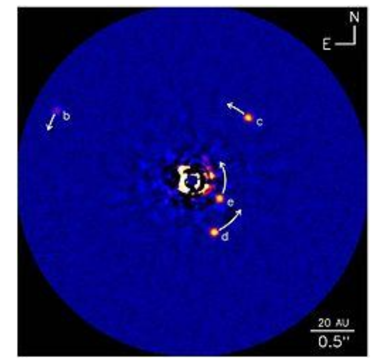


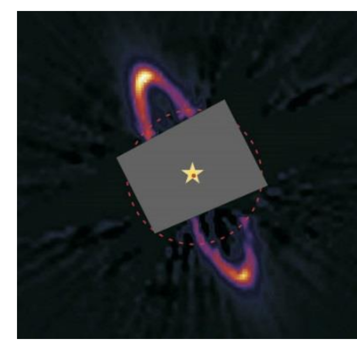
Coronagraph image (linear)   Coronagraph contrast (logarithmic)   Coronagraph contrast (color)

Science Opportunities for Exoplanet Probes

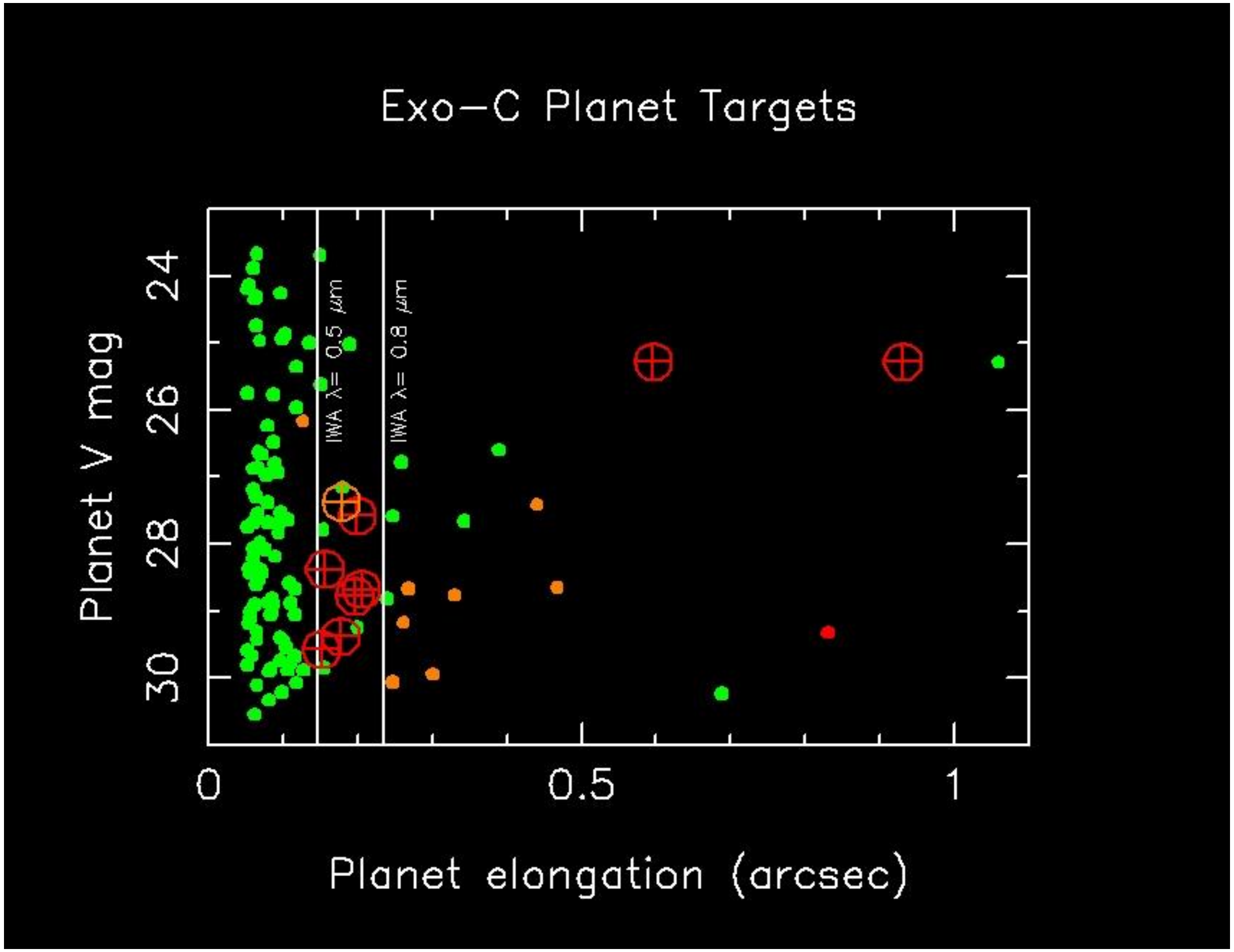
- Obtain optical spectra of nearest RV planets: Measure gas absorbers, fix planet mass.
- Search for planets beyond RV limits (Neptunes, super-Earths) in a nearby star sample. Measure orbits, do spectroscopy of the brightest ones
  - alpha Centauri system is a very important case
- Image circumstellar disks beyond HST, AO, and ALMA limits
  - Resolve structures driven by planetary perturbations, including dust in nearest habitable zones
  - Time evolution of disk structure & dust properties from protoplanetary to debris disks
- Probe a few systems for exo-Earths, if telescope stability and exozodi are favorable







Accessible exoplanet targets



Points are known RV planets

⊕ Earth analog in nearby star HZ

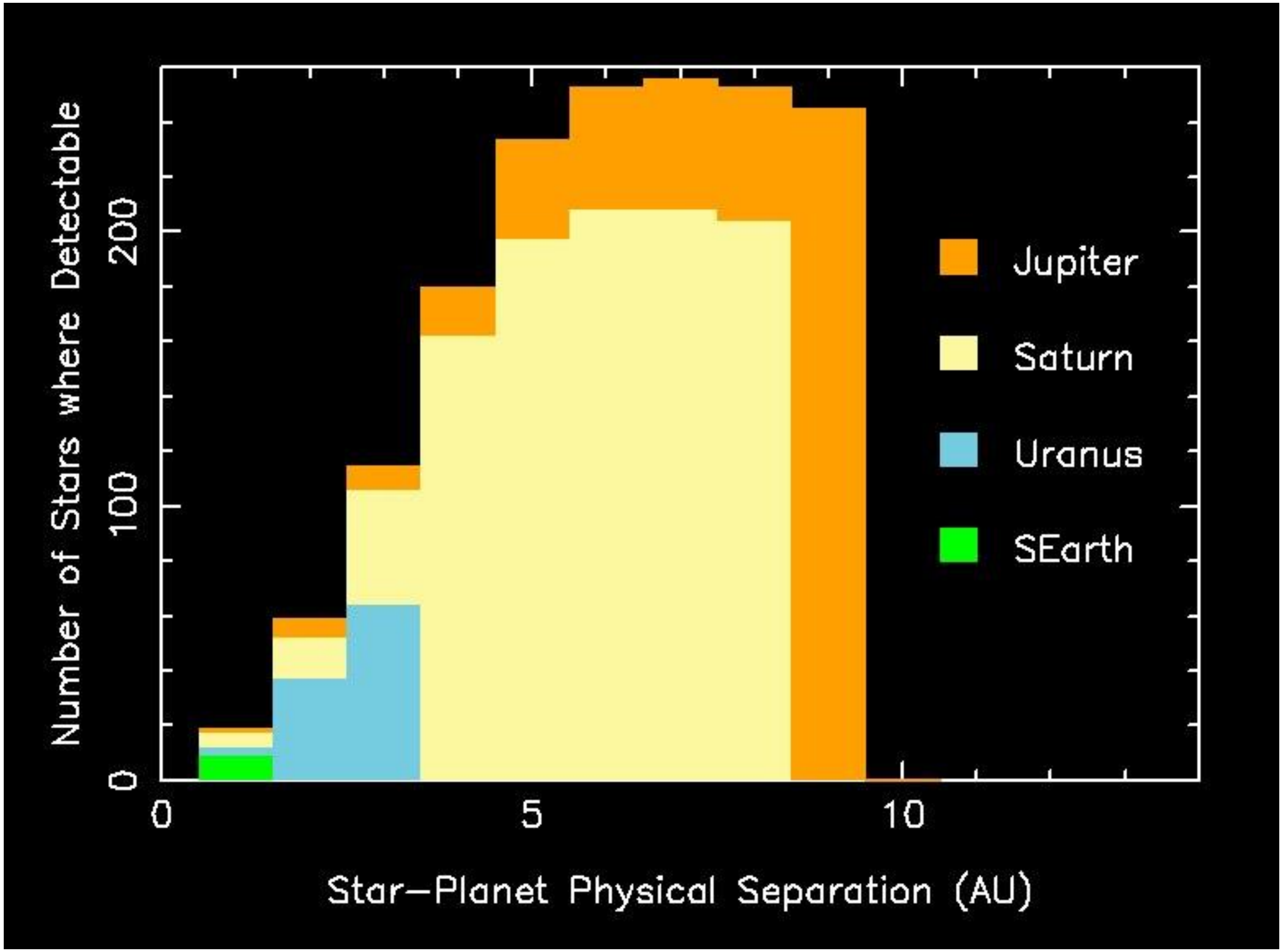
Contrast ≥ 1e-9

3e-10 ≤ Contrast < 1e-9

Contrast < 3e-10

Vertical lines show inner working angle for 1.5m telescope at 500 and 800 nm

Exo-C Planet Search Space



In V band filter in maximum of 10 days integration, 0.75 years total search time

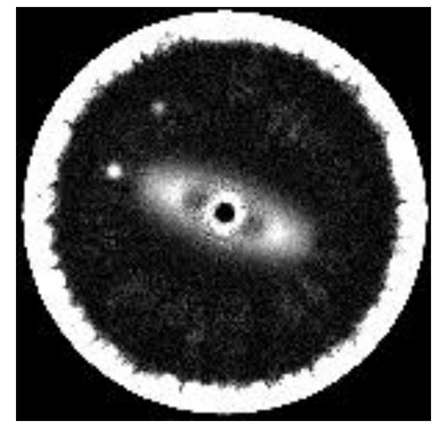
Current Working Science Requirements

Primary diameter	$\geq$ 1.3	m
Uncontrolled speckle contrast	1e-09	raw
Stability over 48 hours	1e-10	
Bandwidth	450-1000	nm
IWA = 2 λ/D @800 nm	0.22	arcsec
OWA ~22 λ/D @ 800 nm	2.8	arcsec
Stray light from binary companion	1e-9	@ 8 arcsec separation
Spectral resolution λ < 630 nm	R > 25	
Spectral resolution λ > 630 nm	R ~ 70	
Astrometric precision	< 30	milli-arcsec
Mission Life	3+	years

Preliminary DRM / expected science yield

- **Planet characterizations:**
  – Measure spectra of **~20** exoplanets
  – Measure multi-color photometry of an additional **~20** exoplanets
- **Planet discovery surveys:**
  – Survey **20** nearby stars for super-Earths in the HZ
  – Survey **140** nearby stars for giant planets
- **Disk Imaging Surveys:**
  – Deep search for disks in **60** RV planet systems
  – **60** known/resolved debris disks within 40 pc
  – **100** young debris disks from WISE
  – **80** protoplanetary disks in nearby molecular clouds

Below: Simulated 3 hr V band exposure of Altair: Jupiter & Saturn analogs detected, 1 zodi dust ring

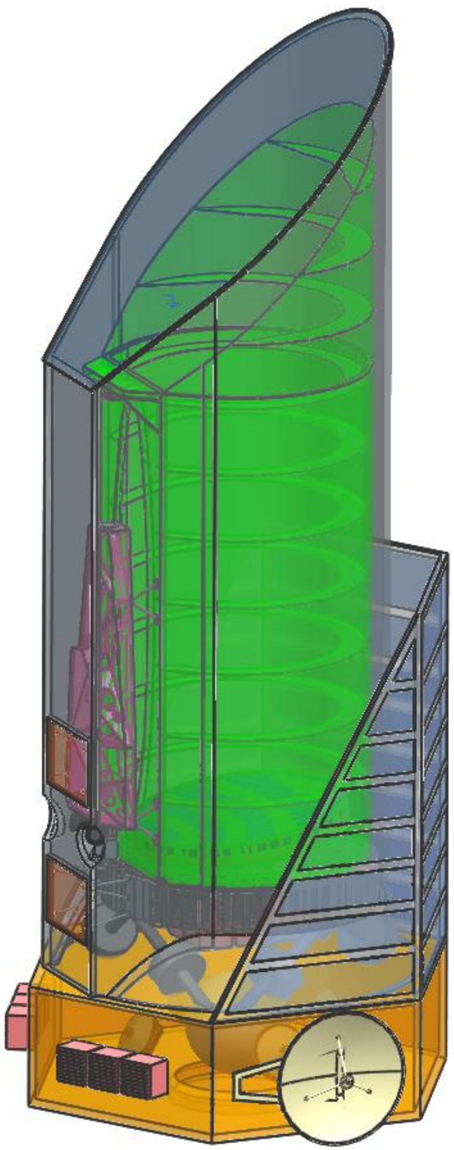


A wide range of science, containing characterizations and surveys

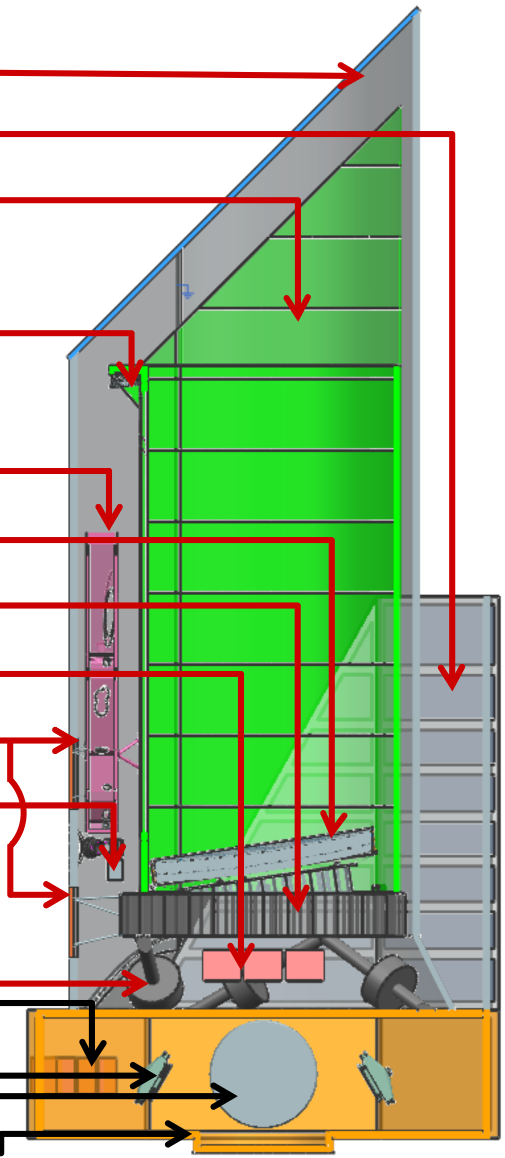
Baseline design at interim report

- Earth-trailing orbit
  - Good thermal stability & sky visibility, no propulsion needed
- Unobscured 1.5m Cassegrain telescope
  - Better throughput, resolution, stiffness, coronagraph technical readiness. Slightly higher cost
- Hybrid Lyot coronagraph; Vector Vortex and PIAA-CMC still under consideration as backup options
- Active thermal control of telescope & instrument
- Bright science target star is reference for precision pointing and compensation of low-order wavefront drifts
- ~900 kg payload , Kepler-like spacecraft bus, Falcon 9 class launch vehicle

Subsystem Description

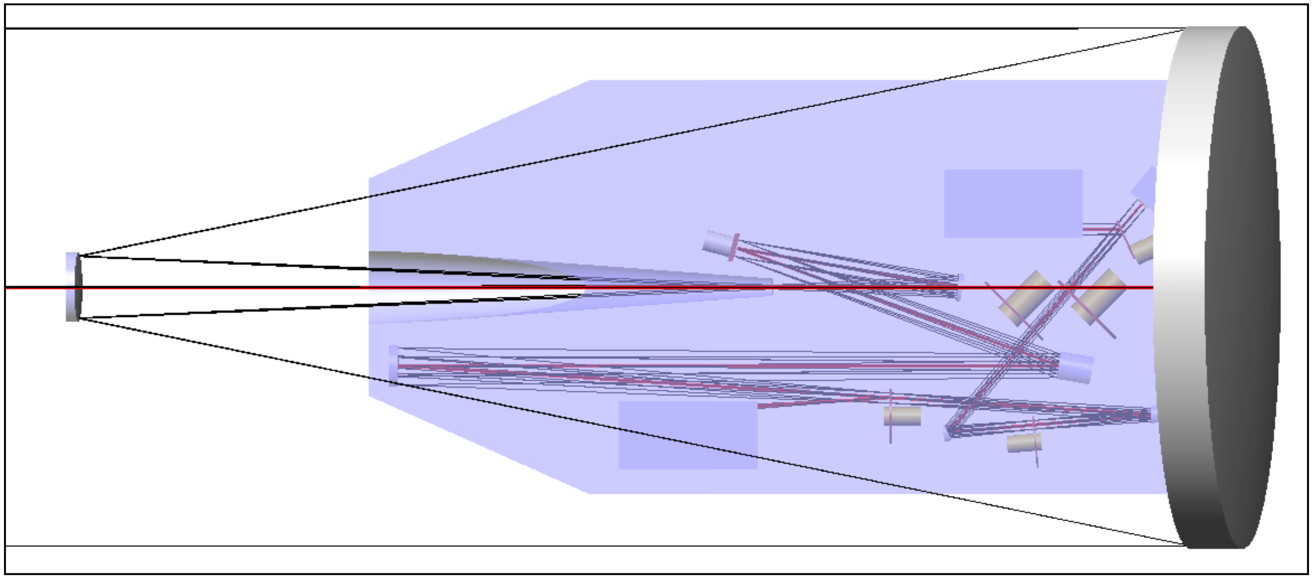


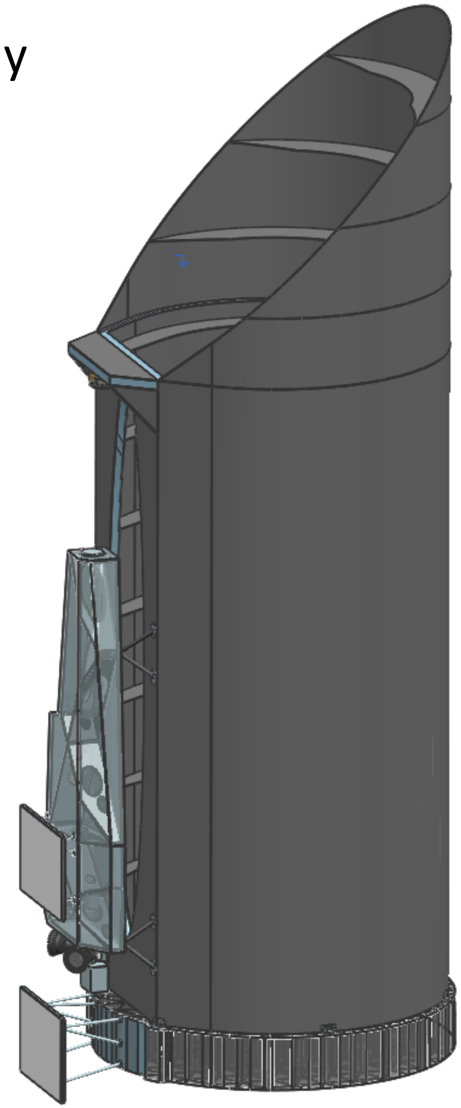
- Outer Barrel Assy
- Solar Array Assembly
- Inner Barrel Assy
- Secondary Mirror Assy
- Instrument Bench Assy
- Primary Mirror Assembly
- Primary Support Structure
- PL Avionics Assemblies
- Radiator Panel Assembly
- Star Tracker Assembly
- Isolation Assembly
- Spacecraft Assembly
  - SC Avionics Assy
  - Reaction Wheel Assy
  - Propulsion Assy
  - LV interface Ring Assy



Instrument Layout

- Lateral instrument configuration, side of Inner Barrel Assembly
- Imaging camera, integral field spectrograph, pointing/wavefront sensor(s)
- Wavefront control using two 48x48 Deformable Mirrors
- 1 kHz fine steering mirror keeps star centered on occulting spot to ~0.4 mas accuracy

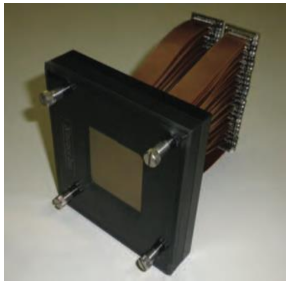




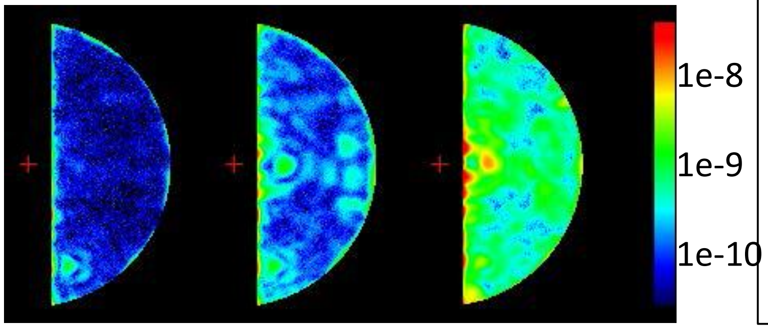
Path to 2017 technology readyness

- Exo-C technology is built on years of TPF & TDEM investments and is closely aligned with planned AFTA coronagraph investments and demonstrations.
- Exo-C bandwidth & contrast specs already met by Hybrid Lyot coronagraph; 2 λ/D inner working angle requirement met by PIAA & Vortex coronagraphs
- Need to demonstrate all the above in a single coronagraph in the presence of dynamic pointing & wavefront errors → Low-order wavefront control.

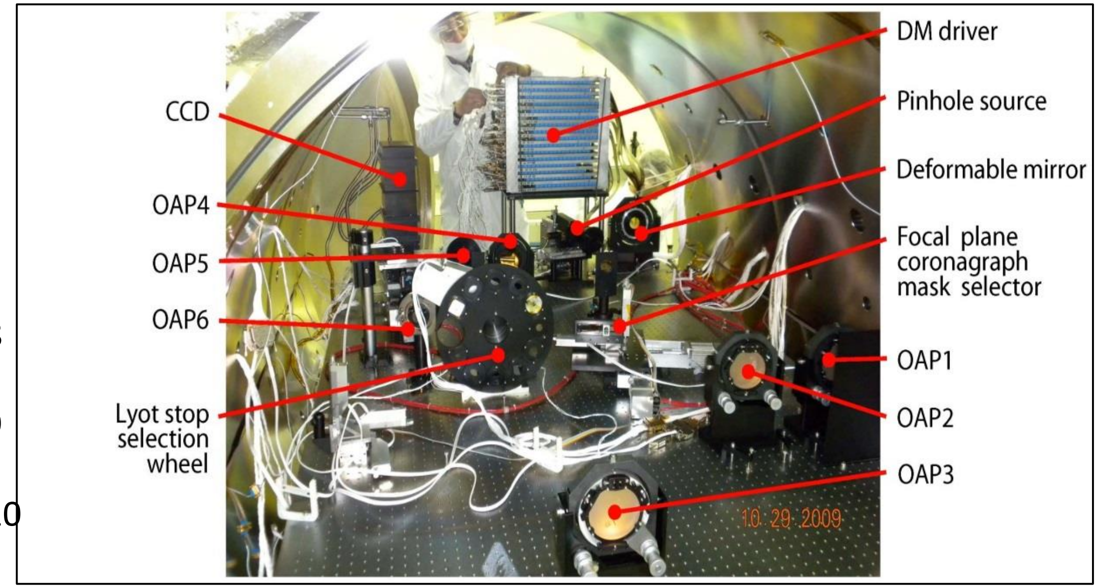
48x48 Xinetics deformable mirror has been shake tested



HCIT Lab contrast demonstration



JPL High Contrast Imaging Testbed



Interim study report http://exep.jpl.nasa.gov/stdt

Next steps

- Finalize coronagraph choice(s)
- Finalize dynamic stability assessment from modeling and Kepler experience
- Higher fidelity science modeling
- Continued design steps to reduce cost and risk. Fall costing iteration with Aerospace Corporation
- Final report January 2015
- Please see me here, or send suggestions for things we should look into or how you'd like to help: karl.r.stapelfeldt@nasa.gov