Jet Propulsion Laboratory
California Institute of Technology

WFIRST/AFTA Coronagraph Status Report -- SDT

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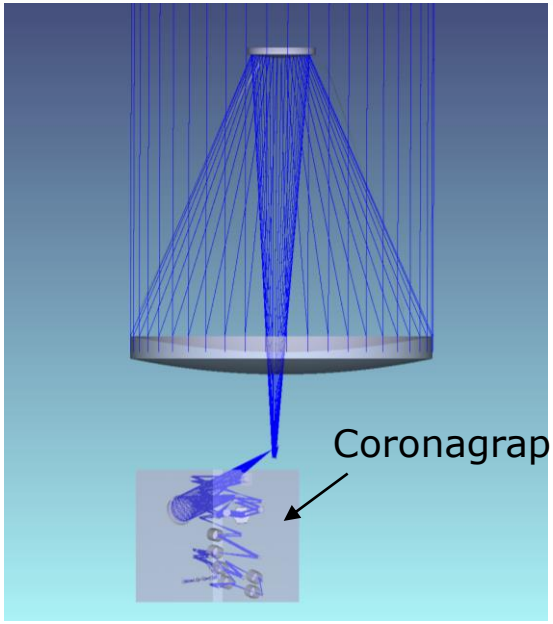
11/20/2014

Outline

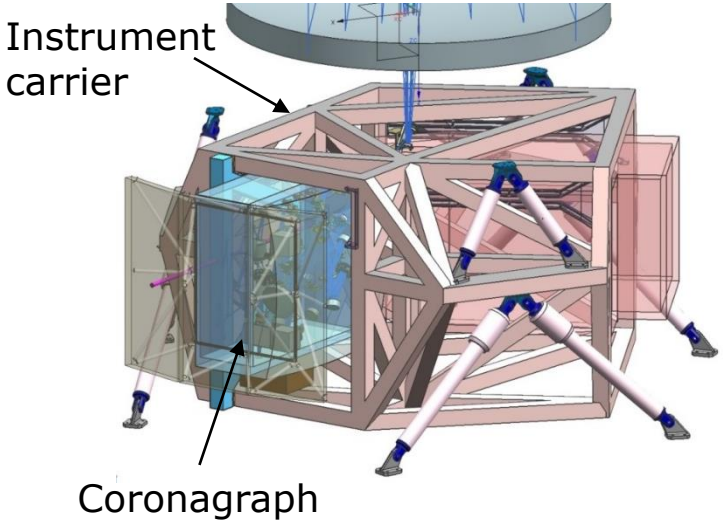
- Coronagraph design status (cycle #5)
- Instrument Simulations progress
- Technology development progress
- Next steps

Coronagraph Instrument Cycle #5

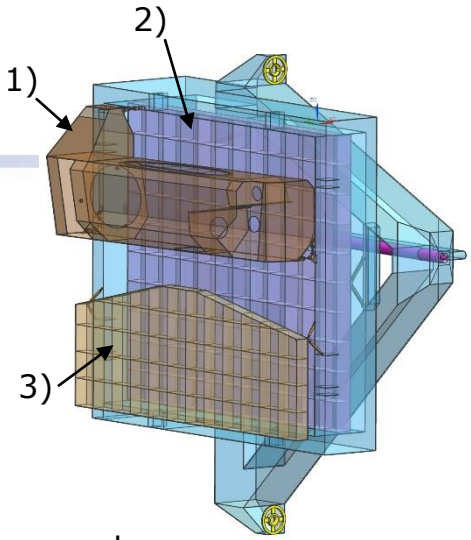
- Delivered Cycle #5 design, FEMs, etc to GSFC
- Major changes from last cycle: mechanical interface with a new “instrument carrier”



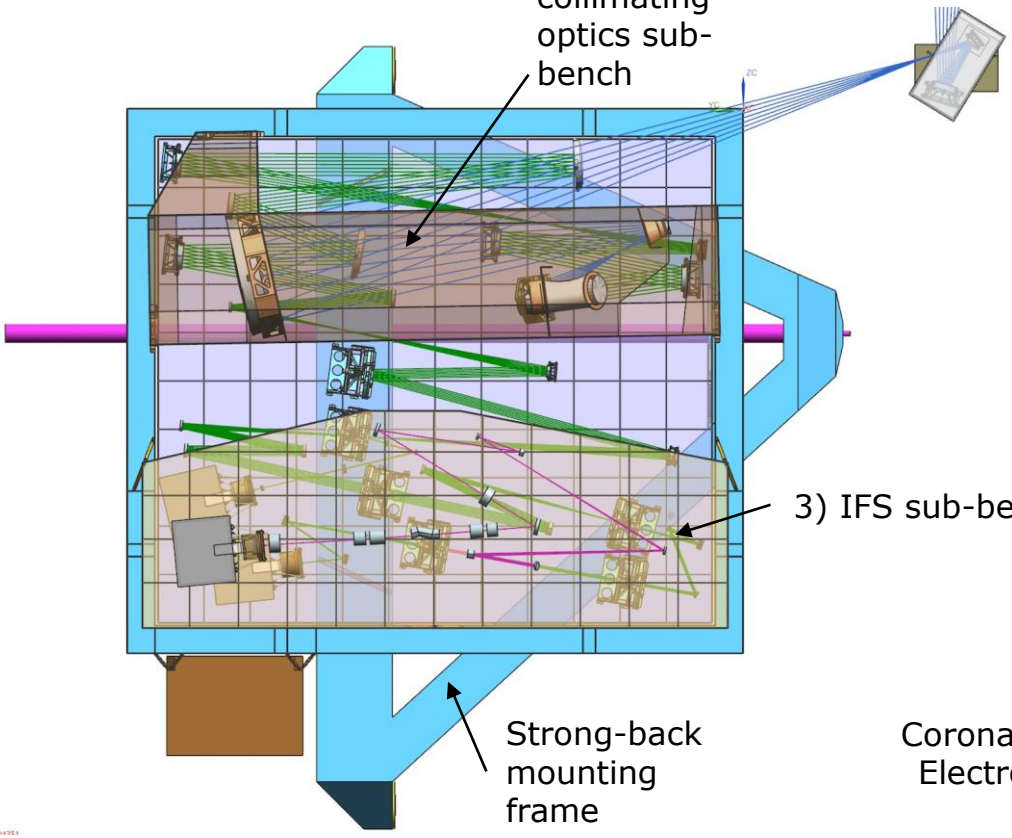
Mass (30% contingency)	**151kg**
Power (30% contingency)	**~218W**
Temperature	**20C for instrument**
Temperature	**~160k for focal plane arrays**
Data volume	**~30 Gbits/day**
Imaging	**0.4 – 1.0 microns,4.8" FoV 0.009" pixel scale, 1k×1k EMCCD. 10^{-9} contrast after PSF calibration, IWA: 0.1 arcsec, OWA: 2 arcsec. Polarization: Wollaston polarizer creating two images (p,s)**
Integral field spectrograph	**0.6 – 1.0 microns R~70, 1k×1k EMCCD**

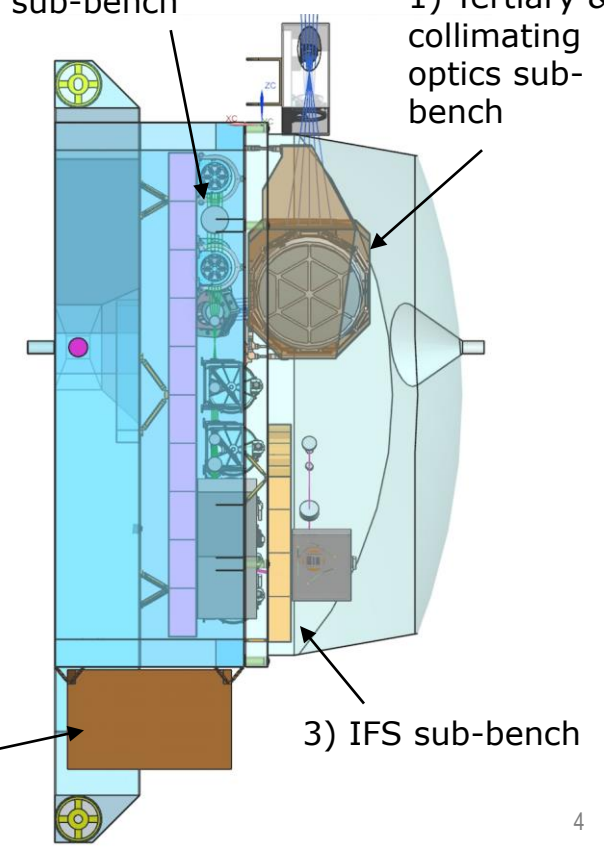


Cycle #5 Coronagraph Design



- Robotic assembly interface to instrument carrier
- Three sub-assemblies:
  1) Tertiary and collimating optics sub-bench
  2) Coronagraph sub-bench
  3) IFS sub-bench





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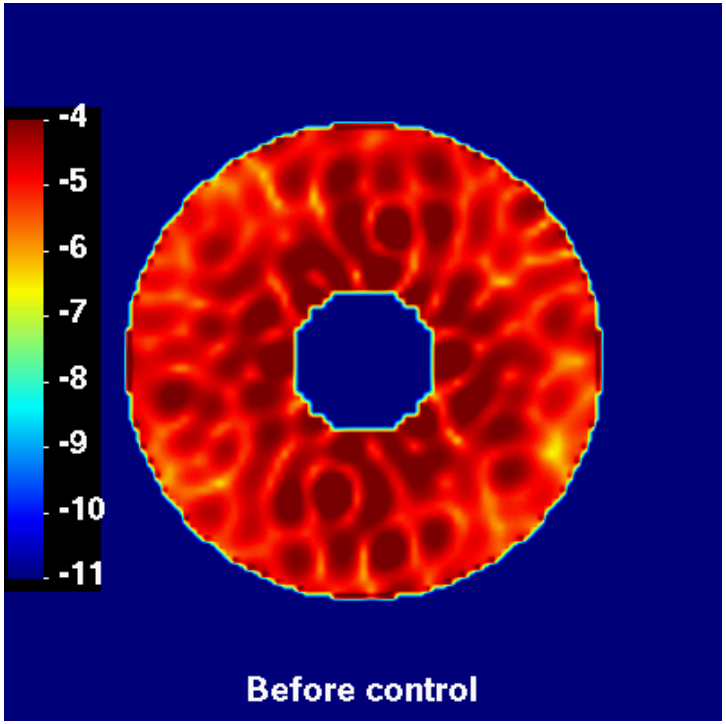
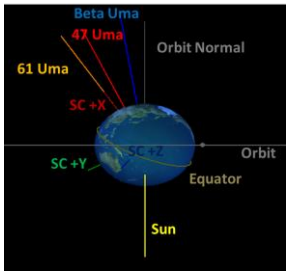
Creating Dark Holes

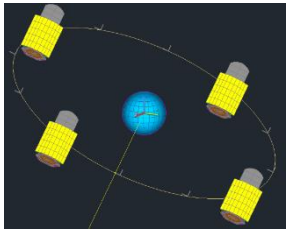
The coronagraph is inserted into a computer numerical model with realistic optical phase & amplitude errors and then wavefront control is used to control the deformable mirrors to create a dark hole around the star over a broad bandpass. Pointing jitter is added to the solution

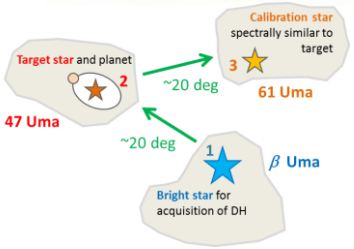


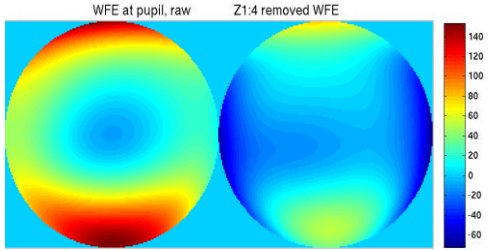
AFTA Hybrid Lyot Coronagraph λ = 760 – 840 nm

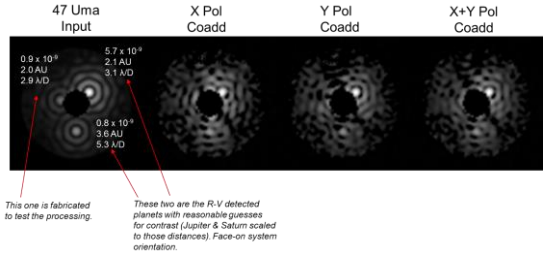
Integrated Modeling: Observing Scenarios – Case OS1



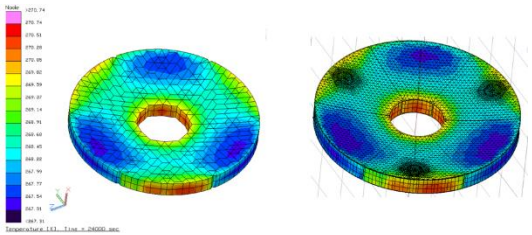






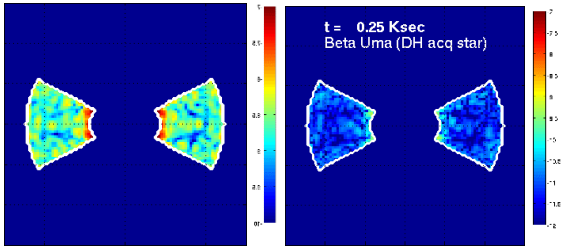


Scenario Defined → Thermal Loads → Structural Deformations → Ray Trace (Sig-Fit + Code V) → Exit Pupil WFE → DM Control (EFC) → Coronagraph (PROPER) → Images/Spectra



Raw speckle, S(t)

ΔSpeckle (rel. to nominal): S(t) – S(0)

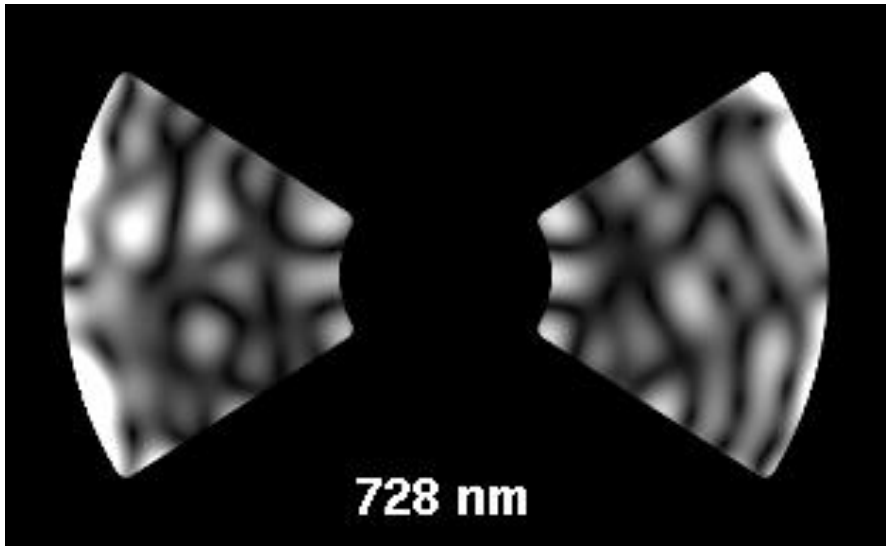


Typical Mean Contrast: ~5.3e-9

Typical Mean Δ Contrast: ~4.4e-11

AFTA Shaped Pupil Wavelength Variations

Post-EFC, 728 – 872 nm



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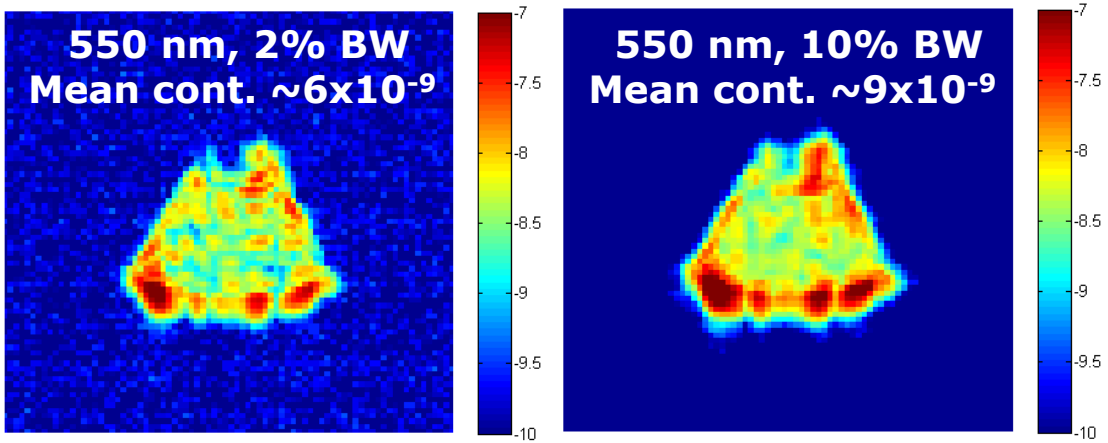
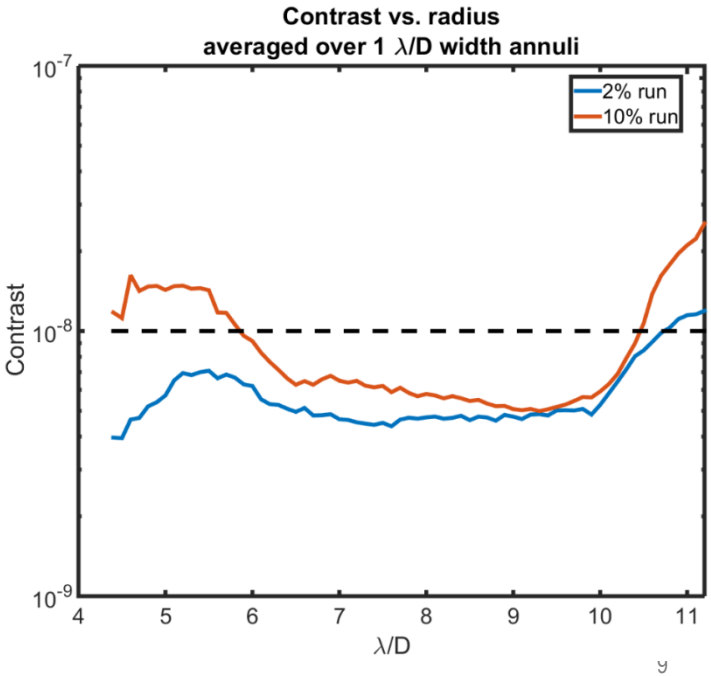
WFIRST-AFTA Coronagraph Key Milestones

MS #	Milestone	Date
1	First-generation reflective Shaped Pupil apodizing mask has been fabricated with black silicon specular reflectivity of less than 10^{-4} and 20 µm pixel size.	7/21/14
2	Shaped Pupil Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with narrowband light at 550 nm in a static environment.	9/30/14
3	First-generation PIAACMC focal plane phase mask with at least 12 concentric rings has been fabricated and characterized; results are consistent with model predictions of 10^{-8} raw contrast with 10% broadband light centered at 550 nm.	12/15/14
4	Hybrid Lyot Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with narrowband light at 550 nm in a static environment.	2/28/15
5	Occulting Mask Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a static environment.	9/15/15
6	Low Order Wavefront Sensing and Control subsystem provides pointing jitter sensing better than 0.4 mas and meets pointing and low order wavefront drift control requirements.	9/30/15
7	Spectrograph detector and read-out electronics are demonstrated to have dark current less than 0.001 e/pix/s and read noise less than 1 e/pix/frame.	8/25/16
8	PIAACMC coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a static environment; contrast sensitivity to pointing and focus is characterized.	9/30/16
9	Occulting Mask Coronagraph in the High Contrast Imaging Testbed demonstrates 10^{-8} raw contrast with 10% broadband light centered at 550 nm in a simulated dynamic environment.	9/30/16

Milestone 2: SPC Testbed Demonstration

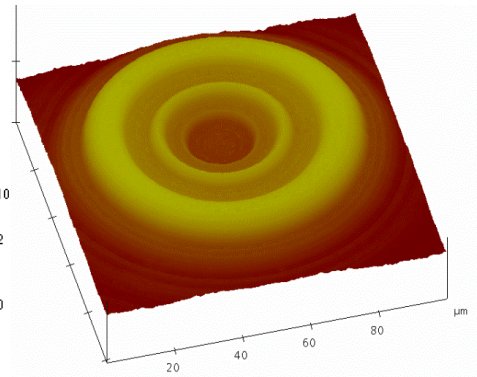
- Obtained narrowband (2% BW) and early broadband (10% BW) high-contrast starlight suppression results for the shaped pupil coronagraph
  - Operating with 1 DM, stopped down to 48x48 actuators
- Milestone 2 results submitted to TAC on 9/17/2014, approved during review on 10/8/2014
- The broadband result meets Milestone 5 success criterion 12 months early
- Switch to 2 32x32 DMs in November
- Switch to Gen 2 / SPLC on static testbed in February

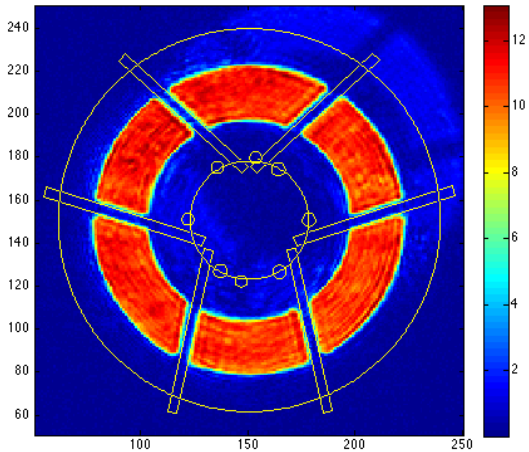


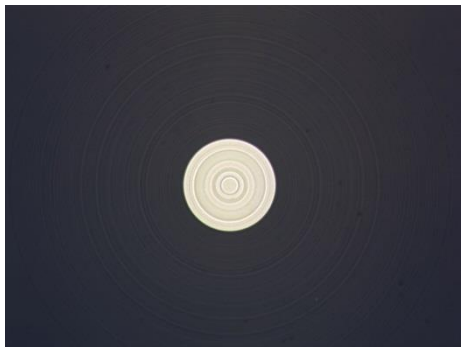


Hybrid Lyot Status

- **Circular HLC mask successfully fabricated**
  - Characterized with AFM, Wyko
  - Modeling of mask imperfections predicts good results
- HLC testbed has been aligned and calibrated in a vacuum chamber
- First time working with 2 new 48x48 DMs and Gen 5 electronics
  - Had teething problems with DM elex, resolved them successfully last week
- **Second HLC nulling run to start later this week or early next week**
- Milestone 4 (narrowband contrast) in Feb 2015







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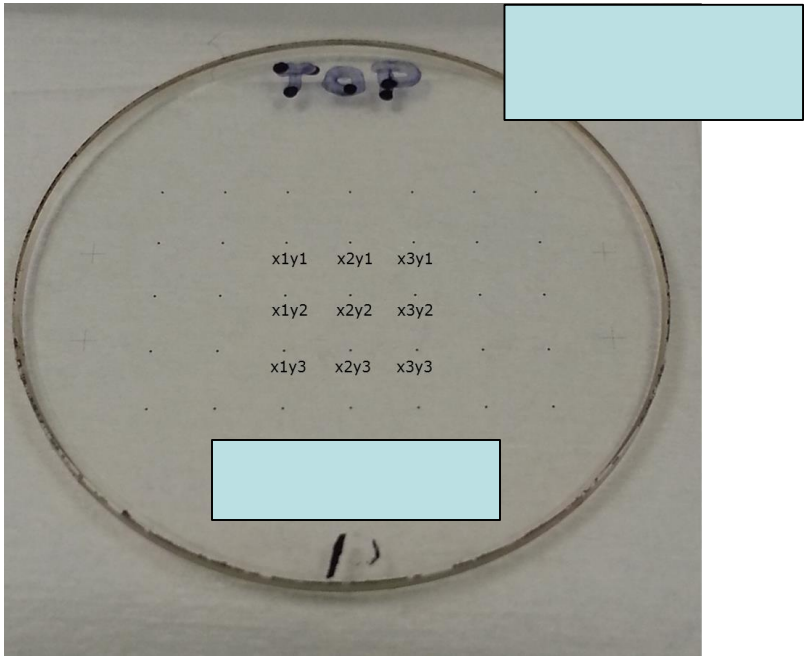
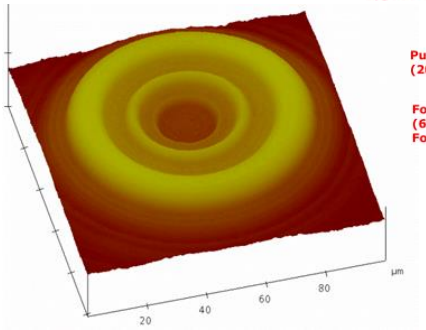
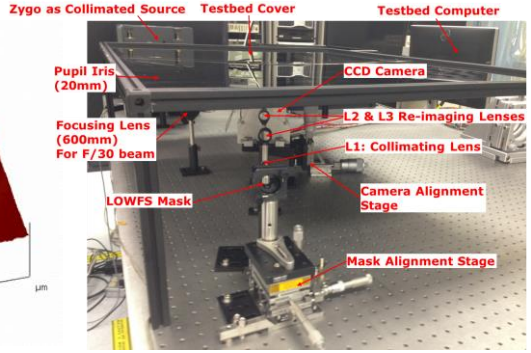
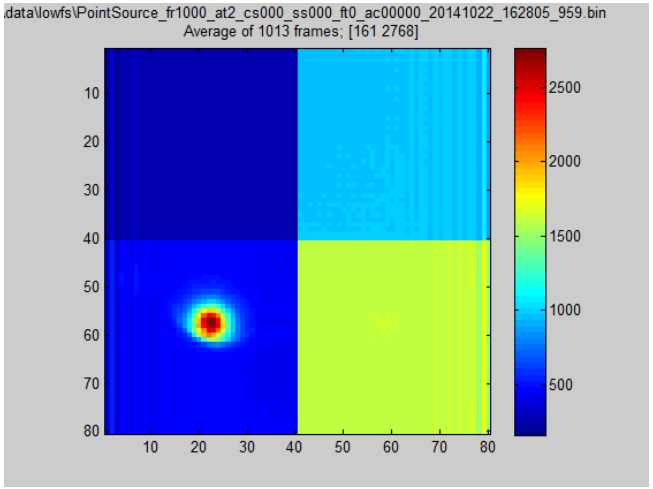
Low Order Wavefront Sensing / Control

- **Zernike WFS selected for the dynamic testbed demo**
  - Zernike phase dimple on HLC and SPC focal plane masks
  - Rejected star-light for (1) fast tip/tilt, (2) slow Z4-Z11 measurements
  - LOWFS testbed just received HLC/LOWFS mask, saw first light @1kHz









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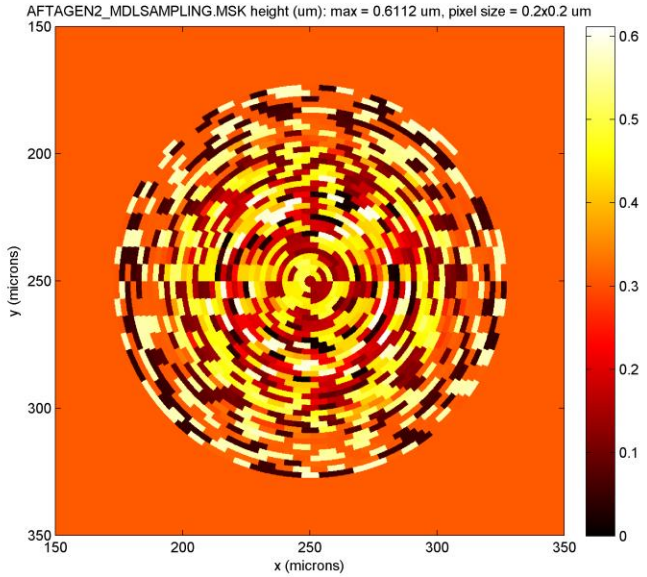
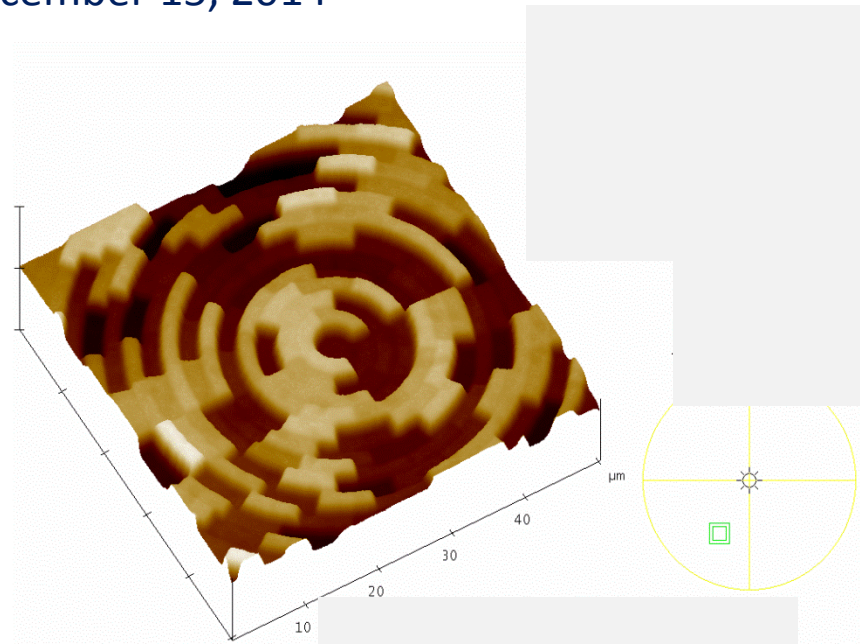
PIAA-CMC (Backup) Status

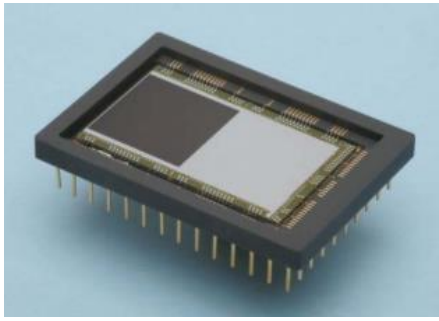
- PIAACMC team delivered new (Gen 2) design on 7/21/2014
  - 1 DM, simplified optical layout
  - New mask design, rings divided into many azimuthal zones
  - Sensitivity to jitter performance is the main design weakness
    - Olivier Guyon working on a Gen 3 design with improved jitter sensitivity
- Two iterations of Gen 2 reflective PIAA mask made at MDL
  - Feature replication accuracy is promising, particularly after switching to PMMA
  - Working towards Milestone 3 on December 15, 2014





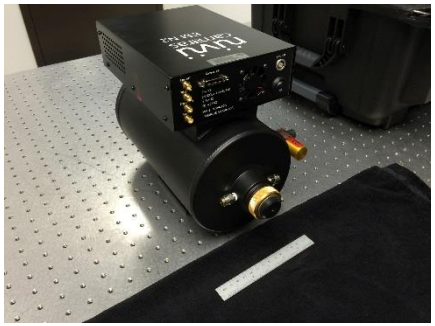
Coronagraph Detector

- Baseline IFS detector: e2v CCD201, ~~deep depletion~~
  - can be operated in three modes:
    1. Conventional CCD (high flight heritage)
    2. EMCCD with analog gain (high SNR)
    3. EMCCD with photon counting (clock waveform and electronics design are key to low noise operation)
- Only possible modification: modify implant to enable 4-phase clocking
  - Mitigation for radiation induced performance degradation



e2v CCD201
Electron Multiplying CCD
(1K×1K CCD)

- Status
  - Received NüVü EMCCD camera
  - Characterization to begin soon
  - Camera to be used as test bed for different CCD chips
    - Standard CCD201 EM-CCD
    - Custom version with reduced implant (if necessary)
  - CCCP “V3” controller (firmware designed with space applications in mind)
  - Control of clocking/waveform architecture



Next Steps

- Revisit IFS requirement and flight design
- Continue instrument simulations to support SDT priorities
- SDT final report 1/2015
- CATE 2/2015
- Deliver Technology Milestone #3: PIAACMC mask fabrication and characterization 12/15/2014
- Deliver Technology Milestone #4: HLC narrow band contrast demonstration 2/28/2015

Acknowledgement

- Contributions from team members from JPL, GSFC, Princeton, Univ of Arizona, Ames, Stanford, STScI, Caltech