ExEP Resources for Technology Demonstrations at JPL

Nick Siegler
Program Chief Technologist
NASA Exoplanet Exploration Program (ExEP)

Pre-Proposal TDEM-15 Briefing Telecon
01/19/16

See 2016 ExEP Technology Plan Appendix: http://exep.jpl.nasa.gov/technology/
(to be posted 1/22/16)

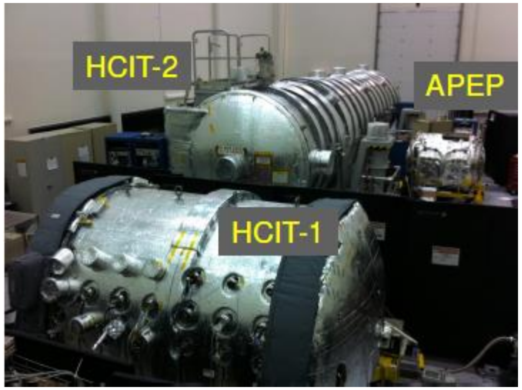
ExEP Resources for Technology Demonstrations

- **This presentation provides an overview of the ExEP resources located at JPL available to support a TDEM-15 proposal.**

- **The available resources, if appropriate for your needs, may help you more efficiently meet your milestone goals and reduce your proposal costs and schedule.**

Unavailable Resources at JPL for TDEM-15

- HCIT-1 (dedicated to WFIRST)



Available Resources at JPL for TDEM-14

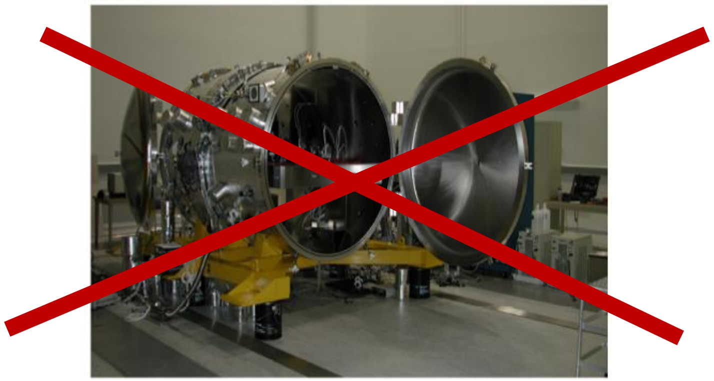
- HCIT-2
- Apep Vacuum Chamber (HCIT-3)
- Vacuum Surface Gauge
- Microdevices Laboratory (MDL)
- Scatterometer
- Starshade Deployable Testbed
- Starshade Optical Shield Testbeds (new)
- Large deployable structures lab

Available ExEP Resources at JPL for TDEM-15

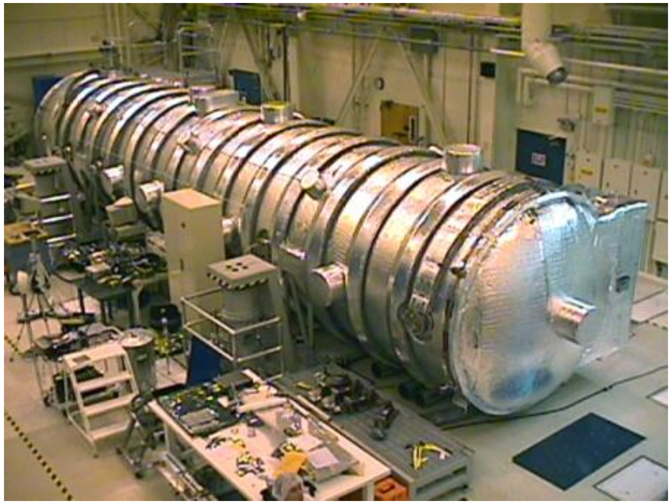
High Contrast Imaging Testbeds (HCITs)

Test Facility

- Two vacuum chambers with 1 mTorr capability
- Seismically isolated, temperature-stabilized ~ 10 mK at RT.
- Narrow or broad band coronagraph system demos
  - Achieved 3×10^{-10} contrast (narrowband)
- Fiber/Pinhole "Star" Illumination
  - Monochromatic: 635, 785, 809, and 835 nm wavelengths
  - 2, 10, and 20% BW around 800 nm center
  - Medium and high power super-continuum sources
- CCD camera ($5e^-$), 13 μm pixels
- Complete computer control with data acquisition and storage
- Coronagraph model validation & error budget sensitivities
- Remote access through FTP site



HCIT-1
Single-testbed capacity (5'x8')



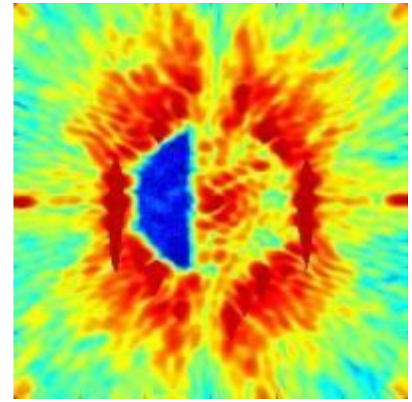
HCIT-2
Two-testbed capacity (6'x10')

Availability for two testbed in HCIT-2 expected beginning of CY17

Wavefront Sensing & Control

Nulling Algorithms

- Electric Field Conjugations (EFC) algorithms exist for single and dual DM control
- Demonstrated to < 10^{-9} contrast and 20% bandwidth
- Coupled to HCIT coronagraph models and DM calibration data for optimal efficiency



Best Results to Date

Band-Limited Coronagraph **:**
6 e-10, @ 3 λ/D with 10% BW
2 e-9, @ 3 λ/D with 20% BW

Shaped-Pupil Coronagraph**:**
1.2 e-9, @ 4 λ/D with 2% BW
2.4 e-9, @ 4 λ/D with 10% BW

PIAA Coronagraph**:**
<1e-9, @ 2 λ/d with 0% BW

Vector Vortex Coronagraph**:**
<1e-9, @ 3 λ/d with 0% BW

EFC Nulling and current performance

Deformable Mirrors

- **Wavefront control and speckle nulling available with Xinetics PMN deformable mirrors.**
  - Format sizes: 32x32mm, 48x48, and 64x64 mm with 1 mm pitch and 500 nm stroke size.
  - Continuous fuse silica facesheet polished to λ/100 rms
  - Two-DM configurations available

Xinetics DM

Availability expected beginning of CY17

HCIT-3

Recently used for Visible Nulling Coronagraph

- Optical layout as shown on the right
- Includes segmented BMC DM, pupil, and science cameras

16-Bit DM Electronics for Vacuum

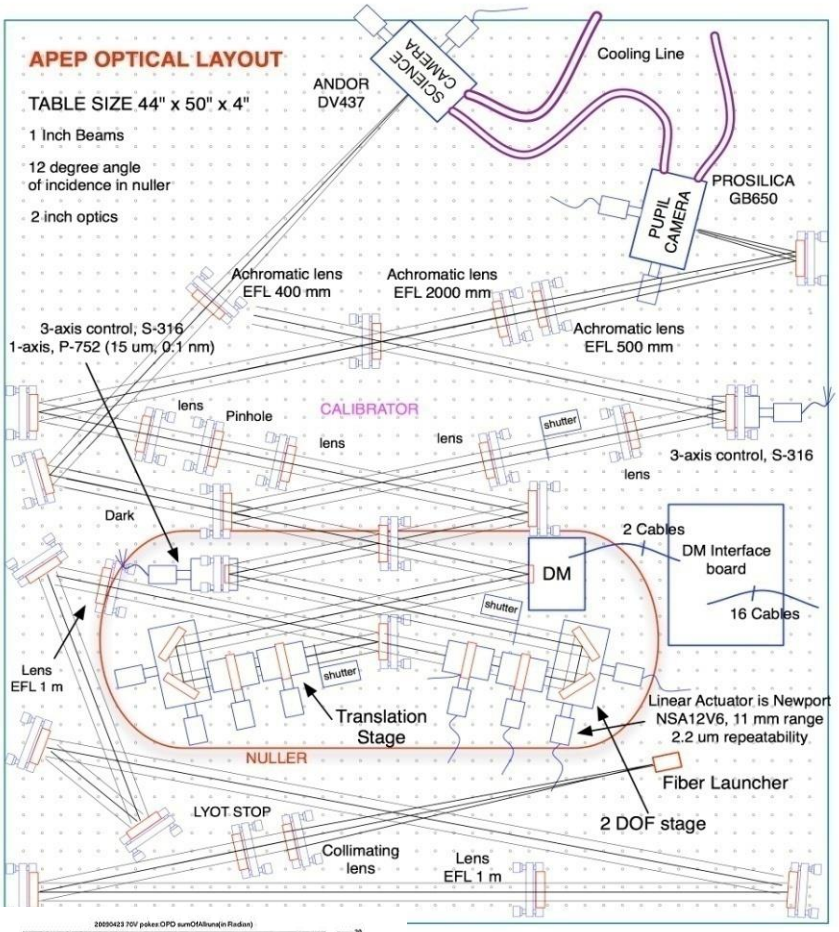
- Minimizes feed-throughs into vacuum tank
- Designed for Boston Micromachines segmented DM
- Conductively cooled electronics and chassis

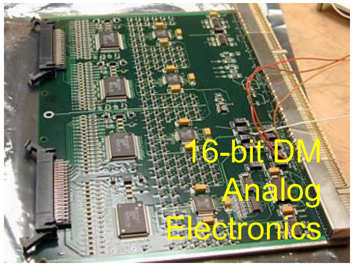
Coherent Fiber Bundle and Lens Array

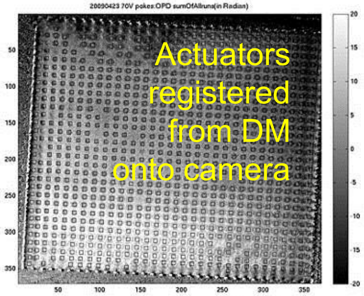
- Prototype of 217 fibers, with map of fiber positions
- Fiber bundle and lenslet array now integrated
- System performance demonstrated

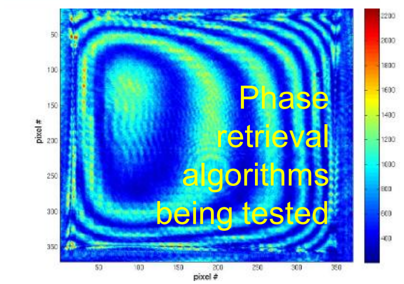
Control System Based on RTC

- Real-time phase retrieval demonstrated
- DM control better than 5nm







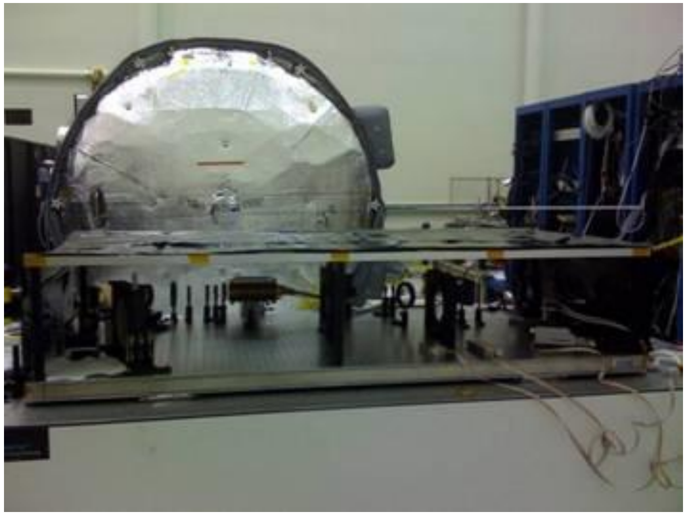


Availability for small vacuum testbed demonstrations

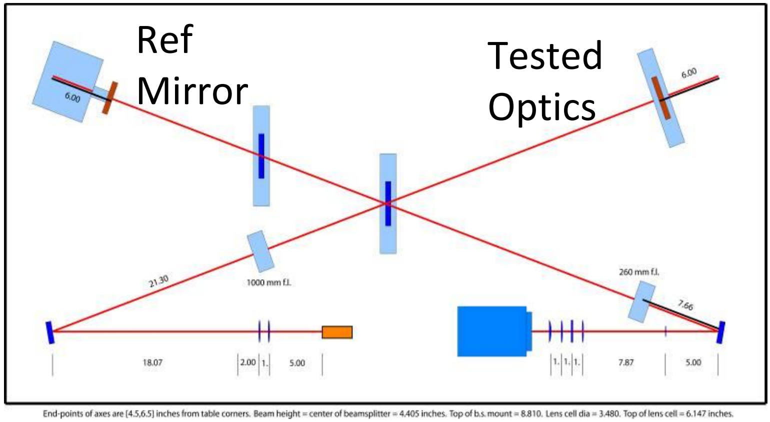
Vacuum Surface Gauge

Purpose: Accurate surface error measurement and deformable mirror calibration.

- **Demonstrated optical surface measurement accuracy: ≤ 100 pm rms**
- **Customized Michelson interferometer set-up**
  - Reference mirror w/ absolute position feedback
  - Frequency stabilized laser source
- **Dedicated algorithms for wavefront extraction over > 10^6 pixels**



Vacuum Surface Gauge testbed



Surface Gauge optical layout

MicroDevices Laboratory (MDL)

Exoplanet Exploration Program

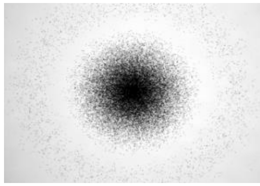


Figure 1. Microscope image (above) and AFM profile (below) of a micro dot patterned mask for JWST NIRCam coronagraph

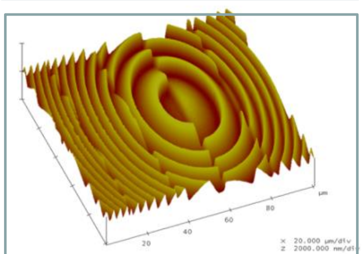
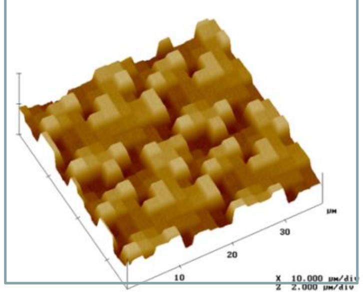


Figure 2. Diffractive optical devices



Purpose: Precision sub-micron materials fabrication and characterization

Advanced fabrication and characterization techniques

- Electron Beam Lithography
- Deep Reactive Ion Etching
- ICP Cryo Etching of Black Silicon microstructures

- Scanning Electron Microscopy
- Precision Optical Microscopy
- Atomic Force Microscopy
- 2D and 3D profilometry

Light suppression mask fabrication processes developed for:

- Micro dot patterned mask for JWST (Fig 1)
- Diffractive optical structures for spectrometer gratings and other computer generated holograms (Fig 2)
- Shaped pupil masks with fine structures and slits for transmission geometry (Fig 3)
- Shaped Pupil masks with black silicon structures in reflective aluminum background (Fig 4)
- LOWFS masks (Fig 5) incorporating a black silicon region (Fig 6) as well as shaped aperture through a silicon wafer
- Achromatic focal plane masks with deep diffractive structures (Fig 7)
- PIAACMC mask (Fig 8)
- Hybrid Lyot mask for WFIRST(Fig 9)

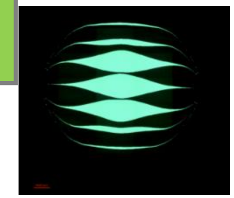


Figure 3. Transmissive slit SP mask

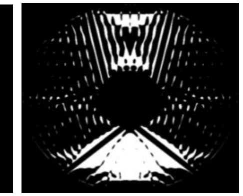


Figure 4. Reflective and absorptive SP mask

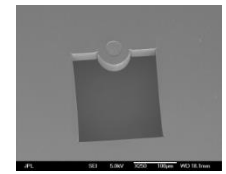


Figure 5. LOWFS mask

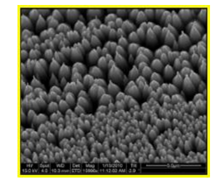
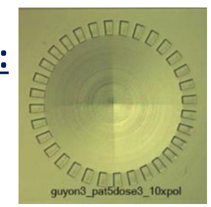


Figure 6. Black Si Microstructure



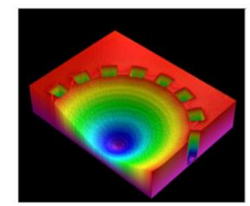


Figure 7 . Achromatic Focal Plane Masks (AFPM)

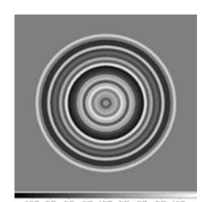


Figure 8 . PIAACMC mask

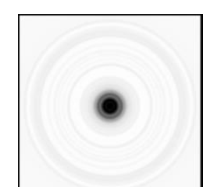


Figure 9 . Hybrid Lyot mask

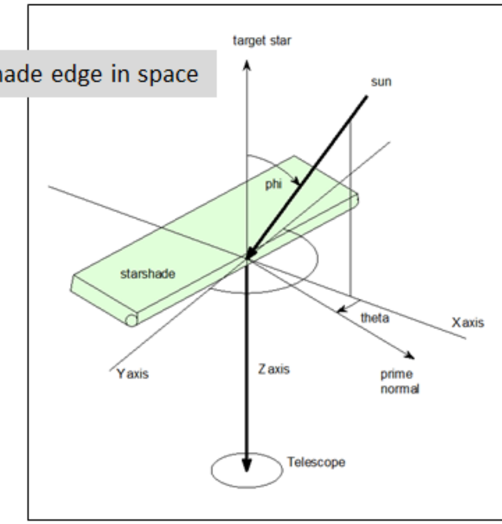
Scatterometer

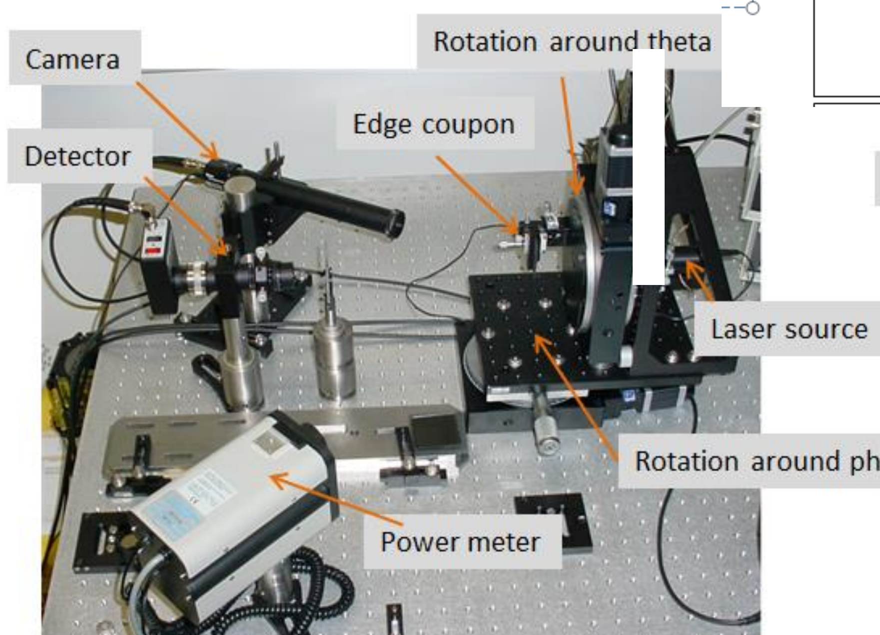
Purpose: measurement of light scatter from material coupons

Scatterometer Testbed

- Accurate for both specular and diffuse scatter
- Measures down to ~10^{-23} W/m^2 equivalent in space
- Optical chopping eliminates background light
- Separate measurements for s and p polarizations

Starshade edge in space





Starshade Deployment Testbed

Purpose: Enable maturation of key starshade deployment components

- **Testbed Description**
  - 10m motorized deployable starshade inner disk from 1.5m stowed configuration
  - Gravity compensation fixtures
  - Flight-like perimeter truss

- **Starshade Technology Opportunities**
  - Petal/perimeter truss interfaces
  - Petal and inner disk optical shields
  - Petal deployment tolerances

Starshade Optical Shield Testbeds (*new*)

Purpose: Enable maturation of optical shield designs and interfaces

- **Testbed Descriptions**
  - 2m perimeter truss, manual deployment
  - 5m and 10m perimeter truss, motorized deployment

- **Starshade Technology Opportunities**
  - inner disk optical shield design, fabrication, and demonstrations
  - interface development

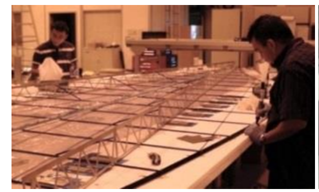
2m testbed

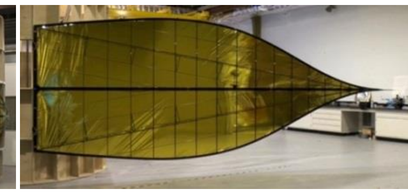
5m origami prototype

Advanced Large Precision Structures Lab

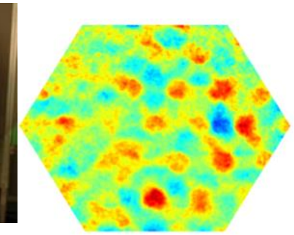
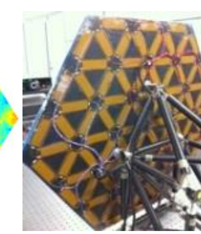
Purpose: Laboratory for demonstrating accuracy and stability of large deployable structures

Facility





- **Dimensions: 10m x 5m x 3m**
- **Stable testing environment**
  - Thermal stability: < 0.01 K/hr, < 0.02 K/24 hr
  - Vibration: < 75 u-g rms (0-500 Hz)
  - Acoustics: 35 dbA
  - Relative humidity stability: 1%
- **Active thermal control**
  - < 5 min for air temp stabilization (30 min from cold start)
  - Up to 1 kW heat load while maintaining performance
- **Class 100,000 clean room capable**
- **Wall and ceiling mounting possible**

Measurement Capabilities

- **Scanning laser vibrometer**
- **Labview data acquisition and control**
  - 60 high-speed simultaneous sampling for accelerometers
- **Laser holography system for in- or out-of-plane deformations of 10 nm to 25 um.**
- **Photogrammetry for < 0.5 mm measurements at up to 16 frames/s for 20 min**
- **FLIR thermal imaging camera, modal test exciters**

Gaining Access to the ExEP Resources at JPL

How to Request Use of ExEP Resources at JPL

- **Submit preliminary Statement of Work (SOW) for use of ExEP resources to Nick Siegler no later than March 3, 2016.**
  - Follow SOW questionnaire on next page.

- **Schedule telecon with Nick Siegler between March 3 – 10, 2016 to discuss use of the resources of interest and to obtain costing guidelines.**

- **Nick Siegler will evaluate workforce, labor, and infrastructure access required across all received SOWs.**
  - Assessment will be provided to Doug Hudgins for consideration in proposal review process.

- **Nick Siegler will supply the proposal PI a Letter of Commitment for use of any ExEP resources.**
  - PIs are to include both the SOW and the Letter of Commitment in their proposal.
  - HCIT will provide labor to set up testbeds; additional labor and procurements specific to your proposal must be costed within the proposal to support the work.

SOW Questionnaire for Use of ExEP Resources

1. **Brief description of the proposed TDEM**

2. **What resources are requested?**

3. **Milestone (s) to be accomplished and performance goals**

4. **Brief description of how the work will be conducted**

5. **Period(s) and preferred dates, if any, over which the resource is requested, stating whether in vacuum or air for testbeds. Include any time required for preparatory work.**

6. **A list of the personnel, expertise, and level of effort (if any) who will assist in the use of the resource.**

7. **Any anticipated changes to the resource needed to accommodate your demonstrations.**

8. **List of items needed for all testbed modifications. Identify items you will be procuring within your proposal's budget and provide approximate cost of needed items.**
    a. Otherwise, state that no additional procurements will be necessary for the use of the infrastructure under consideration.

9. **Provide any other relevant information or constraints.**

ExEP Technology Resources POC

For questions concerning use of ExEP technology resources or requests for more detail contact:

Dr. Nick Siegler

Jet Propulsion Laboratory

4800 Oak Grove Drive

Pasadena, CA 91109

Office: (818) 354-1293

Email: nsiegler@jpl.nasa.gov