Using JWST Heritage to Enable a Future Large Ultra-violet Optical Infrared Telescope

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Key Science Drivers to Find Earth 2.0:

Need large diameter, many visits, $10^{-10}$ contrast

Fig. 5.— Comparison of ExoEarth candidate yield (left) and number of unique stars observed (right) as functions of aperture size for the single visit and multi-visit cases. No spectral characterization time is included in these calculations.

Using Methane to Rule out False Positives (most H atoms are gone) – from S. Domagal-Goldman

Earth Observed Reflectance Spectrum From HDST Report

Degraded Modern Earth Spectra $R=120$

Lower Limits on Aperture Size for an ExoEarth-Detecting Coronagraphic Mission

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General Approach taken since 2009

• To the extent it makes sense, leverage JWST knowledge, designs, architectures, GSE

• Develop a scalable design reference mission (9.2 meter)
  • Do just enough work to understand launch break points in aperture size

• Demonstrate 10 pm stability is achievable on a design reference mission

• Make design compatible with starshades

• While segmented coronagraphs with high throughput and large bandpasses are important, make the system serviceable so you can evolve the instruments

• Keep it room temperature to minimize the costs associated with cryo
  • Focus resources on the contrast problem

• Start with the architecture and connect it to the technology needs
Aperture Sizes Studies since 2009

- 9.2m in Delta IVH: Circular Geometry JWST SM deployment, 3 JWST-wings per side
- 11.9m in Delta IVH Clamshell SMSS Low margins
- 12m is SLS, Dual Fold Wing
- 18m is Block 2 SLS, 16m deemed feasible

SIZE

20m Assembled

Space Launch System Launch Vehicle/Panels in Notional Shroud
Scalable Segmented Design Reference Mission

- **36 JWST-Size Segments**
- **9.2 m Aperture**
- **Actively controlled SM**
  - 6-dof control metrology to SI
- **Telescope Isolated from SC**
  - 6-dof magnetic isolation
  - Signal and power fully isolated
  - Near Zero-Q over Field of Regard

**Deployable Baffle**

**Serviceable Instruments are Externally Accessible**

**Three-layer sunshield,**
- Constant angle to sun, warm, stable sink
- Sunshield deployed from below using four booms

**Pointing gimbal maintains**
- Constant sun angle;
- Single pointing axis enhances stiffness

**Stowed Configuration**

**90 degree pitch plus roll**
## Multi-layer stability approach:
**Add layers based on performance and cost**

<table>
<thead>
<tr>
<th>Layer 1: Minimum observatory (active heater, non-contact isolation)</th>
<th>Layer 2: Use internal coronagraph sensing and control methods</th>
<th>Layer 3: Use telescope metrology systems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Segment Thermal Stability</strong></td>
<td>Low Q architecture, Active PM heater control, material choice</td>
<td>Zernike Sensor with continuous DM control</td>
</tr>
<tr>
<td><strong>Segment to Segment Thermal Stability</strong></td>
<td>Active heater and MLI control, material choice, joint design</td>
<td>Zernike Sensor with Continuous or Segmented DM control (piston, tip/tilt), Use bright star (reduce 10 minute update rates)</td>
</tr>
<tr>
<td><strong>Segment Dynamics Stability</strong></td>
<td>Stiffness and Design, Possibly smaller segments, materials</td>
<td></td>
</tr>
<tr>
<td><strong>Segment to Segment Dynamic Stability</strong></td>
<td>Reaction Wheel isolators, Non-contact Isolation between SC and telescope, Design, TMD’s (if needed), material choice</td>
<td>Zernike Sensor, Feed forward DM control, Use bright star (reduce update rate)</td>
</tr>
<tr>
<td><strong>Line of Sight/SM Thermal Stability</strong></td>
<td>Low Q architecture, Heater</td>
<td>LOS sensor and control mirror, MIMF for SM alignment</td>
</tr>
<tr>
<td><strong>Line of Sight/SM Dynamic Stability</strong></td>
<td>Reaction wheel isolators, Non-contact isolation, Design, TMD (if needed)</td>
<td>LOS sensor and control with feed forward control</td>
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</table>
Notional End to End Architecture?

12m diameter
PM to SM spacing: 13m
SM obscuration is 19.5% area
Design for 8x12 arcminutes
TMA
Coronagraph uses PM-SM

Stability:
Backplane motions removed with Segmented DM (speed?)
Segments Stable

Segmented Coronagraph Channels

PIAA CMC, APLC, VNC/PVNC, Vector Vortex, etc
Deformable Mirrors
Lyot Stops
Masks

Out of band Zernike Sensor
Mirror stability demonstrated

AMSD: Lightweight Closed Back ULE Heritage

- See paper by M. Eisenhower/SAO on mirror thermal control architecture
  - Next generation ULE 1.2m flat to flat, 12Kg mass
- Silicon Carbide also assessed, can work with slightly better thermal control, lower mass per stiffness
- JWST segment size is in a good sweet spot for the trade between thermal and dynamic stability and coronagraph throughput and gaps
Integrated Modeling Results

- Based on published non-contact isolation values, passive reaction wheel isolation
- Caveats:
  - Results include NO MUF and damping knock-down factor.
  - Mechanical and finite element models are at preliminary stages of development.
  - All isolation systems are implemented as idealized analytical filters.
  - Assumes system behaves linearly down to picometer scale (plan to validate this at joint/interface level)

Total WFE: Vibe+RW Isolators, 1° Strut

LOS Results: Vibe+RW Isolators
General Class Instruments
Early Notional ATLAST FOV

Central Field Science Cassegrain Focal Plane

- UV IFU
- Coronagraph
- COS
- Exo-CAM
- Exo-Spec

WFOV Total Available Focal Plane

- Guider 3 x 3 arcmin
- Multi-Object Spectr. (MOS)
- Integral Field Unit (IFU)
- 12 arc min
- Vis/NIR
- Wide Field Imager (may use Dichroic for 2 channels)
- Up to 8 x 8 arc min

WFOV Science Focal Plane

- Guider 3 x 3 arcmin
- 8 arc min

General Class Instruments

Early Notional ATLAST FOV

HST Cosmic Origins Spectrograph:
UV Rowland Spectrograph

JWST NIRSPEC
Multi object Spectrograph

HST Wide Field Camera-3
Vis and NIR WFOV

Pictures from Wikipedia
Large Aperture UVOIR Telescope Can Be Enabled by JWST Technology and Design Heritage

Potential HDST
Large Aperture UVOIR Telescope Can Be Enabled by JWST Integration and Testing
Conclusion

• There is potential for us to leverage the JWST architecture
• The JWST segment geometry and size is turning out to be in a good sweet spot for stability and performance
• Contrast and Number of Visits are the key challenges
• We need industry involvement to help develop:
  • Stable segments
  • Isolation systems
  • Active systems
  • Deformable mirrors
  • Backplane technologies
  • Metrology systems
• A stable, serviceable large telescope could last decades and enable multiple generations of high contrast coronagraphs