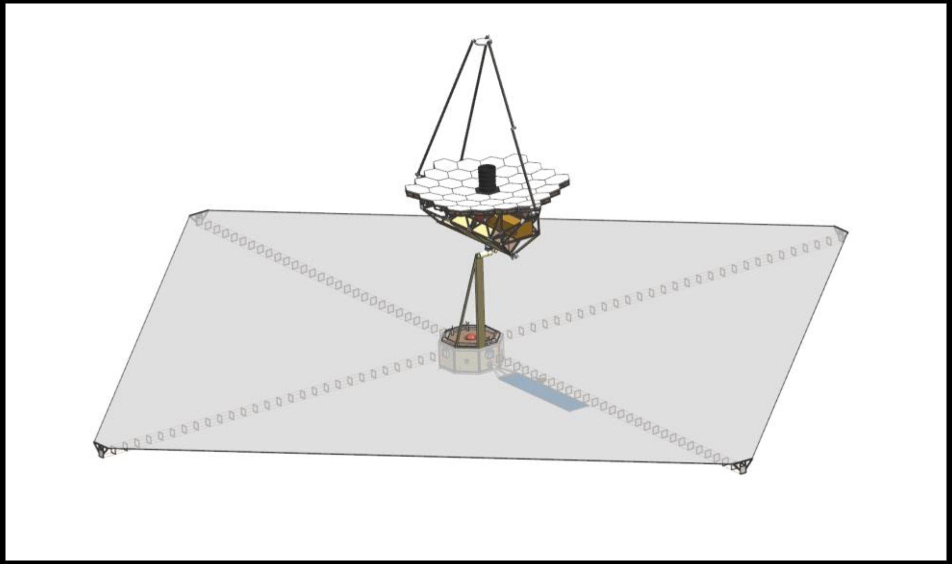
Using JWST Heritage to Enable a Future Large Ultra-violet Optical Infrared Telescope

Lee Feinberg, NASA GSFC



Key Science Drivers to Find Earth 2.0:

Need large diameter, many visits, 10^-10 contrast

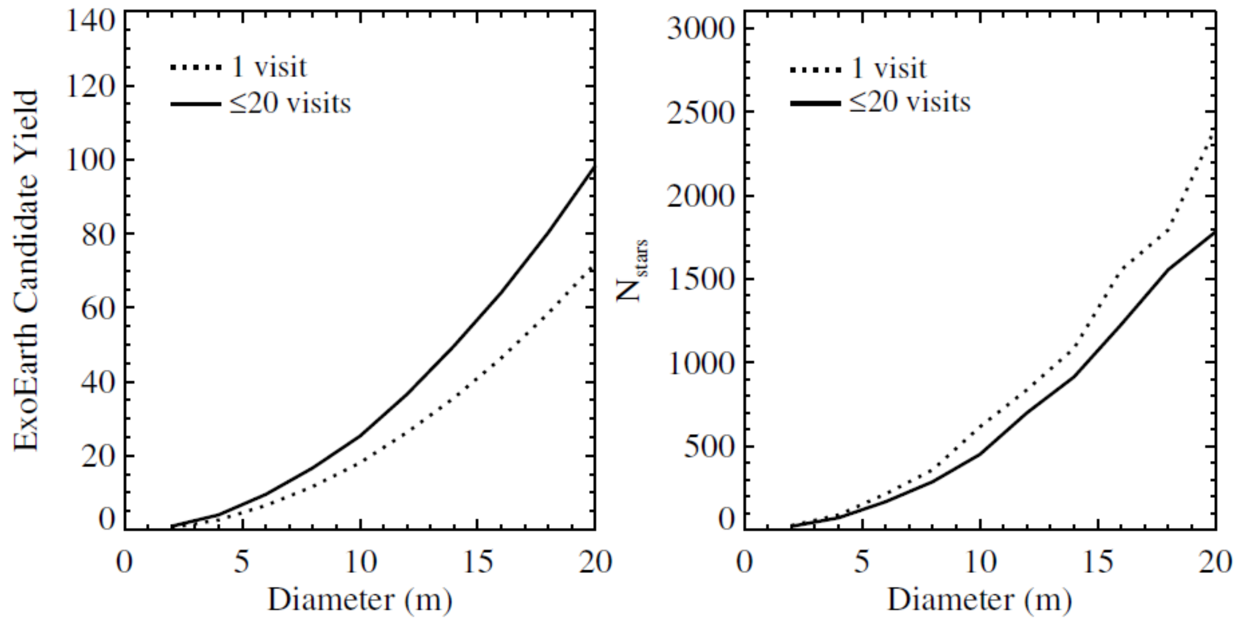
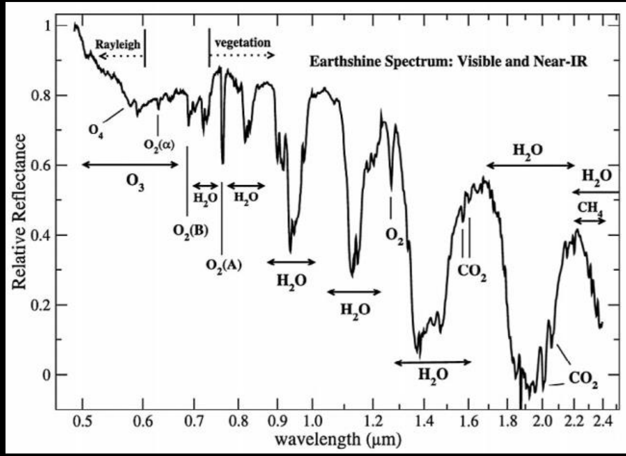


Fig. 5.— Comparison of ExoEarth candidate yield (left) and number of unique stars observed (right) as functions of aperture size for the single visit and multi-visit cases. No spectral characterization time is included in these calculations.

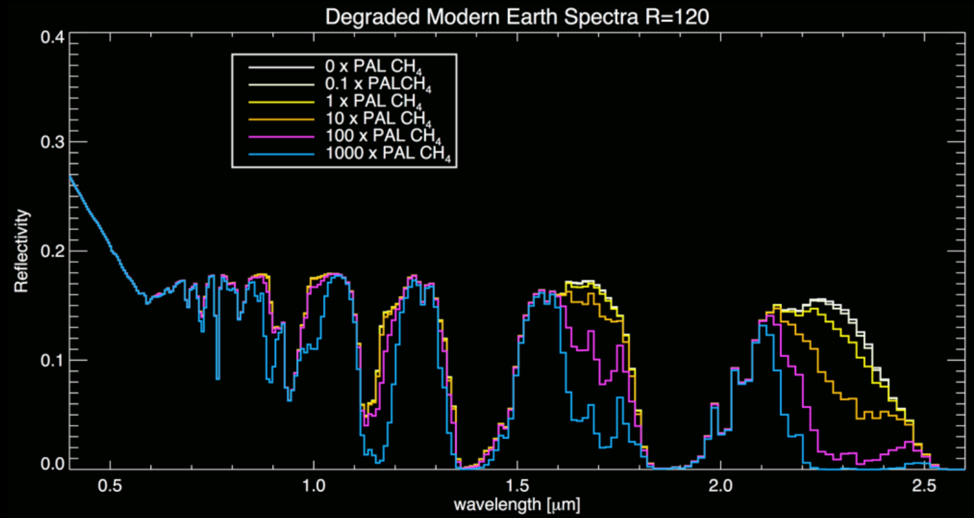
Lower Limits on Aperture Size for an ExoEarth-Detecting Coronagraphic Mission

Christopher C. Stark[1], Aki Roberge[2], Avi Mandell[2], Mark Clampin[2], Shawn D. Domagal-Goldman[2], Michael W. McElwain[2], Karl R. Stapelfeldt[2]

Need to Survey Lots of Spectrum



Earth Observed Reflectance Spectrum From HDST Report

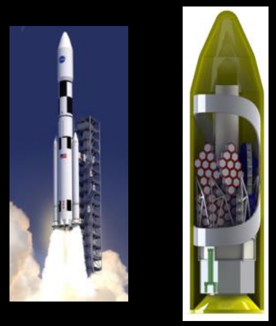


Using Methane to Rule out False Positives (most H atoms are gone) – from S. Domagal-Goldman

General Approach taken since 2009

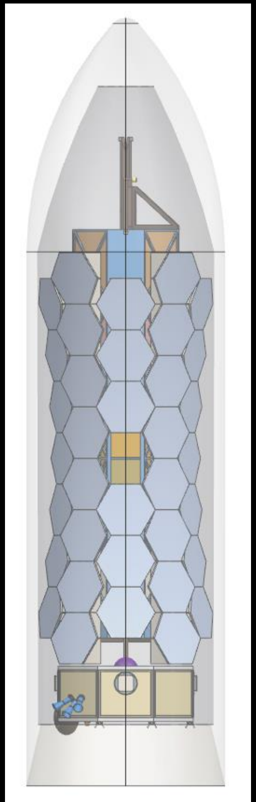
- To the extent it makes sense, leverage JWST knowledge, designs, architectures, GSE
- Develop a scalable design reference mission (9.2 meter)
  - Do just enough work to understand launch break points in aperture size
- Demonstrate 10 pm stability is achievable on a design reference mission
- Make design 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

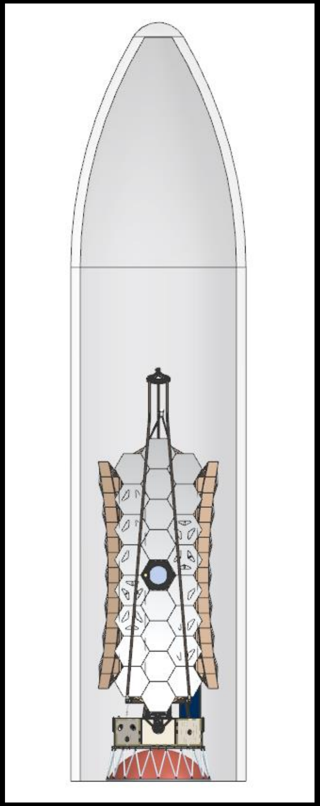


Space Launch System
Launch Vehicle/Panels in Notional Shroud

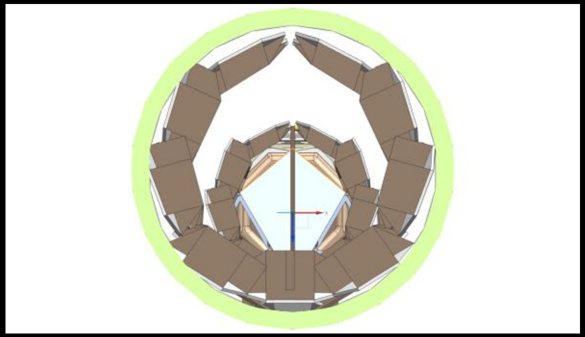
9.2m in Delta IVH:
Circular Geometry
JWST SM deployment,
3 JWST-wings per side



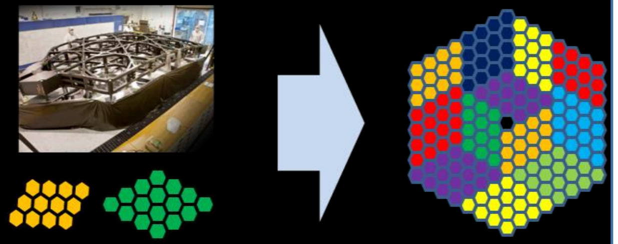
11.9m in Delta IVH
Clamshell SMSS
Low margins

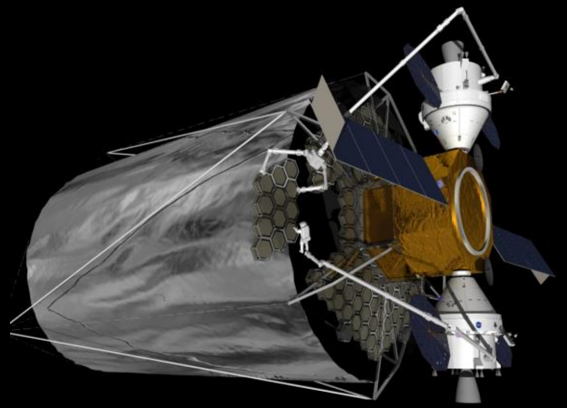


12m is SLS,
Dual Fold
Wing



18m is Block 2 SLS,
16m deemed
feasible





20m Assembled

SIZE

Scalable Segmented Design Reference Mission

36 JWST-Size Segments

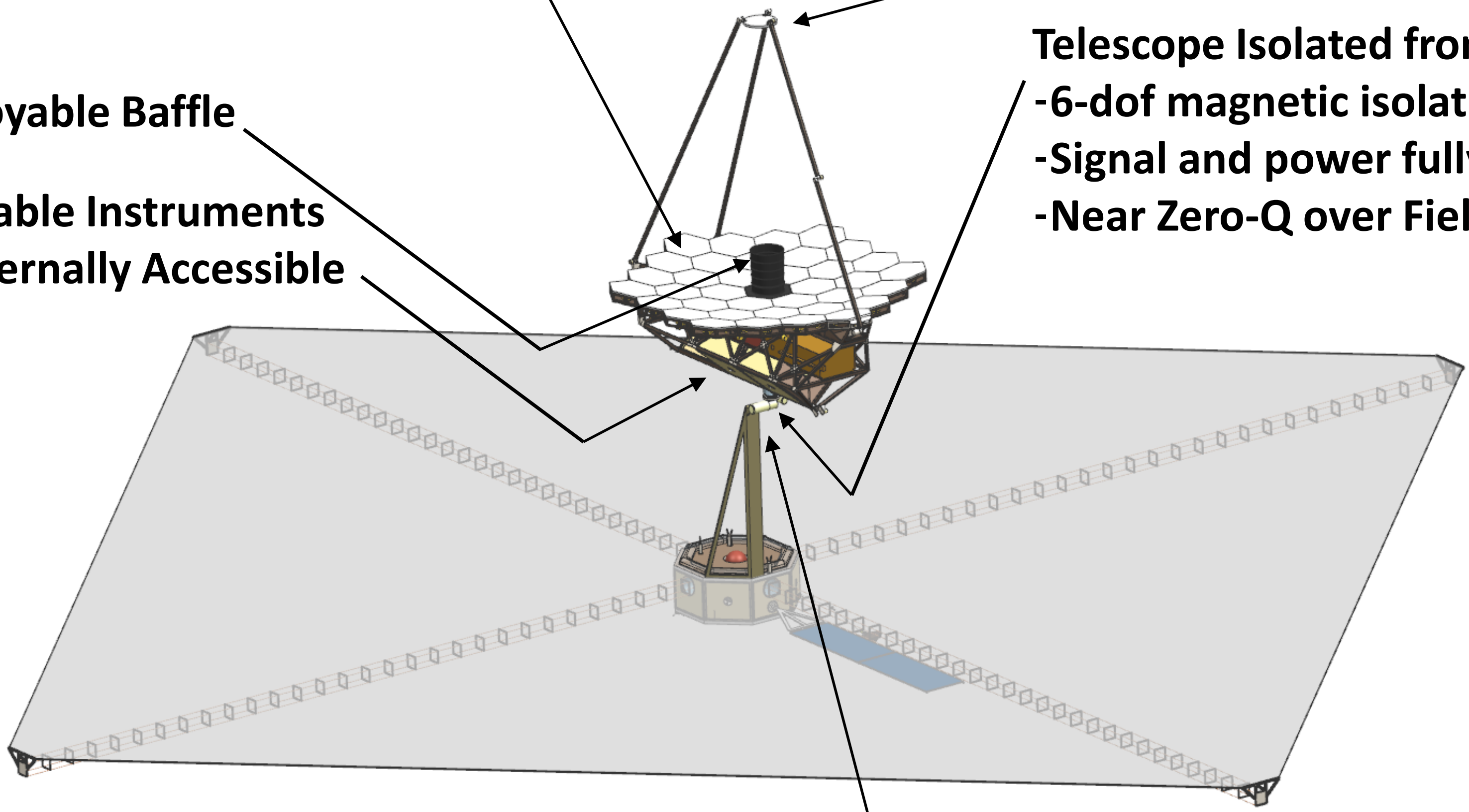
9.2 m Aperture

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

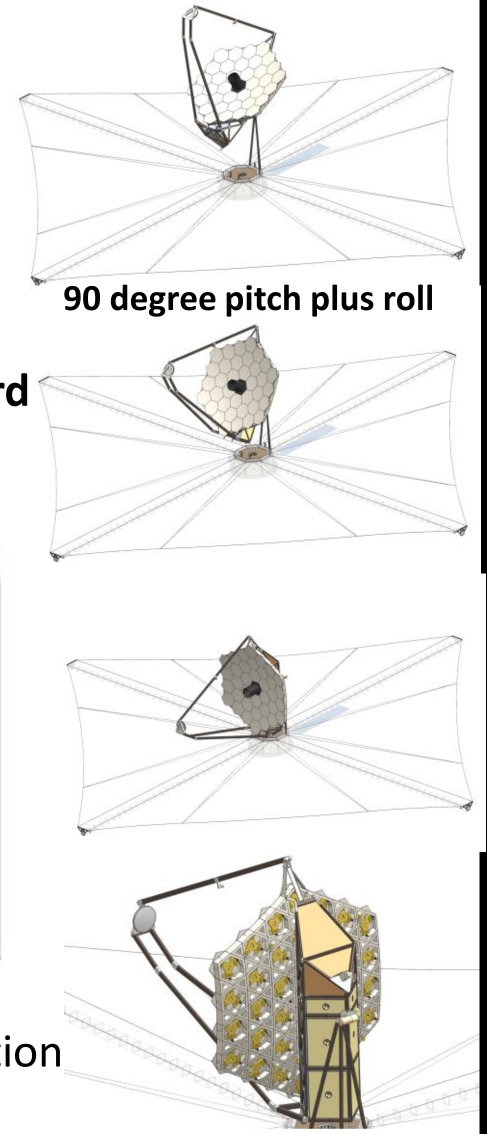
Serviceable Instruments
are Externally Accessible



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

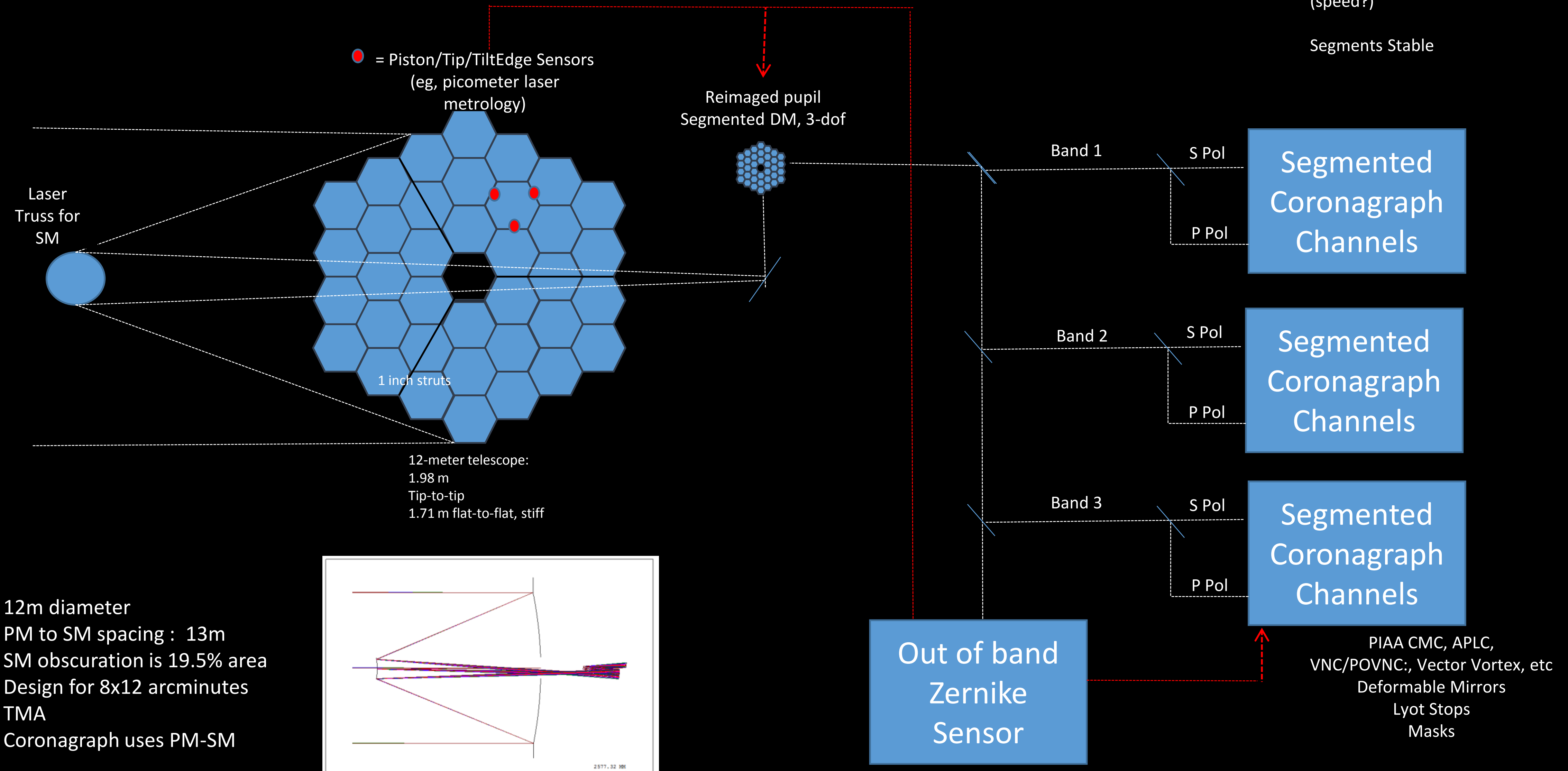
	Layer 1: Minimum observatory (active heater, non-contact isolation)	Layer 2: Use internal coronagraph sensing and control methods	Layer 3: Use telescope metrology systems
Segment Thermal Stability	Low Q architecture, Active PM heater control, material choice	Zernike Sensor with continuous DM control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

Notional End to End Architecture?

Stability:

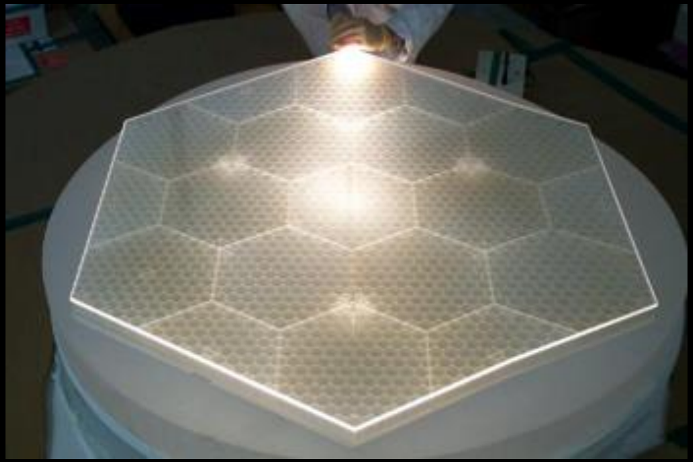
Backplane motions removed with Segmented DM (speed?)

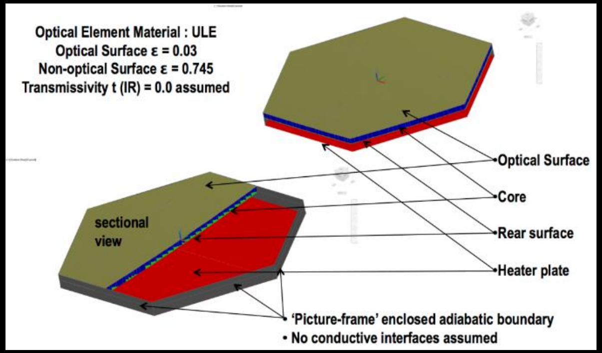
Segments Stable

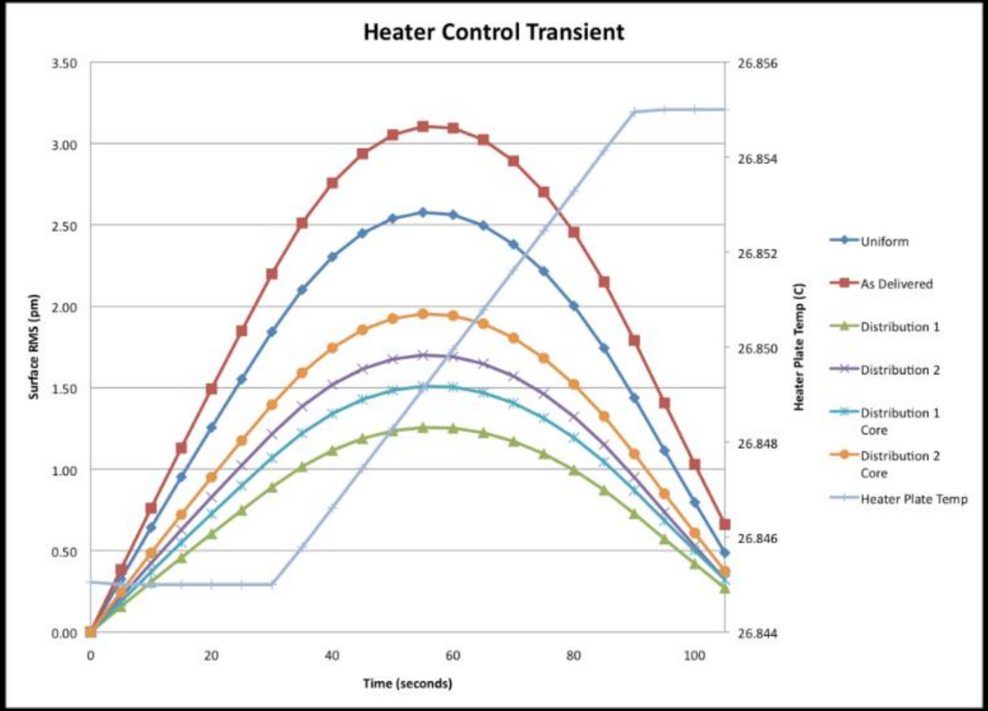


Mirror stability demonstrated

AMSD: Lightweight Closed Back ULE Heritage





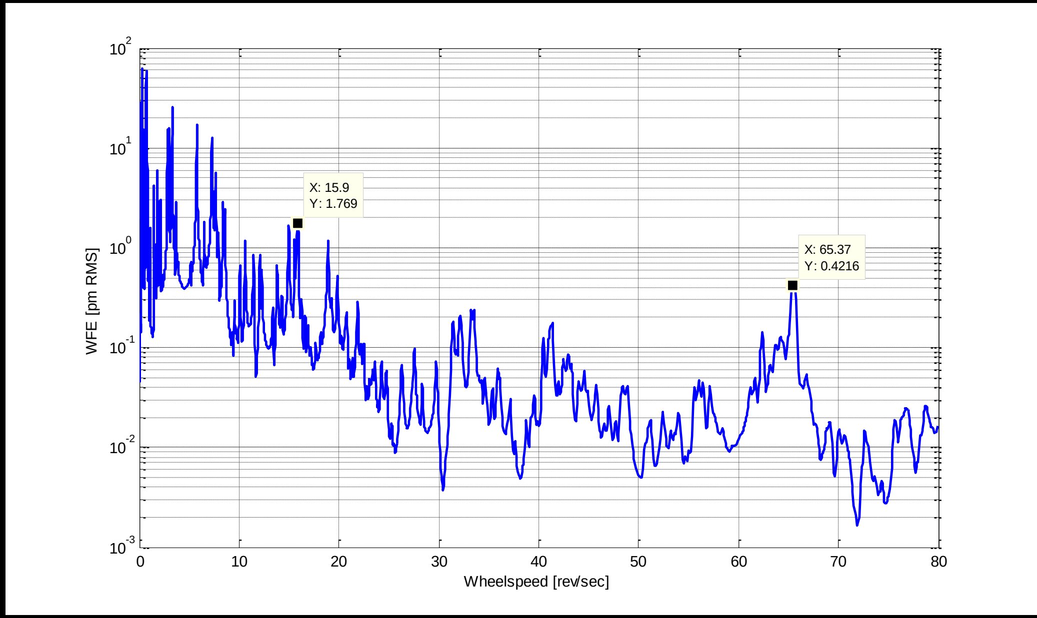


- See paper by M. Eisenhower/SAO on mirror thermal control architecture
  - Next generation ULE 1.2m flat to flat, 12Kg mass
- Silicon Carbide also assessed, can work with slightly better thermal control, lower mass per stiffness
- JWST segment size is in a good sweet spot for the trade between thermal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

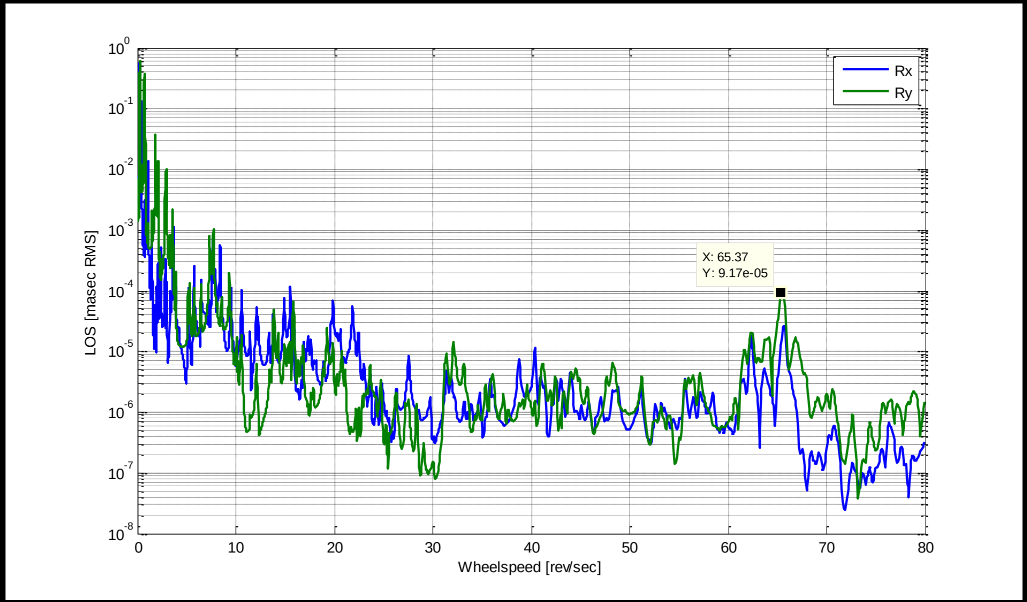
Integrated Modeling Results

- 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)

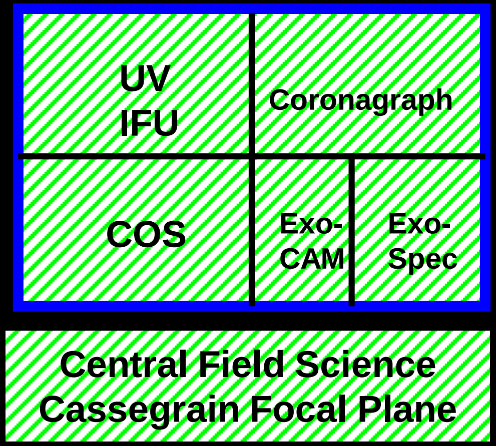
Total WFE: Vibe+RW Isolators, 1” Strut

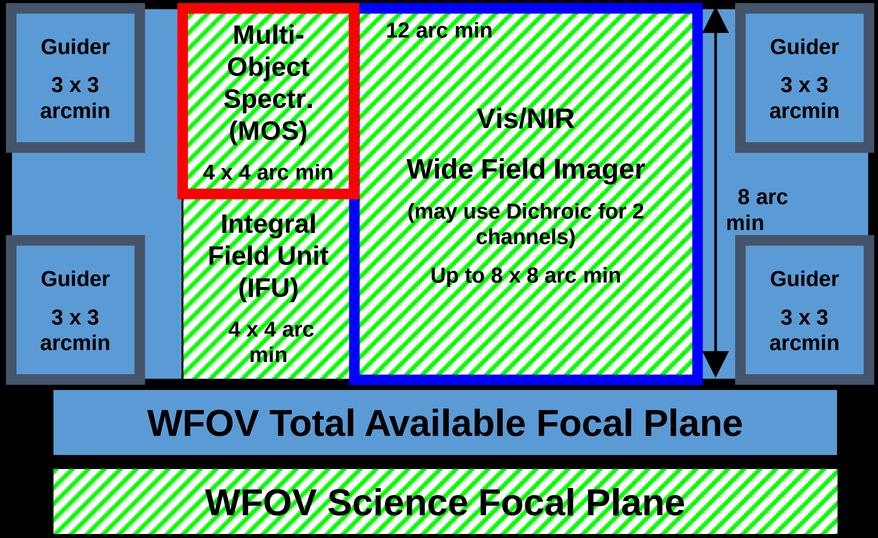


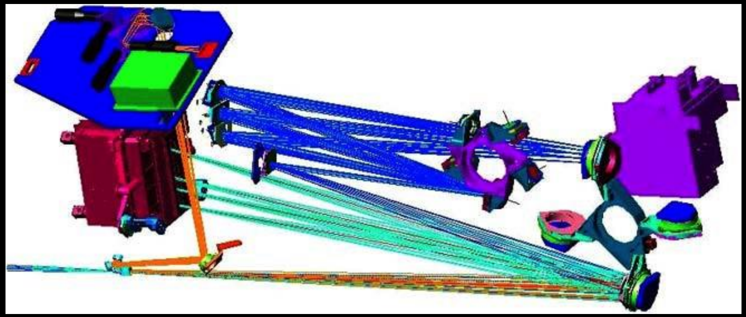
LOS Results: Vibe+RW Isolators



General Class Instruments
Early Notional ATLAST FOV







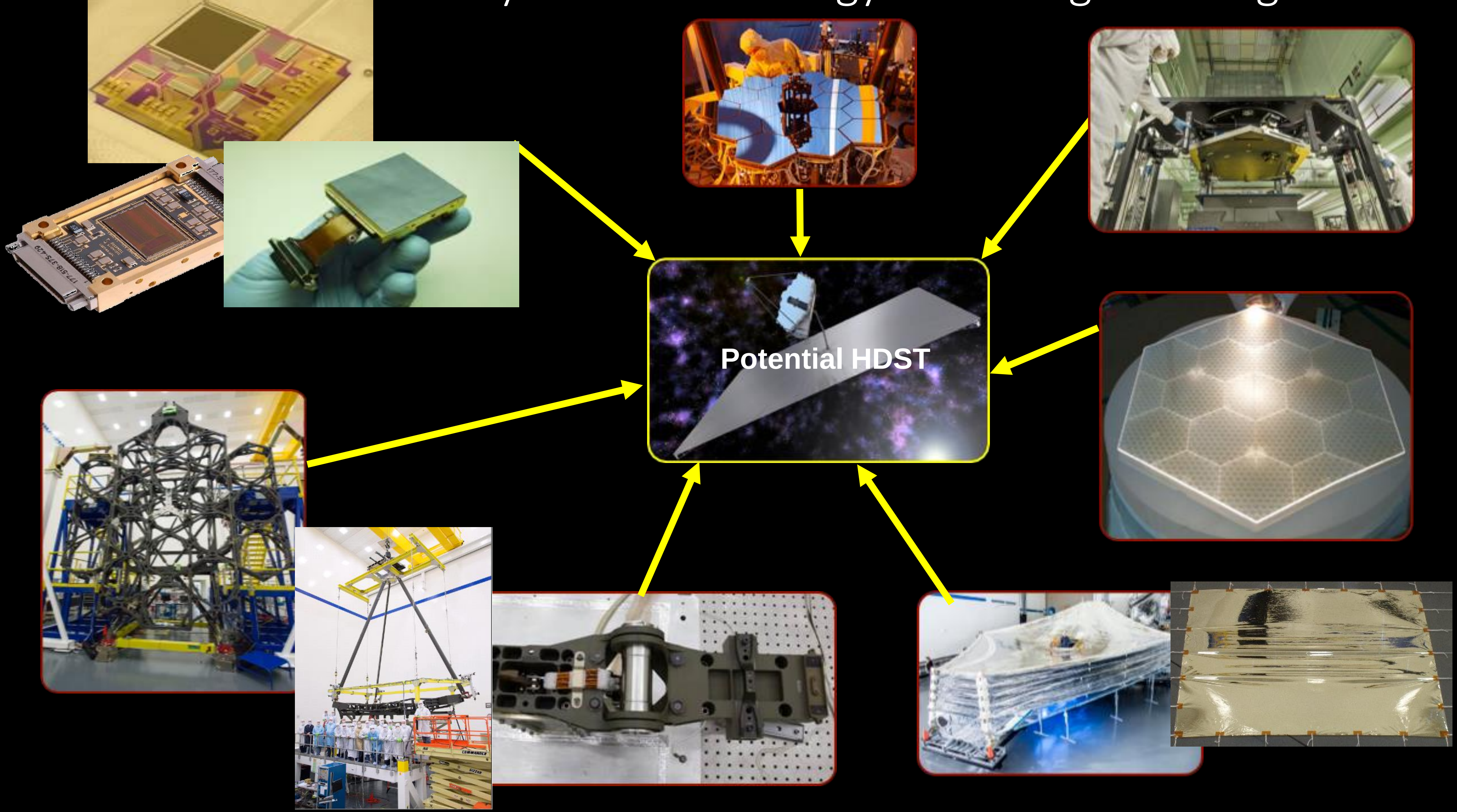
HST Cosmic Origins Spectrograph:
UV Rowland Spectrograph

JWST NIRSPEC
Multi object Spectrograph

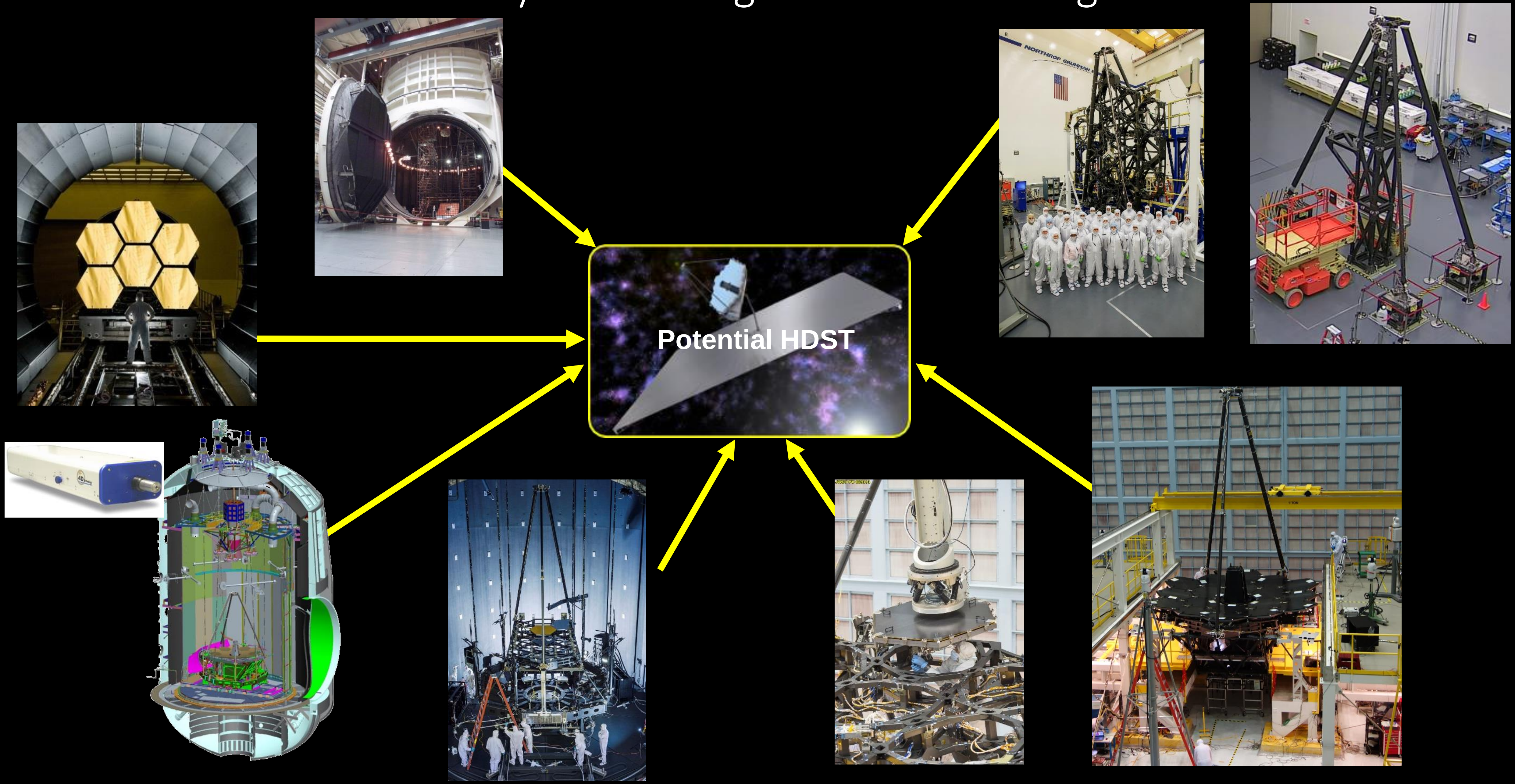
HST Wide Field Camera-3
Vis and NIR WFOV

Pictures from Wikipedia

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



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