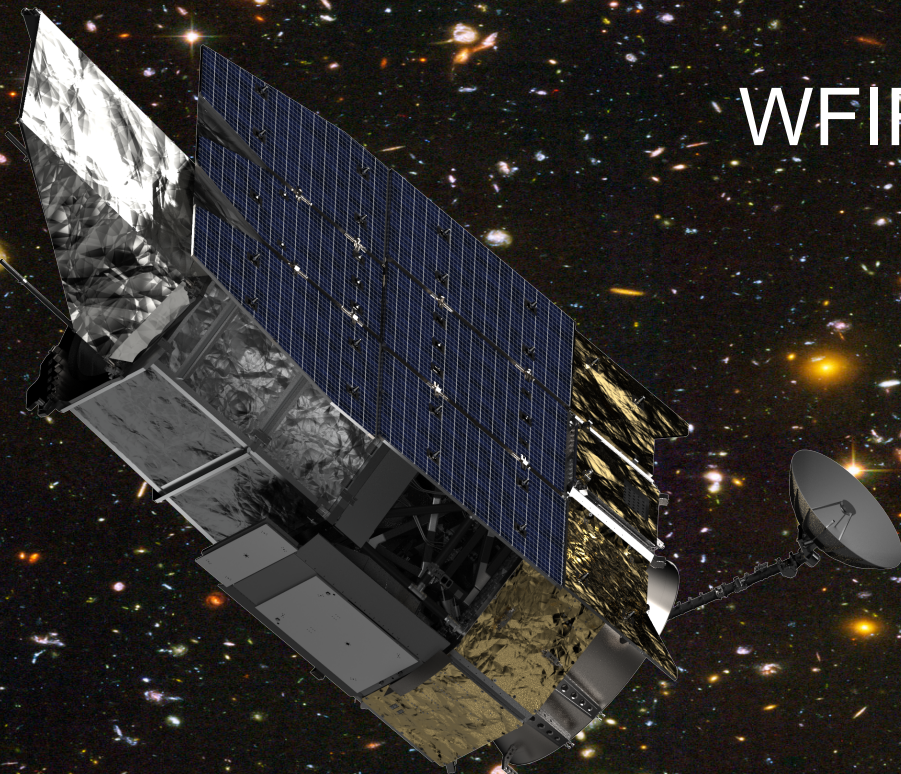




# WFIRST Project Status

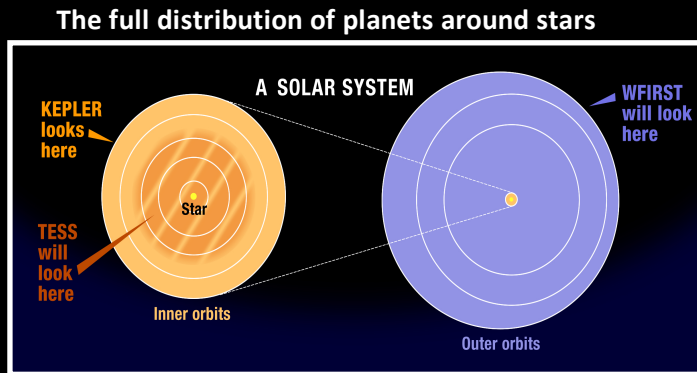
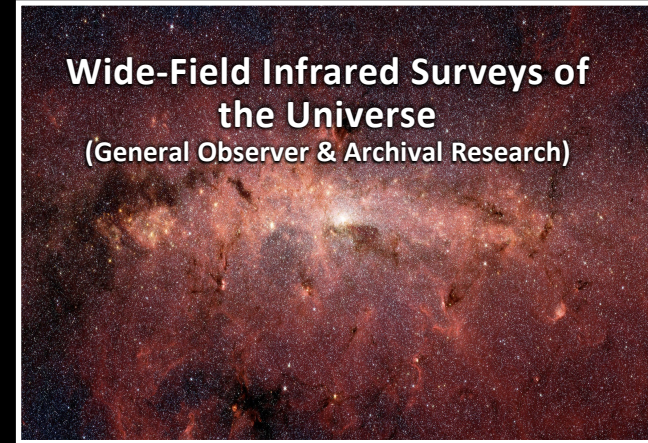
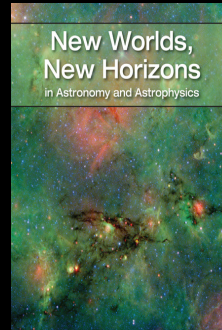
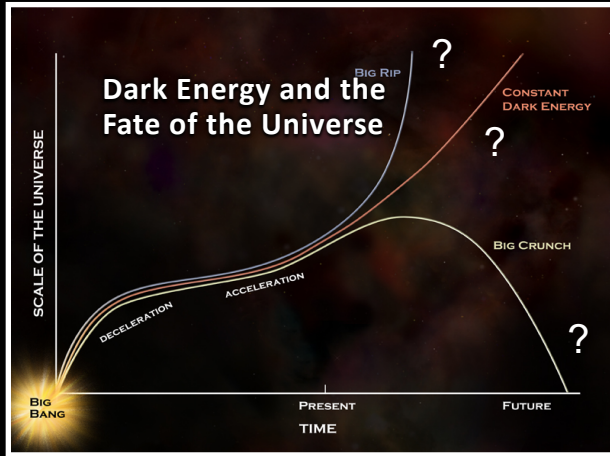
March 17<sup>th</sup>, 2020



Jeffrey Kruk  
WFIRST Project Scientist

• NASA GODDARD SPACE FLIGHT CENTER • JET PROPULSION LABORATORY •  
• HARRIS • BALL AEROSPACE • TELEDYNE • NASA KENNEDY SPACE CENTER •  
• SPACE TELESCOPE SCIENCE INSTITUTE • INFRARED PROCESSING AND ANALYSIS CENTER •







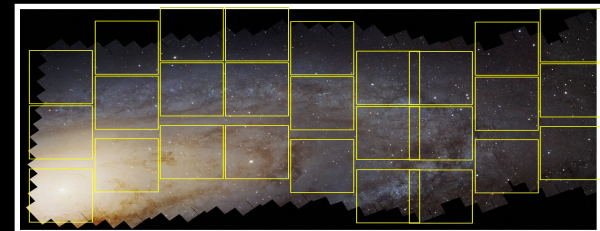
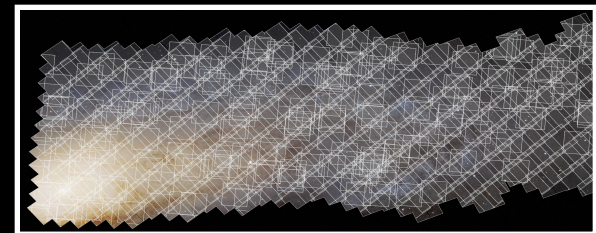
- Assembly and star-formation histories of galaxies
  - Nearby galaxies & globular clusters out to high redshift
  - Compare high & low density environments, including voids
- Probing the epoch of reionization
- Milky Way kinematics and formation history
- EM counterparts of GW events; multi-messenger astronomy
- Transiting planets in MW disk and bulge
- Astrometric planet detection around nearby stars
- Census of free-floating planets, neutron stars, black holes in MW disk
- Growth & evolution of galaxy clusters (+ X-ray, SZ, LSST, ELTs...)
- Cosmic infrared background
- Discovery of high-z quasars
- Stellar IMF in different environments

Sample from WFIRST-related white papers submitted to Astro-2020



- The power of WFIRST is not *just* that it has a large field of view: it is also very efficient
  - Rapid slew & settle, no Earth occultations, no South Atlantic Anomaly
- Comparisons of total elapsed time for large HST surveys with WFIRST for equivalent area+depth:
  - 3-D HST: 1400 ksec grism spectroscopy over 0.17 sq deg
    - -> WFIRST: 1.9 ksec or **730x faster**
  - COSMOS: 3300 ksec imaging over 2 sq deg
    - -> WFIRST: 26 ksec or **125x faster**
  - CANDELS *Wide NIR*: 0.22 sq deg in 1790 ksec
    - -> WFIRST: 1.7ksec or **1050x faster**
  - PHAT: 2360 ksec multi-band imaging over 0.5 sq deg
    - -> WFIRST: 1.6 ksec or **1475x faster**

HST PHAT survey: 438 pointings



WFIRST PHAT survey: 2 pointings

For details, see Akeson et al 2019 <https://arxiv.org/abs/1902.05569>



## Wide-Field Infrared Surveys of the Universe

Large legacy surveys, smaller focused surveys

All data to be public immediately

Legacy Surveys under consideration:

High-latitude imaging and  
spectroscopic surveys

Enables WL and GRS  
cosmology investigations

High-latitude time-domain  
survey

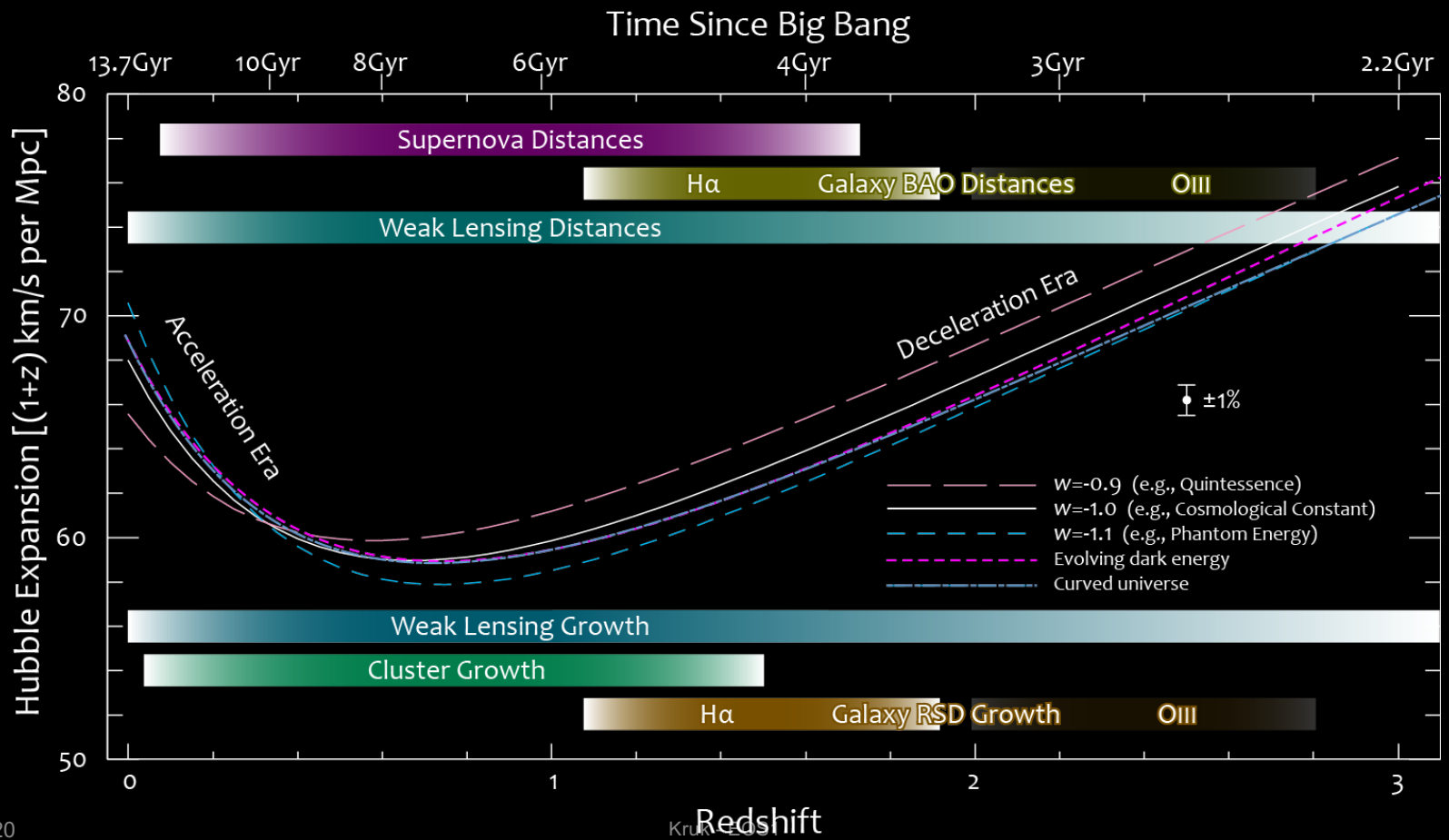
Enables SNIa  
cosmology investigations

Galactic Bulge time-domain  
survey

Enables exoplanet microlensing  
investigations

Each has a core set of requirements, but potential scope is far broader and design can be adjusted to maximize total science return



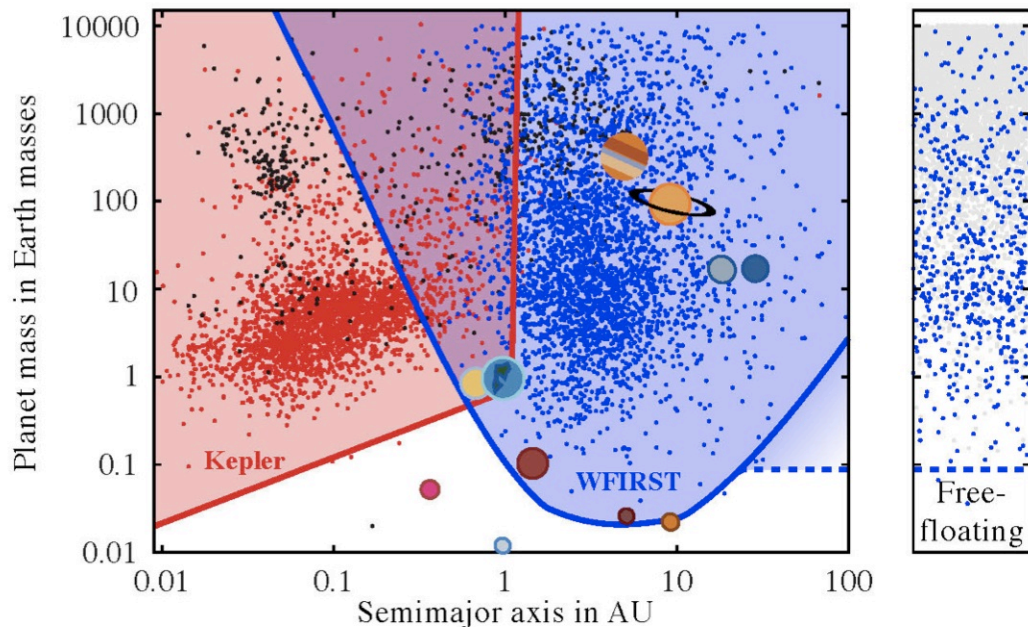
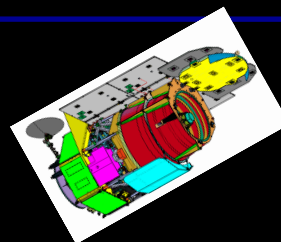




Kepler



WFIRST



# Representative Surveys

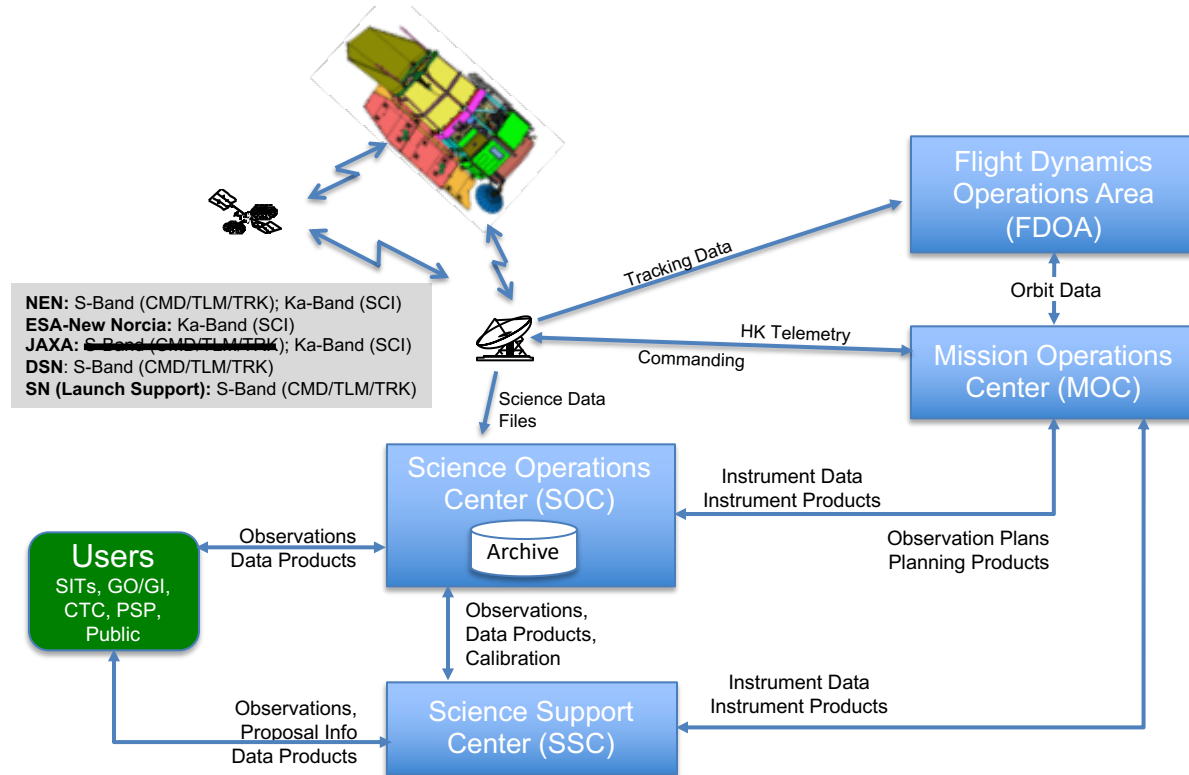
(from the design reference mission)

- **Cumulative point-source depth in wide-area surveys:**
- **High Latitude Survey**

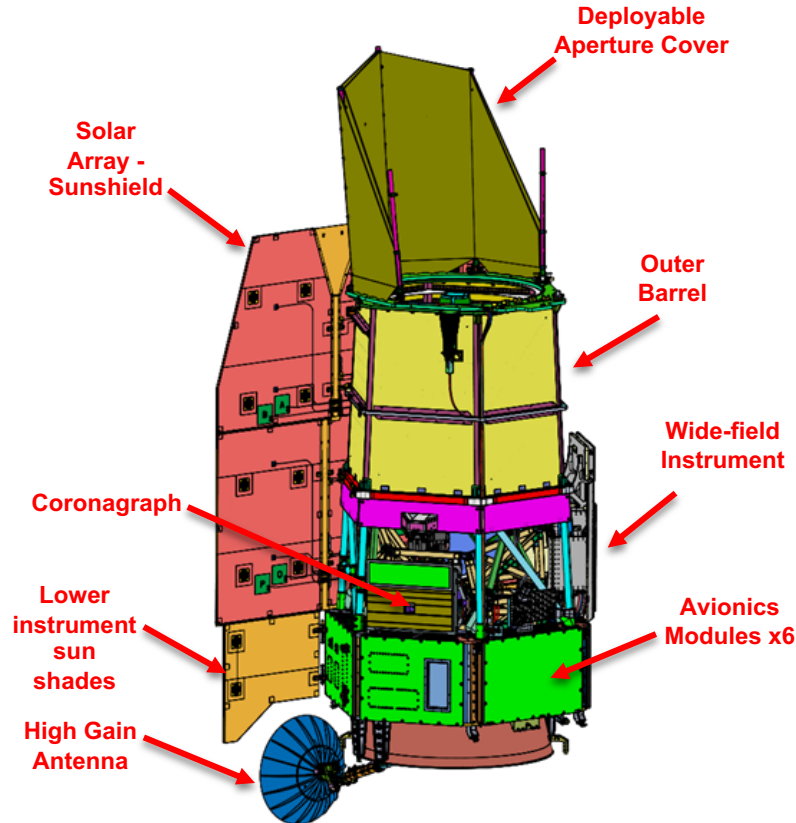
|                                                                   | Wide 2000 deg <sup>2</sup>  | Deep 20 deg <sup>2</sup>    |
|-------------------------------------------------------------------|-----------------------------|-----------------------------|
| – Imaging in 4 filters (5 $\sigma$ )                              | AB ~26.5                    | AB ~28.2                    |
| – Grism (6.5 $\sigma$ line flux 1.8 $\mu$ 0.2" r <sub>eff</sub> ) | 8 $\cdot$ 10 <sup>-17</sup> | 3 $\cdot$ 10 <sup>-17</sup> |
- **SN Ia Survey (5-day cadence)**

|                                                      | Wide: 29 deg <sup>2</sup> | Deep 12 deg <sup>2</sup> |
|------------------------------------------------------|---------------------------|--------------------------|
| – Imaging (5 $\sigma$ )                              | AB ~27.8                  | AB ~29.5                 |
| – Prism (10 $\sigma$ continuum)                      | AB ~23.8                  | AB ~26.4                 |
| – There are many possible SN survey implementations! |                           |                          |
- **Microlensing:**
- Monitor 2+ deg<sup>2</sup>, 15 minute cadence over 72-days, S/N=100 @ AB=21.4 per visit
- Exoplanet detections by microlensing, other time-domain astronomy,
- Precision astrometry (tens of micro-arcsec)





CMD – Command; TLM – Telemetry; TRK – Tracking; HK – Housekeeping; SCI – Science; SIT – Science Investigation Teams; GO/GI – General Observer/Guest Investigator; CTC – Coronagraph Technology Center; PSP – Participating Scientist Program;



## Key Features

**Telescope:** 2.4m aperture

**Instruments:**

Wide Field Imager / Slitless Spectrometer

Coronagraph w/ prism Spectroscopy

**Data Downlink:** 275 – 500 Mbps

**Data Volume:** 11 - 16 Tb/day

**Orbit:** Sun-Earth L2

**Launch Vehicle:** 3 options

**Mission Duration:** 5 yr, 10yr goal

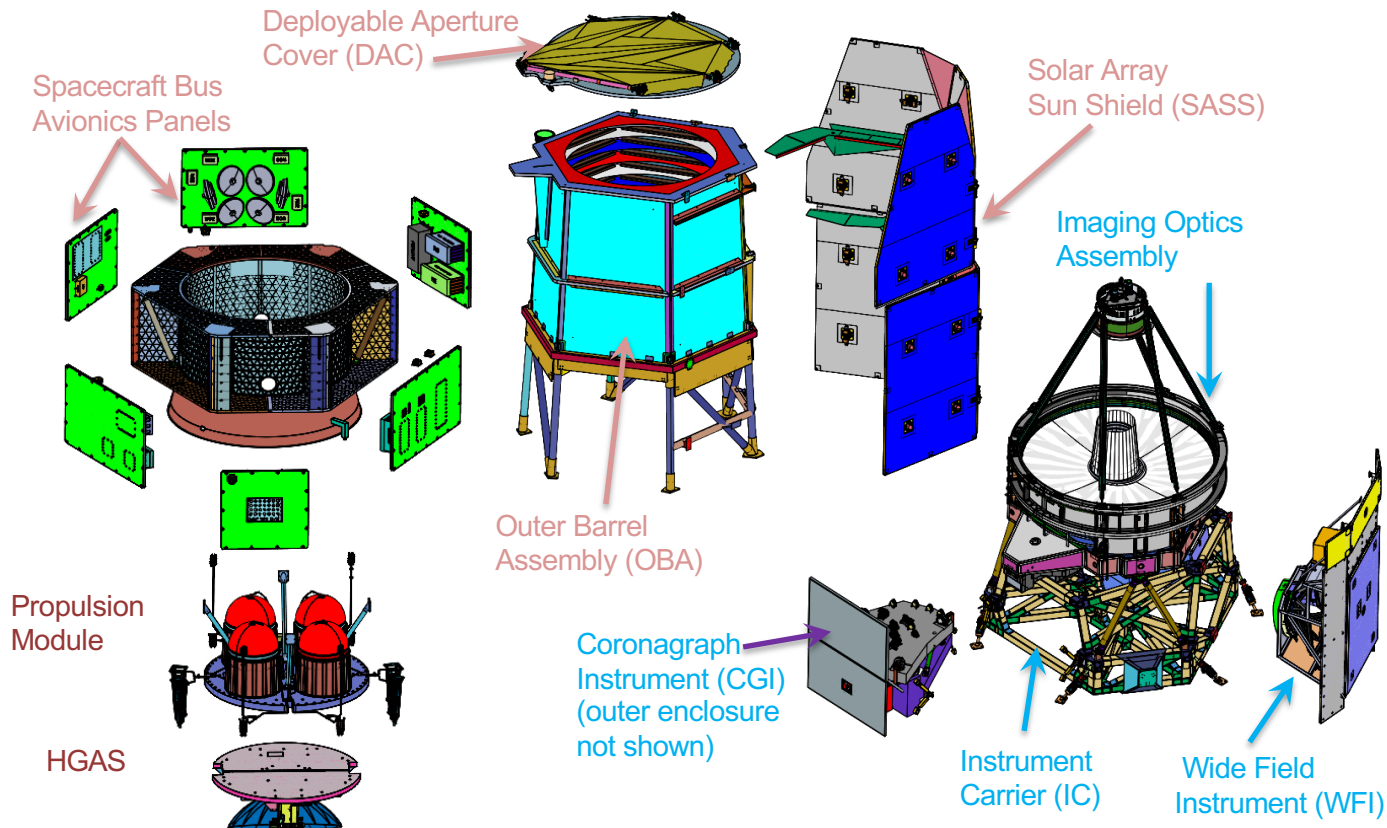
**Serviceability:**

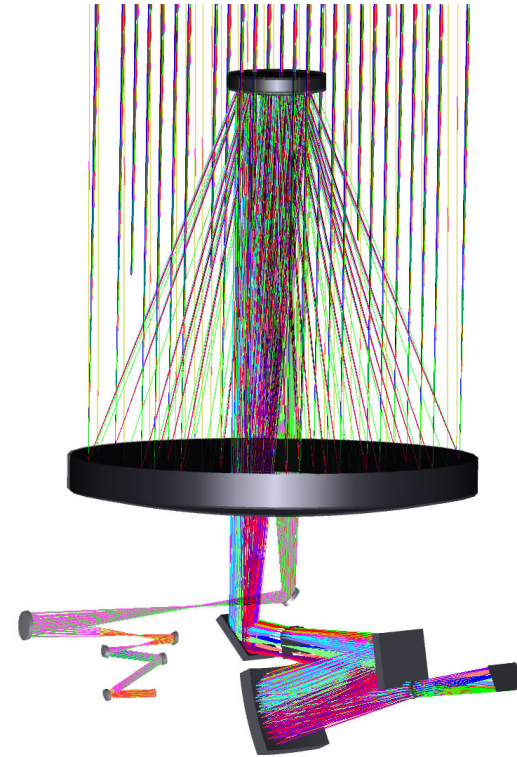
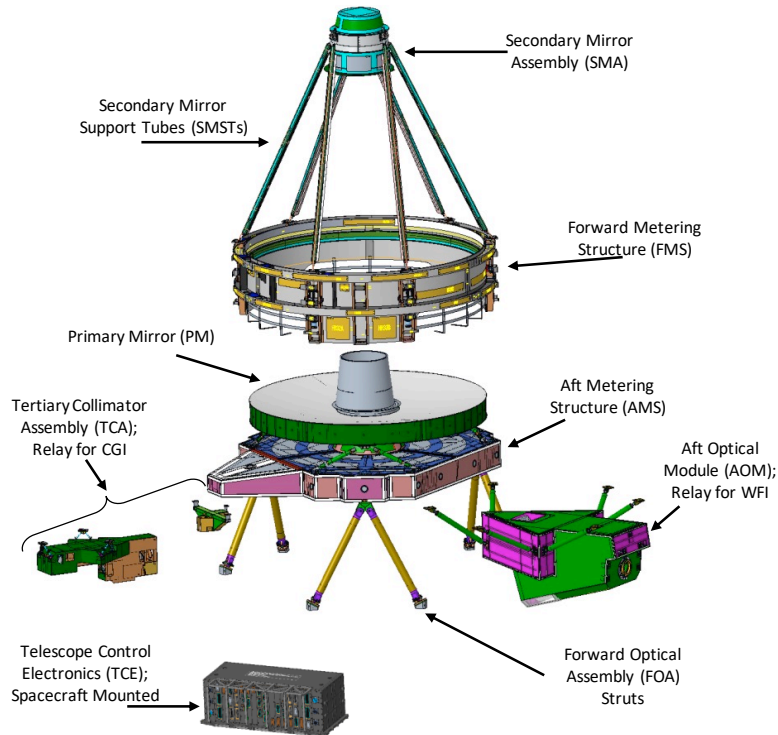
Observatory designed to be robotically serviceable

**Starshade compatible**

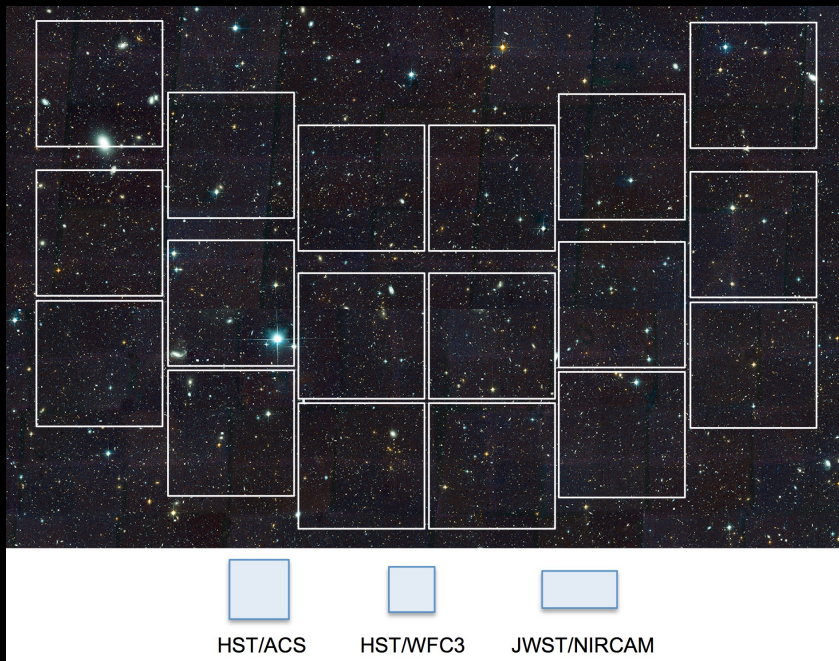


# Observatory Expanded View





## WFIRST Field of View

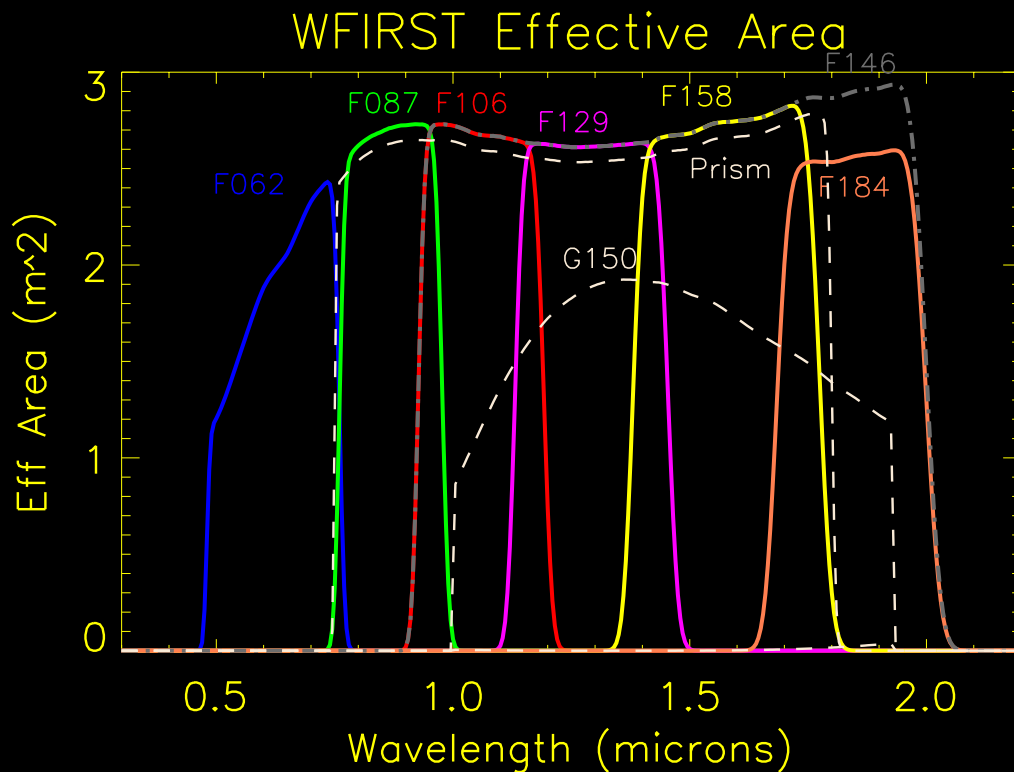


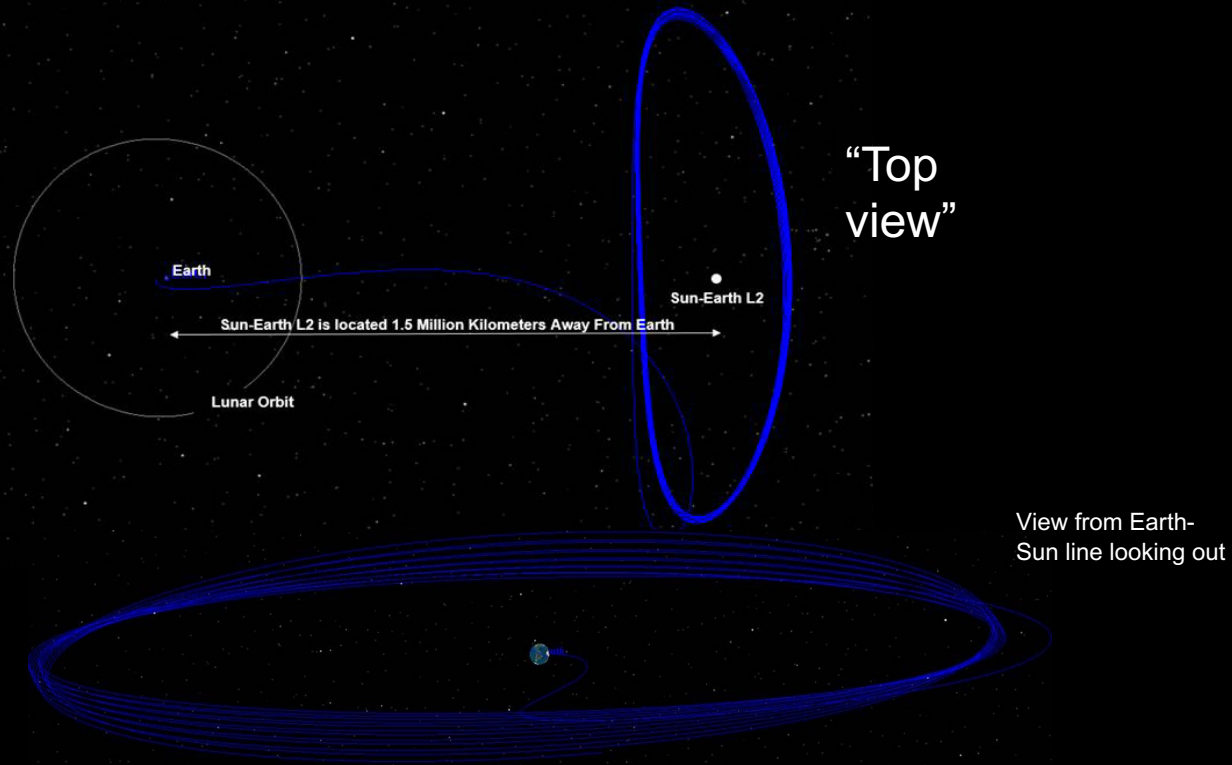
Diffraction-limited imaging  
 0.28 square degree FoV  
 0.11" pixels  
 18 4kx4k NIR detectors  
 R~4 filters spanning 0.48-2.0  $\mu\text{m}$   
 Sensitivity: 27.8 H(AB) @5 $\sigma$  in 1hr

Slitless grism:  
 1.0-1.93  $\mu\text{m}$   
 R: 435-865

Slitless prism:  
 0.75-1.8  $\mu\text{m}$   
 R: 80-170





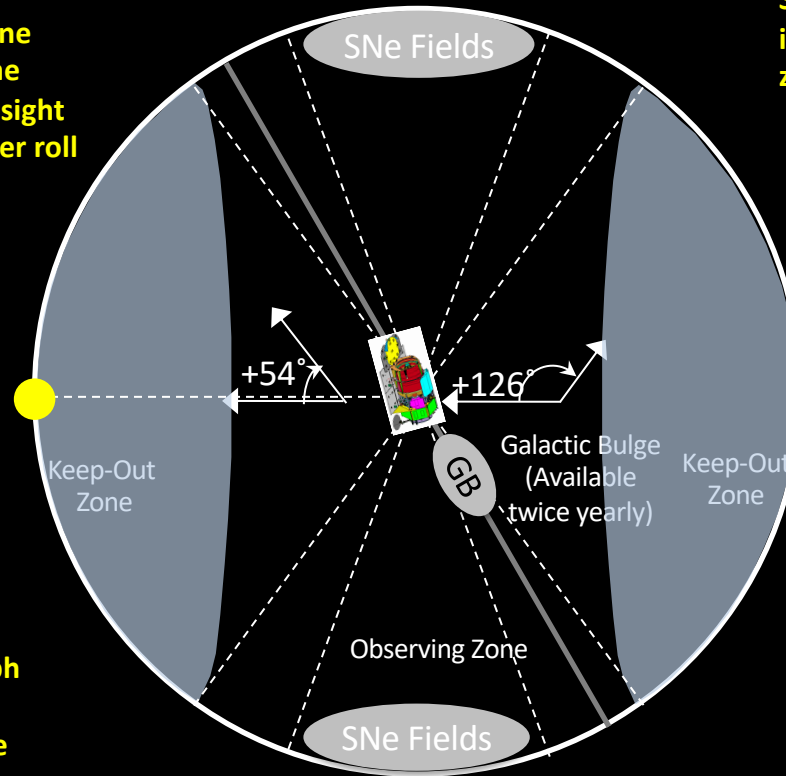


## Observing Zone:

- $54^\circ$ - $126^\circ$  off Sun Line
- $360^\circ$  about Sun Line
- $\pm 15^\circ$  about line of sight (LOS) off max power roll angle

SNe fixed fields located in continuous viewing zone

Earth/Moon LOS avoidance angles are a minor sporadic constraint



HLS/GO/Coronagraph observations can be optimized within the full Observing Zone

Microlensing can observe inertially fixed fields in the Galactic Bulge (GB) for 72 days twice a year



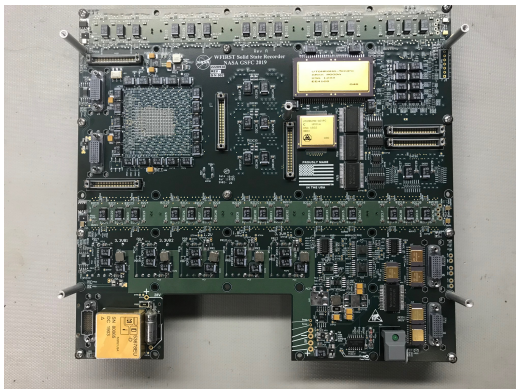
- Milestones to date:
  - Mission Concept Review: December 8-9, 2015
  - KDP-A: February 17, 2016
  - SRR/MDR: February 27 - March 2, 2018
  - KDP-B: May 22, 2018
  - Mission PDR: October 28 – November 1, 2019
  - KDP-C: February 28, 2020 ☐ ← Confirmation Review!
- Upcoming Milestones:
  - Mission CDR: July 2021
  - System Integration Review: July 2023
  - KDP-D: September 2023
  - Launch Planning Date: October 2025

- Preliminary Design Reviews :
  - Instrument Carrier: May 29, 2019
  - Wide Field Instrument: June 18, 2019
  - Telescope: August 22, 2019
  - CGI: September 17, 2019
  - Ground System part 1 (MOC): September 24, 2019
  - Mission/Spacecraft: Oct 28-Nov 1, 2019
  - ~130 internal reviews in 2019 in preparation for element PDRs
  - Ground System part 2 (SOC): July 21, 2020

- Engineering Peer Reviews and Element PDRs – throughout 2019
  - GSFC and JPL internal review boards
  - A number of SRB members participated in the lower level reviews
- MPDR – October 28 – November 1, 2019
  - SRB concerns led to creation of CGI Tiger Team by Program Office
- Center Management Council – December 20, 2019
  - SRB presents findings
- DPMC – January 31, 2020
  - SRB presents findings
  - By this point, CGI Tiger Team recommendations had been largely implemented (or implementation plan agreed-upon)
  - Other SRB concerns likewise addressed
- APMC – February 28, 2020
  - SRB presents updated findings
  - No actions
  - Plans had been pre-briefed to stakeholders in advance
  - All concerns had been addressed by time of the meeting

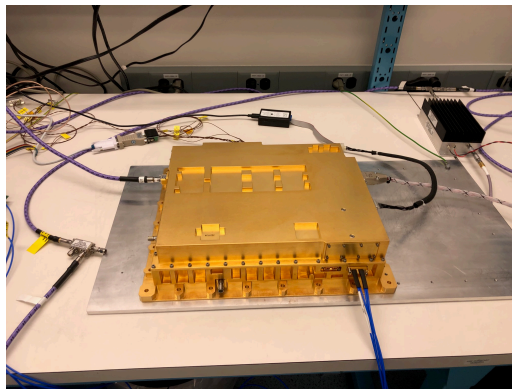


- Design complete for PDR; most subsystems ready for prototyping
- Procurement activities:
  - Awarded or in process: high-gain antenna (HGA) gimbal actuators, TWTA and S-band transponder, propulsion latch valves & tanks, reaction wheels (RW), RW isolator, gyros, solar array substrate, Outer Barrel Assembly structure, Ka-band antenna, HGA boom damper, spacecraft primary structure, printed wiring boards, much more



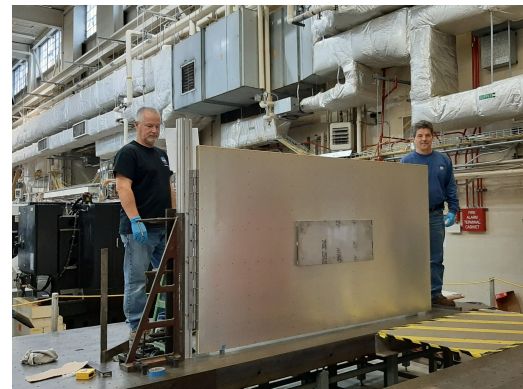
Solid State Recorder prototype board is complete and in testing

3/17/20



Ka-band ETU is complete and in testing with PACE (shared development)

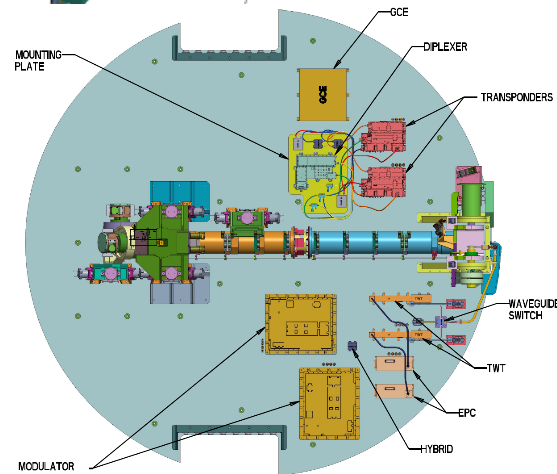
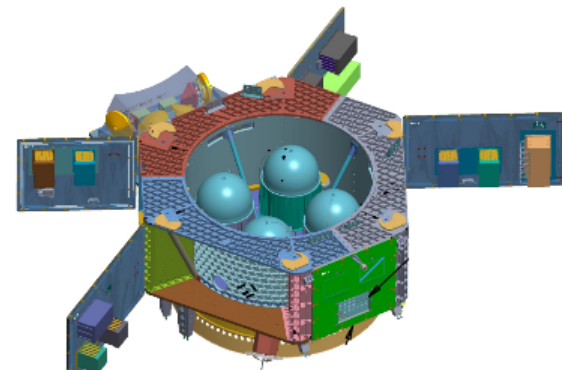
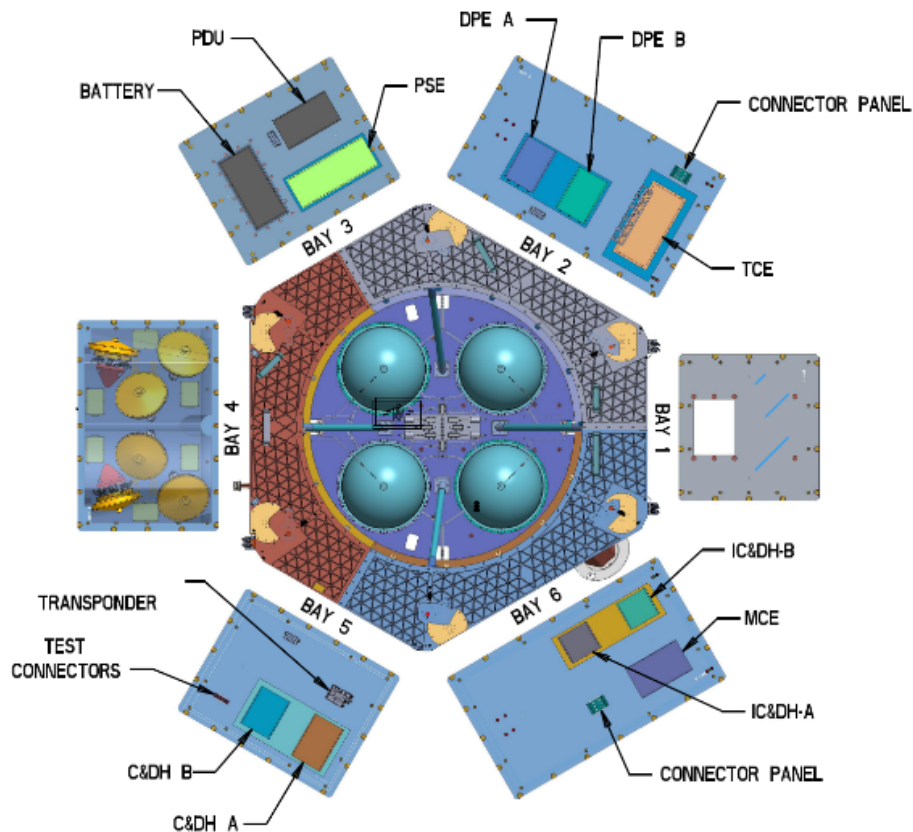
Kruk - EOS1



Full-scale mock-up of Spacecraft Avionics Panel (Bay #2 and #6)

20

# Spacecraft Layout



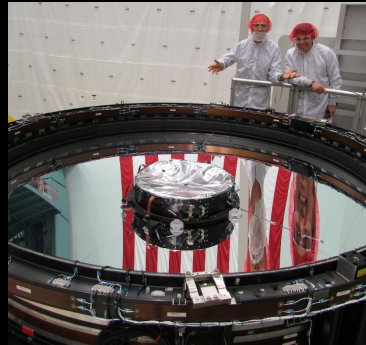
Communications panel – bottom of S/C  
1.7m antenna not shown

- Work is progressing on plan
- Primary mirror figuring is on track: completed full tool polishing, ion figuring run #4, and cold surface figure test
  - Total of 6 ion figuring runs planned – may only need 5
- Disassembly of all inherited hardware is complete
- Secondary mirror ready for final ion figuring run
- Thermal zones & control approaches defined (nearly all optical and baffle surfaces  $\leq 267\text{K}$ )
- Engineering models of new & modified components being built
- Flight models of build-to-print items being fabricated
  - Alignment drive mechanisms, focus drive mechanisms

# Inherited hardware progress (1)



**Primary Mirror Assembly  
+ Forward Metering  
Structure At  
SRR/Pedigree Review**

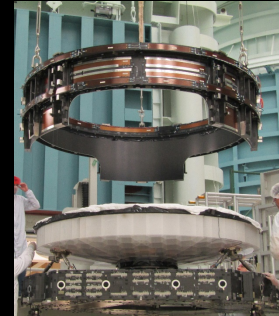


3/17/20

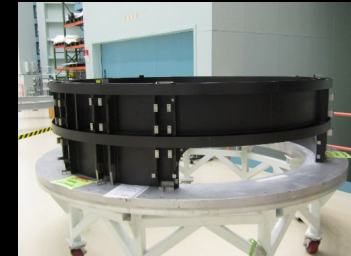
Photos courtesy of L3Harris Corp.



**Removal of PM Scraper  
7/2018**



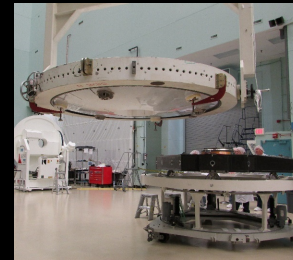
**Forward  
Metering Shell  
Removal 7/2018**



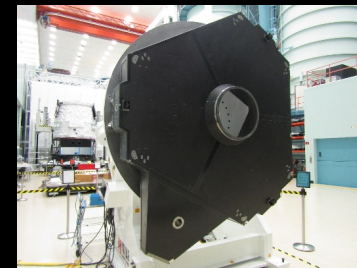
**Forward  
Metering  
Structure June  
2019**



**Removal of PM Baffle  
Adaptor 7/2018**

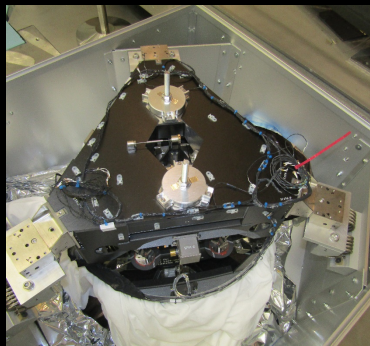


**Removal of Spare PM  
from Aft Metering  
Structure May 2019**

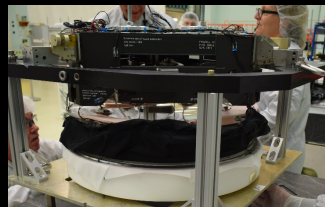


**Aft Metering  
Structure June 2019**

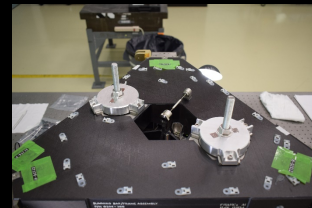




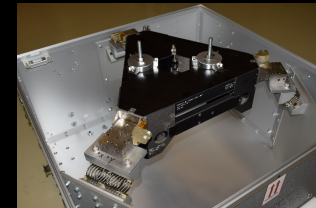
**Secondary Mirror Assembly at SRR/Pedigree Review**



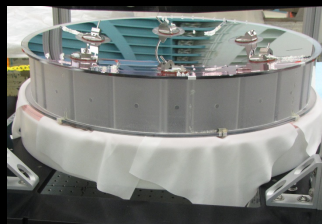
**Disassembly of support structure from mirror**



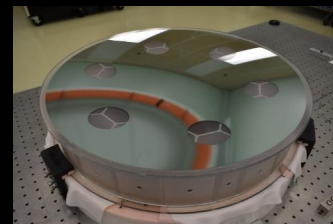
**Removal of thermal-electric hardware**



**Secondary Mirror Support Structure (SMSS) ready for re-use**



**Secondary Mirror removed from support structure**



**Back Pad Removal**

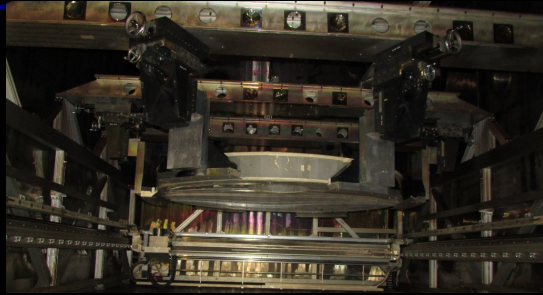


**In process shaping of SM to WFIRST prescription**



***Flight Primary  
Mirror  
As received***

Photos courtesy of L3Harris Corp.



***Ion Figuring  
- Ongoing***



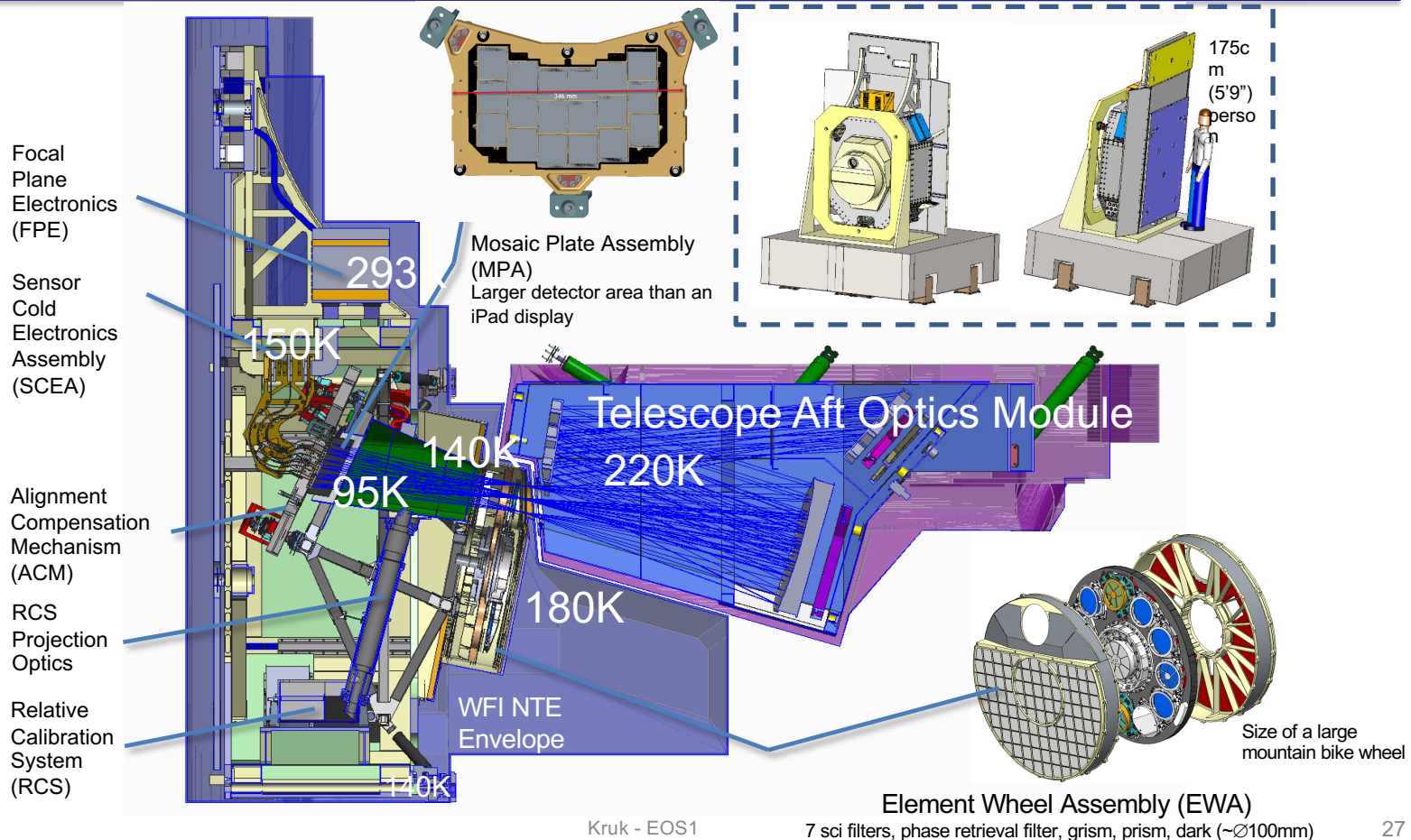
Kruk - EOS1

***Full Tool Polish May 2019***

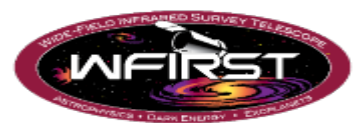
- Interface Control Documents released or will be very soon
- Structure procurement activities are on track
  - Contract awarded for composite components
  - Titanium forgings for nodes procured
    - Fabrication to begin - passed Manufacturing Readiness Review
- Launch lock & vibration isolation system contract awarded
  - Trade in progress on cutoff frequency
  - Launch lock design qualified



# WFI Cold Sensing Module





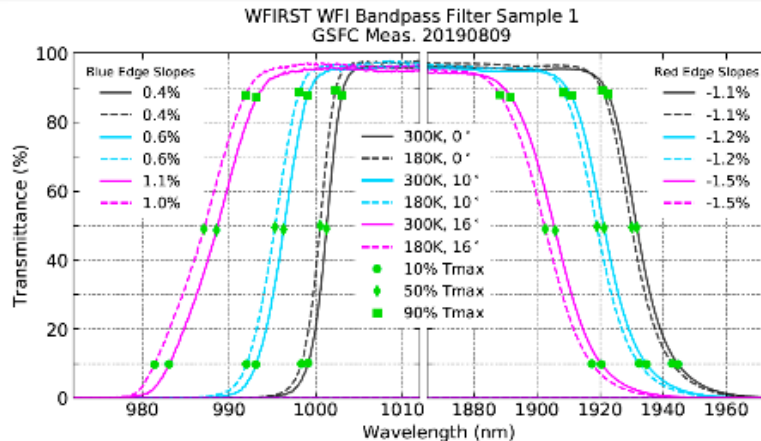
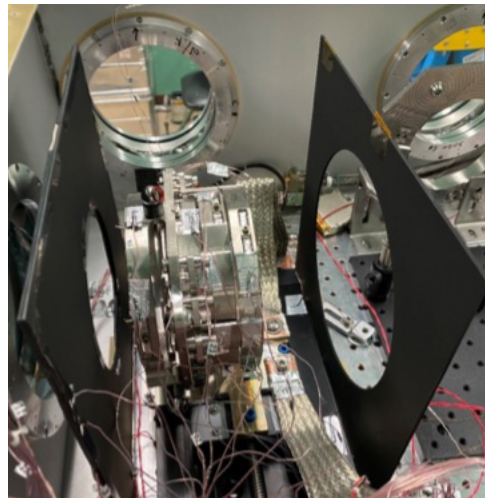


# Wide-Field Instrument Progress

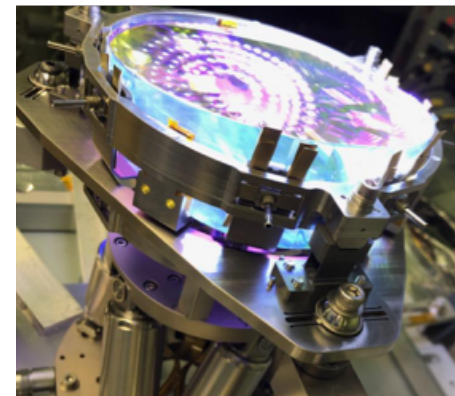


- Overall WFI design has converged: still a few tweaks on the way to CDR
- Grism assembly engineering unit undergoing tests & characterization
  - Diffraction efficiency close to model prediction
  - Thermal tests in progress to verify alignment through cooldown
- Prism EDU under construction to verify mounting approach
  - Thermal tests to follow the grism tests
- ETU filters for wide-field instrument being characterized
  - Meet specs; one has slight exceedance of ripple spec, but deviation is very small.

# Wide-Field Instrument components



ETU grism bandpass measurement



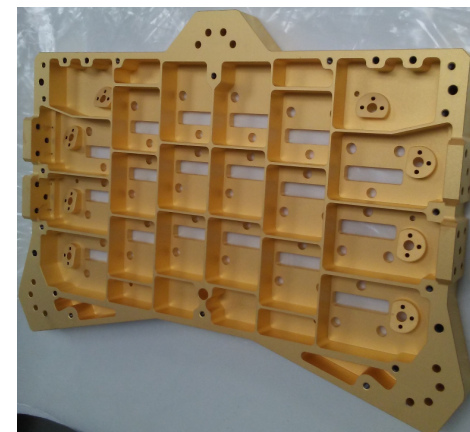
EDU prism assembly

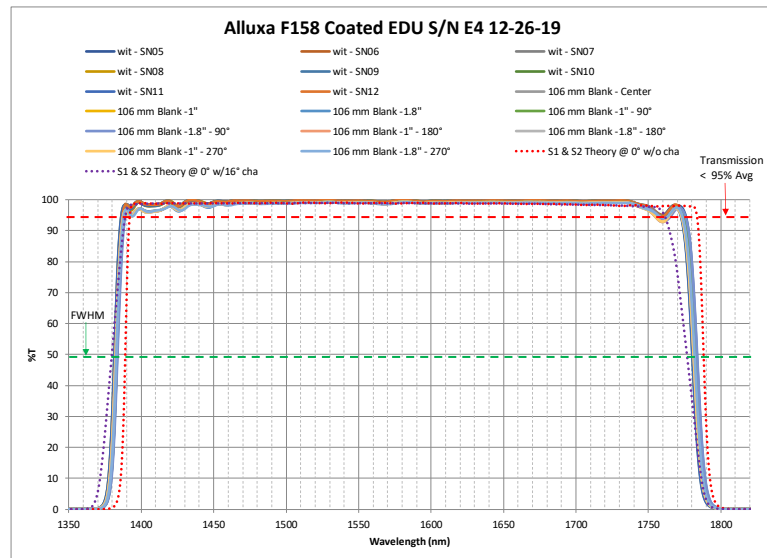
ETU grism thermal gradient test



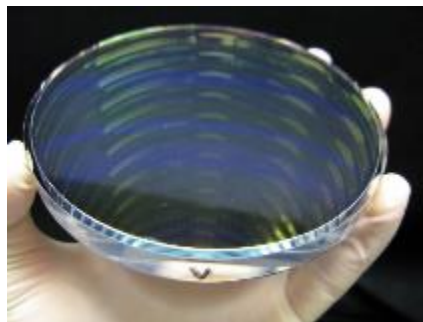
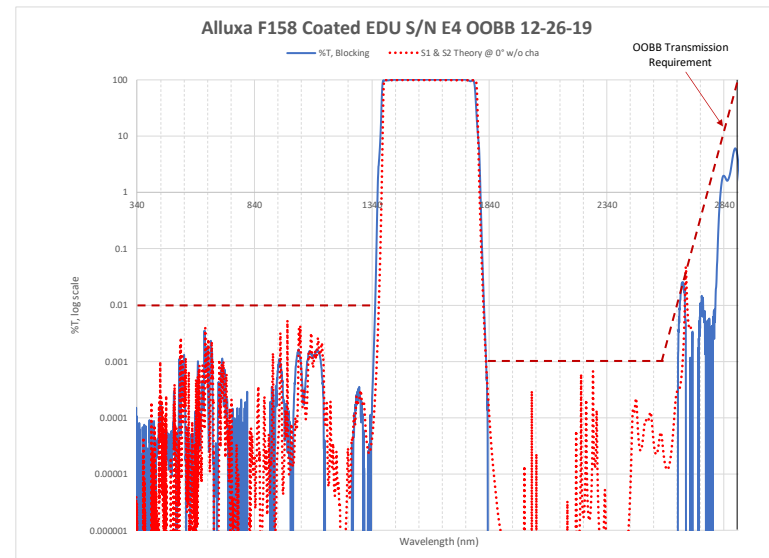
ACADIA ASIC EDU

ETU Mosaic Plate

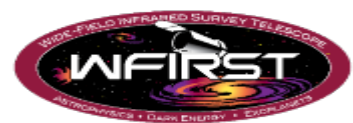




## F158 EDU



Log scale to show out of band transmission



# Wide-Field Instrument Progress



- 5 SCAs have passed acceptance testing in the DCL and appear to be good flight candidates.
- SCA characterization testing has started.
  - Intra-Pixel response showed similar results to test program SCAs (meets expectations)
  - Flux Dependent Non-linearity testing on first detector has started
  - Accelerated life testing almost completed.
- If the flight yield continues to meet expectations, we should receive our 18<sup>th</sup> flight SCA in January 2021, meeting FPS schedule needs for an on-time delivery.
  - Current yield is slightly higher than the yield assumption.
  - Yield projection is based on the use of only high Zn substrate material
- The first flight SCAs will need to be selected in June 2020 in order to support the start of triplet testing (SCA + cable + SCE) in late summer 2020
- SCA alignment (5 SCAs used) has been demonstrated to meet requirements on an EDU Mosaic Plate
  - 18 SCAs to be aligned this summer 2020 during ETU FPA build and test
- SCE development: 2<sup>nd</sup> generation ACADIA passed ambient tests; now testing cold
  - ACADIA performance thus far exceeds expectations! Radiation testing in EDU package this month



- First **5** flight candidate detectors identified. See properties in table.
- Total SCAs tested at DCL passing Teledyne Cold Functional: **14**
- Flight candidate SCAs are being delivered and tested at a rate of 1/week.

|       | Total Noise | Dark Current | Persistence (300 ke)* |                    |
|-------|-------------|--------------|-----------------------|--------------------|
| Spec  | <6.5 e      | <0.05 e/s    | <0.50 e/s             | <0.8 e/s/pix       |
| SCA   | Median (e)  | Median (e/s) | Median (e/s)          | (%) Pixels passing |
| 20829 | 5.73        | 0.000        | 0.207                 | 99.96              |
| 20833 | 4.97        | 0.000        | 0.074                 | 99.93              |
| 20828 | 5.34        | 0.000        | 0.144                 | 99.90              |
| 20663 | 5.48        | 0.000        | 0.100                 | 99.88              |
| 20849 | 5.41        | 0.001        | 0.173                 | 99.90              |

\*10 min after stimulus

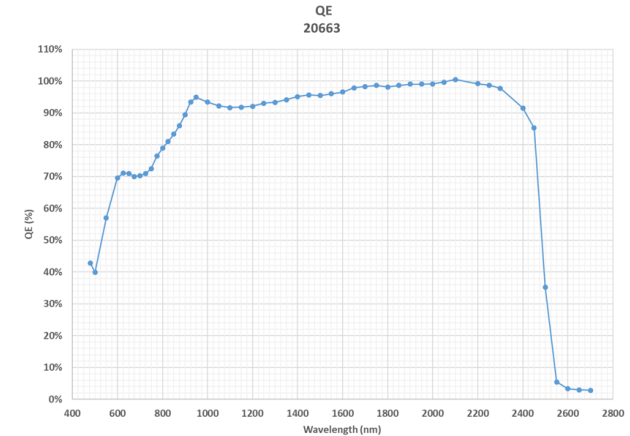


Total Noise (e-)



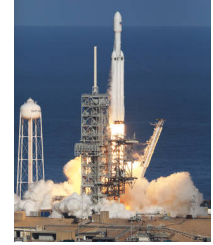
Dark Current (e-)

Kruk - EOS1



- Mission Operations Center (MOC) and ground station design is on track
  - Technical interchanges on ground stations w/ international partners continuing
    - Both JAXA and ESA to provide Ka-band antennas
  - Planning & scheduling system architecture work has begun
  - Data processing system architecture work beginning
  - Calibration plan close to being baselined
  - MOC PDR held, Science Operations PDR early next Summer

- Launch Vehicle Certification
  - NASA's Launch Service Program (LSP) is beginning the process of certifying the SpaceX Falcon Heavy. They expect that to be completed in 2021.
  - LSP typically waits for a mission to be awarded on a vehicle **before** starting the certification effort. A typical certification effort takes ~2 years. In those cases, LSP's goal is to certify the vehicle no later than L-6 months. LSP expects any other LV candidate to follow this approach.
- WFIRST is pursuing an early acquisition of the launch vehicle. The expected award is ~L-56 months (as opposed to a typical L-30 months).
- Coupled Loads Analysis (CLA) cycle 2 was completed prior to Mission PDR for SpaceX Falcon Heavy launch vehicle.
- CLA cycle 3 will be moved forward (ahead of Mission CDR) to accommodate element testing.
- Design environments have enveloped all candidate launch vehicles through PDR.



SpaceX Falcon Heavy



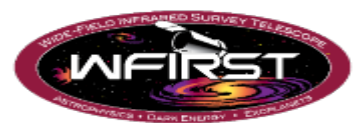
Blue Origin New Glenn



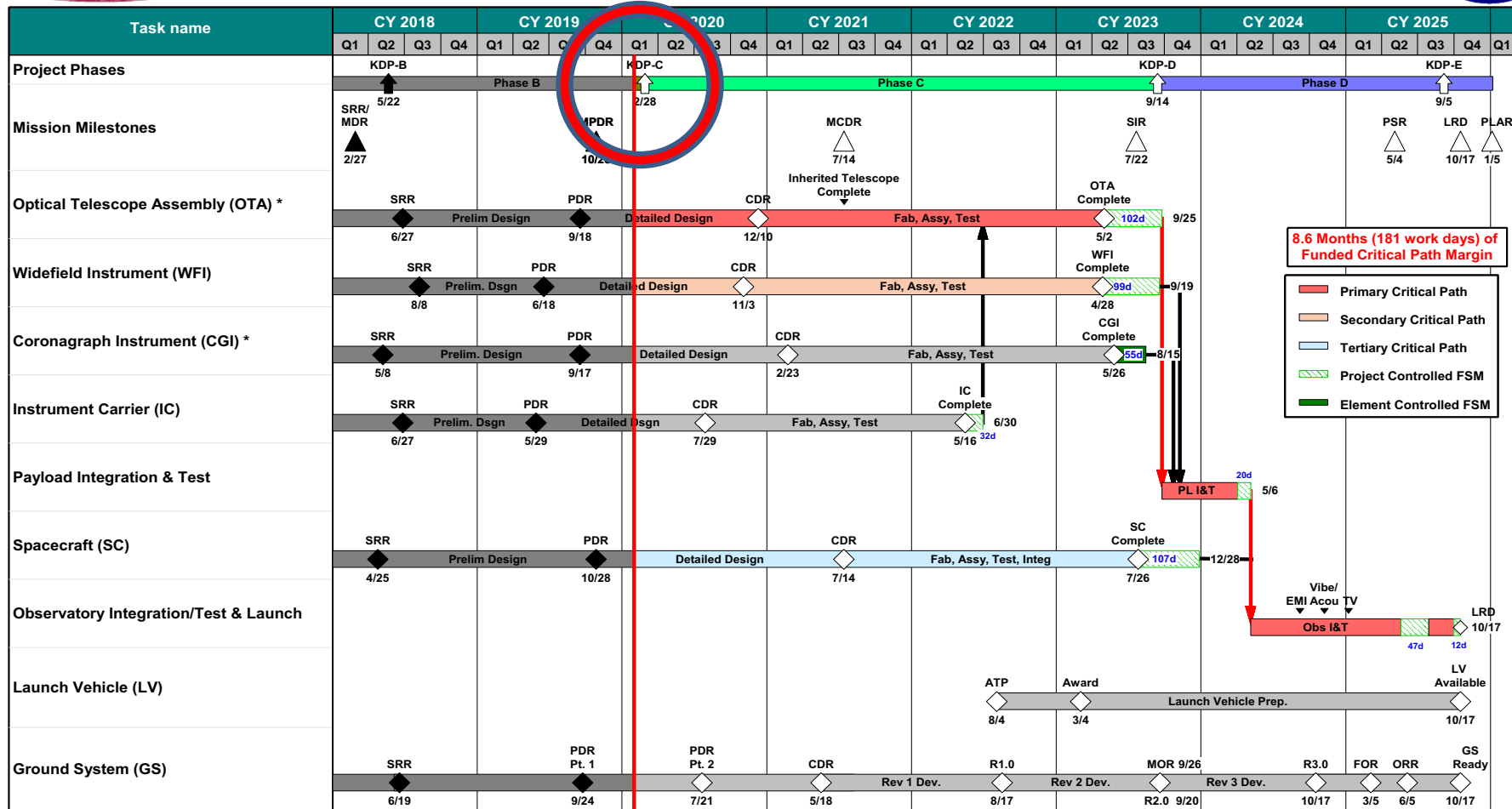
United Launch Alliance  
Vulcan

- Early development of all new items (detectors, ACADIA ASIC, Ka-band modulator)
- Extensive engineering peer reviews (EPRs)
- Engineering units built for electronics, mechanisms, optics, etc. that aren't build-to-print
- Integrated modeling began pre-Phase A and continually updated
  - WFE and pointing budgets established early and tracked through every design iteration
  - Used for trades on thermal control approaches, opto-mechanical tolerances, vibration isolation, etc.
- Early coupled-loads analysis with launch vehicle provider(s)
- Aggressive schedule management
  - Worked with HQ to develop an efficient budget profile
  - Work closely w/ GSFC management on lifecycle plans for optimizing staffing profile, access to facilities, etc.
  - Work closely with vendors on process reviews/inspections, provide help with procurements, provide technical help as-needed
  - For challenging procurements, carry multiple vendors through initial phases





# WFIRST Project Master Schedule



# Budget Profile

Budget profile assumed for cost commitment; subject to annual appropriate process.  
Administration proposes no funding and termination starting in FY21.

|                                   | Prior Years | Cost phasing by year |          |          |          |          |          | To Launch | Ops      | Total      |
|-----------------------------------|-------------|----------------------|----------|----------|----------|----------|----------|-----------|----------|------------|
|                                   |             | FY20                 | FY21     | FY22     | FY23     | FY24     | FY25     |           |          |            |
| WFIRST KDP-C Management Agreement | \$540.3M    | \$445.7M             | \$400.6M | \$323.2M | \$287.8M | \$298.0M | \$282.7M | \$53.7M   | \$367.9M | \$3,000.0M |
| CGI KDP-C Management Agreement    | \$112.5M    | \$65.0M              | \$83.3M  | \$35.6M  | \$24.2M  | \$7.1M   | \$5.8M   | \$0.0M    | \$9.3M   | \$342.7M   |
| Agency-held Reserve               |             |                      | \$21.3M  | \$95.0M  | \$85.0M  | \$85.0M  | \$85.0M  | \$197.7M  | \$22.3M  | \$591.3M   |
| Agency Baseline Commitment        | \$652.8M    | \$510.7M             | \$505.2M | \$453.8M | \$397.0M | \$390.1M | \$373.5M | \$251.5M  | \$399.5M | \$3,934.0M |

Development cost excluding coronagraph (sum lines 1 & 3 through launch): \$3.2B

Launch no later than October 2026. Present Project planning date for launch is October 2025

- Have just completed “Preliminary Design”
- The flight mission elements have been in Phase C since their respective PDRs
  - Instrument Carrier, WFI are half-way to their CDRs
- The SOC/SSC work is still effectively in Phase B, until Ground System PDR part 2
- Engineering development units of many hardware items already built, more in progress
- *For much of observatory, design today is what will be built and what will fly*
- PDR & KDP processes include extensive management and cost reviews
  - Plan to execute the mission is as big a part of the reviews as the engineering design
- FY2020 and FY2021 are the peak budget years
  - Approaching 1000 people working on WFIRST!
- FY21 White House Budget proposes termination of WFIRST
  - Direction is to proceed according to plan while Congress deliberates

**We are on track for a launch “no later than 2026”**  
**Project planning date is October 2025**

# QUESTIONS?

For more information, see:

<https://wfirst.gsfc.nasa.gov/>

[https://wfirst.gsfc.nasa.gov/science/WFIRST\\_Reference\\_Information.html](https://wfirst.gsfc.nasa.gov/science/WFIRST_Reference_Information.html)



## Acronym list

|        |                                                            |
|--------|------------------------------------------------------------|
| ABC    | Agency Baseline Commitment                                 |
| ACADIA | ASIC for Control and Digitization of Imagers for Astronomy |
| CDR    | Critical Design Review                                     |
| CGI    | Coronagraph instrument                                     |
| CLA    | Coupled Loads Analysis                                     |
| EDU    | Engineering Development Unit                               |
| ETU    | Engineering Test Unit                                      |
| KDP    | Key Decision Point                                         |
| LSP    | Launch Services Program                                    |
| MOC    | Mission Operations Center                                  |
| PDR    | Preliminary Design Review                                  |

|        |                                      |
|--------|--------------------------------------|
|        |                                      |
|        |                                      |
| PM     | Primary Mirror                       |
| SCA    | Sensor Chip Assembly                 |
| SCE    | Sensor Cold Electronics              |
| SOC    | Science Operations Center            |
| SSC    | Science Support Center               |
| SRB    | Standing Review Board                |
| SRR    | System Requirements Review           |
| WFI    | Wide-Field Instrument                |
| WFIRST | Wide-Field Infrared Survey Telescope |

**Limiting point-source sensitivity (AB mag) in 1 hour of exposure time, Zodiacal light set at twice minimum.**

| Imaging, 5 $\sigma$ |      |      |      |      |      |      |
|---------------------|------|------|------|------|------|------|
| R062                | Z087 | Y106 | J129 | H158 | F184 | W149 |
| 28.5                | 28.2 | 28.1 | 28.0 | 28.0 | 27.5 | 28.3 |

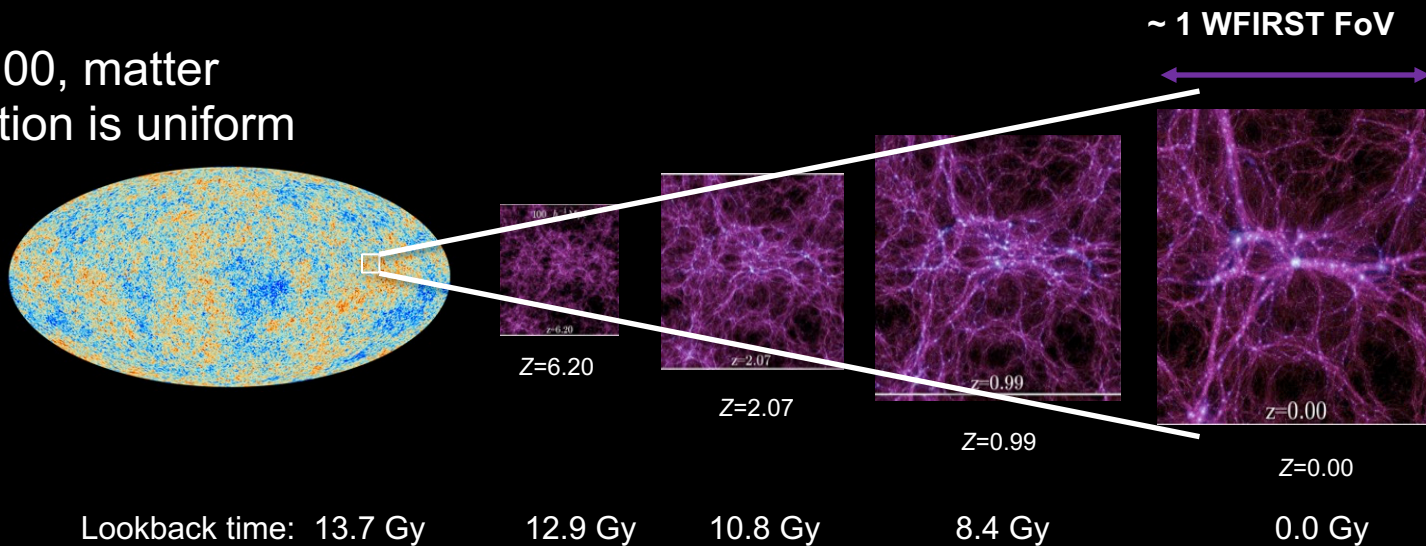
| Spectroscopy, 10 $\sigma$ per pixel in continuum |                   |                   |                   |
|--------------------------------------------------|-------------------|-------------------|-------------------|
|                                                  | 0.8 $\mu\text{m}$ | 1.1 $\mu\text{m}$ | 1.5 $\mu\text{m}$ |
| Grism                                            | N/A               | 20.78             | 20.48             |
| Prism                                            | 22.87             | 23.45             | 23.54             |

WFIRST will measure expansion history *and* growth of structure

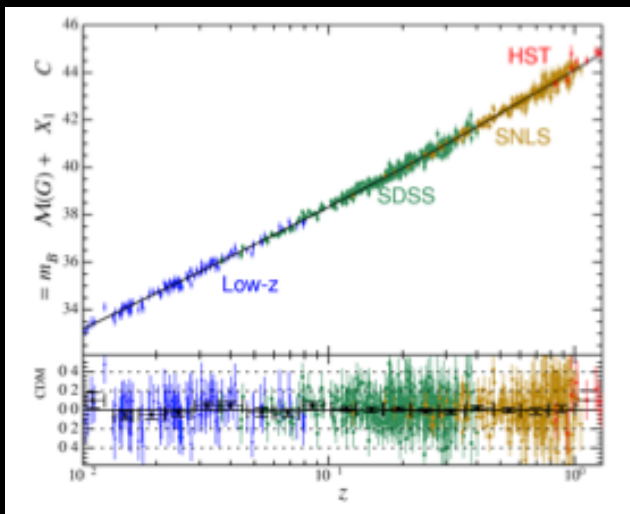
- If results discrepant  $\rightarrow$  breakdown of general relativity
- If results agree  $\rightarrow$  learn about nature of dark energy

WFIRST provides multiple probes, enabling cross-checks for astrophysical and instrumental systematics

At  $z \sim 1100$ , matter distribution is uniform to  $10^{-5}$

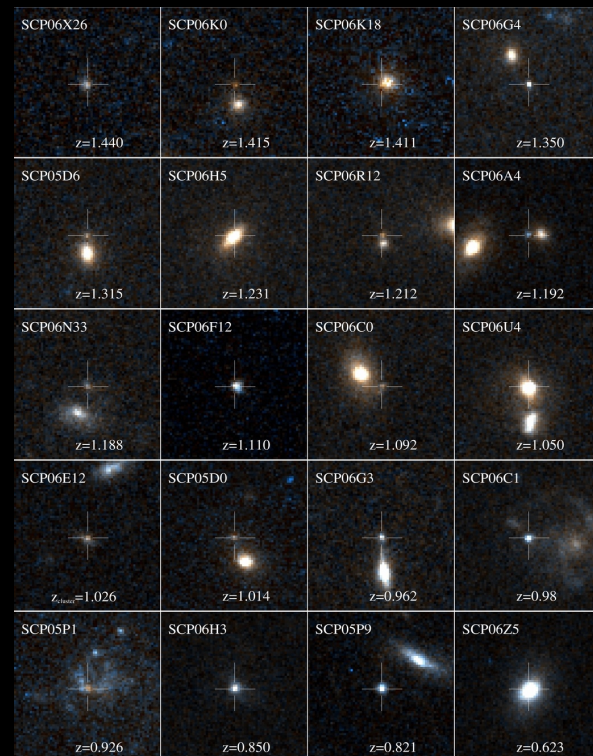


# Luminosity distance from SNIa



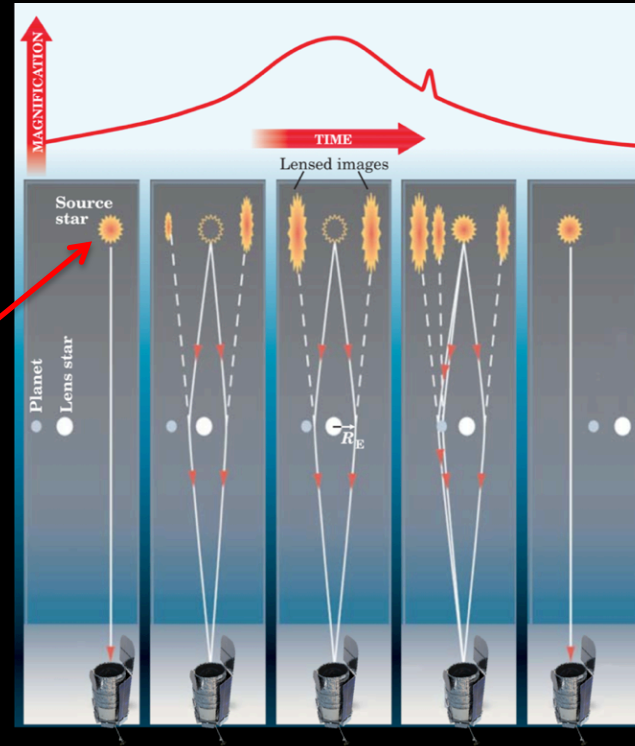
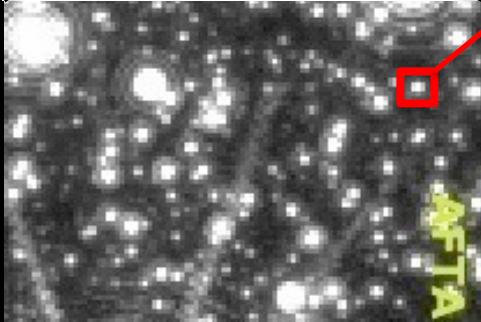
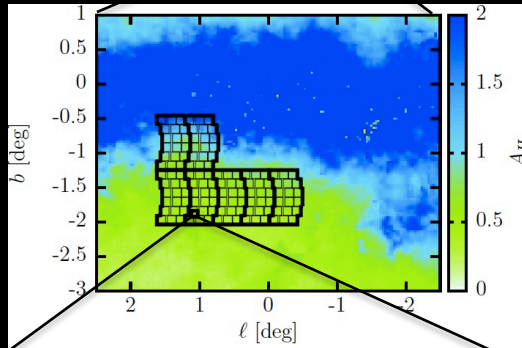
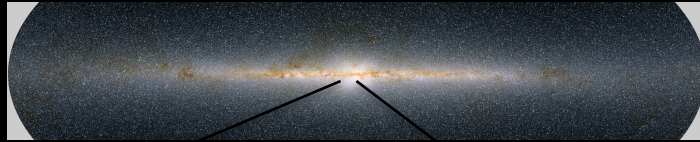
Hubble diagram from Betoule et al 2014, w/best-fit  $\Lambda$ -CDM model

Key next steps are to  
 reduce systematic  
 uncertainties, increase  
 sample at redshift  $> 1$





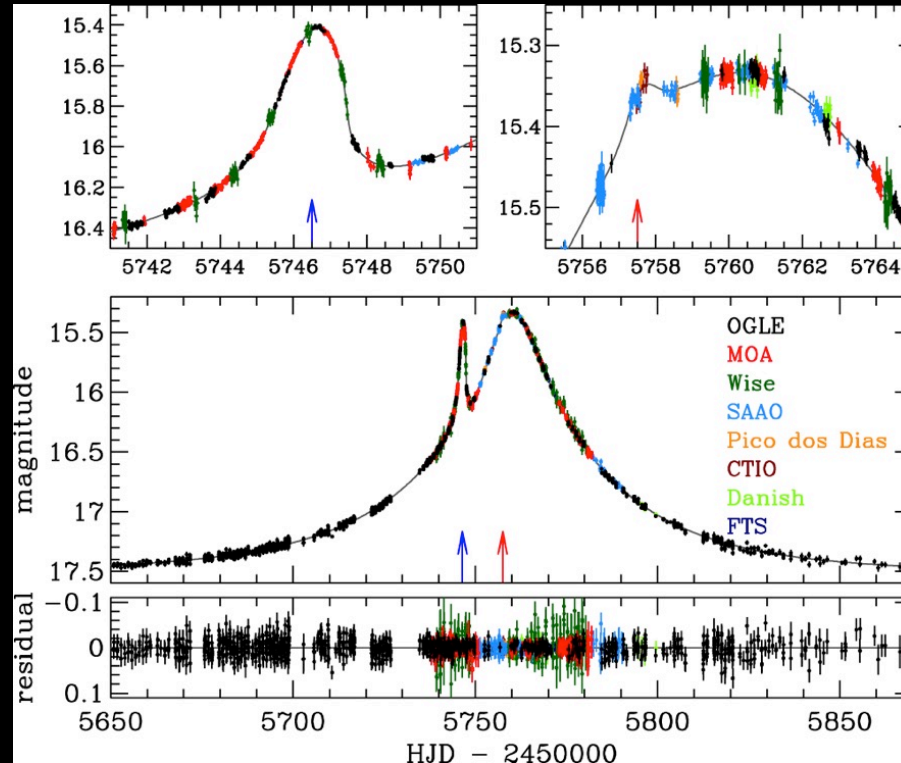
# Microlensing Observation Concept



Great benefit of space observations in the crowded galactic bulge field

Microlensing event from Jupiter-mass planet around an M-dwarf (Skowron et al 2015)

Shape of light curve is governed by changing geometry of source & host stars & planet; motion of Earth about Sun affects shape of star-star light curve.



| Band | Element name | Min ( $\mu\text{m}$ ) | Max ( $\mu\text{m}$ ) | Center ( $\mu\text{m}$ ) | Width ( $\mu\text{m}$ ) | R                    |
|------|--------------|-----------------------|-----------------------|--------------------------|-------------------------|----------------------|
| R    | F062         | 0.48                  | 0.76                  | 0.620                    | 0.280                   | 2.2                  |
| Z    | F087         | 0.76                  | 0.977                 | 0.869                    | 0.217                   | 4                    |
| Y    | F106         | 0.927                 | 1.192                 | 1.060                    | 0.265                   | 4                    |
| J    | F129         | 1.131                 | 1.454                 | 1.293                    | 0.323                   | 4                    |
| H    | F158         | 1.380                 | 1.774                 | 1.577                    | 0.394                   | 4                    |
|      | F184         | 1.683                 | 2.000                 | 1.842                    | 0.317                   | 5.81                 |
| Wide | F146         | 0.927                 | 2.000                 | 1.464                    | 1.070                   | 1.37                 |
| GRS  | G150         | 1.0                   | 1.93                  | 1.465                    | 0.930                   | 461 $\lambda$ (2pix) |
| PRS  | P127         | 0.75                  | 1.80                  | 1.275                    | 1.05                    | 80-170 (2pix)        |

# Representative Emission Line Sensitivity (grism)

**Emission line flux detected at  $6.5\sigma$  in one hour, with zodiacal light set at twice minimum.**

**Units are  $10^{-17}$  ergs/cm<sup>2</sup>/sec**

| Wavelength    | Source half-light radius |       |
|---------------|--------------------------|-------|
| $\mu\text{m}$ | 0.0"                     | 0.2"  |
| 1.05          | 7.8                      | 17.0  |
| 1.15          | 5.6                      | 12.25 |
| 1.25          | 5.0                      | 10.5  |
| 1.35          | 4.8                      | 9.7   |
| 1.45          | 4.8                      | 9.6   |
| 1.55          | 5.0                      | 9.8   |
| 1.65          | 5.5                      | 10.5  |
| 1.75          | 5.9                      | 11.3  |
| 1.85          | 6.7                      | 12.3  |

## Structure

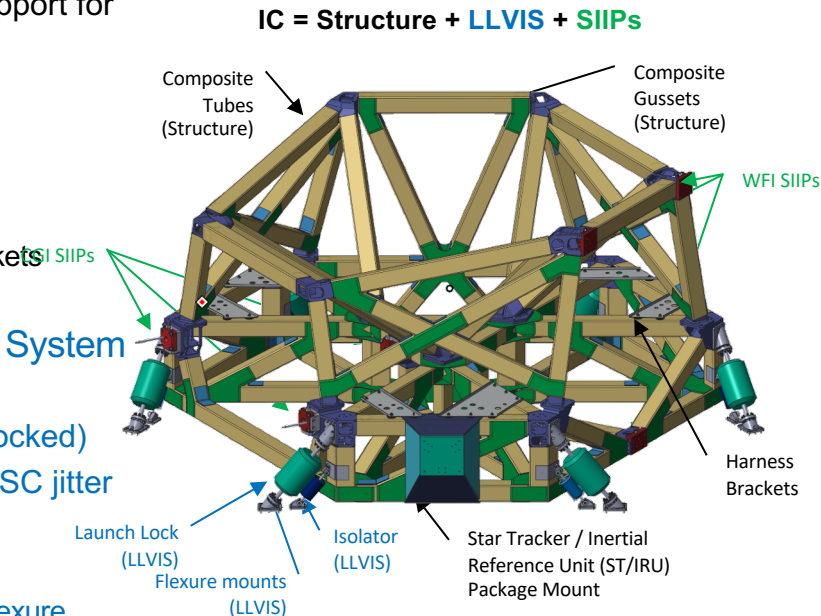
- Provides stiff, strong, and stable support for WFIRST Payload
- Similar construction to JWST ISIM
  - Leveraging lessons learned
- Includes:
  - Composite tubes and gussets
  - Ti nodes and clips; Harness brackets
  - ST/IRU mount

## Launch Lock and Vibration Isolation System (LLVIS)

- Mounts Payload to SC for launch (locked)
- Isolates the WFIRST Payload from SC jitter (unlocked)
- Includes:
  - Launch lock; Vibration isolator; Flexure mounts to IC and SC

## Science Instrument Interface Plates (SIIPs)

- Align instruments to telescope pupils
- Similar to ISIM SIIPs
  - Leveraging lessons learned





- **What the Design Reference Mission is:**
  - **A required product at major mission reviews**
  - **An existence proof that mission objectives can be met in required lifetime**
  - **A tool for exercising the ground system**
    - Does proposal system support all the observing modes?
    - Can planning/scheduling tools build the timeline & command loads?
    - Will command loads execute on the spacecraft & instrument simulators?
    - Does observing efficiency in simulator match expectations?
    - Does telemetry support data processing of all observing modes?
    - Are pipeline products properly ingested into the archive?

- **What the DRM is:**

- **A required product at major mission reviews**
- **An existence proof that mission objectives can be met in required lifetime**
- **A tool for exercising the ground system**
  - Does proposal system support all the observing modes?
  - Can planning/scheduling tools build the timeline & command loads?
  - Will command loads execute on the spacecraft & instrument simulators?
  - Does observing efficiency in simulator match expectations?
  - Does telemetry support data processing of all observing modes?
  - Are pipeline products properly ingested into the archive?

- **What the DRM is not:**

- **The actual observing plan**