WFIRST Status

March 5th, 2020

Jeffrey Kruk
WFIRST Project Scientist

• NASA GODDARD SPACE FLIGHT CENTER • JET PROPULSION LABORATORY •
• HARRIS • BALL AEROSPACE • TELEDYNE • NASA KENNEDY SPACE CENTER •
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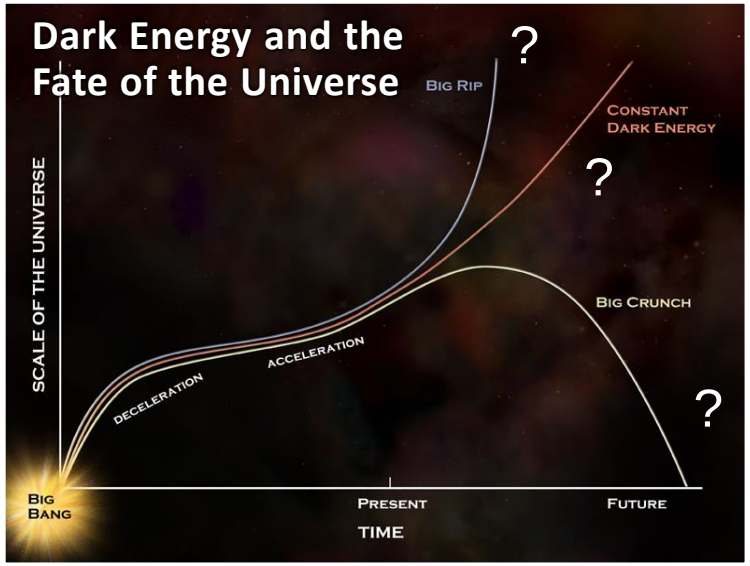
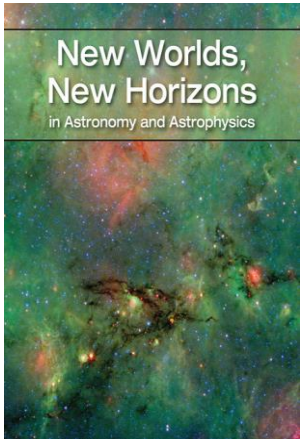
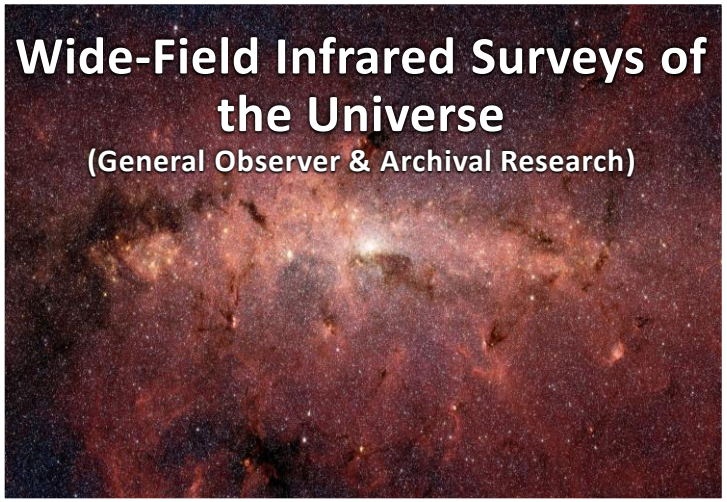
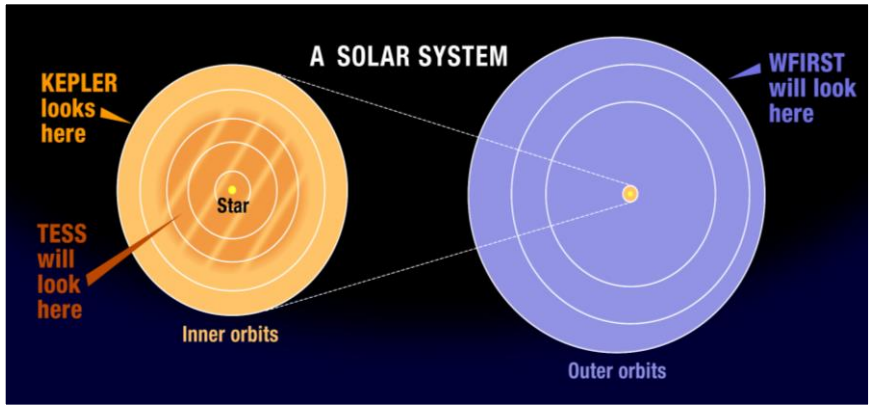
Science Program (no changes)







The full distribution of planets around stars



Recent Status

- We passed the Confirmation Review!
- We are in Phase C!

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Yipee!

Overview

- Last presentation to the APAC was late last October, during the Mission PDR
- Only changes to the mission baseline since then:
  - Coronagraph programmatic status:
    - CGI is now Class D
    - No Level-1 Baseline performance requirements
    - Has separate cost cap and schedule
    - No changes to CGI design
      - Increased flexibility to respond to potential delays in schedule

KDP-C Process

- 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

Next Steps

- CGI Stakeholders team formed
  - First meeting February 25th 2020
  - Group is to provide input to CGI Project to guide decision-making (more in later slides)
  - Includes representatives of potential future coronagraph missions
- Decadal Survey EOS1 panel briefing – March 17th
  - “The panel should get a brief reminder of the science that WFIRST is designed to address -- you can skip the CGI part as that will be addressed by a separate talk.
  - We would like to know what the status is of completing the design, retiring risks, and getting started on fabrication of long-lead items.
  - We would also like to understand the project schedule and the projected funding needed until the start of Phase E.
  - The SRB representative should address the risk, costs, and schedule concerns that they may have. ”

Next Steps

- Build the mission!
  - Next major milestone: Mission CDR in July 2021
    - This does not have an HQ KDP associated with it.
- 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
  - The data processing S/W workshops this week (and perhaps more later) along with the working groups are an important part of the preparations for the Ground System PDR part 2.
- Engineering test unit filters for wide-field instrument
  - Meet specs; one has slight exceedance of ripple spec, but deviation is very small.

Next Steps

- Telescope primary mirror has finished 4 of 6 ion figuring runs and has just completed cold tests
  - Test report due soon
  - Progress continues ahead of schedule
- Fabrication of engineering test units for new hardware components
- Fabrication of flight units for build-to-print hardware not inherited from the original owner is under way.
- Refiguring of secondary mirror close to done – one more ion-figuring run planned.

Detector Status

- To date, 5 SCAs have passed acceptance testing in the DCL and appear to be good flight candidates.
  - Test reports for the flight candidates and test results for all SCAs are available on the project file server
- Test data for all SCAs is being made available to FSWG
- 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
- If the flight yield continues to meet expectations, we should receive our 18th 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

Detector Status

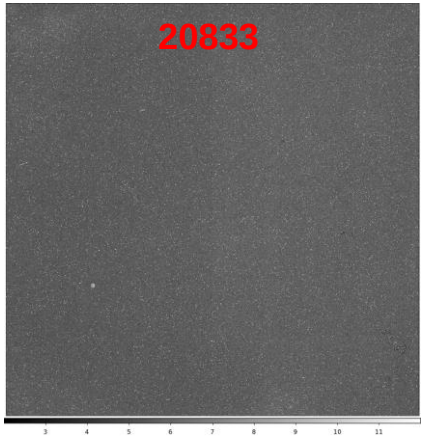
- The first flight SCAs will need to be selected in June 2020 in order to support the start of triplet testing (SCA + cable + SCE) in late summer 2020
- SCA alignment (5 SCAs used) has been demonstrated to meet requirements on an EDU Mosaic Plate
  - 18 SCAs to be aligned this summer 2020 during ETU FPA build and test
- SCE development: 2nd generation ACADIA passed ambient tests; now testing cold
  - ACADIA performance thus far exceeds expectations!

Detector Status continued

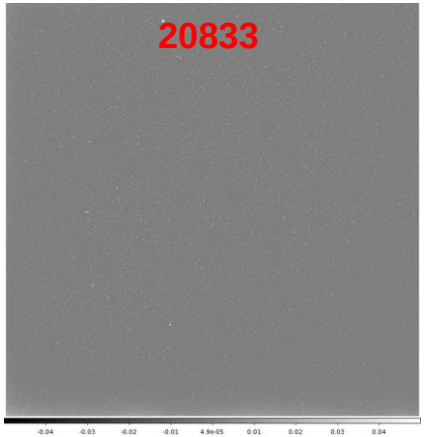
- First **5** flight candidate detectors identified. See properties in table.
- Total SCAs tested at DCL passing Teledyne Cold Functional: **14**
- Flight candidate SCAs are being delivered and tested at a rate of 1/week.
- The current flight yield and delivery schedule will support an on-time integration of the flight FPA.

	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

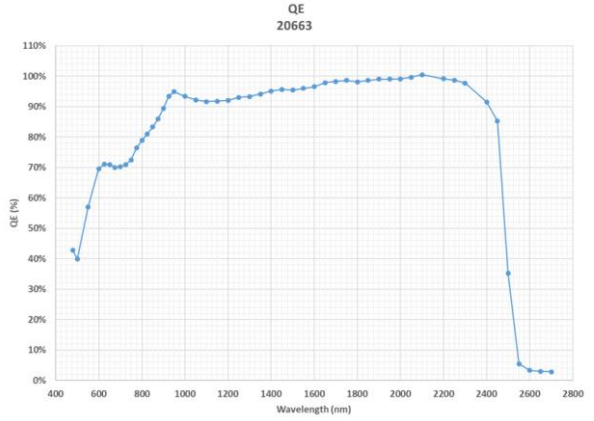
*10 min after stimulus



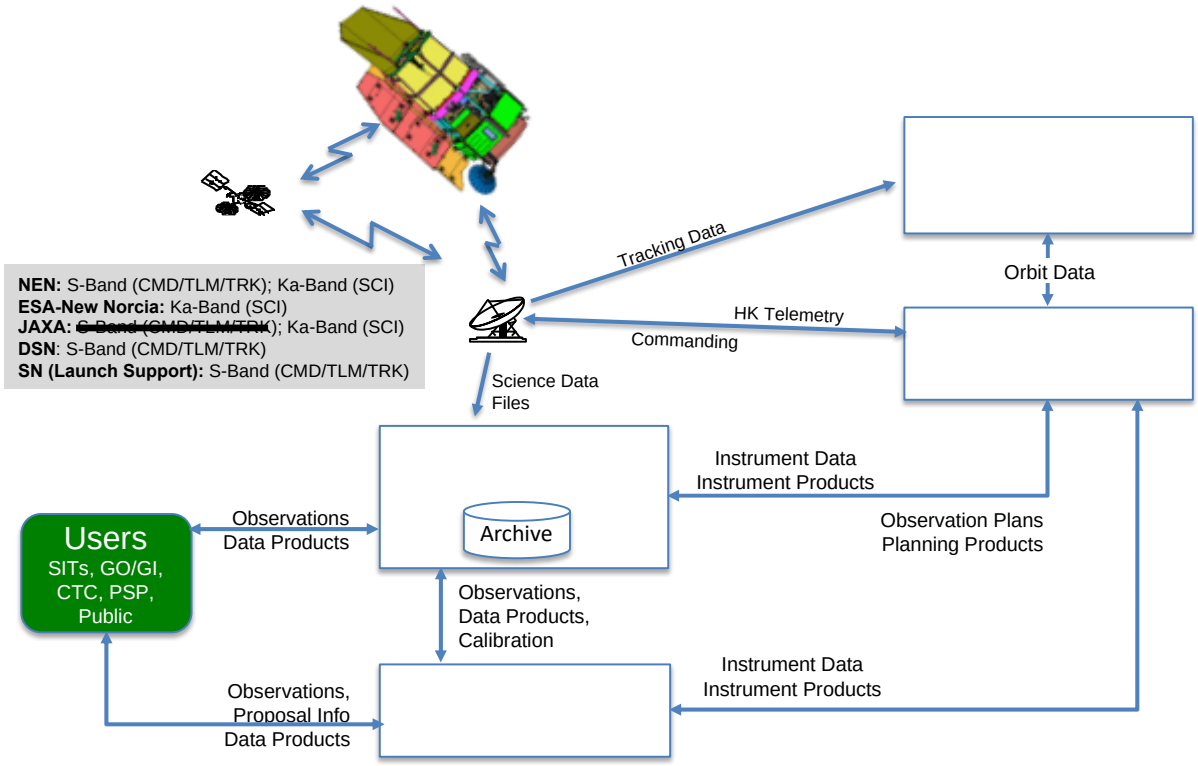
Total Noise (e-)



Dark Current (e-)

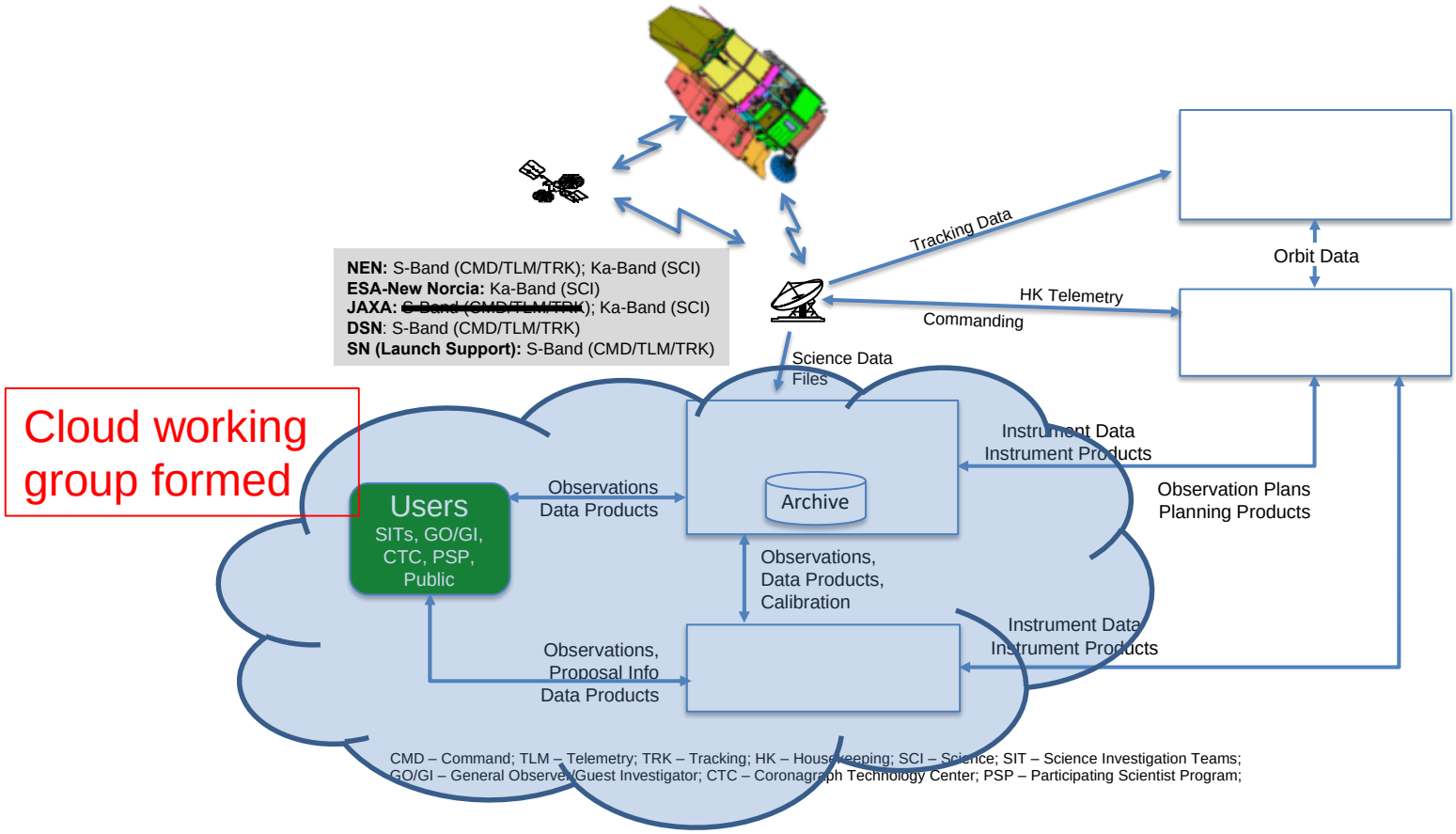


Ground System Architecture



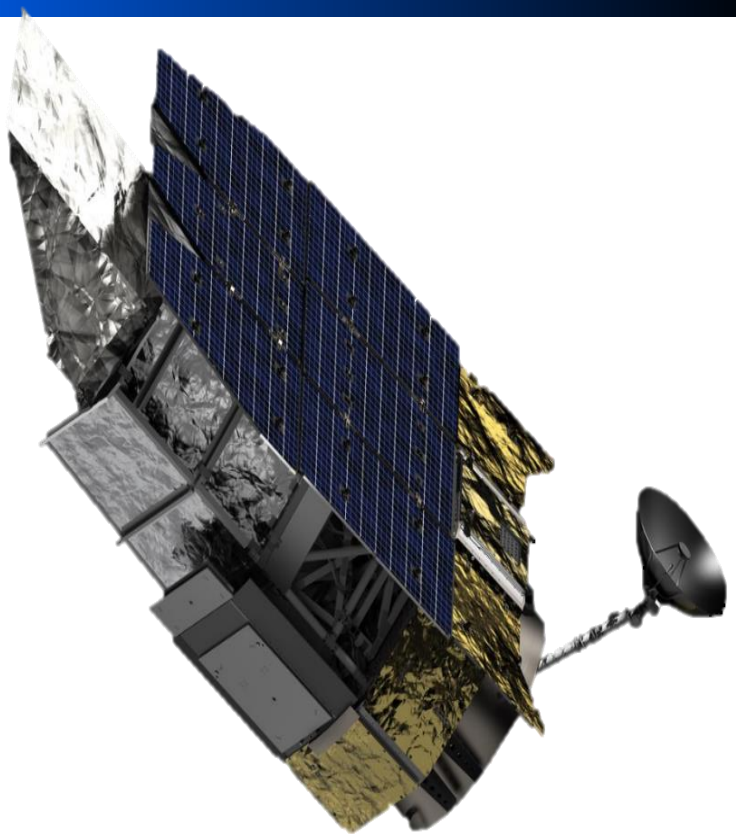
CMD – Command; TLM – Telemetry; TRK – Tracking; HK – Housekeeping; SCI – Science; SIT – Science Investigation Teams; GO/GI – General Observer/Guest Investigator; CTC – Coronagraph Technology Center; PSP – Participating Scientist Program;

Ground System Architecture



Cloud Computing Architectures

- SMD has begin a cloud-computing initiative
- Looking to provide option of a NASA-funded cloud environment
  - Bulk purchasing discounts are significant
  - Provides infrastructure (e.g. IT security) at no cost to Project
- Number of basic questions to be considered in coming months
  - Which computing and storage functions to put in cloud, and which to keep on-site
  - Should all cloud functions go into a common cloud (likely lowest cost) or are there reasons to use different clouds?
    - Possible further segmentation within a given “cloud”
  - The NASA DAPHNE system can send data from ground station directly to a cloud
    - Tempting to never move the data again – bring *all* the computing to the data, not just high-level user processing. Whether this really makes sense is TBD.



Launch Vehicle

Status / Update

Jason Hylan

WFIRST Observatory Manager - https://wfirst.gsfc.nasa.gov
NASA Goddard Space Flight Center -
https://www.nasa.gov/goddard

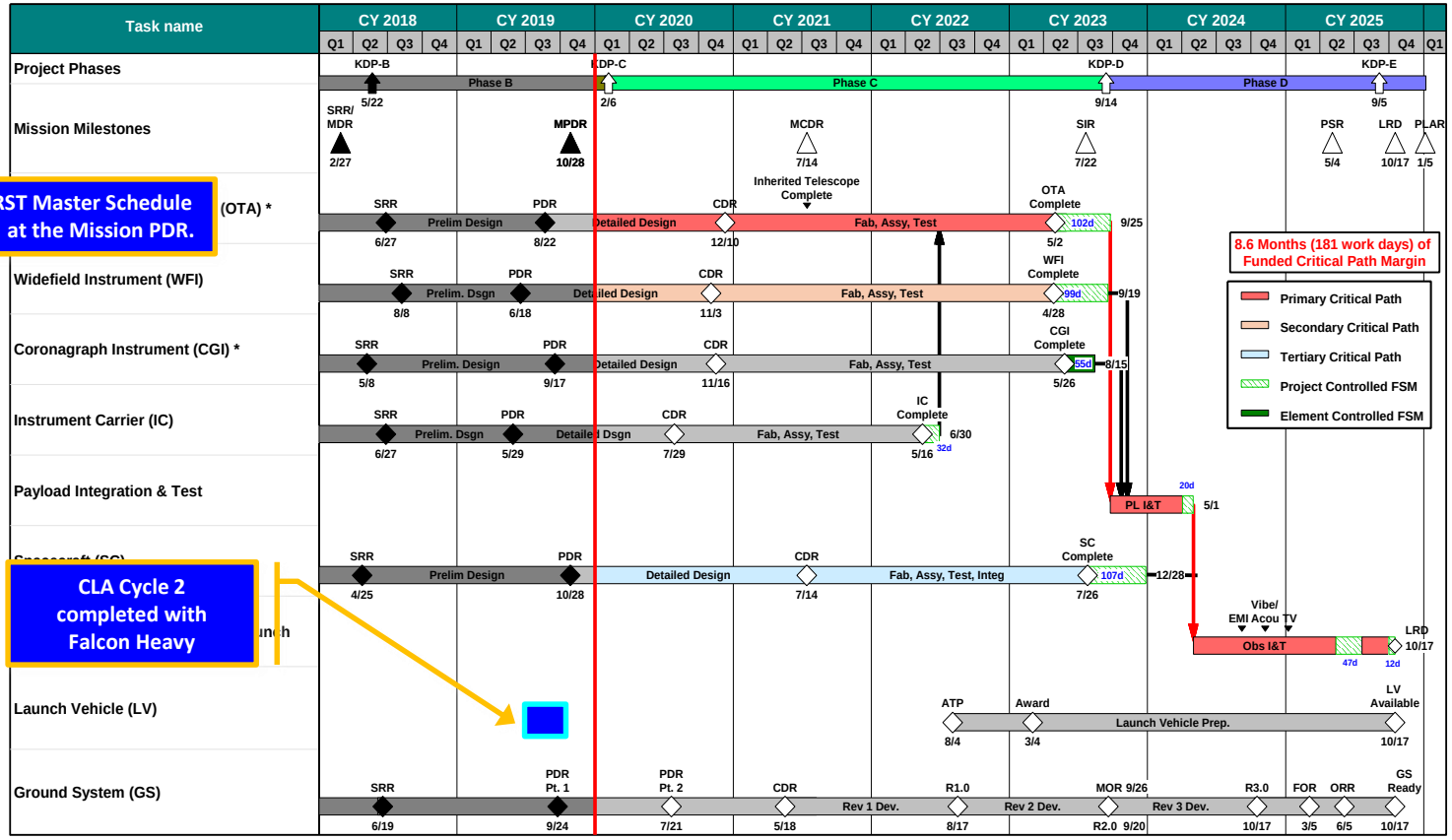
Launch Vehicle Status / Update - Summary

- 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).
- CLA cycle 3 is being moved forward to better accommodate element testing.
- Environments have enveloped all candidate launch vehicles through PDR. This is conservative and is driving design. Environment are being revised.

Schedule / Risks / CLA

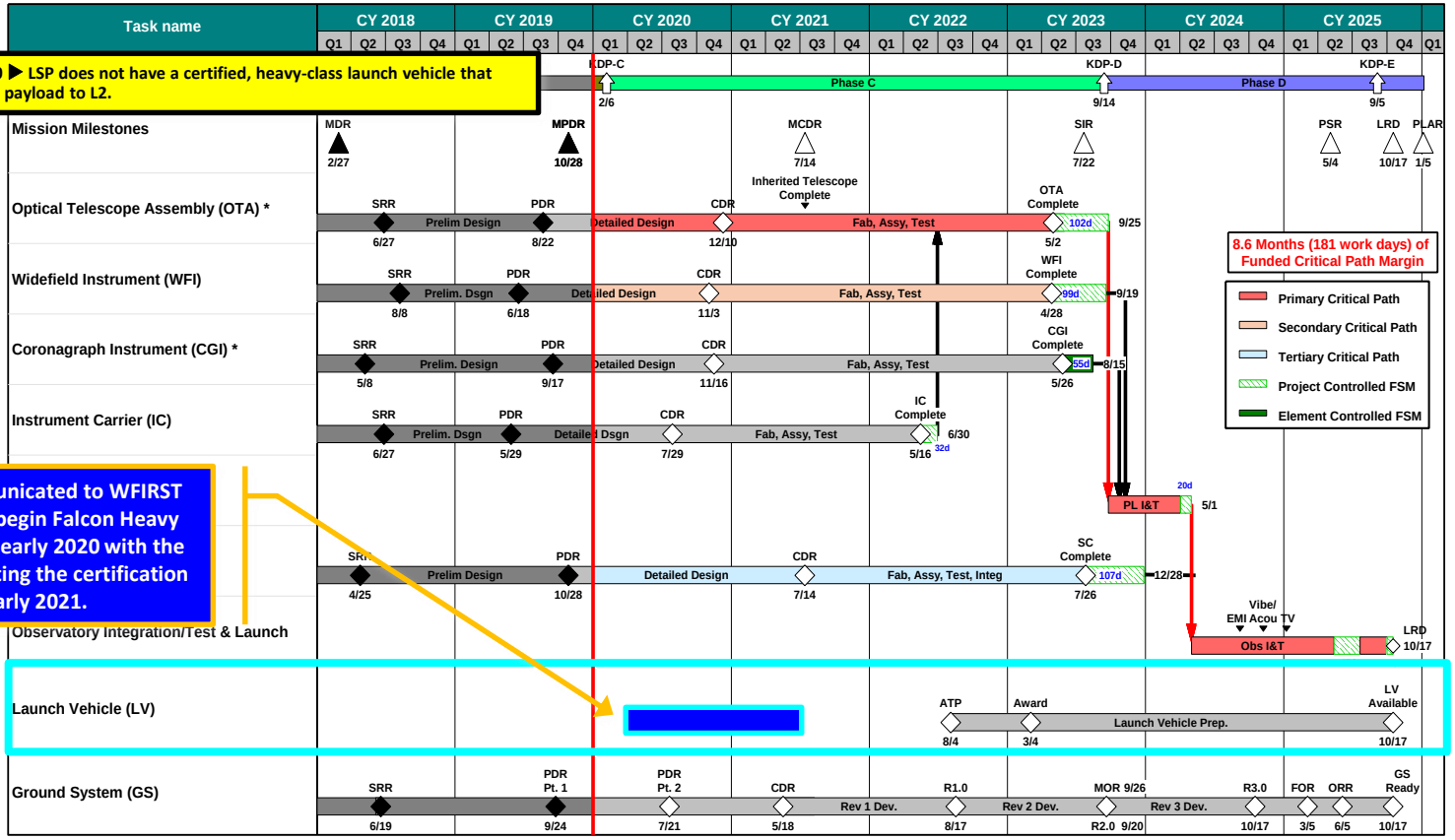
This is the WFIRST Master Schedule that was shown at the Mission PDR.

CLA Cycle 2 completed with Falcon Heavy



Schedule / Risks / CLA

Risk : Mission-00050 ▶ LSP does not have a certified, heavy-class launch vehicle that can lift an 11,000 kg payload to L2.



LSP has communicated to WFIRST that they will begin Falcon Heavy certification in early 2020 with the goal of completing the certification by early 2021.

Schedule / Risks / CLA

Risk : OBS-00175 ▶ Without a selected launch vehicle, the capabilities and interfaces of the selected launch vehicle may fall outside of those assumed during the Observatory design phase

WFIRST is going to start an early LV procurement. The acquisition will be ~L-56 months as opposed to the planned L-30 months.

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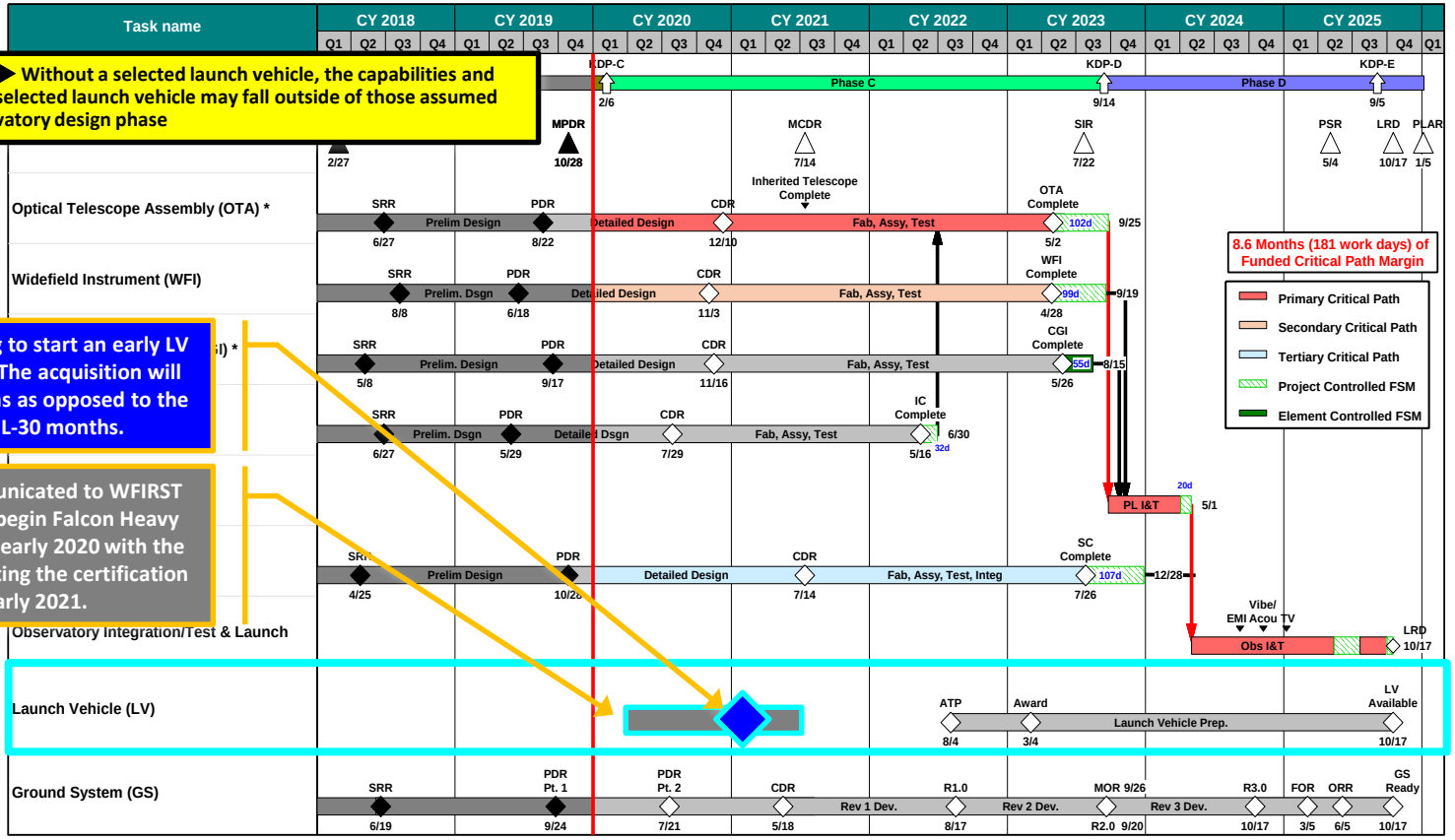

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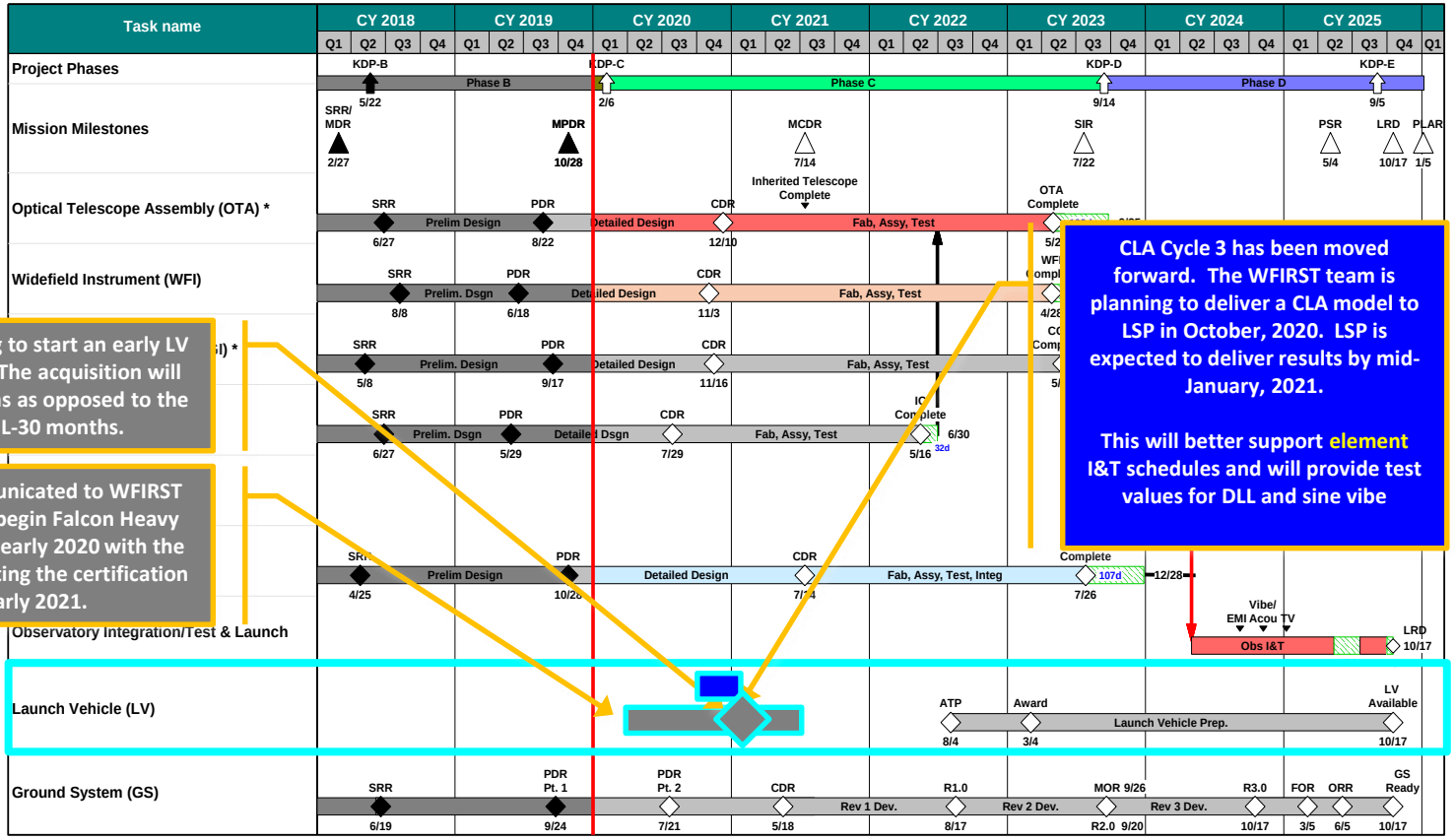

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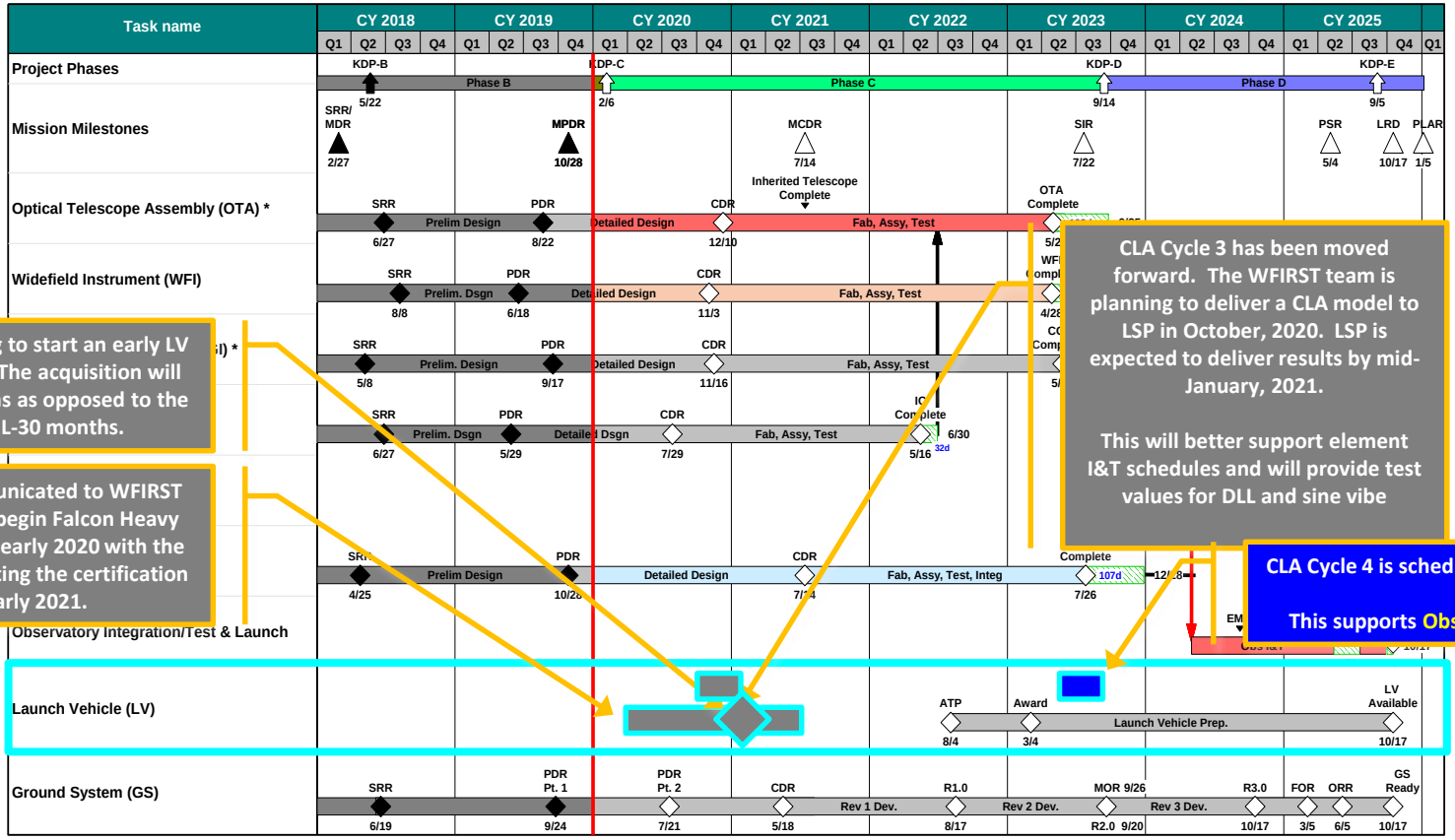
This will better support element I&T schedules and will provide test values for DLL and sine vibe

Schedule / Risks / CLA



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CLA Cycle 4 is scheduled for 7/2023.

This supports Observatory I&T.

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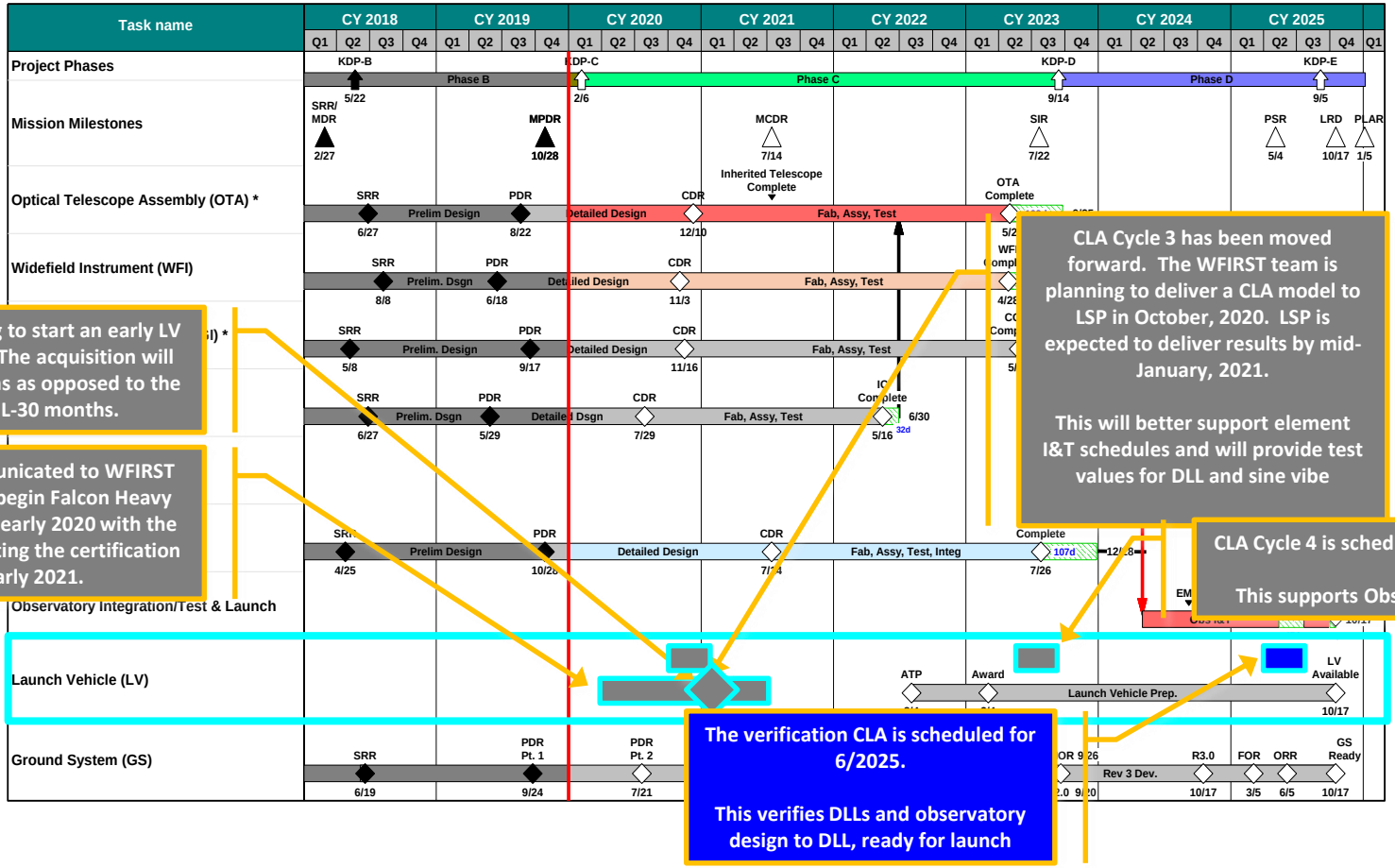

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This supports Observatory I&T.

The verification CLA is scheduled for 6/2025.

This verifies DLLs and observatory design to DLL, ready for launch

LV Environments

- Environments
  - Designs through PDR have been compliant with environments that envelope all candidate LVs.
  - However, enveloping all candidate LV environments throughout design lifecycle will overdrive design.
  - As the environments are refined, WFIRST will document environments used for design in
    - the LV Interface Requirements Document (IRD) which is delivered to LSP for the purpose of communicating requirements to potential LV vendors.
    - The Mechanical Systems Spec (MSS) which is used to govern mechanical design on WFIRST.

SpaceX
Falcon Heavy

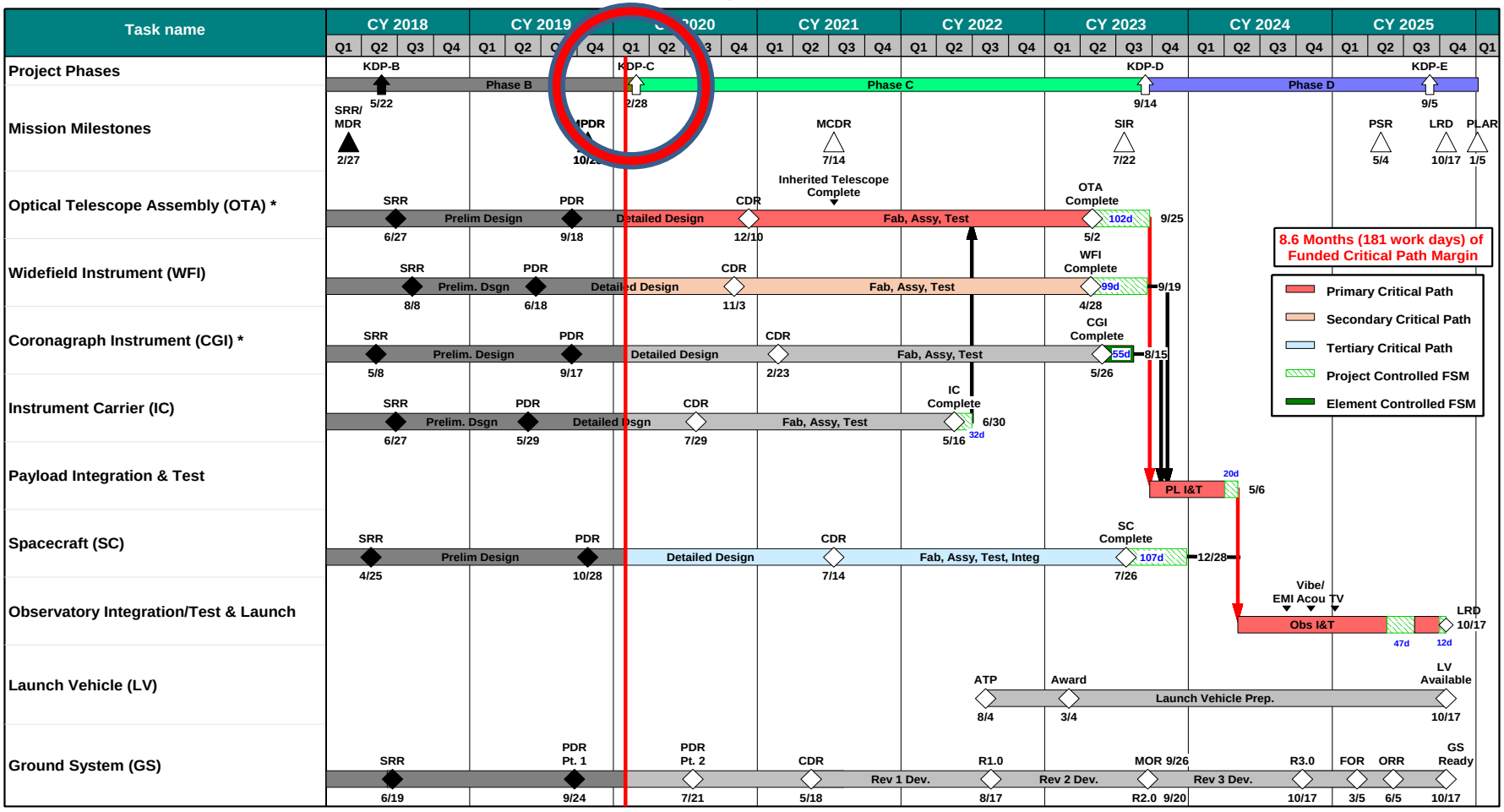
Blue Origin
New Glenn

United Launch Alliance
Vulcan

Phase C SRD Requirements Verification

- First cut at defining verification approaches to the SRD requirements flowdown is under way.
  - Survey level requirements will be assessed via large scale simulations
    - First round already done and most published
    - Additional work needed to be comprehensive
  - Calibration requirements will be linked to entries in the calibration plan, and from there to ground tests, flight observing plans, etc.
  - Data product requirements will likely be by roll-up.
  - First iteration of spreadsheet for tracking verification already done
  - Have begun working with SITs on inputs we need from them (primarily simulations of candidate observing scenarios)

WFIRST Project Master Schedule



Status Summary

- Have just completed “Preliminary Design”
  - ~130 engineering peer reviews leading up to Preliminary Design Review
  - Engineering development units of many hardware items already built, more in progress
  - For much of observatory, design now 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!

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- **FY21 White House Budget proposes termination of WFIRST - for 3rd time, 4th time if you count 2013**
  - **Direction is to proceed according to plan while Congress deliberates**

We are on track for a launch “no later than 2026”

Project working to October 2025 launch

QUESTIONS?

For more information, see:

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

https://wfirst.gsfc.nasa.gov/science/WFIRST_Reference_Information.html

Science Investigations

- All observing time to be selected competitively
  - Some close to launch, the rest periodically thereafter
- All data will be public immediately
  - Archival research will be funded on a par with GO programs
- Scientific priorities to be updated throughout mission, based on landscape at the time
- Coronagraph available through a Participating Scientist Program
- Present Science Investigation Teams in place until CDR
  - Call for new teams to follow as soon as possible

HQ – science program planning

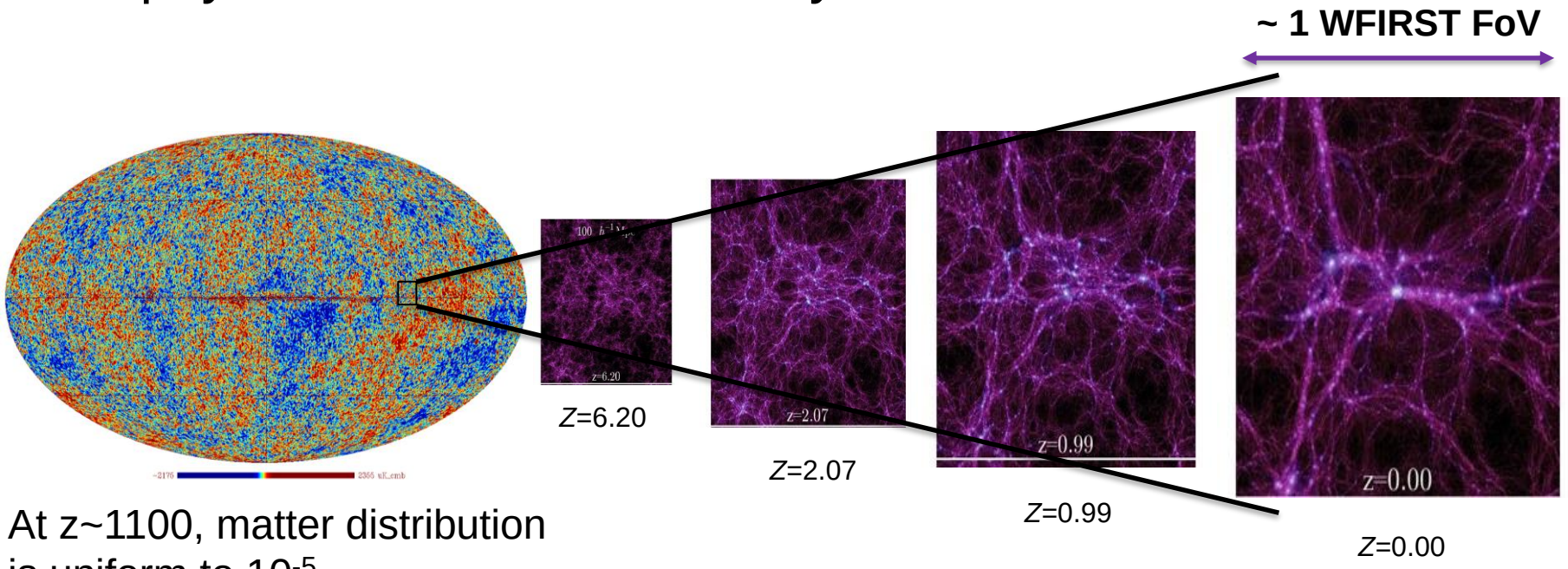
- Future science team call for proposals
  - HQ looking to put a placeholder in ROSES 2020 so that we can insert a real call for proposals in late 2020 should that turn out to be the right timing.

Wide FoV enables study of evolution of the Universe

WFIRST will measure expansion history *and* growth of structure

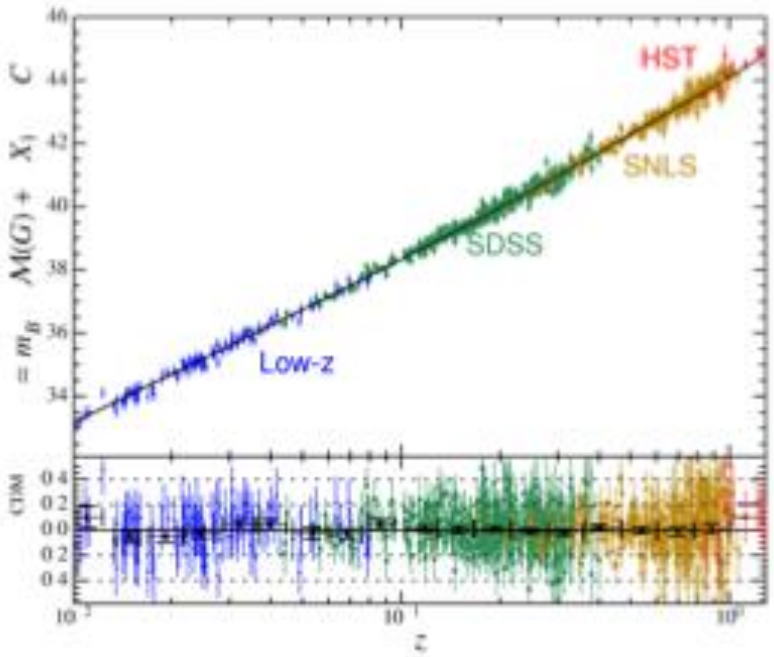
- If results discrepant -> breakdown of general relativity
- If results agree -> learn about nature of dark energy

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

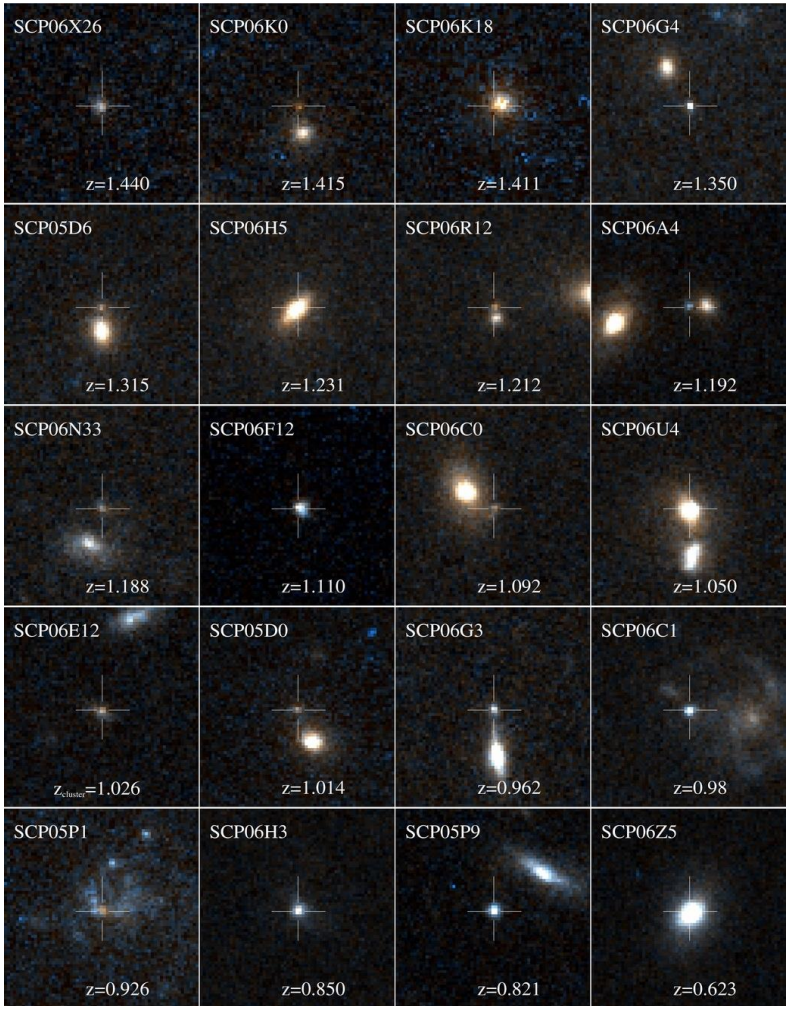


At z~1100, matter distribution is uniform to 10^{-5}

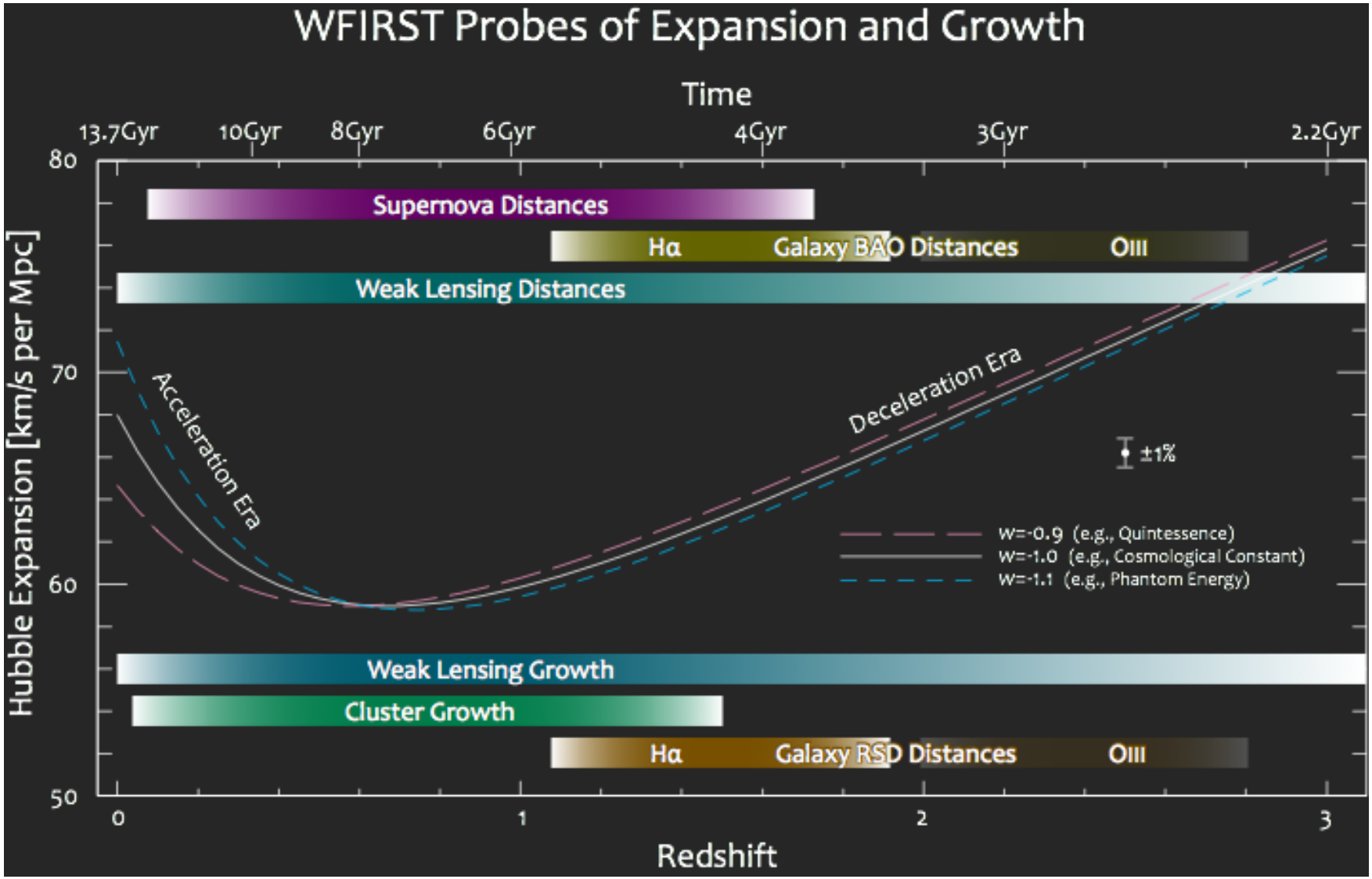
Luminosity distance from SNIa



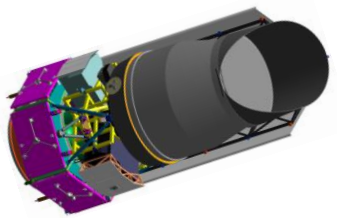
Hubble diagram from Betoule et al 2014, w/best-fit Λ-CDM model



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

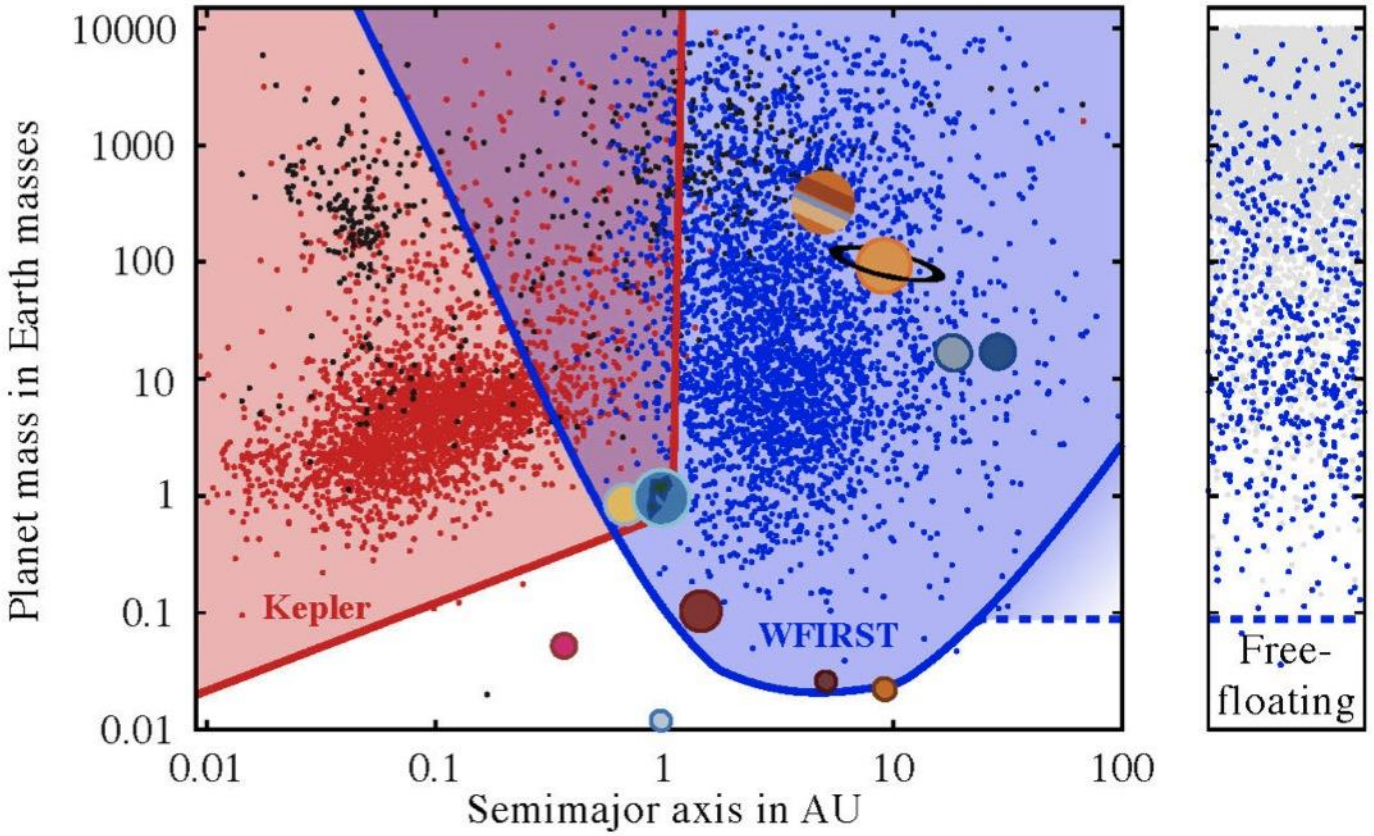

WFIRST Probes of Expansion and Growth
Time
13.7Gyr
10Gyr
8Gyr
6Gyr
4Gyr
3Gyr
2.2Gyr
Supernova Distances
Hα
Galaxy BAO Distances
OIII
Weak Lensing Distances
Acceleration Era
Deceleration Era
±1%
w=-0.9 (e.g., Quintessence)
w=-1.0 (e.g., Cosmological Constant)
w=-1.1 (e.g., Phantom Energy)
Weak Lensing Growth
Cluster Growth
Hα
Galaxy RSD Distances
OIII
Hubble Expansion [km/s per Mpc]
H(z) / (1+z)
80
70
60
50
0
1
2
3
Redshift

Compete the Census of Exoplanets - Microlensing



Kepler

WFIRST



But that is just the beginning…

- 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 50+ WFIRST-related white papers submitted to Astro-2020

WFI Filters & dispersers

Band	Element name	Min (μm)	Max (μm)	Center (μm)	Width (μm)	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	461λ(2pix)
PRS	P127	0.75	1.80	1.275	1.05	80-170 (2pix)

Representative Continuum Sensitivity

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

Imaging, 5σ						
R062	Z087	Y106	J129	H158	F184	W149
28.5	28.2	28.1	28.0	28.0	27.5	28.3

Spectroscopy, 10σ per pixel in continuum			
	0.8 μm	1.1 μm	1.5 μm
Grism	N/A	20.78	20.48
Prism	22.87	23.45	23.54

Representative Emission Line Sensitivity (grism)

Emission line flux detected at 6.5σ in one hour, with zodiacal light set at twice minimum.
Units are 10^{-17} ergs/cm^2/sec

Wavelength	Source half-light radius	
µm	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

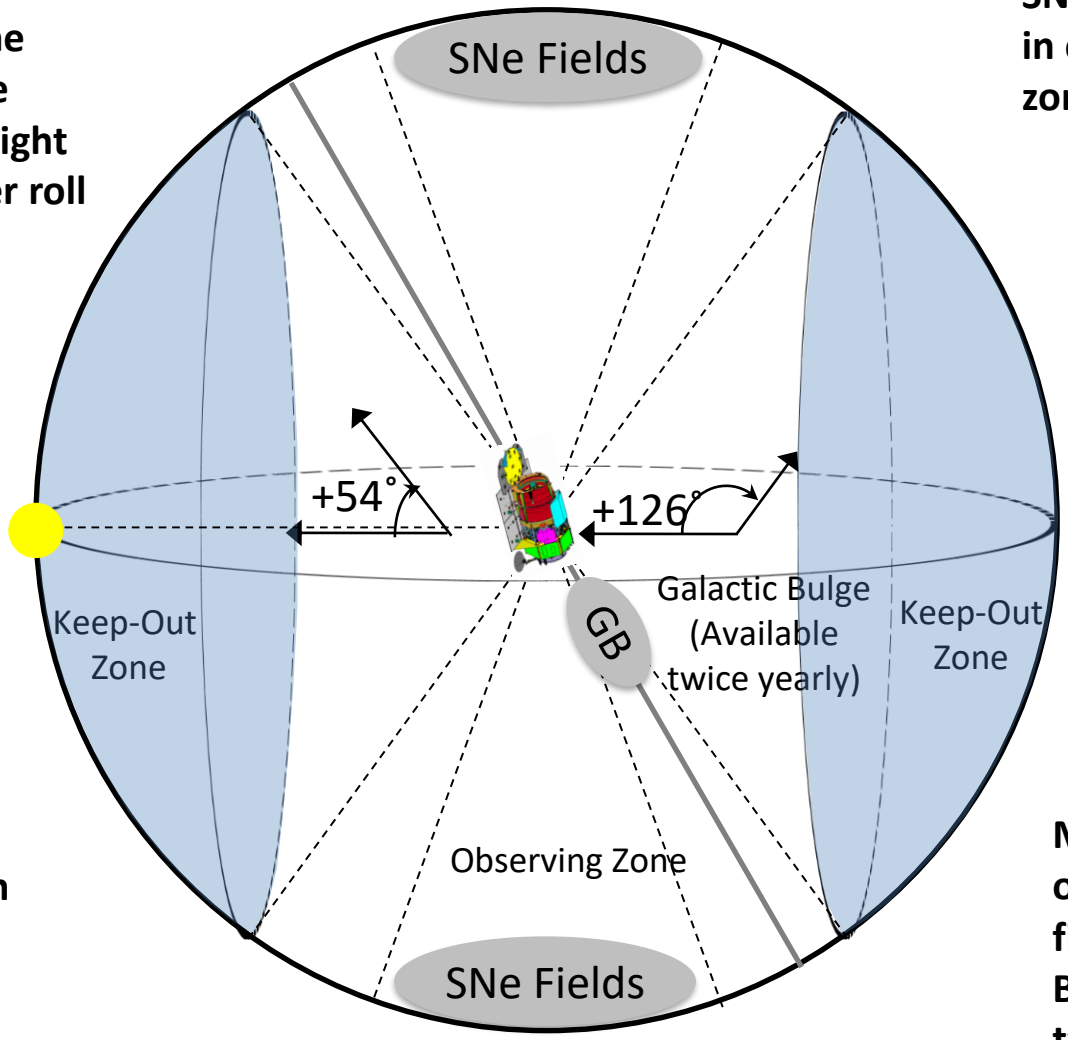
WFIRST as a Survey Facility

- 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

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

Field of Regard

Observing Zone:
- **54˚-126˚ off Sun Line**
- **360˚ about Sun Line**
- **±15˚ about line of sight (LOS) off max power roll angle**



SNe fixed fields located in continuous viewing zone

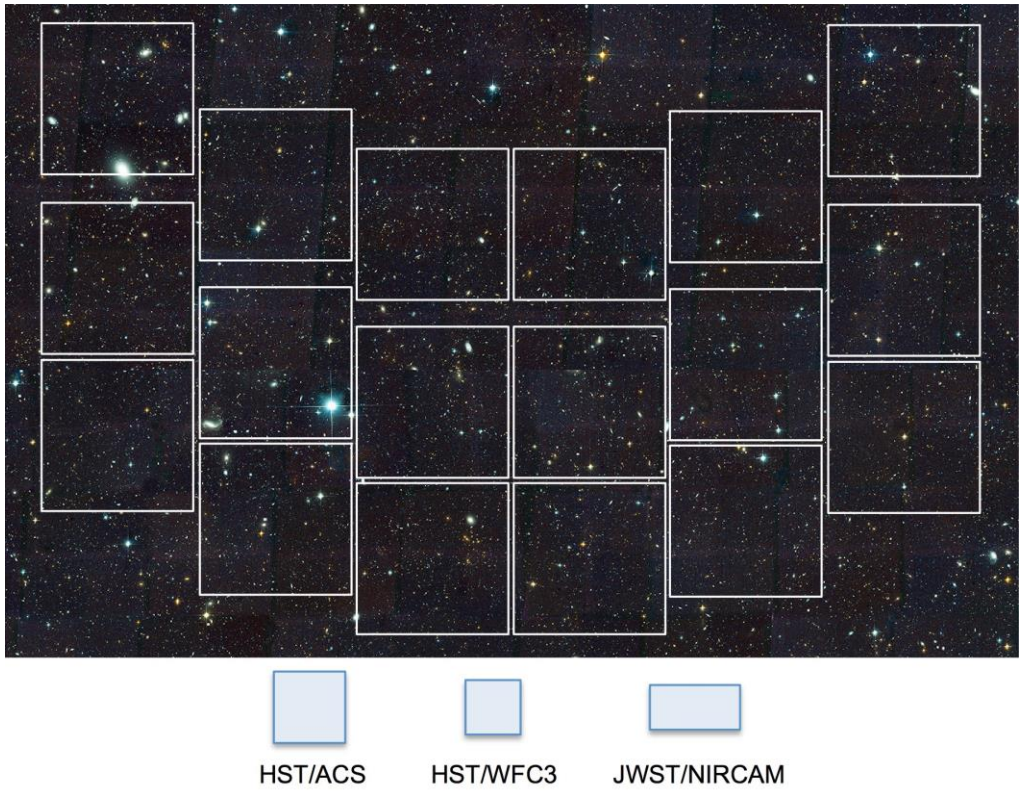
Earth/Moon LOS avoidance angles are a minor sporadic constraint

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

Wide-Field Instrument

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 μm
Sensitivity: 27.8 H(AB) @5σ in1hr

Slitless grism:
1.0-1.93 μm
R: 435-865

Slitless prism:
0.75-1.8 μm
R: 80-170