WFIRST Status

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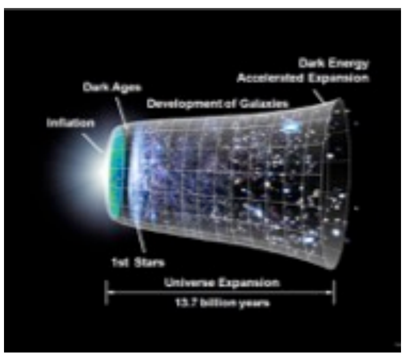
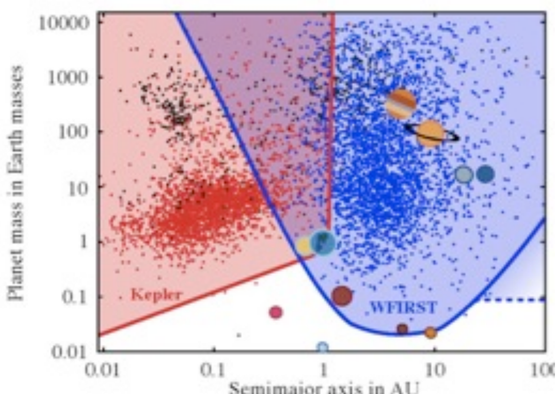
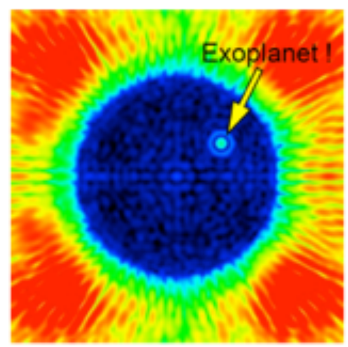
- WFIRST highest ranked large space mission in 2010 Decadal Survey
  - Study Dark Energy, Exoplanet Census, NIR Sky Survey
- Use of 2.4m telescope enables
  - Hubble quality imaging over 100x more sky
  - Imaging of exoplanets with 10^{-8}-10^{-9} contrast with a coronagraph

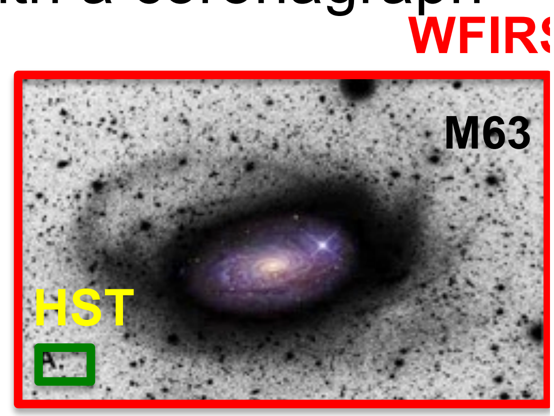


Dark Energy





Exoplanets



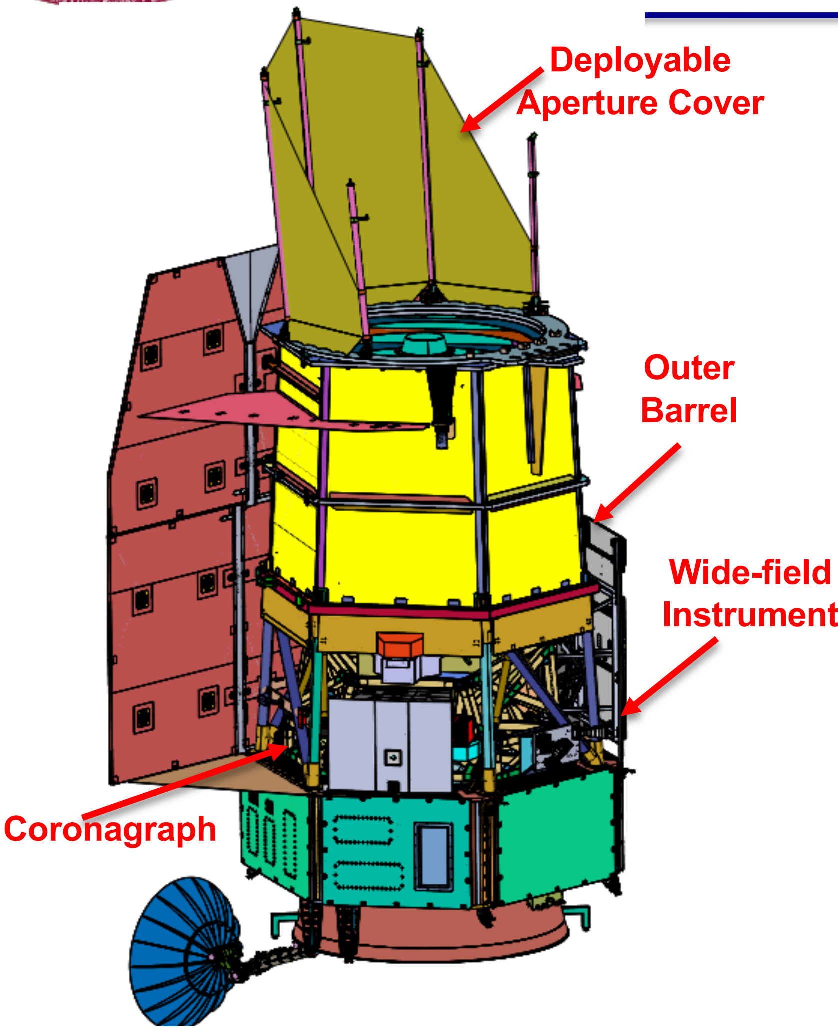
Astrophysics

…and Much More

- 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

WFIRST Observatory and Instruments



Telescope: 2.4m aperture

Two Instruments:

Wide Field Imager / Slitless Spectrometer

- Near IR bandpass
- Field of view 0.281 deg^2 (~200xHST WF3-IR)
- 18 H4RG detectors (288 Mpixels)

Coronagraph with Integral Field Spectrometer

- Visible bandpass
- Contrast 10^{-8}-10^{-9}

Data Volume: 11 Tb/day, **Downlink**: 275 Mbps

Orbit: Sun-Earth L2

Mission Duration: 5 yr, 10yr goal

Serviceability: robotically serviceable

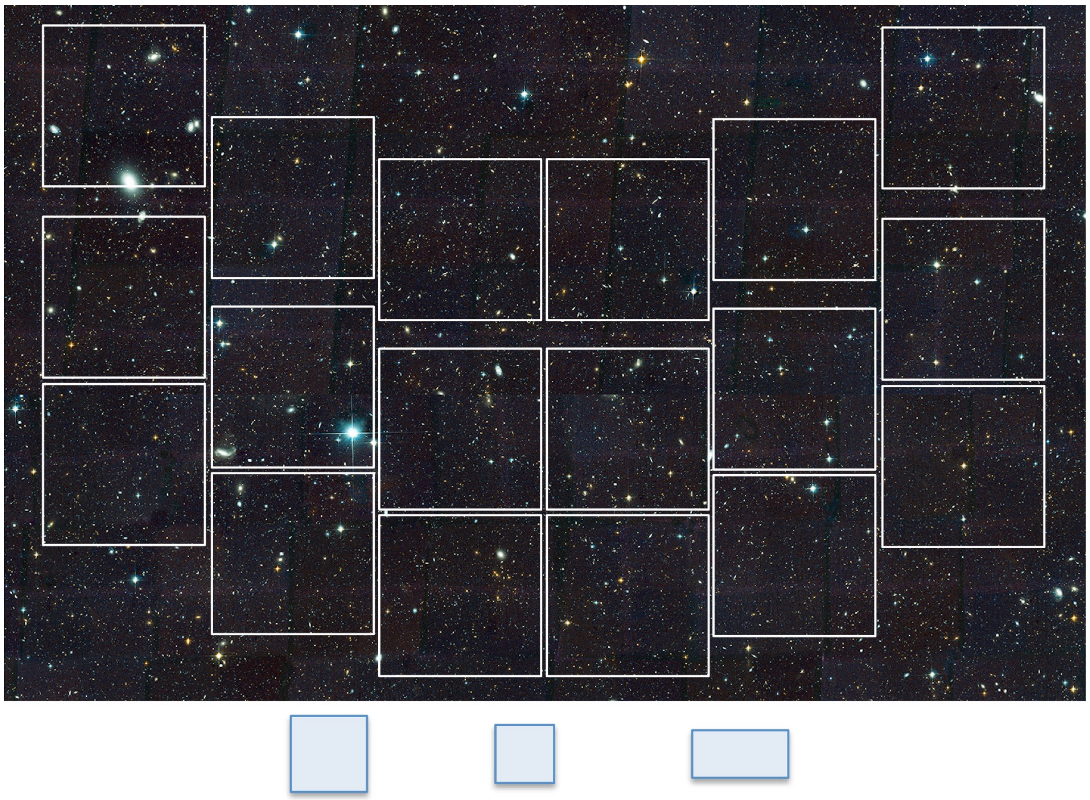
Starshade compatible

Technical Baseline

- Largely unchanged since February 2018
- Major exception is descope of the integral field channel
  - Had been baselined as an international contribution, which did not materialize
  - Replaced with low-dispersion prism in wide-field instrument
    - Slitless spectroscopy, with parameters optimized for Supernova program
- Ongoing design and analysis work has led to improved performance margins:
  - Reduced pupil obscuration & lower baffle temperatures
    - Improved WFI & CGI throughput, reduced WFI thermal background
  - Improved margins on wavefront stability
  - Improved margins on slew and settle time
  - Significant mass savings
  - CGI testbed performance continues to meet contrast goals

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

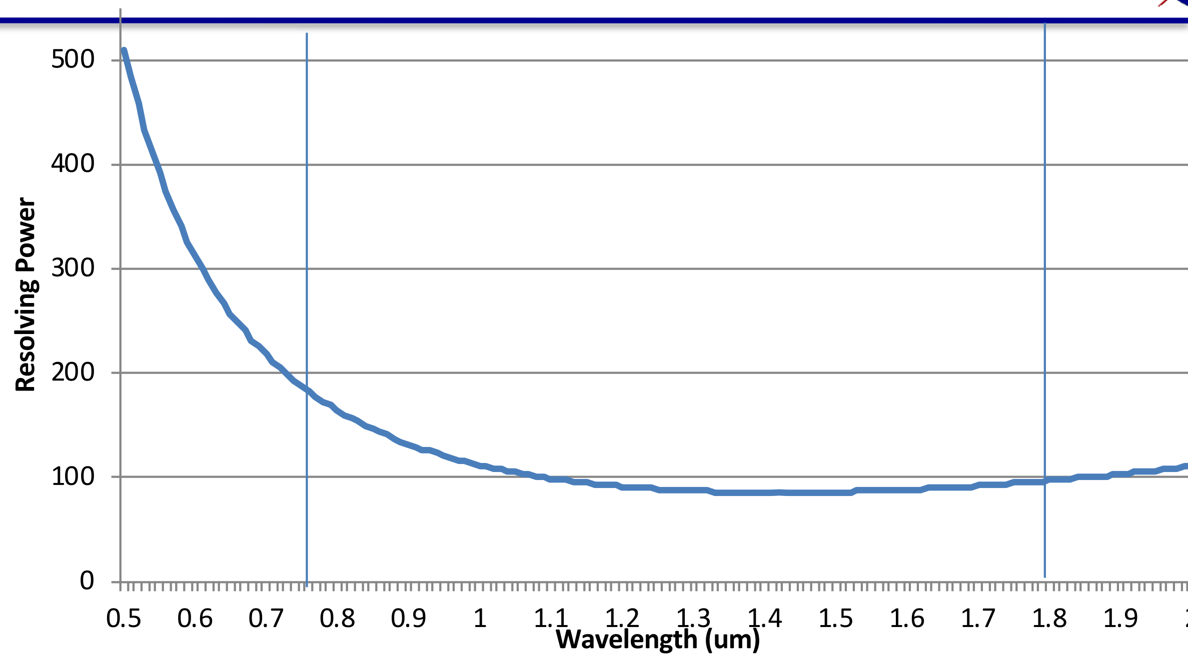
Slitless grism:
1.0-1.93 μm
R: 435-865

Slitless prism:
0.75-1.8 μm
R: 80-170

e

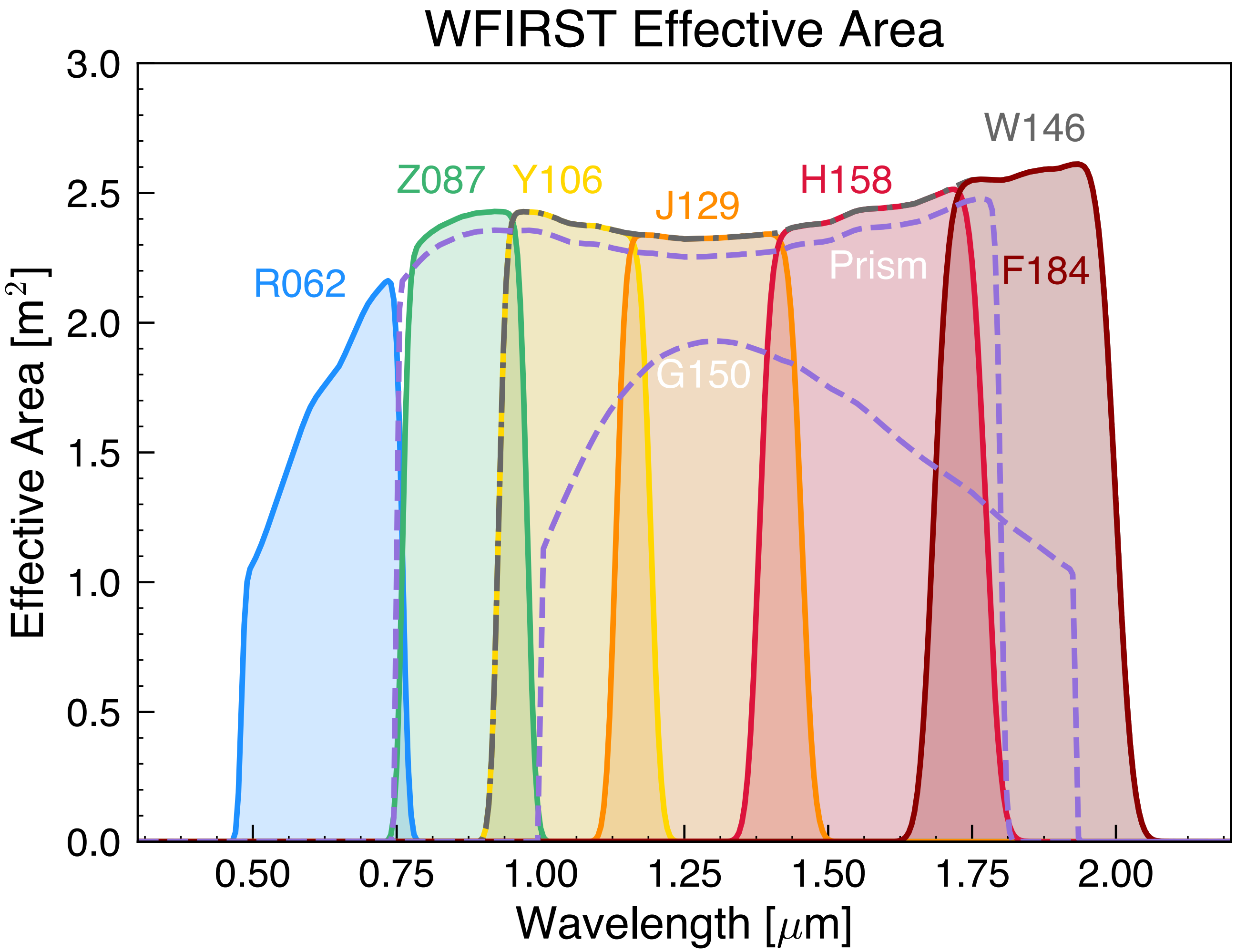
WFI – slitless prism

Table shows 1st attempt at SN program using prism – optimization ongoing
Modeling to date shows acceptable performance over desired redshift range

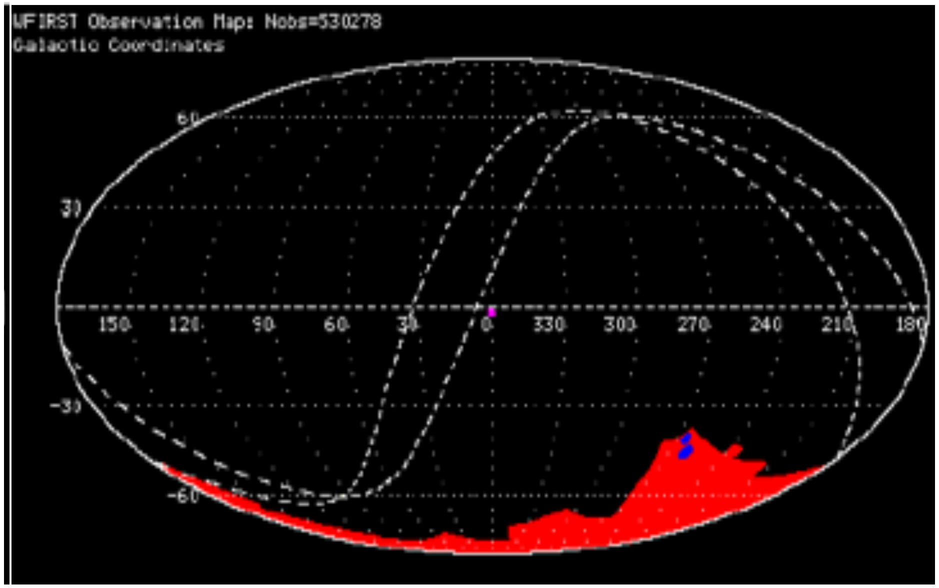


Exposure time/epoch	Max z to measure redshifts	Max z for SN Typing	Max z for SN Ia subtyping	Area surveyed in 6 month total, over 2 yrs, 5 day cadence
600 sec	1.3	1.1	0.8	4.76 deg^2
3600 sec	2.1	1.8	1.4	1.12 deg^2
9000 sec	2.2	2.1	1.8	0.84 deg^2

WFI bandpass coverage



WFIRST Surveys



Microlensing Survey: 2 deg^2, 15 min cadence for W filter, 12 hour cadence for R or Z and Y or J

Supernova Survey: 14 deg^2, (wide), 5 deg^2 (deep), 4 filters (R, Z, Y, J – wide) /(Z, Y, J, H – deep), 5 day cadence, and prism spectroscopy

High Latitude Survey: 2000 deg^2 (wide), 20 deg^2 (deep), 4 filters (Y, J, H, F) for wide and deep fields and grism spectroscopy

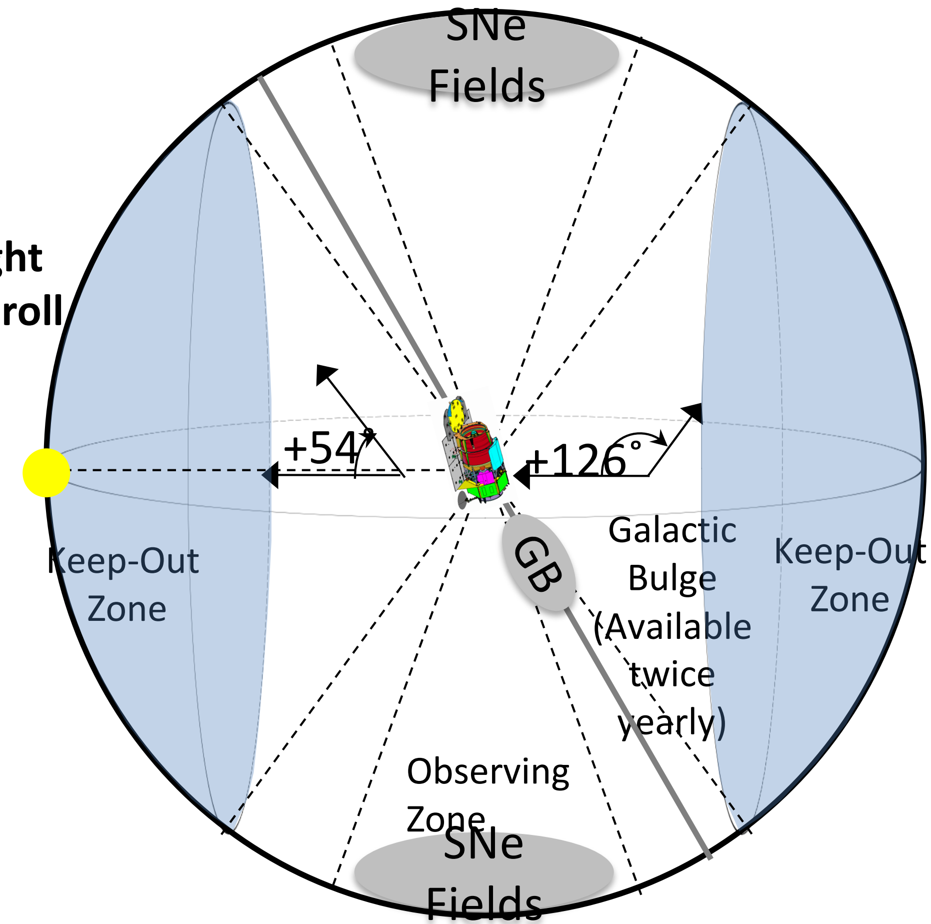
5 sigma J-band sensitivity

	HLS Wide	HLS Deep	SN Wide	SN Deep	ML
Per Visit	26.1.	26.1.	25.5	26.6	27.5
Integrated	26.95	28.2	28.3	29.4	--

WFIRST 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**

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



SNe fixed fields ±20° off of the ecliptic poles, located in continuous viewing zone

Earth/Moon LOS avoidance angles are a minor sporadic constraint

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

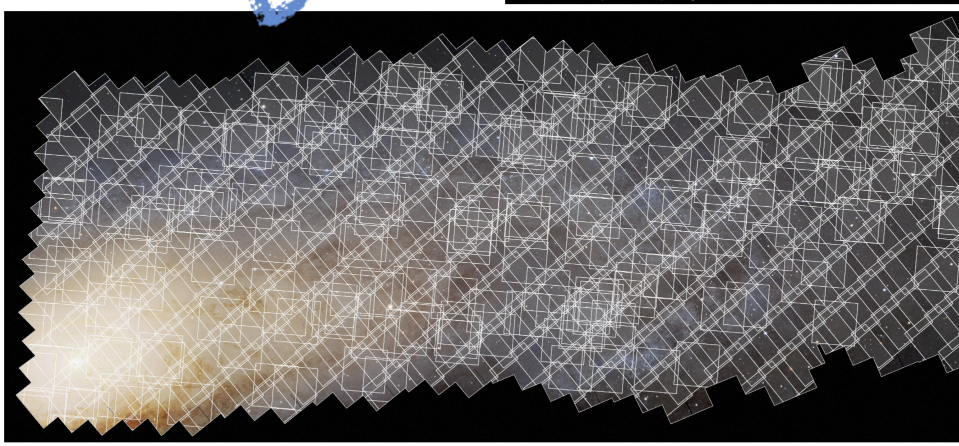
WFIRST as a Survey Facility

- 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

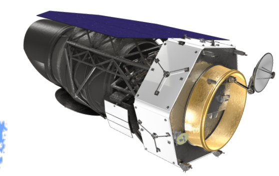
For details, see Akeson et al 2019 https://arxiv.org/abs/1902.05569

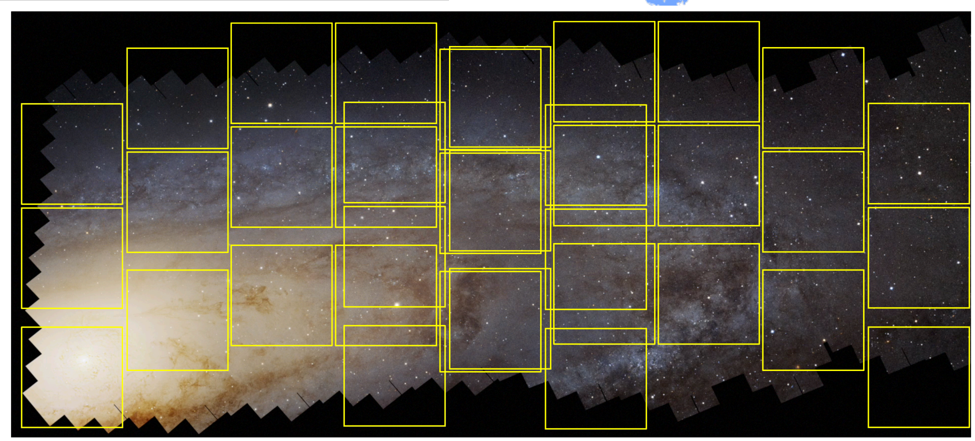
Sample GO Program
Andromeda - PHAT Survey

The Hubble Way
(400+ individual pointings)



The WFIRST Way
(2 pointings)



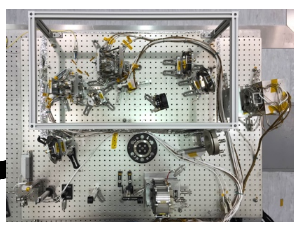


WFIRST will survey nearby galaxies ~>100x faster than Hubble

Coronagraph Technology Demonstration Instrument

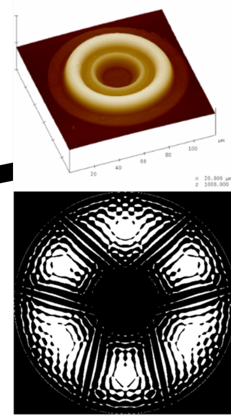
Technology	• Low-order Wavefront Sensing and Control • Deformable Mirrors • Broad-band Coronagraphic Masks for Very High Contrast • Ultra-low Noise Photon Counting Detectors • High Contrast Imaging on Obscured / Discontinuous Aperture • Integral Field Spectrograph at Very High contrast

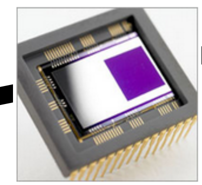
Autonomous Ultra-Precise Wavefront Sensing & Control System



First Use of Deformable Mirrors in Space

High Contrast Coronagraph Masks





Ultra-low Noise Photon Counting Visible Detectors

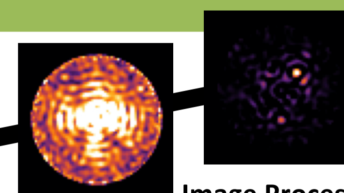


Image Processing at Unprecedented Contrast Levels

CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone (HZ), significantly reducing the risk and cost of future possible mission concepts such as HabEx and LUVOIR

CGI is a direct & necessary predecessor to these missions, and is a crucial step in the exploration of Sun-like planetary systems

Current Status

- Project remains on the development track established last year
  - Final approved FY19 budget allowed significant progress
- Telescope primary mirror 'full tool polish' now almost complete
- CGI phase B work is progressing in key areas, including controls, Deformable mirrors, emCCD detectors, electronics, active optics, processor
- Wide Field Instrument configuration is ”frozen” for Preliminary Design Review happening now
- Lots and lots and lots of reviews
  - Over 130 planned for CY19 (component through system, peer level through Mission)
  - Mission Preliminary Design Review in October

Engineering progress highlights

- Detailed design work throughout observatory and ground system
- Integrated modeling (structural-thermal-optical performance) used to validate detailed design and guide allocation of performance budgets
- Detailed signal-to-noise budgets likewise used to guide engineering trades and low-level requirements flowdown
  - New approach to outer barrel assembly thermal control
  - Refined telescope thermal requirements: able to relax some requirements while simultaneously improving pupil obscuration & thermal background, reduced demands on heater power
  - New low-dispersion prism design optimized through close collaboration of optical and mechanical designers with science teams
  - New WFI design reduced mass and improved detector cooling
  - New aperture cover design reduced mass
  - CGI improving contrast over wider bandpasses w/dynamic disturbances

Science Operations

- Work on approaches to data processing, archiving, operations have continued over past year
  - Several new working groups established with Science Investigation Teams
  - Work defining pipeline architectures and processing environment has begun
  - Prototype archive environment with embedded analysis S/W environment is running – may not be final choice but is exercising many of the tools and architectures we expect to employ
  - Have some simulation tools ready for production running, others to come soon (some already public, others will be public as they become available)
    - Several square degrees of high-latitude survey imaging and grism simulations in progress
    - Several square degrees of nearby galaxies for resolved stellar populations in progress
    - Microlensing simulations for community data challenge released last Fall
    - Coronagraph simulations for community data challenge to be released later this year.

Science Investigations

- All observing time to be selected competitively
- 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 through CDR (mid 2021)
  - Call for new teams to follow as soon as possible
- Some open questions:
  - How best to allocate time to large programs
  - How best to organize teams for large programs
  - Community workshops and data challenges will provide some input
    - Deep field workshop held last August, special session at Summer AAS
    - Microlensing community challenge & workshop last Fall & winter
    - Coronagraph data challenge/workshops later this year
    - Other topics in the future (Milky Way and nearby galaxies conference this summer)
  - Will be setting up a panel of scientists from the community to provide input.

The Year Ahead

- Finalize contracts with STScI and IPAC
- Fabrication/testing of engineering development/test unit hardware ramping up; a few examples
  - Launch lock & vibration isolation system
  - Instrument latches
  - WFI focal plane electronics, grism
- Beginning/continuation of flight hardware fabrication
  - Detectors
  - Instrument latches
  - Instrument carrier structure
  - Completion of primary mirror figuring
  - Spacecraft components
- Beginning of flight hardware integration
  - OTA Tertiary Optical Mirror Assembly

PM (S/N3) going into ion figuring

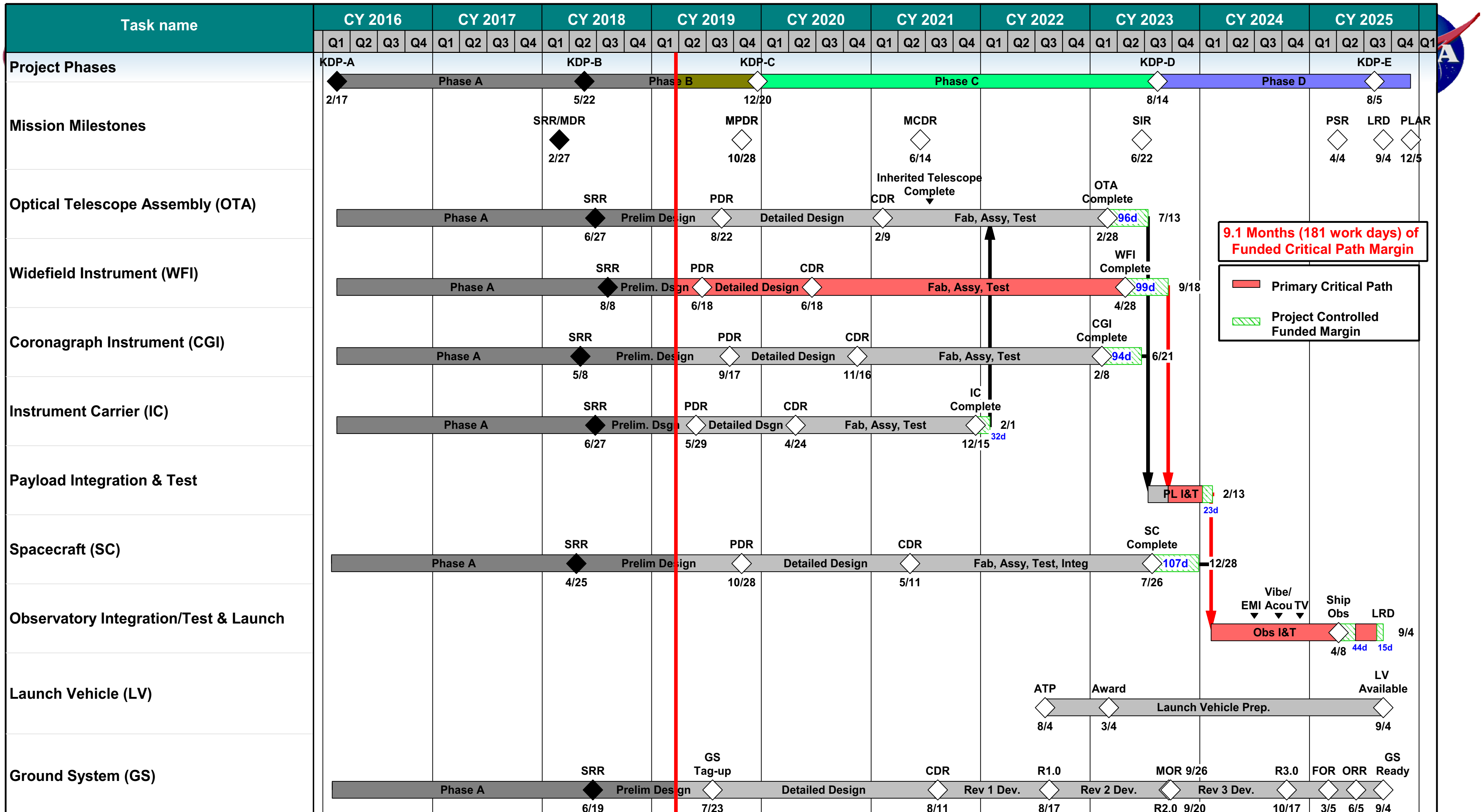
We are poised to make huge progress this year toward KDP-C/Confirmation in early CY2

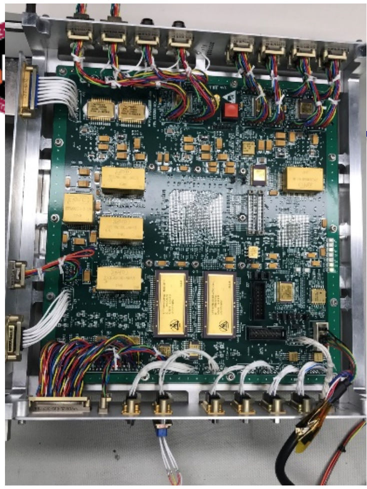
QUESTIONS?

Coronagraph Modes

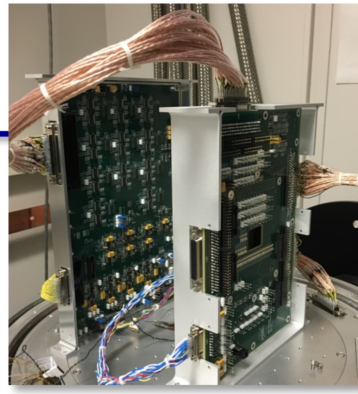
- As a technology demonstration instrument, the supported modes are limited to those necessary to implement three basic observing scenarios:
  - Point-source imaging over a narrow field of view
    - Includes polarimetry of a bright source
  - Integral-field spectroscopy over a narrow field of view
  - Extended source imaging over a wide field of view
- These three “official” modes will be fully commissioned before launch.
  - the flight hardware will by fully tested with flight software before launch

CGI Filter	λ_{center} (nm)	BW	Channel	Mask Type	Working Angle	Can use w/ linear polarizers	Starlight Suppression Region
1	575	10%	Imager	HLC	3-9 λ/D	Y	360°
3	730	15%	IFS	SPC bowtie	3-9 λ/D		130°
4	825	10%	Imager	SPC wide FOV	6.5-20 λ/D	Y	360°

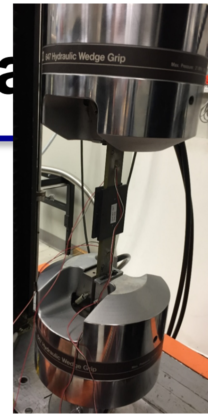

Task name
CY 2016
CY 2017
CY 2018
CY 2019
CY 2020
CY 2021
CY 2022
CY 2023
CY 2024
CY 2025
Q1 Q2 Q3 Q4
Project Phases
KDP-A
2/17
Phase A
KDP-B
5/22
Phase B
KDP-C
12/20
Phase C
KDP-D
8/14
Phase D
KDP-E
8/5
Mission Milestones
SRR/MDR
2/27
MPDR
10/28
MCDR
6/14
SIR
6/22
PSR
4/4
LRD
9/4
PLAR
12/5
Optical Telescope Assembly (OTA)
Phase A
SRR
6/27
Prelim Design
PDR
8/22
Detailed Design
CDR
2/9
Inherited Telescope Complete
Fab, Assy, Test
OTA Complete
2/28
96d
7/13
Widefield Instrument (WFI)
Phase A
SRR
8/8
Prelim. Dsgn
PDR
6/18
Detailed Design
CDR
6/18
Fab, Assy, Test
WFI Complete
4/28
99d
9/18
Coronagraph Instrument (CGI)
Phase A
SRR
5/8
Prelim. Design
PDR
9/17
Detailed Design
CDR
11/16
Fab, Assy, Test
CGI Complete
2/8
94d
6/21
Instrument Carrier (IC)
Phase A
SRR
6/27
Prelim. Dsgn
PDR
5/29
Detailed Dsgn
CDR
4/24
Fab, Assy, Test
IC Complete
12/15
32d
2/1
Payload Integration & Test
PL I&T
23d
2/13
Spacecraft (SC)
Phase A
SRR
4/25
Prelim Design
PDR
10/28
Detailed Design
CDR
5/11
Fab, Assy, Test, Integ
SC Complete
7/26
107d
12/28
Observatory Integration/Test & Launch
EMI
Vibe/ Acou
TV
Ship Obs
Obs I&T
4/8
44d
15d
LRD
9/4
Launch Vehicle (LV)
ATP
8/4
Award
3/4
Launch Vehicle Prep.
LV Available
9/4
Ground System (GS)
Phase A
SRR
6/19
Prelim Design
GS Tag-up
7/23
Detailed Design
CDR
8/11
Rev 1 Dev.
R1.0
8/17
Rev 2 Dev.
MOR 9/26
R2.0 9/20
Rev 3 Dev.
R3.0
10/17
FOR
3/5
ORR
6/5
GS Ready
9/4
9.1 Months (181 work days) of Funded Critical Path Margin
Primary Critical Path
Project Controlled Funded Margin



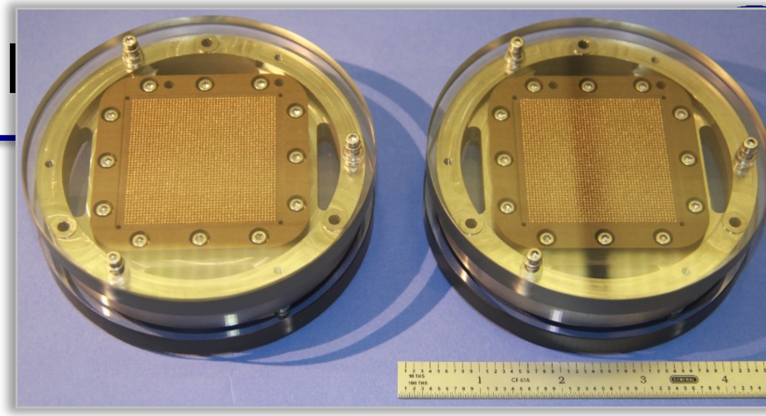
WFIRST processor card prototype



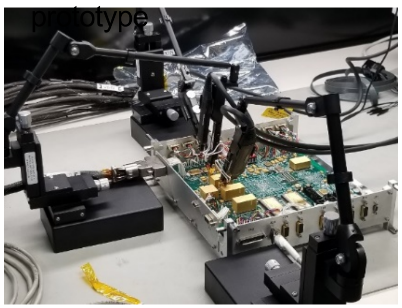
ACADIA cryogenic test setup in GSFC B11



IC double lap shear testing at GSFC B30

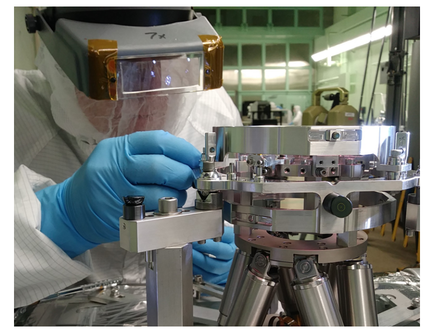


Fuzz button assembly complete and passed inspection

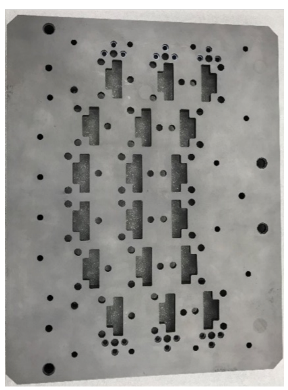


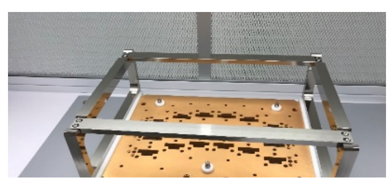
WPC Test Setup

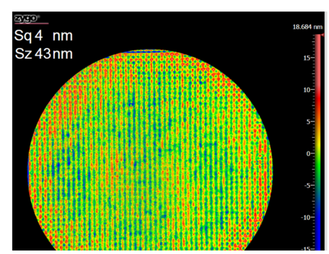
EDU Mosaic Plate Assembly

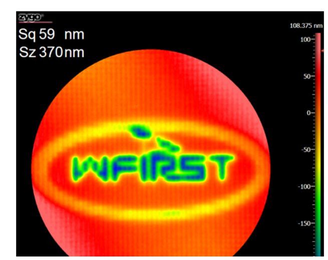


Grism E3 EDU cell bonding









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