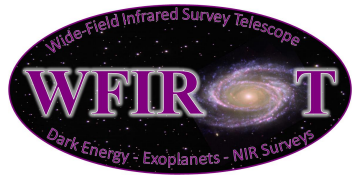# WFIRST Project Activities

Neil Gehrels
WFIRST Project Scientist
NASA-GSFC

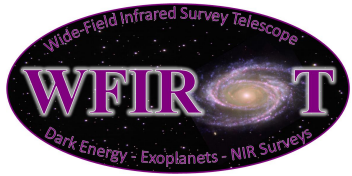IPAC – Wide-Field IR Science
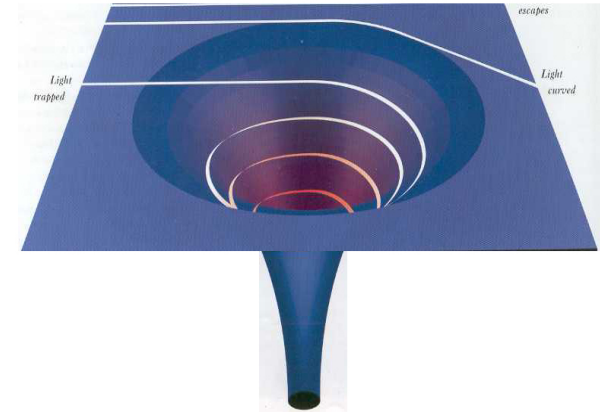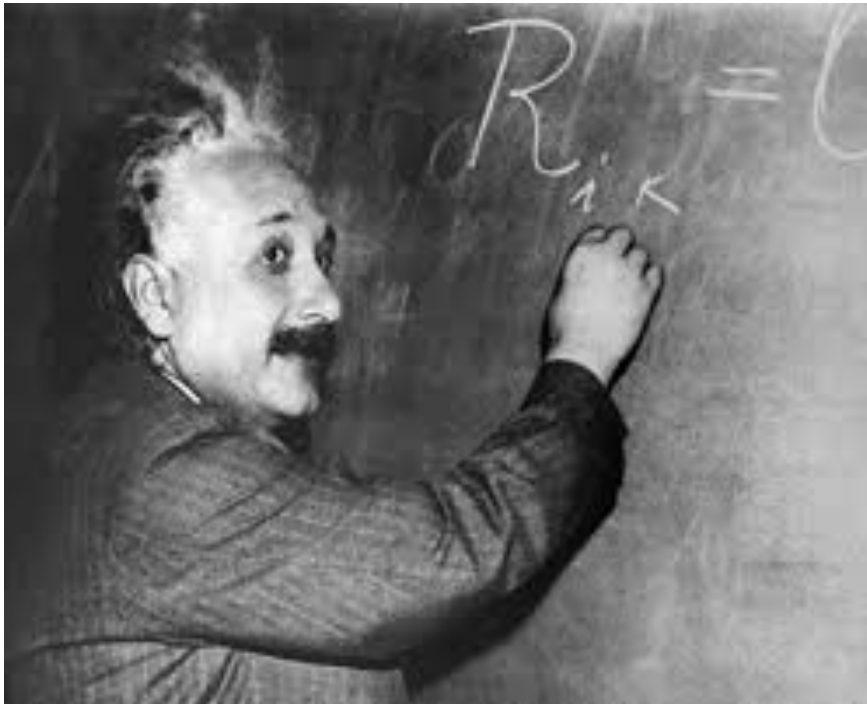February 15, 2012

Outline

- Project history

- Concept development and costing

- Scientific requirements flowdown

- GSFC-JPL-IPAC team

- Detector development

- Simulations

- Schedule to launch

- Science outreach

General Relativity

Einstein General Relativity connection to WFIRST through
- field equations, cosmological constant
- gravitational bending of light (weak lensing, microlensing)

$$G_{\mu\nu} = (8\pi G/c^4)\, T_{\mu\nu}$$

WFIRST History

JDEM

- 1998: Discovery of accelerated expansion of the universe
- 2006: 3 teams selected for study (ADEPT, DESTINY, SNAP)
- 2008: NASA & DOE formulate JointDEM as a strategic mission
- 2009: JDEM proposed to Astro2010

MPF

- 1998: Mather suggests space application of microlensing at Notre Dame
- 2000-2001 GEST proposed to Discovery and MIDEX
- 2004-2006: MPF proposed as Explorer and Discovery
- 2009: MPF proposed to Astro2010

NIRSS

- 2009: NIRSS proposed to Astro2010
- 2009: 14 white papers submitted on wide-field IR survey science
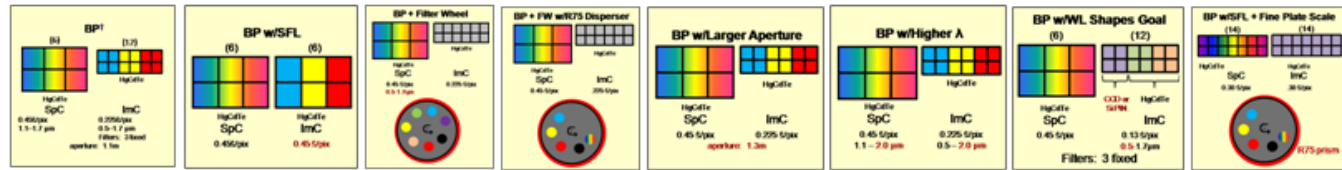
WFIRST

- 2010: WFIRST ranked 1st in large mission category by Astro2010
- 2011: Science Definition Team formed to study WFIRST
- 2011: Nobel prize for acceleration of universe
- 2011: Free-floating planets detected by ground microlensing
- 2012: WFIRST science conference at IPAC
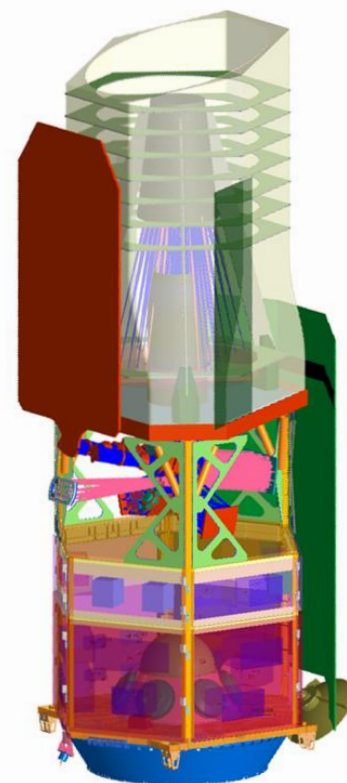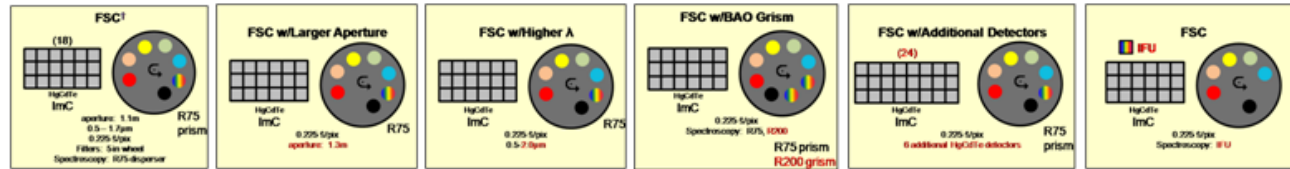

JDEM-Omega

Over 80 Concepts Developed

1. Benchmark Probe (8 of 18 cases shown)
2. Focal Single Channel Imagers (6 of 11 cases shown)
3. Focal/ Dichroic Imagers (6 of 10 cases shown)
4. Dichroic Spec/Imager (8 of 10 cases shown)
5. Single Focal Plane Transformer (7 of 7 cases shown)
6. Heterogeneous Focal Single Focal Plane (5 of 5 cases shown)
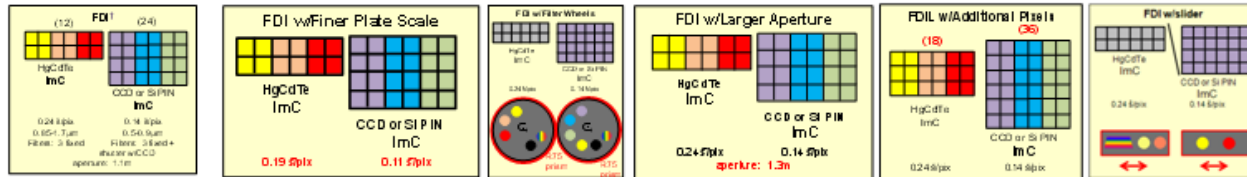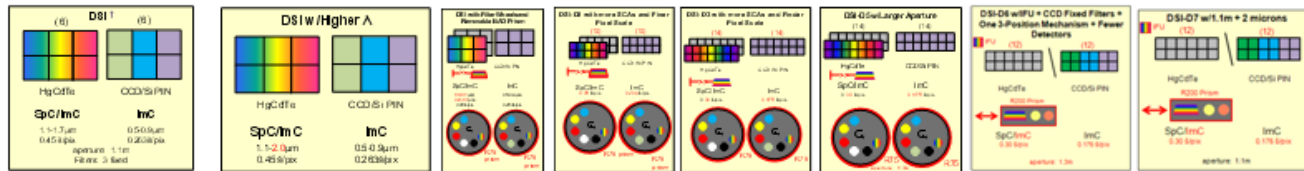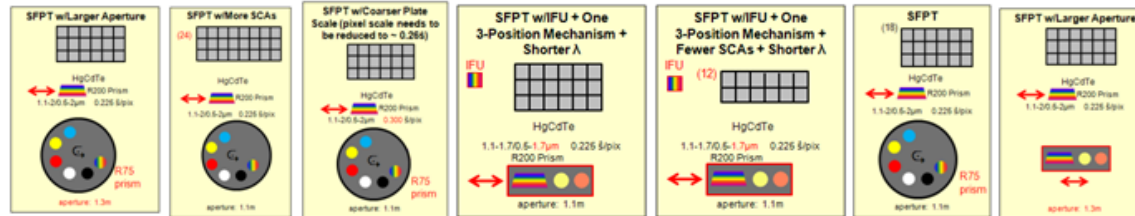
JDEM - WFIRST DRM Evolution
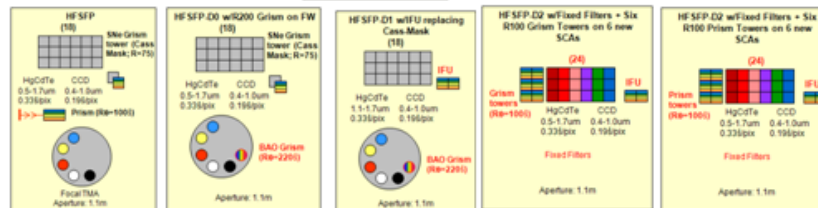
JDEM - WFIRST DRM Evolution

IDECS 2009

BAO / RSD / SNe / WL / Surveys
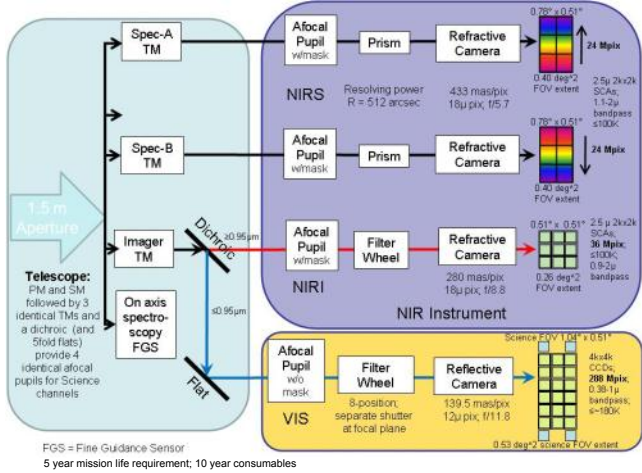
JDEM Omega 2009

Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program
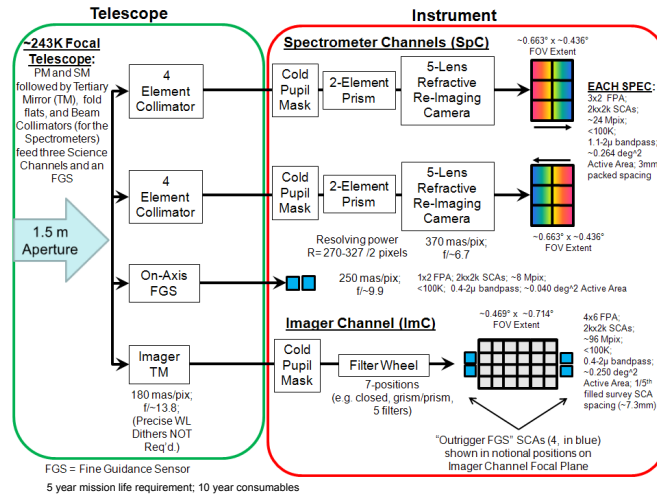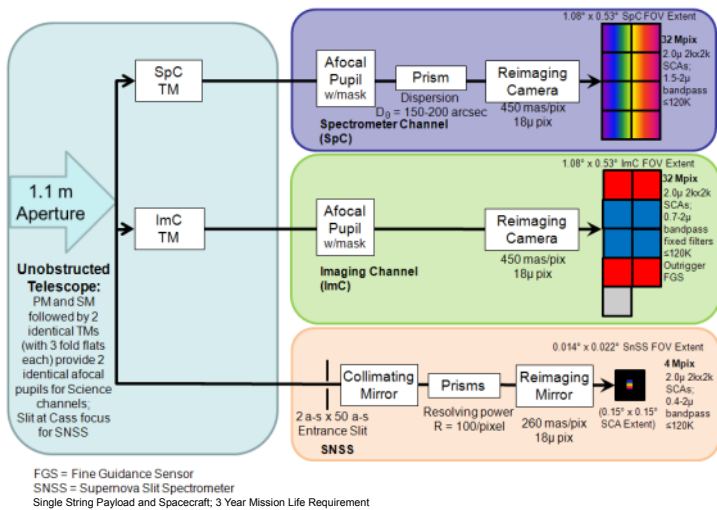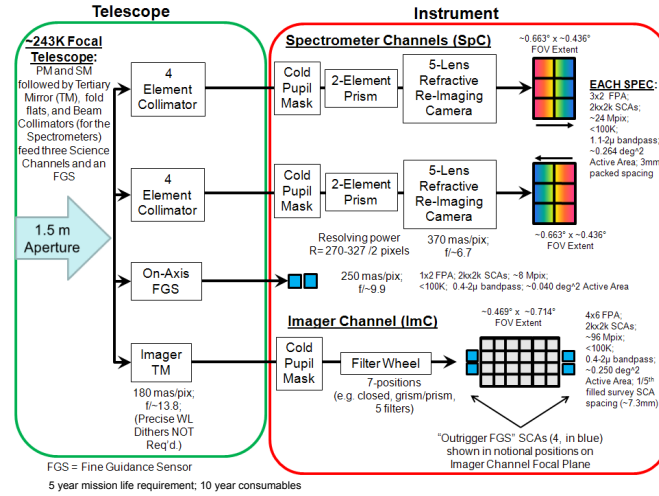
IDRM 2011

Micro-lensing / BAO / RSD / SNe / WL / Surveys / GI Program

magnification

" / p

0.45

0.18
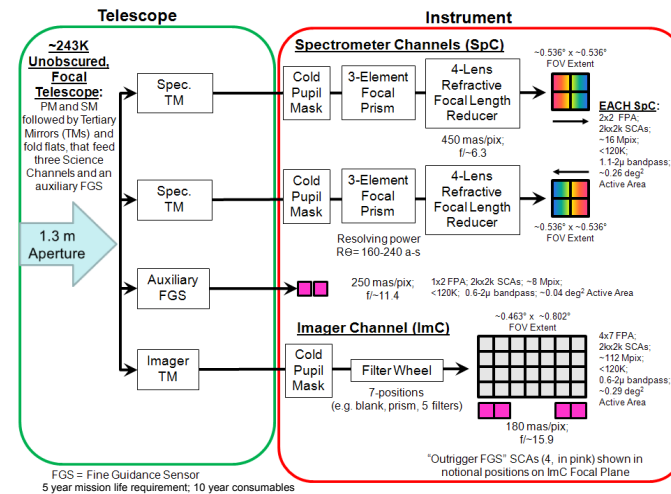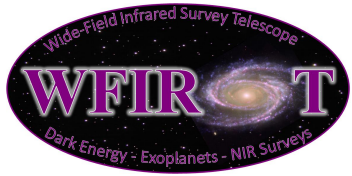
Independent Cost Estimate

- Performed by Aerospace Corp

- CATE = Cost And Technical Evaluation

- Input was Interim Design Reference Mission

- Aerospace cost estimate is within 7% of $1.6B cost estimate from the Decadal Survey

- **"Project has presented a feasible technical design consistent with stated science goals"**

Requirements Flowdown

- Substantiation that WFIRST can achieve NWNH science
- Traces science requirements from top level objectives

WFIRST Science Objectives:

1) Complete the statistical census of planetary systems in the Galaxy, from habitable Earth-mass planets to free floating planets, including analogs to all of the planets in our Solar System except Mercury.

2) Determine the expansion history of the Universe and its growth of structure so as to test explanations of its apparent accelerating expansion including Dark Energy and modifications to Einstein's gravity.

3) Produce a deep map of the sky at NIR wavelengths, enabling new and fundamental discoveries ranging from mapping the Galactic plane to probing the reionization epoch by finding bright quasars at z>10.

WFIRST Survey Capability Rqts

Exoplanet (ExP) Microlensing Survey

- Planet detection capability to ~0.1 Earth mass ($M_\oplus$)
- Detects ≥ 125 planets of 1 $M_\oplus$ in 2 year orbits in a 500 day survey, with the masses of ≥ 90 of these planets being determined to better than 20% *
- Detects ≥ 25 habitable zone† planets (0.5 to 10 $M_\oplus$) in a 500 day survey *
- Detects ≥ 30 free floating planets of 1 $M_\oplus$ in a 500 day survey *

* Assuming one such planet per star

† 0.72-2.0 AU, scaling with the square root of host star luminosity

Dark Energy Surveys

BAO/RSD Galaxy Redshift Survey

- ≥11,000 deg² sky coverage per dedicated year ("WIDE" Survey mode)
- Goal of ≥2,700 deg²/yr "DEEP" Survey acquired during the WL Survey
- A comoving density of galaxy redshifts at z=2 of 4.9x10⁻⁵ Mpc⁻³ (WIDE) or 2.1x10⁻⁴ Mpc⁻³ (DEEP). [The source density is higher at lower redshifts, peaking at z=1 at 2.2x10⁻⁴ Mpc⁻³ (WIDE) or 5.9x10⁻⁴ Mpc⁻³ (DEEP)]
- Redshift range 0.7 ≤ z ≤ 2
- Redshift errors σ_z≤0.001(1+z), equivalent to 300 km/s rms
- Misidentified lines ≤TBD% per source type, ≤10% overall; contamination fractions known to 0.2% (TBR)
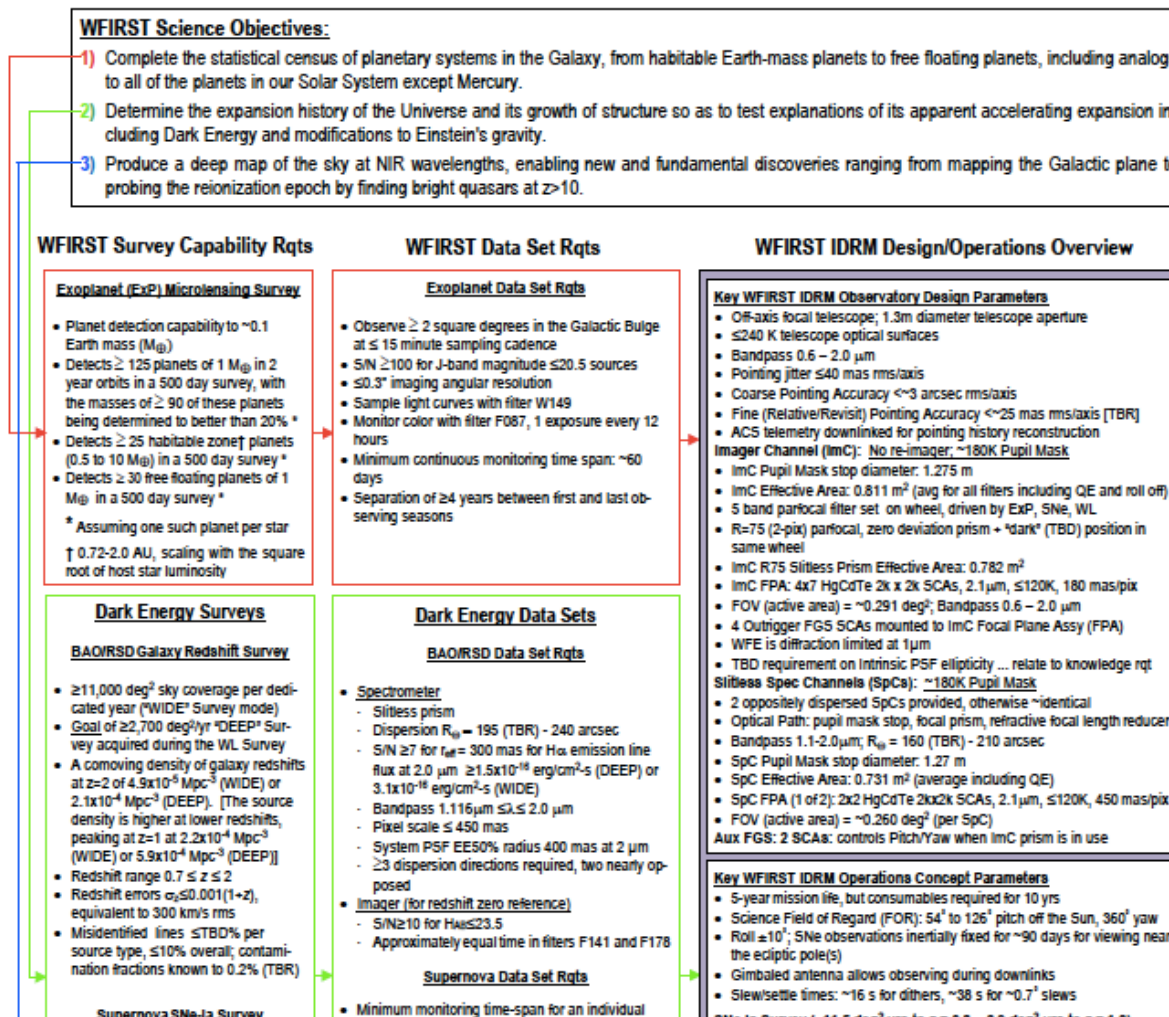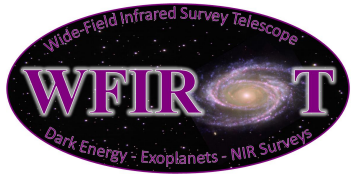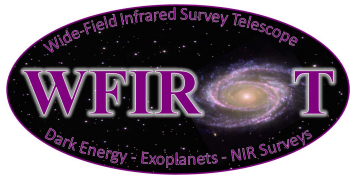
Supernova SNe-Ia Survey

WFIRST Data Set Rqts

Exoplanet Data Set Rqts

- Observe ≥ 2 square degrees in the Galactic Bulge at ≤ 15 minute sampling cadence
- S/N ≥100 for J-band magnitude ≤20.5 sources
- ≤0.3" imaging angular resolution
- Sample light curves with filter W149
- Monitor color with filter F087, 1 exposure every 12 hours
- Minimum continuous monitoring time span: ~60 days
- Separation of ≥4 years between first and last observing seasons

Dark Energy Data Sets

BAO/RSD Data Set Rqts

- Spectrometer
  - Slitless prism
  - Dispersion R_λ = 195 (TBR) - 240 arcsec
  - S/N ≥7 for r_{eff} = 300 mas for Hα emission line flux at 2.0 μm ≥1.5x10⁻¹⁶ erg/cm²-s (DEEP) or 3.1x10⁻¹⁶ erg/cm²-s (WIDE)
  - Bandpass 1.116μm ≤λ≤ 2.0 μm
  - Pixel scale ≤ 450 mas
  - System PSF EE50% radius 400 mas at 2 μm
  - ≥3 dispersion directions required, two nearly opposed
- Imager (for redshift zero reference)
  - S/N≥10 for H$_{AB}$≤23.5
  - Approximately equal time in filters F141 and F178

Supernova Data Set Rqts

- Minimum monitoring time-span for an individual

WFIRST IDRM Design/Operations Overview

Key WFIRST IDRM Observatory Design Parameters

- Off-axis focal telescope; 1.3m diameter telescope aperture
- ≤240 K telescope optical surfaces
- Bandpass 0.6 – 2.0 μm
- Pointing jitter ≤40 mas rms/axis
- Coarse Pointing Accuracy <~3 arcsec rms/axis
- Fine (Relative/Revisit) Pointing Accuracy <~25 mas rms/axis [TBR]
- ACS telemetry downlinked for pointing history reconstruction

Imager Channel (ImC): No re-imager; ~180K Pupil Mask

- ImC Pupil Mask stop diameter: 1.275 m
- ImC Effective Area: 0.811 m² (avg for all filters including QE and roll off)
- 5 band parfocal filter set on wheel, driven by ExP, SNe, WL
- R=75 (2-pix) parfocal, zero deviation prism + "dark" (TBD) position in same wheel
- ImC R75 Slitless Prism Effective Area: 0.782 m²
- ImC FPA: 4x7 HgCdTe 2k x 2k SCAs, 2.1μm, ≤120K, 180 mas/pix
- FOV (active area) = ~0.291 deg²; Bandpass 0.6 - 2.0 μm
- 4 Outrigger FGS SCAs mounted to ImC Focal Plane Assy (FPA)
- WFE is diffraction limited at 1μm
- TBD requirement on Intrinsic PSF ellipticity ... relate to knowledge rqt

Slitless Spec Channels (SpCs): ~180K Pupil Mask

- 2 oppositely dispersed SpCs provided, otherwise ~identical
- Optical Path: pupil mask stop, focal prism, refractive focal length reducer
- Bandpass 1.1-2.0μm; R_λ = 160 (TBR) - 210 arcsec
- SpC Pupil Mask stop diameter: 1.27 m
- SpC Effective Area: 0.731 m² (average including QE)
- SpC FPA (1 of 2): 2x2 HgCdTe 2kx2k SCAs, 2.1μm, ≤120K, 450 mas/pix
- FOV (active area) = ~0.260 deg² (per SpC)

Aux FGS: 2 SCAs: controls Pitch/Yaw when ImC prism is in use

Key WFIRST IDRM Operations Concept Parameters

- 5-year mission life, but consumables required for 10 yrs
- Science Field of Regard (FOR): 54° to 126° pitch off the Sun, 360° yaw
- Roll ±10°; SNe observations inertially fixed for ~90 days for viewing near the ecliptic pole(s)
- Gimbaled antenna allows observing during downlinks
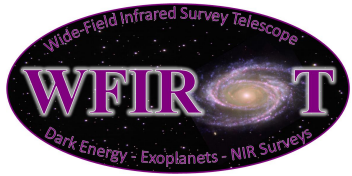- Slew/settle times: ~16 s for dithers, ~38 s for ~0.7° slews

Workshare Assignments

- WFIRST Project resides in Exoplanet Exploration Program (ExEP) at JPL and is managed by GSFC

- WFIRST Project work is joint effort between GSFC and JPL

- GSFC responsibilities
  – Project management
  – System engineering
  – Instrument & spacecraft management

- JPL responsibilities
  – Telescope design & implementation
  – Participate in system engineering
  – Data center (IPAC)

- HQ program oversight
 – Program Executive: Lia LaPiana
  – Program Scientist: Rita Sambruna
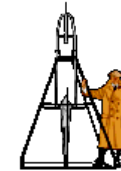
Detector Program

- H2RG detectors

  - H >> HAWAII = HgCdTe Astron. Wide Area IR Imager

  - 2 >> 2048 x 2048 pixels

  - R >> reference rows & columns to correct bias fluctuations

  - G >> guiding function, selectable window for guide star

- Space H1Rs used on HST.   Space H2RGs developed for JWST

- Goals of WFIRST program

  - Larger mosaics than JWST

  - Silicon carbide support structure

  - H4RG development

Sensor Chip Assembly
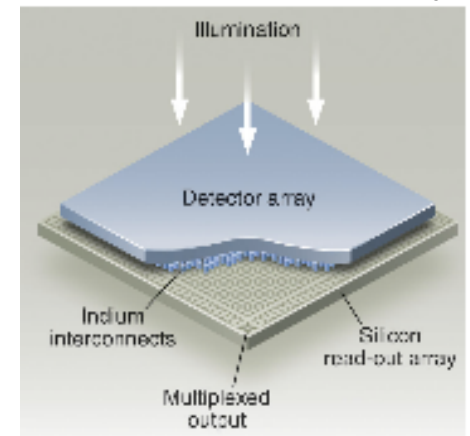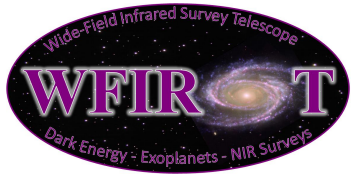
Detector Array EDU

- Development of 3x6 HgCdTe Engineering Development Unit detector array at GSFC
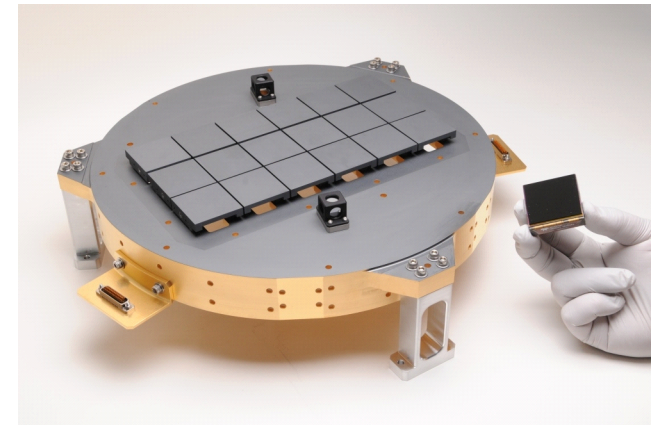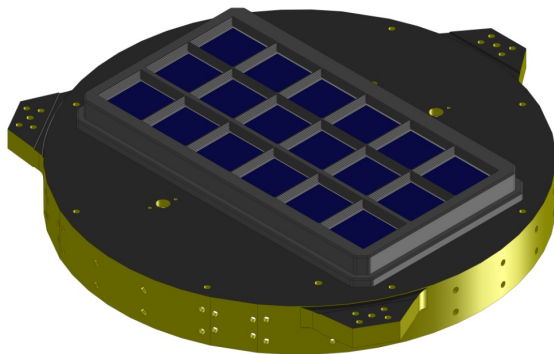
EDU Focal Plane Array

- Silicon carbide mounting of HgCdTe detectors is under development and will be space qualified with EDU
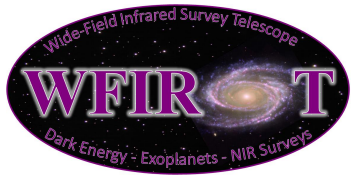
SDT with H4RG Array


3 Feb 2012

HgCdTe Performance Studies

- Potential issues with HgCdTe capabilities for WL shapes

  - Interpixel capacitance (IPC)

  - Persistance

  - Linearity & reciprocity

- Laboratory test program in place to assess issues (JPL, Caltech, Goddard, Teledyne, STScI, U Hawaii)

- Preliminary results are encouraging

Riess – HST WFC3 Linearity Study

Marchant et al. – IPC Study

Change in Moment induced by IPC

Moment of unmodified images

14
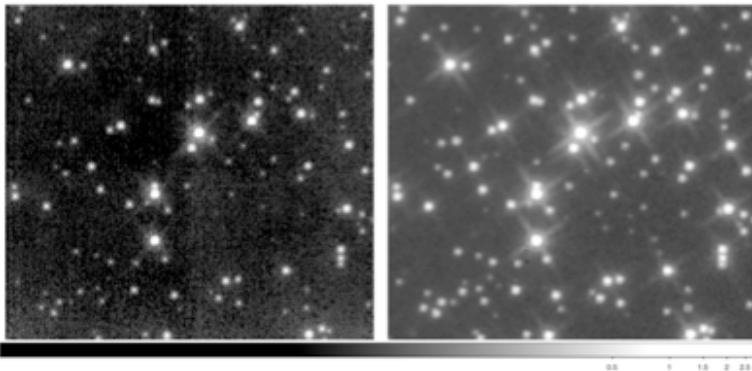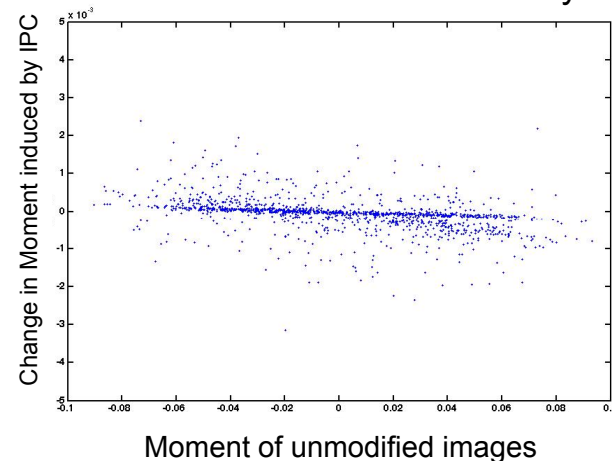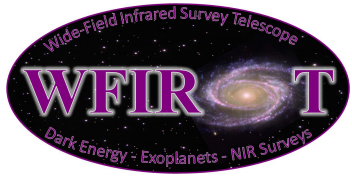
Simulations

- Pixel scale study for WL at JP/Caltech (Rhodes, Hirata, Rowe)

  - Shapelet simulations, image combination software, dithering study

  - Results show that 0.18 "/pixel of WFIRST Imager is adequate for WL

  - WL image simulation software will be available to community via IPAC
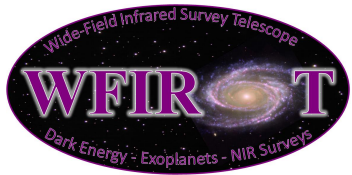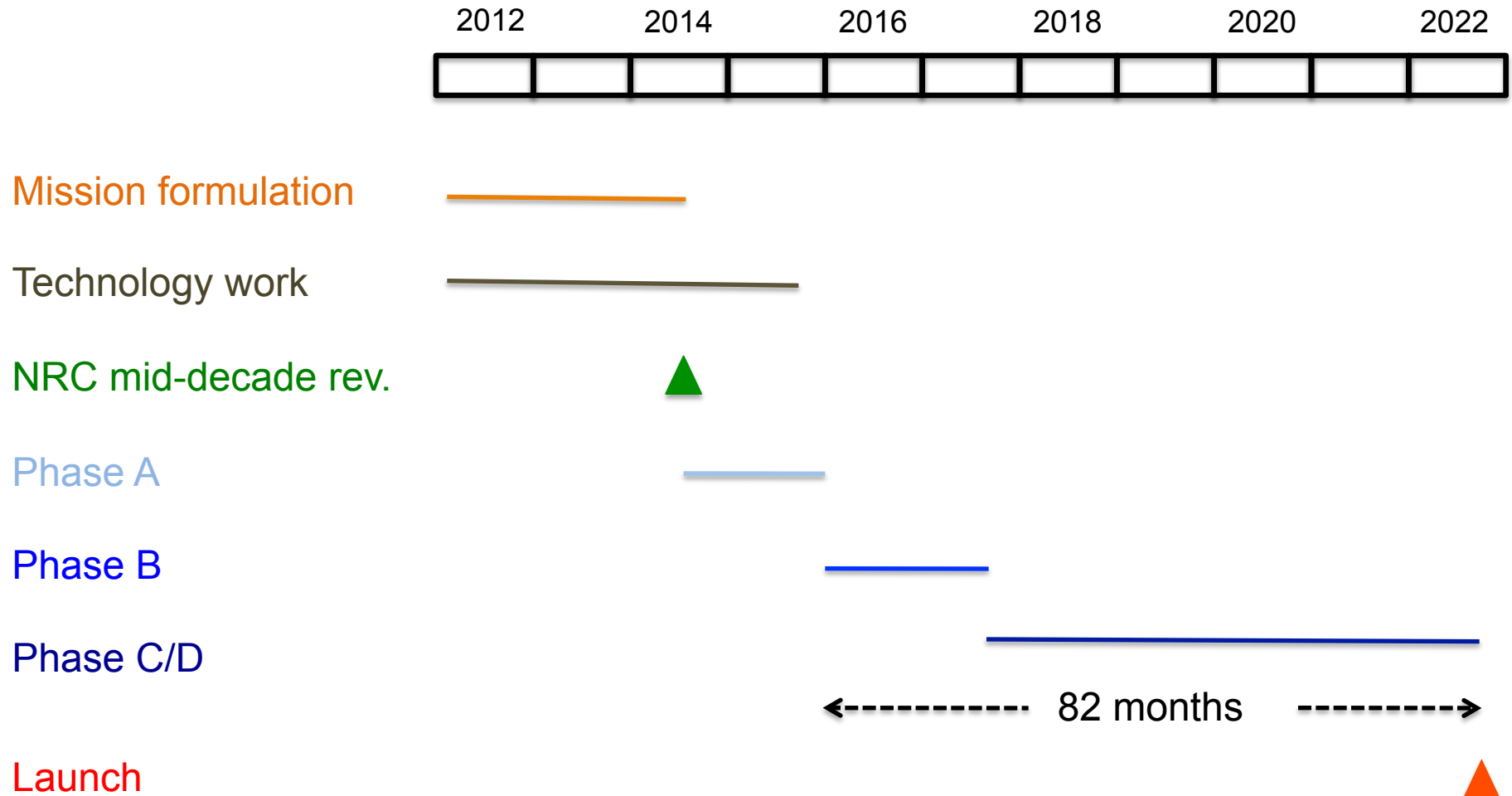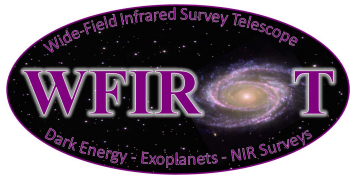
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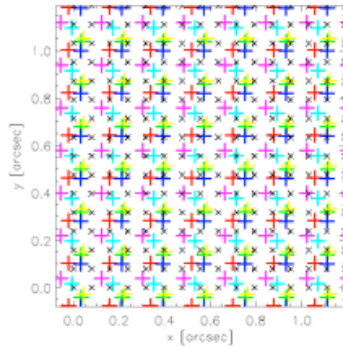
residuals
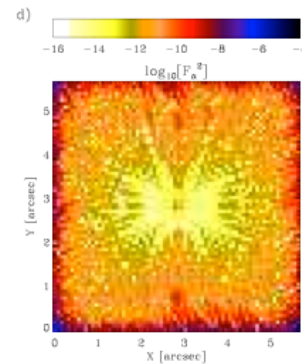
Rowe, Hirata & Rhodes 2011

- Sky tiling sims for BAO & SNe at GSFC (Kruk)

- Microlensing sims at Notre Dame/OSU (Bennett, Rhie, Gaudi)

Science Outreach

- Science calculators and estimators being deployed to the community through IPAC

- WFIRST booth developed and displayed at conferences

- IPAC Conference

- WFIRST "Meeting-In-A-Meeting" June 12-13 AAS in Anchorage

- Need for a brochure