Payload overview:
WFIRST AFT SDT #1 11/19/12

- 1. Use As Is definition
- 2. Wide field instrument requirements from past DRMs
  - Stray light requirement & approach
- 3. Payload optical form and optical layout
- 4. Payload packaging
- 5. Payload performance [outline only so far]
- *IDRM temperature & wavefront stability as suggestion of stability of AFTA [not yet included]*

1. Definition of "Use as is" (1 of 2)

- Point is to **minimize cost and risk of telescope element**
  - No change to mirror prescriptions for primary and secondary mirrors
  - Use current protected Silver coatings; if absolutely necessary (probable based on the test report), re-coat using same or other mature process.
  - The current secondary mirror is on a 7 DoF mount, and this system may have scientific utility (e.g. for weak lensing and precision photometry)
- The optical elements and structure been designed for specific operating and survival temperature ranges, and Observatory operating temperature should be consistent with this, recognizing:
  - Telescope will run colder pointed to space than the Earth-pointing design case
  - The temperature range can be reduced within its survival range consistent with the required optical wavefront accuracy.
  - The optical and/or system performance may degrade as temperature is reduced from design point of 293K, though for the wide field science the error budget allocation may be more tolerant than for the original visible wavelength design.
  - New thermal blanketing will be required (need to replace previous)

Definition of "Use as is" (2 of 2)

- Instruments (optics behind after metering structure) must adjust focal length, and **correct aberrations (including field curvature)** over the field of view, noting the 7 DoF secondary could be used to correct the image
- Coronagraph can use small, already corrected on – axis field of view
- **Work with existing hardware to the maximum extent possible**
  - Use existing outer barrel, but adjust position to improve stray light rejection
  - Use existing doors and hinges. Replace actuators.
  - Use existing heaters; new proportional heater control (no existing thermal control electronics) and possible replacement of temperature sensors
  - Use existing designs and drawings for actuator motors and electronics (need to replace previous)
  - Use existing aft metering structure mounted interfaces to the spacecraft
  - Use existing instrument mechanical interfaces for the instrument carrier

2. WFIRST AFTA wide field instrument requirements overview

- Most of these requirements are 'grandfathered' from smaller [1.1-1.5m telescope aperture] prior point designs
  - The ones most urgently in need of review are called out
    - Temperatures of telescope, instrument, focal plane, & radiator are linked, and also linked with red cutoff wavelength for imaging and spectroscopy of WFI
      - Very preliminary indications that telescope may work well as low as 250K
        - » Pending thermal analysis looking up to determine T range
  - MUST change to H4RG SCAs to allow sky coverage with reasonable # of SCAs (18 H4RGs is same pixel count as 72 H2RGs)
    - Choosing to guide off science SCAs, don't add 'engineering' SCAs when SCAs are designed to provide guide window functionality
  - We are **seeking feedback / updates** on these requirements

SDT report – requirements flowdown foldout

WFIRST Science Objectives:

1) Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets, including analogs of all of the planets in our Solar System with the mass of Mars or greater.
2) Determine the expansion history of the Universe and the growth history of its largest structures in order to test possible 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.
4) Provide a general observer program utilizing a minimum of 10% of the mission minimum lifetime

WFIRST Survey Capability Rqts

Exoplanet Microlensing Survey

- Planet detection capability to ~0.1 Earth mass ($M_{\oplus}$)
- Detects ≥ 1500 bound cold planets in the mass range of 0.1-10,000 Earth masses, including 150 planets with mass <3 Earth masses
- Detects ≥ 20 free floating Earth-mass planets

Dark Energy Surveys

Galaxy Redshift Survey (GRS)

- ≥1400 deg² per dedicated observing year (combined HLS imaging and spectroscopy)
- A comoving density of galaxy redshifts at z=2 of 2.9×10^{-4} Mpc^{-3}
- Redshift range $1.3 \le z \le 2.7$
- Redshift errors $\sigma_z \le 0.001(1+z)$, equivalent to 300 km/s rms
- Misidentified lines ≤5% per source type, ≤10% overall; contamination fractions known to 2×10^{-3}

Supernova SN-Ia Survey

- >100 SNe-Ia per Δz=0.1 bin for most bins for 0.4 < z < 1.2, per dedicated 6 months
- Observational noise contribution to distance modulus error $\sigma_\mu \le 0.02$ per Δz=0.1 bin up to z = 1.7
- Redshift error $\sigma \le 0.005$ per supernova
- Relative instrumental bias ≤0.005 on photometric calibration across the wavelength range

WL Galaxy Shape Survey

- ≥ 1400 deg² per dedicated observing year (combined HLS imaging and spectroscopy)
- Effective galaxy density ≥30/amin², shapes resolved plus photo-z's
- Additive shear error $\le 3\times10^{-4}$
- Multiplicative shear error $\le 1\times10^{-3}$
- Photo-z error distribution width ≤0.04(1+z), catastrophic error rate <2%

Near Infrared Survey

- Identify ≥100 quasars at redshift z ≥7
- Extend studies of galaxy formation and evolution to z > 1 by making sensitive, wide-field images of the extragalactic sky at near-infrared wavelengths, thereby obtaining broad-band spectral energy distributions of ≥ 1×10^9 galaxies at z>1
- Map the structure of the Galaxy using red giant clump stars as tracers

WFIRST Data Set Rqts

Exoplanet Data Set Rqts

- Monitor >2 square degrees in the Galactic Bulge for at least 250 total days
- S/N ≥100 per exposure for a J=20.5 star
- Photometric sampling cadence of ≤15 minutes
- ≤0.4" angular resolution to resolve the brightest main sequence stars
- Monitor microlensing events continuously with a duty cycle of ≥80% for at least 60 days
- Sample light curves with W filter
- Monitor fields with Y filter, 1 exposure every 12 hours
- Separation of >2 years between first and last observing seasons

Dark Energy Data Sets

GRS Data Set Rqts

- Slitless prism, spectrometer dispersion $D_{\lambda/\lambda}$ ~ 150 - 250 arcsec
- S/N ≥7 for r_{eff} = 300 mas for Hα emission line flux at 2.0 μm ≥1.1×10^{-16} erg/cm²-s
- Bandpass $1.5 \le \lambda \le 2.4$ μm
- Pixel scale ≤ 180 mas
- System PSF EE50% radius 325 mas at 2 μm
- ≥3 dispersion directions required, two nearly opposed
- Reach J_{AB}=24.0 AND (H_{AB}=23.5 OR K_{AB}=23.1) for r_{eff}=0.3 arcsec source at 10 sigma to achieve a zero order detection in 2 filters

Supernova Data Set Rqts

- Minimum monitoring time-span for an individual field: ~2 years with a sampling cadence ≤5 days
- Cross filter color calibration ≤0.005
- Three filters, approximately J, H, K
- Slitless prism spec (P130) 0.6-2 μm, λ/Δλ ~75 (S/N ≥ 2 per pixel bin) for redshift/typing
- Photometric S/N ≥15 at lightcurve maximum in each band at each redshift
- Dither with 30 mas accuracy
- Low Galactic dust, E(B-V) ≤0.02

WL Data Set Rqts

- From Space: 3 shape/color filter bands (J,H, and K) and 1 color filter band (Y; only for photo-z)
- S/N ≥18 (matched filter detection significance) per shape/color filter for galaxy r_{eff} = 250 mas and mag AB = 23.9
- PSF second moment ($I_{xx} + I_{yy}$) known to a relative error of ≤ 9.3×10^{-4} rms (shape/color filters only)
- PSF ellipticity $(I_{xx}-I_{yy}, 2*I_{xy})/(I_{xx} + I_{yy})$ known to ≤ 4.7×10^{-4} rms (shape/color filters only)
- System PSF EE50 radius ≤166 (J band), 185 (H), or 214 (K) mas
- At least 5 (H,K) or 6 (J) random dithers required for shape/color bands, and 4 for Y at same dither exposure time
- From Ground: ≥4 color filter bands ~0.4 ≤ λ ≤ ~0.92 μm
- From Ground + Space combined: Complete an unbiased spectroscopic PZCS training data set containing ≥ 100,000 galaxies ≤ mag AB = 23.9 (in JHK bands) and covering at least 4 uncorrelated fields; redshift accuracy required is σ_z<0.01(1+z)

Near Infrared Data Set Rqts

- Image ≥ 2500 deg² of high latitude sky in three near-infrared filters to minimum depths of mag AB = 25 at S/N=5. Fields must also have deep (ground-based) optical imaging
- Image ≥ 1500 deg² of the Galactic plane in three near-infrared filters

WFIRST DRM1 Design/Operations Overview

Key WFIRST DRM1 Observatory Design Parameters

- Off-axis focal telescope; 1.3m diameter telescope aperture
- ≤205 K telescope optical surfaces
- Bandpass 0.6 – 2.4 μm
- Pointing jitter ≤40 mas rms/axis
- Coarse Pointing Accuracy <~3 arcsec rms/axis
- Fine (Relative/Revisit) Pointing Accuracy <~25 mas rms/axis
- ACS telemetry downlinked for pointing history reconstruction

Imaging Mode:

- Pupil Mask temperature: ~150 K
- Effective Area (avg over bandpass): 0.778 m²
- 6 band parfocal filter set on filter wheel, driven by microlensing, SNe, WL, plus open and blank positions
- FPA: 4x9 HgCdTe 2k x 2k SCAs, 2.5μm, ≤100K, 180 mas/pix
- FOV (active area) = ~0.375 deg²; Bandpass 0.6 – 2.4 μm
- 4 Outrigger FGS SCAs mounted to Focal Plane Assy (FPA), control Pitch/Yaw during imaging mode
- WFE is diffraction limited at 1μm
- 1 nm rms wavefront stability during the HLS imaging mode (requires 0.3 K thermal stability)

Spectroscopy Mode:

- SN Prism: R=75 (2-pix) parfocal, zero deviation prism
- SN Prism Effective Area (avg over bandpass): 0.750 m² (0.6 to 2.0 μm)
- 2 oppositely dispersed GRS prisms: $D_{\lambda/\lambda}$ = 160 - 240 arcsec, parfocal, zero deviation prism
- GRS Prism Effective Area (avg over bandpass: 0.953 m² (1.5-2.4μm)
- 6 position prism wheel provides a fail-safe open position between each of the above 3 prisms
- 2 SCAs in an independent auxiliary FGS control Pitch/Yaw during spectroscopy mode

Name	Bandpasses (μm)
Z085	0.732 – 0.962
Y107	0.920 – 1.209
J134	1.156 – 1.520
H168	1.453 – 1.910
K211	1.826 – 2.400
W166	0.920 – 2.400
SN Prism (P130)	0.60 – 2.00
GRS Prisms	1.50 – 2.40

Key WFIRST DRM1 Operations Concept Parameters and Constraints

- 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 about line of sight ±10°, except during SNe observations where allowable roll is ±22.5° to provide inertially fixed viewing for ~45 days near the ecliptic pole(s)
- Gimbaled antenna allows observing during downlinks
- Slew/settle times: ~16 s for dithers, ~38 s for ~0.7° slews

SNe-Ia Survey (6.48 deg² monitored to z = 0.8, 1.8 deg² monitored to z = 1.7, ~6 months total)

- A sample 2-tiered survey capability (given ~6 months dedicated time) is shown, each tier optimized for a different z range
- Tier 1 (to z=0.8):18 "shallow fields" total 6.48 deg²; J134, H168, K211 (300 s @), P130 (1800 s)
- Tier 2 (to z=1.7): 5 "deep" fields total 1.80 deg², J134, H168, K211 (1500 s @), P130 (9500 s)
- SNe dedicated time is distributed in a 5-day cadence over ~1.8 years to provide suitable light curve tracking and accurate host galaxy references (33 hrs of SNe field monitoring would be done every 5 days for ~1.8 years)
- SNe fields are monitored from end of one exoplanet microlensing Galactic Bulge season until the start of the 4th following exoplanet microlensing season (~1.8 yrs)
- Fields located in low dust regions ≤20° off an ecliptic pole (N and S fields not required)
- Sub-pixel dithers, accurate to ~25 mas, performed at each pointing

Galaxy Shape + Galaxy Redshift Survey (~1,400 deg²/yr, 3,400 deg² total)

- 2 imaging passes in each of JHK (shape) and Y (photo-z) filters
- Each imaging pass with the same filter is rotated from the other by ~5°, and includes 4 exposures (150 sec each), with 5 exposures for each J band pass
- 90% of imaging field see ≥5 randomly dithered exposures (≥750 sec total) in YHK bands, ≥6 exposures (≥900 sec total) in J band
- 2 spectrometry passes in each of 2 oppositely dispersed GRS prisms
- Each spectrometry pass with the same prism is rotated from the other by ~5°, and includes 2 exposures (530 sec each)
- 90% of spectroscopy field sees ≥6 randomly dithered exposures (≥3180 sec total)
- Zero order galaxy detection to GRS data set requirements provided in JH or JK bands by WL imaging passes

Exoplanet Microlensing Survey (3.38 deg² monitored every 15 min, 144 days/yr, 1.2 yrs total)

- The Galactic Bulge is observable for two 72-day seasons each year
- The short revisit cadence impacts other observing modes while exoplanet data sets are being acquired. This, in combination with the field monitoring time span required for SN and the ≥60 days required for microlensing, limits the max number of Galactic Bulge seasons useable for exoplanet observations to six (over 5 yrs)
- In each season 9 fields are revisited on a 15 min cadence, viewing in filter W166, for light curve tracking except for one exposure every 12 hours that uses the Y107 filter for color
- Fields are revisited to an accuracy of 1 pixel rms; no precise dithers

Galactic Plane Survey (~6 months total)

- Uses the same survey strategy (both exposure times and tiling) as the imaging portion of the HLS
- Survey area (TBD),assumed to be the 1240 deg² region with |b|<1.72° for scheduling purposes

Figure 35: WFIRST requirements flowdown overview

See pp 6-8

See pp 9-13

Dark Energy Data Set requirements (1 of 2)

- **WL Data Set Rqts**
  - From Space: 3 shape/color filter bands (J,H, and K) and 1 color filter band (Y; only for photo-z)
  - S/N ≥18 (matched filter detection significance) per shape/color filter for galaxy reff = 250 mas and mag AB = 23.9
  - **PSF second moment (Ixx + Iyy) known to a relative error of ≤ 9.3x10-4 rms (shape/color filters only)**
  - **PSF ellipticity (Ixx-Iyy, 2*Ixy)/ (Ixx + Iyy) known to ≤ 4.7x10-4 rms (shape/color filters only)**
  - System PSF EE50 radius ≤166 (J band), 185 (H), or 214 (K) mas
  - At least 5 (H,K) or 6 (J) random dithers required for shape/color bands, and 4 for Y at same dither exposure time **varies with pixel sampling of psf**
  - From Ground: ≥4 color filter bands ~0.4 ≤ λ ≤ ~0.92 um
  - From Ground + Space combined: Complete an unbiased spectroscopic PZCS training data set containing ≥ 100,000 galaxies ≤ mag AB = 23.9 (in JHK bands) and covering at least 4 uncorrelated fields; redshift accuracy required is d*z<0.01(1+z)*

Dark Energy Data Set requirements (2 of 2)

Note: extracted from SDT final report p. 63; changes in red; comments in blue

- **GRS Data Set Rqts**
  - **Slitless prism, spectrometer dispersion Dθ 150 - 250 arcsec**
  - S/N ≥7 for reff = 300 mas for H emission line flux at 2.0 um ≥1.1x10-16 erg/cm2-s
  - Bandpass 1.5 ≤u≤ 2.4 um tracks targeted redshift range and achievable bandpass
  - Pixel scale ≤ 180 mas [under discussion w/ AFTA SDT, 90-130 range]
  - System PSF EE50% radius 325 mas at 2 μm [this is nearly 3x3 pixels, needs to be reworked down from science requirements]
  - ≥3 dispersion directions required, two nearly opposed
  - Reach JAB=24.0 AND (HAB=23.5 OR KAB=23.1) for reff=0.3 arcsec source at 10 sigma to
  - Achieve a zero order detection in 2 filters
- **Supernova Data Set Rqts**
  - Minimum monitoring time-span for an individual field: ~2 years with a sampling cadence≤5 days
  - **Cross filter color calibration ≤0.005**
  - Three filters, approximately J, H, K
  - **Slitless prism spec (P130) 0.6-2 um, λ/dλ ~75 (S/N ≥ 2 per pixel bin) for redshift/typing**
  - **Photometric S/N ≥15 at lightcurve maximum in each band at each redshift**
  - Dither with 30 mas accuracy
  - Low Galactic dust, E(B-V) ≤0.02

Exoplanet microlensing & IR survey data set requirements

Note: extracted from SDT final report p. 63; changes in red; comments in blue

- **Exoplanet Data Set Rqts**
  - Monitor >2 square degrees in the Galactic Bulge for at least 250 total days
    [Required # of stars, improved resolution will reduce required area]
  - S/N ≥100 per exposure for a J=20.5 star
  - Photometric sampling cadence of ≤15 minutes
  - ≤0.4" angular resolution to resolve the brightest main sequence stars
  - Monitor microlensing events continuously with a duty cycle of ≥80% for at least 60 days
  - Sample light curves with W filter
  - Monitor fields with Y filter, 1 exposure every 12 hours
  - Separation of >2 years between first and last observing seasons
- **Near Infrared Data Set Rqts**
  - Image 2500 deg2 of high latitude sky in three near-infrared filters to minimum depths of mag AB = 25 at S/N=5. Fields must also have deep (ground-based) optical imaging
  - Image 1500 deg2 of the Galactic plane in three near-infrared filters

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Key WFIRST DRM1 Observatory Design Parameters

- Off-axis focal telescope; 1.3m diameter telescope aperture
- ≤205 K telescope optical surfaces [250-293K] {Instrument was 150K, focal plane was 100K}
- Bandpass 0.6 – 2.4 um {depends on achievable telescope temperature}
- Pointing jitter ≤40 mas rms/axis {~0.22 pixels, would scale to 24 masec rms/axis, include jitter & in-band slower drift}
- Coarse Pointing Accuracy <~3 arcsec rms/axis
- Fine (Relative/Revisit) Pointing Accuracy <~25 mas rms/axis {~0.14 pixels, would scale to 15 masec rms/axis}
- ACS telemetry downlinked for pointing history reconstruction

Imaging Mode:

- Pupil Mask temperature: ~150 K
- Effective Area (avg over bandpass): 0.778 m^2 {increases by roughly 2.8x}
- 6 band parfocal filter set on filter wheel, driven by microlensing, SNe, WL, plus open and blank positions
- FPA: 4x9 HgCdTe 2k x 2k SCAs, 2.5um, ≤100K, 180 mas/pix {at least 6x3 H4RG 4k x 4k 10um pixel pitch, 110mas/pix SCAs}
- FOV (active area) = ~0.375 deg^2; Bandpass 0.6 – 2.4 um {at least 0.28 deg^2}
- 4 Outrigger FGS SCAs mounted to Focal Plane Assy (FPA), control Pitch/Yaw during imaging mode {guiding on science SCAs}
- WFE is diffraction limited at 1um may relax to allow larger field of view
- 1 nm rms wavefront stability during the HLS imaging mode (requires 0.3 K thermal stability)

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- 6 position prism wheel provides a fail-safe open position between each of the above 3 prisms {failsafe to be reexamined}
- 2 SCAs in an independent auxiliary FGS control Pitch/Yaw during spectroscopy mode {still have this; not part of WFI}

Grism/prism trade – 4 prism assembly v. 2-3 thinner parts w/ grisms at lower bandpass and sensitivity – trade engineering complexity vs. mapping speed

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SNe-Ia Survey (6.48 deg2 monitored to *z = 0.8, 1.8 deg2 monitored to z = 1.7, ~6 months total)* to be redone by SDT

- A sample 2-tiered survey capability (given ~6 months dedicated time) is shown, each tier optimized for a different *z range*
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Galactic Plane Survey (~6 months total)

- Uses the same survey strategy (both exposure times and tiling) as the imaging portion of the HLS
- Survey area (TBD),assumed to be the 1240 deg2 region with $|b|<1.72°$for scheduling purposes

Stray light requirement & approach

- Requirement has been to keep stray light contribution to **10% minimum zodi** (for fields to be observed)
  - Note – distinguish stray (out of field light that gets into FOV) from scattered (in FOV light going other than core of image) light
- Approach has been to design standard set of Cassegrain-like baffles to **prevent out of field contributions**
  - Lesson learned from JWST – contributor to instrument delays
  - Good engineering practice
  - May be revisited in phase A; stray light analysis is more time consuming than design and may be out of scope for current study
- This approach leads to 40% linear obscuration and is sure to meet requirement
- Early look (R. Goullioud) at 30% obscuration may work for WFI; will consider this as an option: further work planned to confirm viability of 30% obscuration

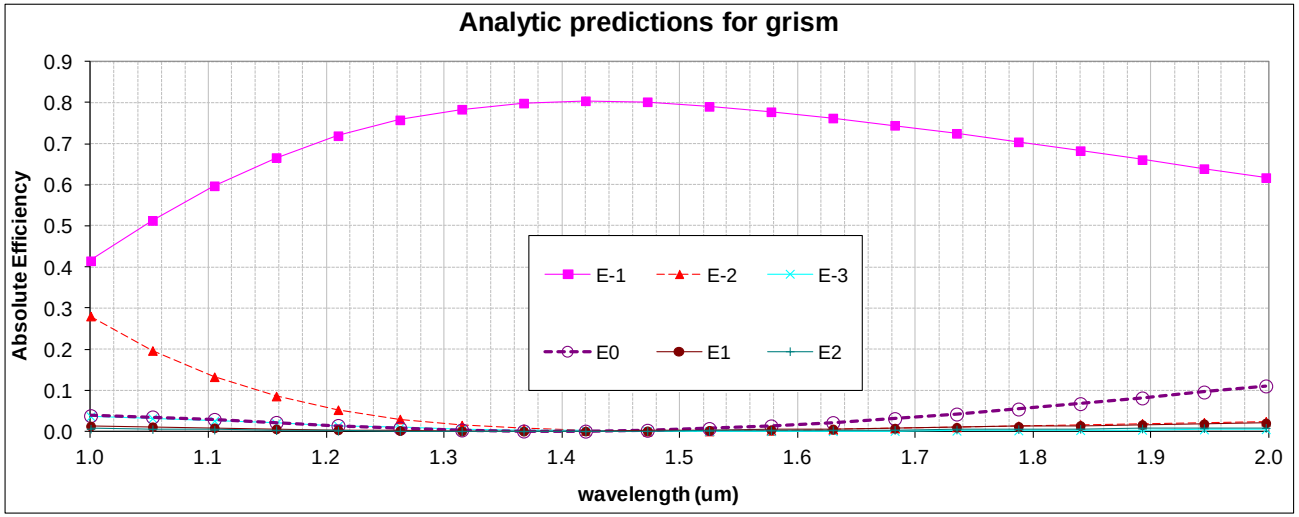
3. Wide field optical form and optical layout

General design rules for wide field optical concepts

- Keep front end axi symmetric and unchanged (PM & SM) [“as is”]
- **Pupil must be accessible** and **reasonable pupil imaging** is required
  - Pupil mask required to limit IR input from telescope to colder instrument
  - Accommodation for filter plus disperser wheel requires even more room after pupil
    - Preference for designs with pupil diameter ≤15cm
- Galaxy redshift (GRS) and SuperNova (SN) **dispersers required**
- **Focal plane curvature limited** to maintain entire focal plane within depth of focus
- Layout must be **consistent with temperature** zones
  - Telescope (past range 205-250K, nominal 250-293K now)
  - Instrument (has been 150K)
  - FPA (100K)
  - Radiator (consistent with orbit & FPA)
- Have worked to 1um diffraction limit (71nm rms) w/ residual being ≤50% max over FFOV
- Telescope/instrument **interface should be testable** in both directions
  - Tbd how this works for instrument stimulus in ‘as is’ case
  - Telescope is testable on axis in field, tbd how would be tested in wide field FOV as it is only the first two mirrors in a three mirror design and is not well corrected at the intermediate focus
- Stray light is well controlled
  - No ‘rogue paths’ allowed
  - Implies large secondary mirror linear obscuration (JDEM-Ω 50%, 40% now)
- Preference for FPA placement at radial edge of payload, on cold side of observatory [thermal design]
- **Packaging should be consistent with existing telescope hardware**

Why prisms

- Grisms have been used on HST to good effect
- Reflection Gratings used for NIRSPEC
- Why have we preferred prisms for WFIRST?
  - Dispersion – higher than e.g. WF3 grism (R_{2pix} ~1000)
  - Bandpass – wider than any HST grism
  - Survey speed; blaze efficiency costs 40% in observing time (depending on bandpass)
  - Confusion; 1 spectrum vs. ~5 bright orders
  - Prism stack must be zero deviation and parfocal with the filter imaging modes
- However, we have designed a 2-grism solution
  - 1.3-1.86, 1.85-2.4um
  - J. Kruk is assessing science impact



Layout & more FOV

- Revised FOV vs pixelsize & layout chart based on maximum radial field allowable
  - Rectangular field assumed for ease of prism design
- SDT telecon Th 11/1 resulted in 4 cases
- ✓ DRM-A: (baseline) 6x3 @0.11”/p, 0.281 sq. deg, yellow in fever chart
- DRM-B: (larger field) 6x3 @0.12”/p, 0.334 sq. deg, yellow
- DRM-C: (finer pixels) 8x3 @0.09”/p, 0.251 sq. deg, green
- ✓ DRM-D (cost savings?) 6x3 @0.11"/p, no prism (grism in wheel), 3 years, diffraction limited at 2 micron

- Note that previous color versions were for rectangular, not arced layouts; discussion 11/1 w/ SDT on difficulty with prism design on arced layouts, we would keep to rectangular format for the moment.

Increasing difficulty

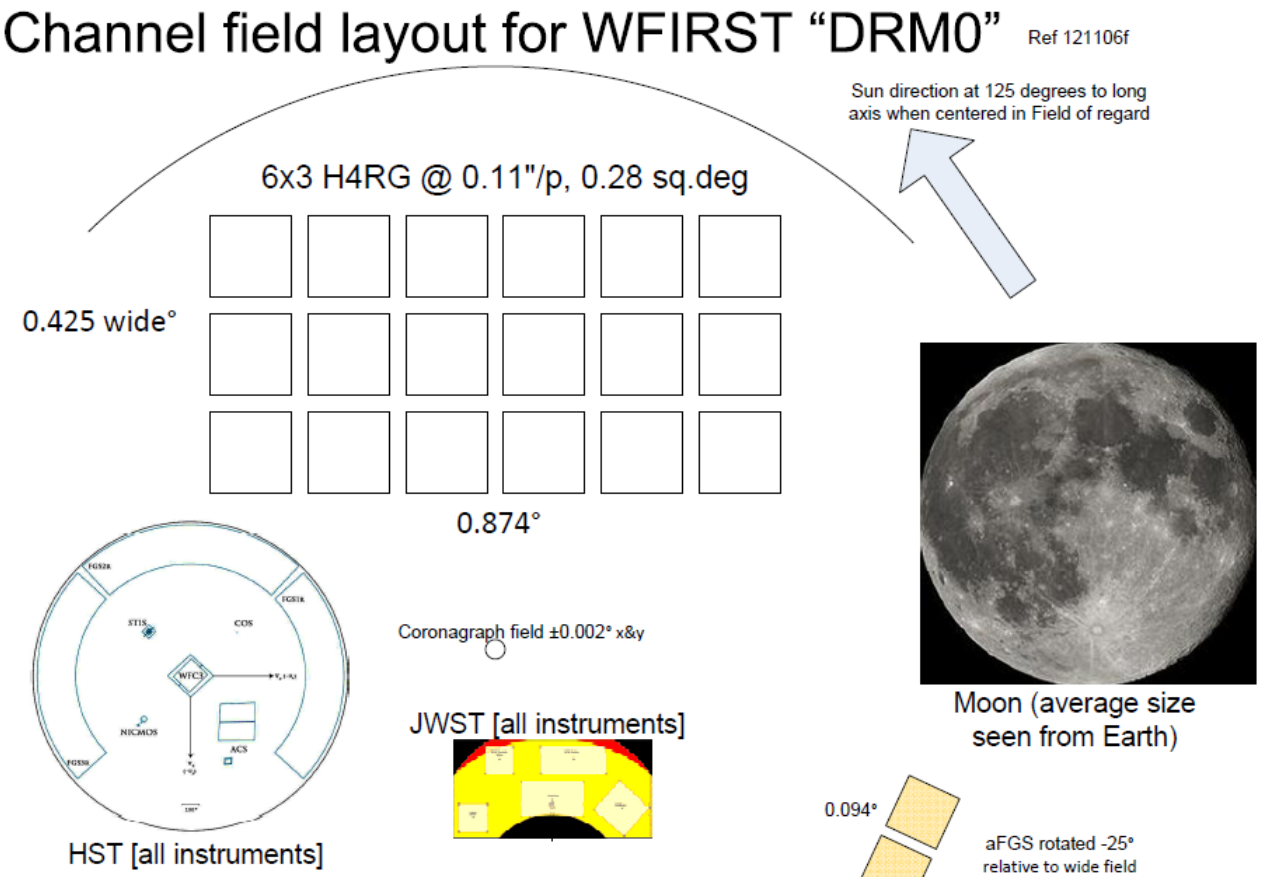
total x	6x3	8x3	10x3
0.09	0.188	0.251	0.313
0.1 A,D	0.232	0.309	0.387
0.11	**0.281**	0.374	0.468
0.12 B	0.334	0.446	0.557
0.13	0.392	0.523	0.654
0.14	0.455	0.607	0.758

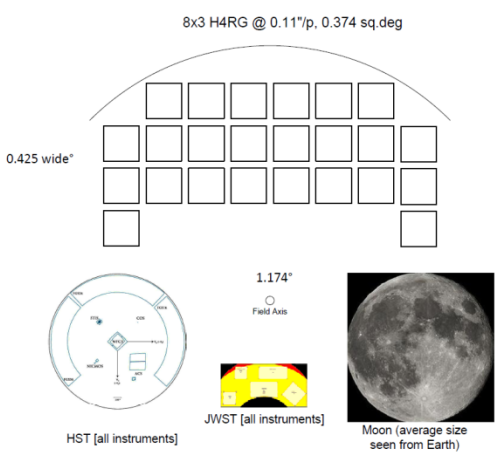
Layout table:
X – layout (H4RG (10um))
Y – pixel scale, arcsec
Data: FOV area, sq. deg.
Baseline is 0.11 6x3

20% gaps		ImC/SpC	aFGS
npix [1 side of SCA]		4088	4088
pixel size	mm/p	0.01	0.01
x gap size	mm	8.18	8.18
y gap size	mm	8.18	8.18
pixel scale	"/p	0.110	0.075
nx		6	2
ny		3	1
total x	deg	0.874	0.187
total y	deg	0.425	0.085
active area	deg^2	0.281	0.015
total area/channel	deg^2	0.371	0.016
total active area	deg^2	0.281	0.015
fov diam.		0.972	0.206
plate scale	mm/"	0.0909	0.1333
focal length	m	18.751	27.502
aperture	m	2.36	2.36
system f/#		7.946	11.653
lin. obscur.		0.400	0.400
A	m^2	3.674	3.674
A - omega est.	m^2deg^2	1.032	0.053
Mpix		300.8	33.4
field size x	mm	286.16	89.936
field size y	mm	138.992	40.88
x gap angle	deg	0.0250	0.0170
y gap angle	deg	0.0250	0.0170
chip size	mm	40.88	40.88
chip angle	deg	0.1249	0.0852

Baseline Layout for wide field channel – not finalized

- Angle of FOV to sun line & rotation of aFGS are preliminary
- Each square is H4RG 10um sensor chip assembly (SCA)

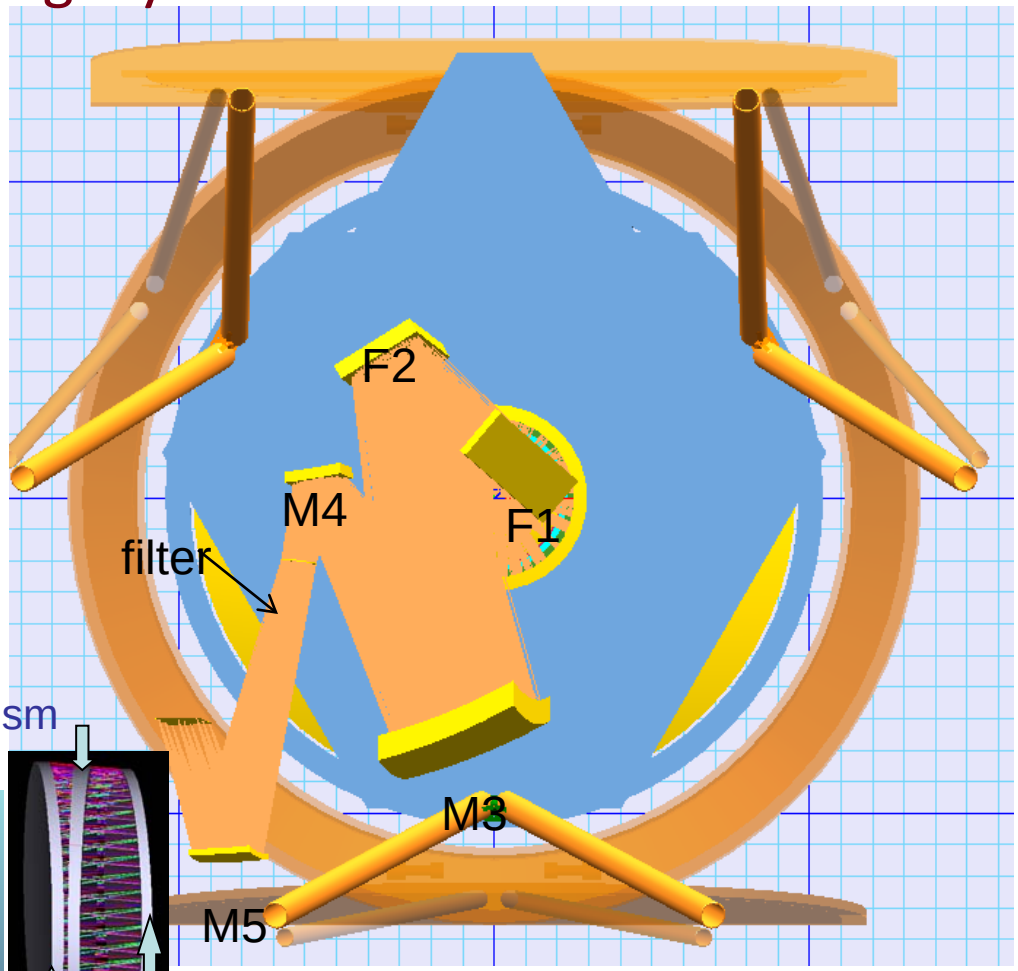




Example of potential expanded field

Resulting layout and form

- Single wide field, imaging mode ray trace shown
- Inset shows example prism assembly (Galaxy redshift spectroscopy prism assembly, highest dispersion)
  - Prisms after filter, before M5
- Alternate GRS grism (blue) shown

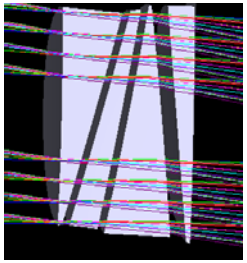


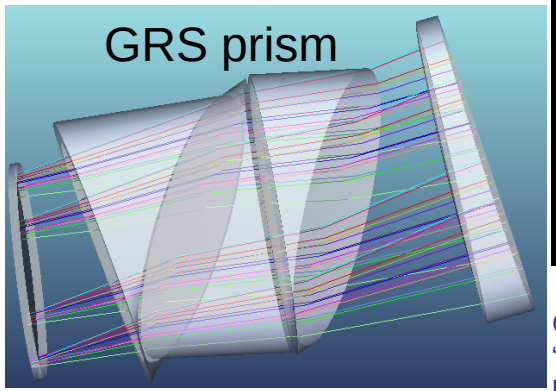
Grism

Chromatic "corrector" lens

Pupil corrector

SN prism

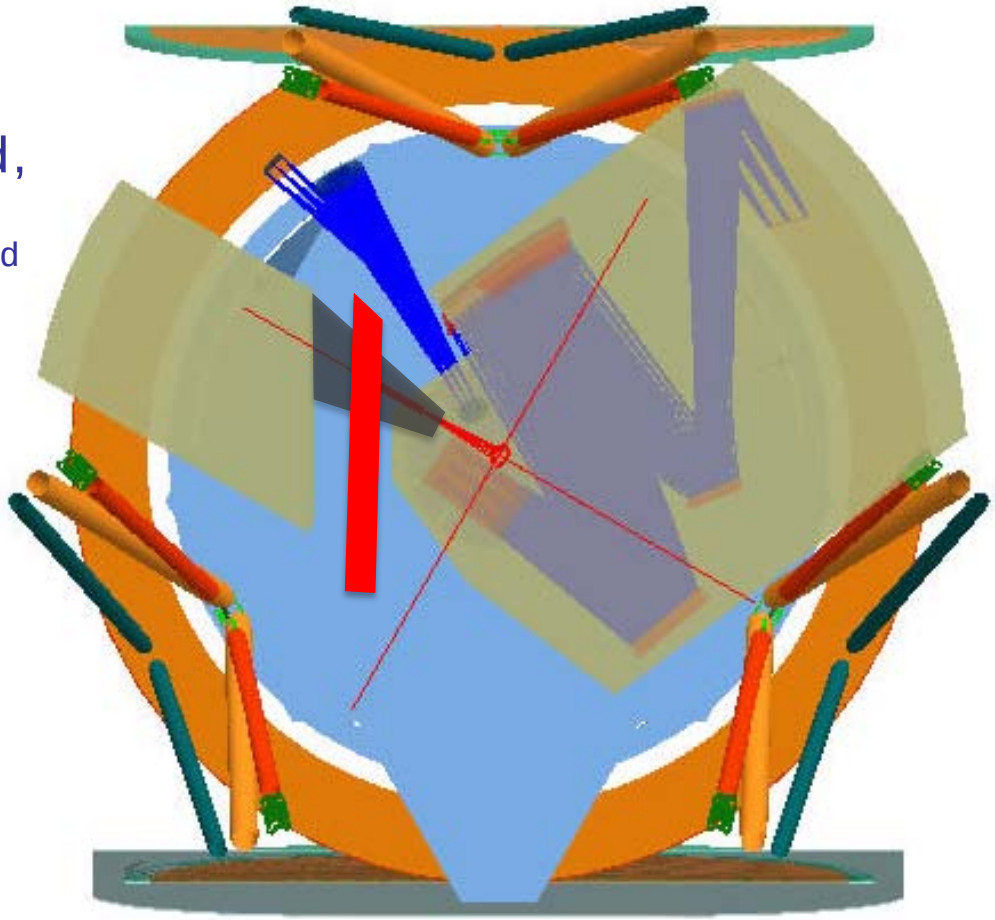




4. Payload packaging

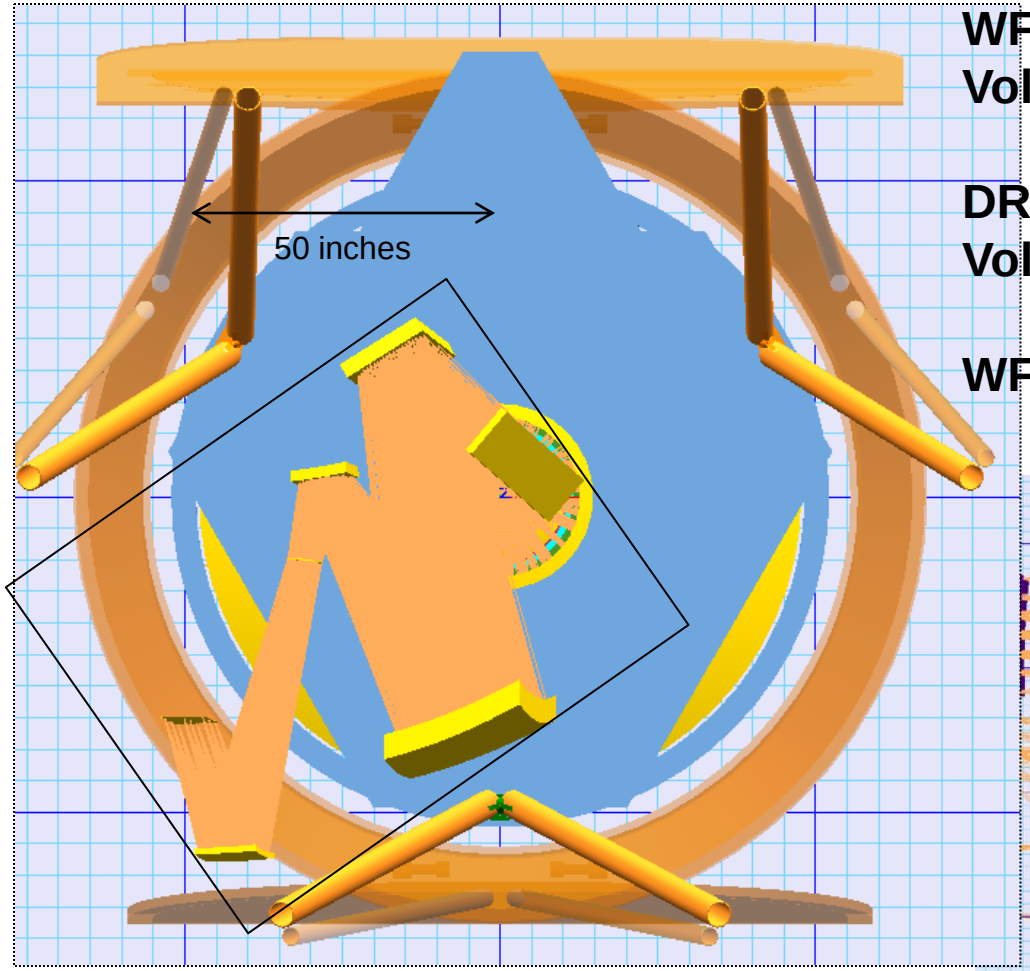
Notional payload accommodation concept

- Aft metering structure is 3-fold symmetric
- Arrange OTA struts, sunshield, etc so that two bays are accessible on cold side and 3rd is on sun side
- Wide field access on one side
- Opposite bay provides access to coronagraph and auxiliary guider (aFGS)
  - Auxiliary guider (as in prev. studies) is needed when disperser is inserted in wide field beam
- Intent is to be able to insert channels in any order
- Working on mechanical layout of carrier now



DRAFT payload volumes, not final!

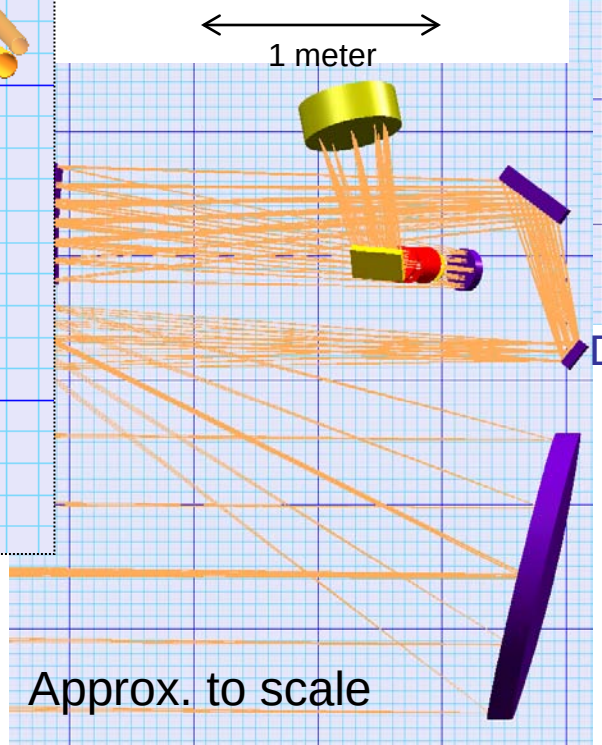
Comparison to DRM2 & HST/WFC3

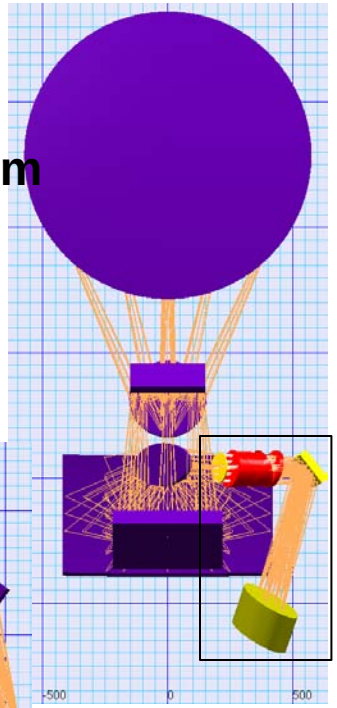


WFI: 1.67 x 2.12 x 1.4m
Volume: 4.1m^3

DRM2: 0.89 x 0.52 x 0.40m
Volume: 0.2m^3

WFC3: ~1.6m^3





DRM2 has 0 cold aspheric mirrors, 1 fold, plus prism wheel, filter wheel, FPA

- AFTA WFI has 3 cold aspheric mirrors, 2 folds, plus prism wheel, filter wheel, FPA

Thermal overview

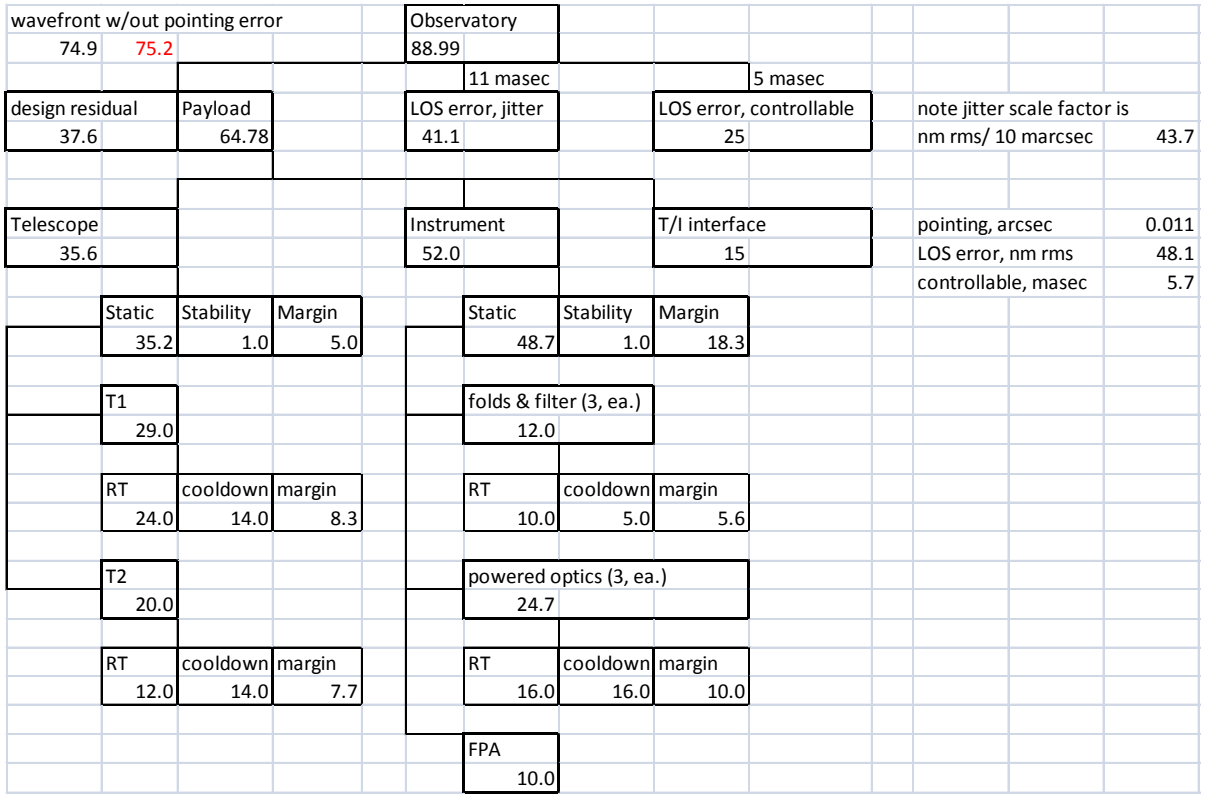
- J. Dooley will present details of this work being done at JPL & ITT
- Working to get thermal models of telescope up & running
- Initial cases: L2, no sunshield;
  - Heaters all off – cold limit
  - Heaters all on full – warm limit
- Trying to get a rough idea – what is achievable temperature range for 'as is' ?
- Adding sunshield (notionally only shadowing to SM, not to front of unheated OBA) will reduce equilibrium temperature
- Working to define instrument volume temperatures
  - Instrument carrier
  - Coronagraph pickoff mirror is very close to wide field optical beam; can we keep it room temperature as desired?

5. Payload performance

- Draft/ notional wavefront error budget
- Imaging residual overlay & FOV layout
- Spot diagram
- Distortion plot
- Filter list
- GRS residual plot & spot diagram
- SN residual plot & spot diagram
- Throughput description
- Throughput plot (all modes)
- aFGS description & ray trace

Wavefront error buget, 1st cut – imaging mode, wide field instrument

- Based on same requirements as IDRM/DRM1&2: 1um diffraction limit plus pointing errors at ~1/7th pixel rms per axis
- T1/T2 room temp (RT) errors from ITT data
- T1 Cooldown is based on the one analysis done so far [may be overly tight, or not, tbd]
  - T2 cooldown set equal to T1
- This is VERY tight:
  - Near state of art polishing
  - Minimal allocation for thermal cooldown distortion
  - Small margins
- Tightened pointing allocations
  - jitter from 15 to 11 masec
  - ACS from to 5.7 masec

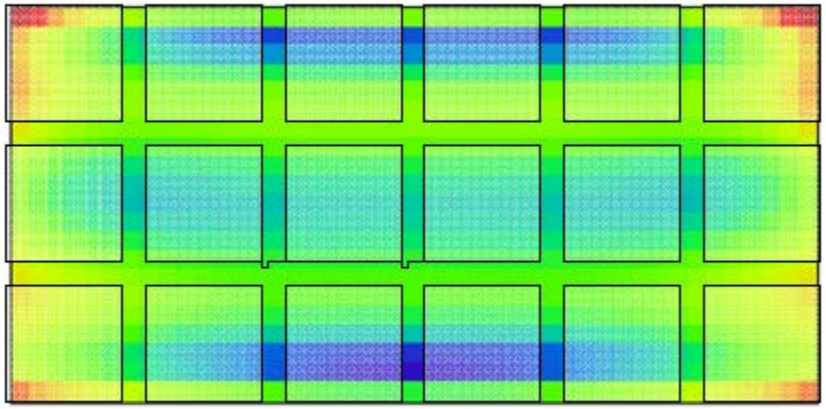


DRAFT/notional

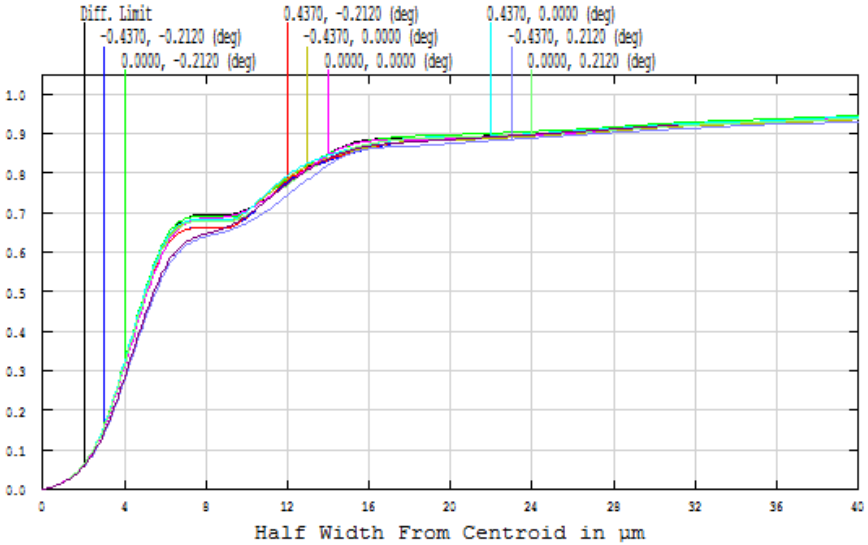
Imaging residual error, 1 um – goal 35nm at worst field

- Meets goal except in corners
- Varies smoothly over the field
- Spot diagram & ensquared energy plots below

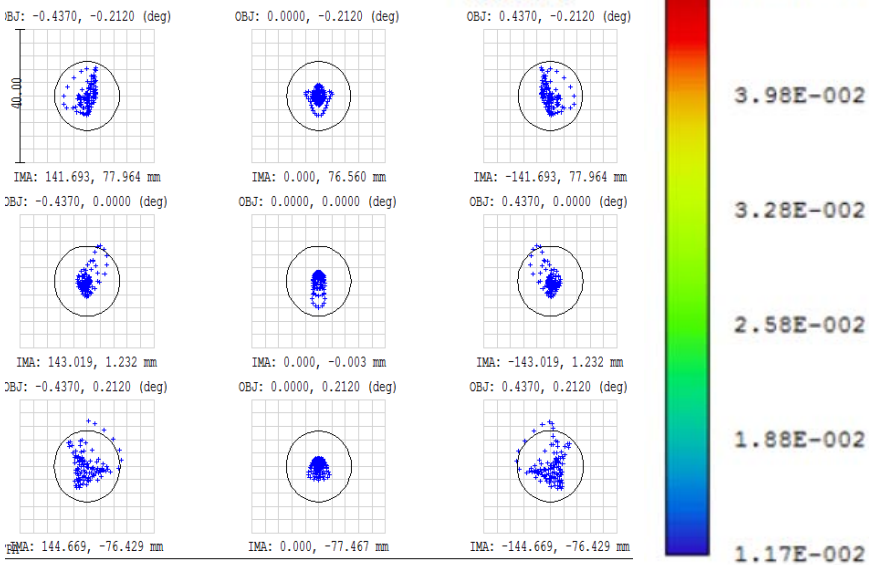
6x3 H4RG @ 0.11"/p, 0.28 sq.deg



0.425 wide°



0.874°

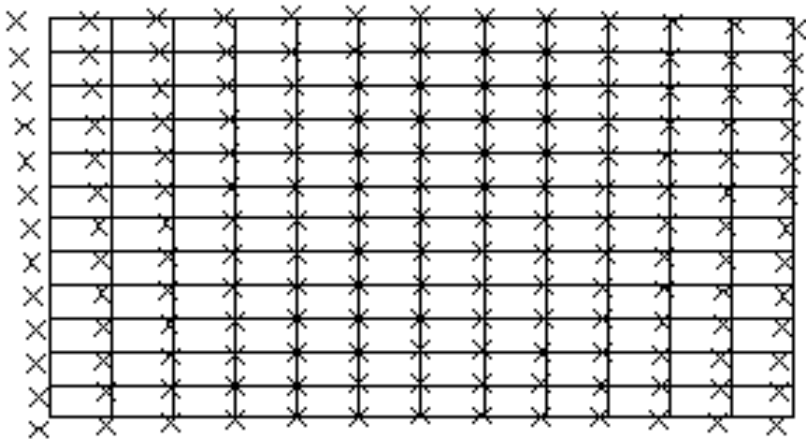


11/14/2012 Units are µm. Airy Radius: 10.05 µm

Field :	1	2	3	4	5	6	7	8	9
RMS radius :	3.944	2.514	3.990	3.475	2.646	3.474	5.158	2.157	5.455
GEO radius :	8.753	5.825	8.755	11.347	7.831	11.366	13.662	4.320	13.315

Scale bar : 40 Reference : Centroid

Imaging distortion [magnified 3x for visibility]



Grid Distortion

11/14/2012
Field: 0.8740 w 0.4239 h Degrees
Image: 285.34 w 152.70 h Millimeters
Maximum distortion: 2.6026%
Scale: 3.000X, Wavelength: 1.0000 µm

Spectral selection element list

Band	Filter Name	Min	Max	Center	Width	Dispersion
Z	Z085	0.732	0.962	0.847	0.230	3.68
Y	Y107	0.920	1.209	1.065	0.289	3.68
J	J134	1.156	1.520	1.338	0.364	3.68
H	H168	1.453	1.910	1.682	0.457	3.68
K	K211	1.826	2.400	2.113	0.574	3.68
Wide	W168	0.920	2.400	1.660	1.480	1.12
	SN	0.60	2.40	1.50	1.90	R (2 pix) ~75
	GRS	1.30	2.40	1.35	1.10	D_θ= ~200

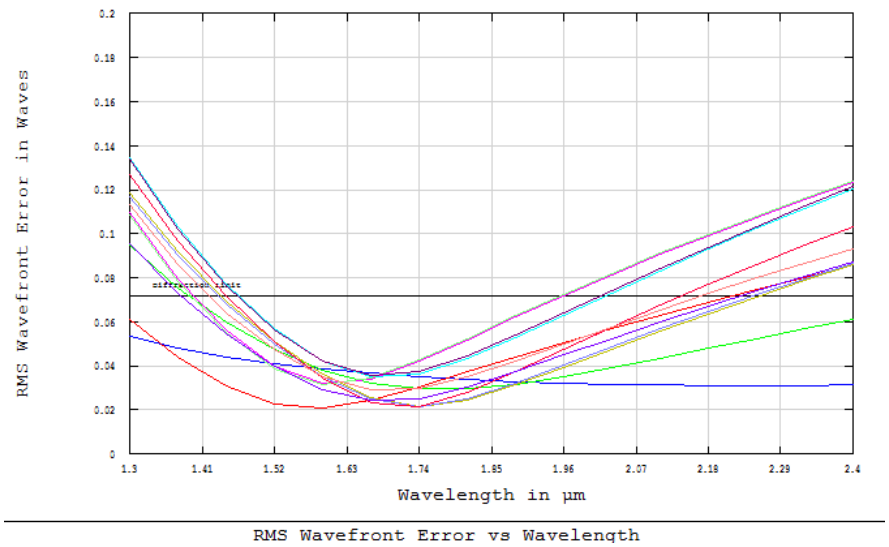
Table: Filter and prism descriptions; Wavelengths are in μm. GRS prism dispersion is in units of arcsec with $D_\theta=\lambda/(\delta\lambda/\delta\theta)$ where θ is sky angle.

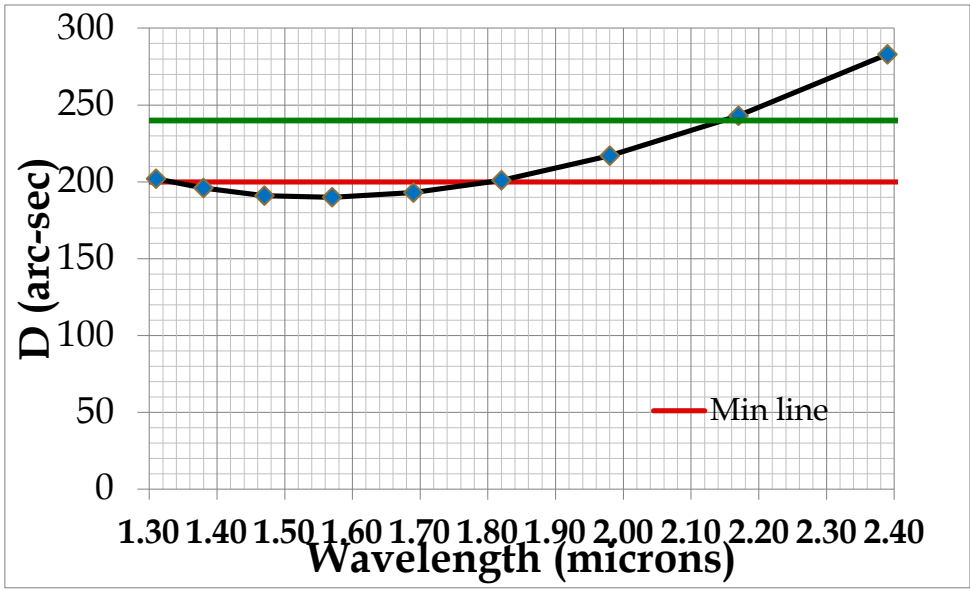
Bandpasses may be adjusted; takeaway is that 6 filters, all wide, can be accommodated

Notes:

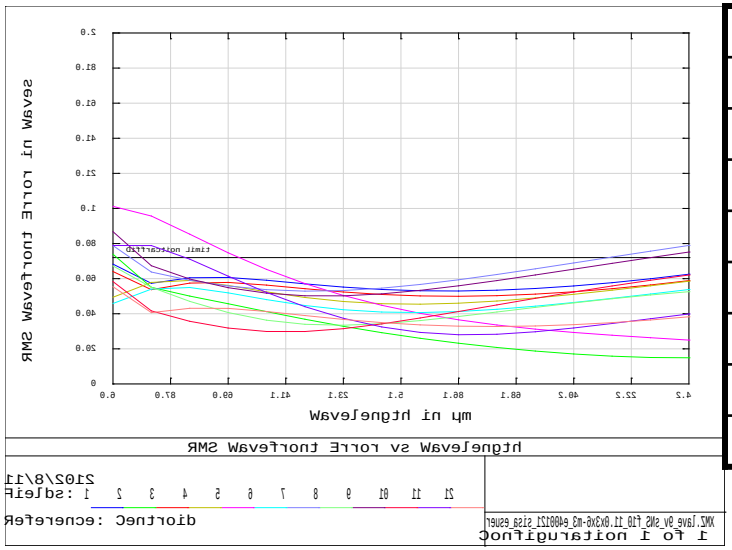
1. SN bandpass extended to 2.4um [can be reduced, this is maximum case]
2. Single GRS (not 2 oppositely dispersed) seems simpler and consistent with adjustment to deeper narrower survey strategy

GRS imaging and dispersion performance

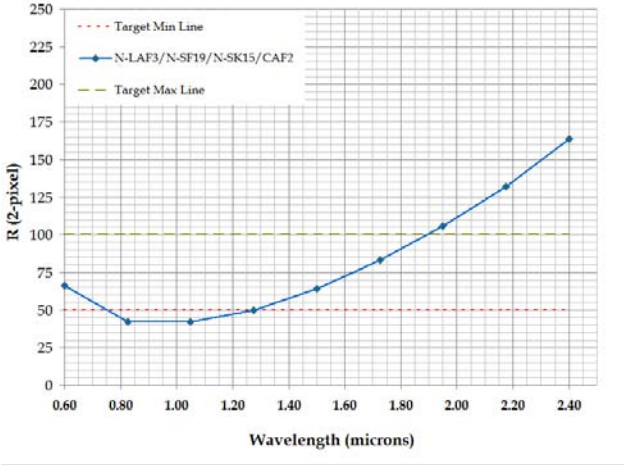




SN prism imaging and dispersion performance

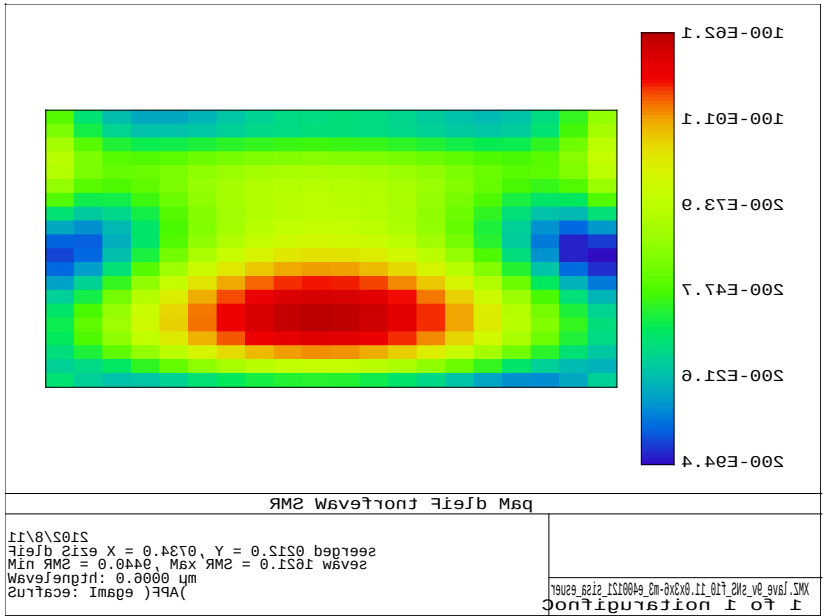


Surface	*Type*	*Glass*
P1S1	Zernike (15)	N-LAF3
P1S2	Sphere	
P2S1	Sphere	N-SF19
P2S2	Sphere	
P3S1	Sphere	N-SK15
P3S2	Sphere	
P4S1	Sphere	CaF2
P4S2	Zernike (15)	



Notes:

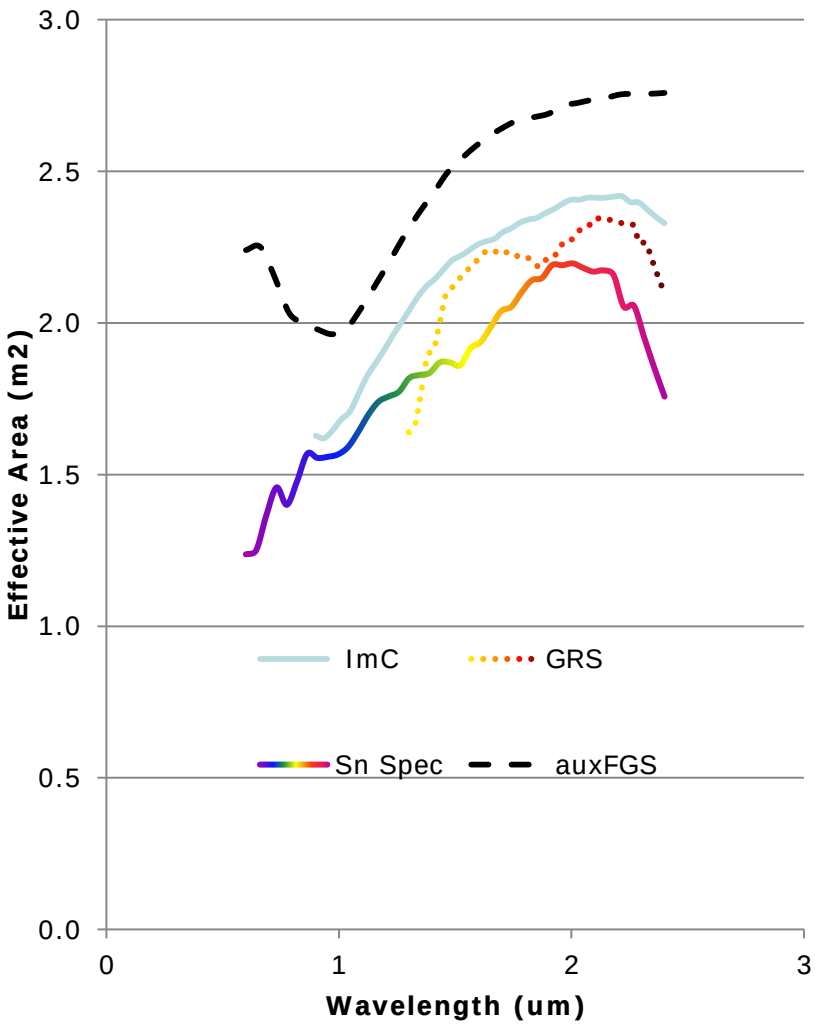
1. Incomplete search of potential material combinations (may flatten dispersion more)
2. Smaller bandpass will improve performance; this is worst-case



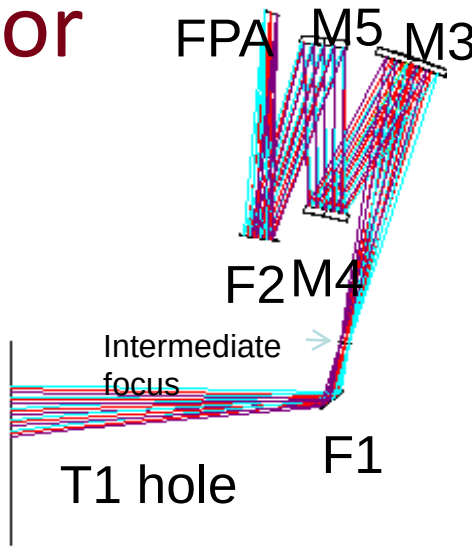
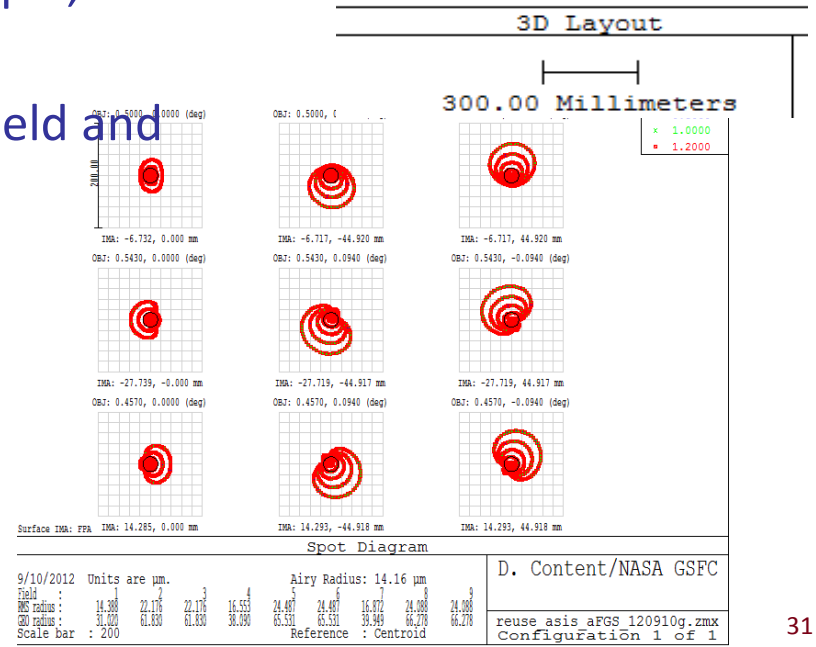
Throughput calculation

- Protected silver mirror coatings
- AR coating model on prisms
- Bandpass filter model
- Strut shadowing
- SM baffle losses
- Pupil mask losses
- 2% (total) end of life contamination assumed

Mode	units	ImC	GRS	Sn Spec.	aFGS
bandpass blue edge	um	0.9	1.3	0.6	0.6
bandpass red edge	um	2.4	2.4	2.4	2.4
Average Aeff	m^2	2.170	2.178	1.833	2.432
min Aeff	m^2	1.620	1.639	1.237	1.963
max Aeff	m^2	2.418	2.346	2.197	2.759



Auxiliary fine guidance sensor



- Used when wide field is in dispersive mode
- H4RG, 0.075”/pixel
- Redundant (2 H4RGs, 1 used at a time)
- Off axis field, 0.085° square FOV each
- AΩ matched to prior aFGS
- ~2x worse than diffraction limited for good centroiding
- All Aluminum diamond turned mirrors (simple, broadband, athermal)
- Packaging flexible; will work around wide field and coronagraph