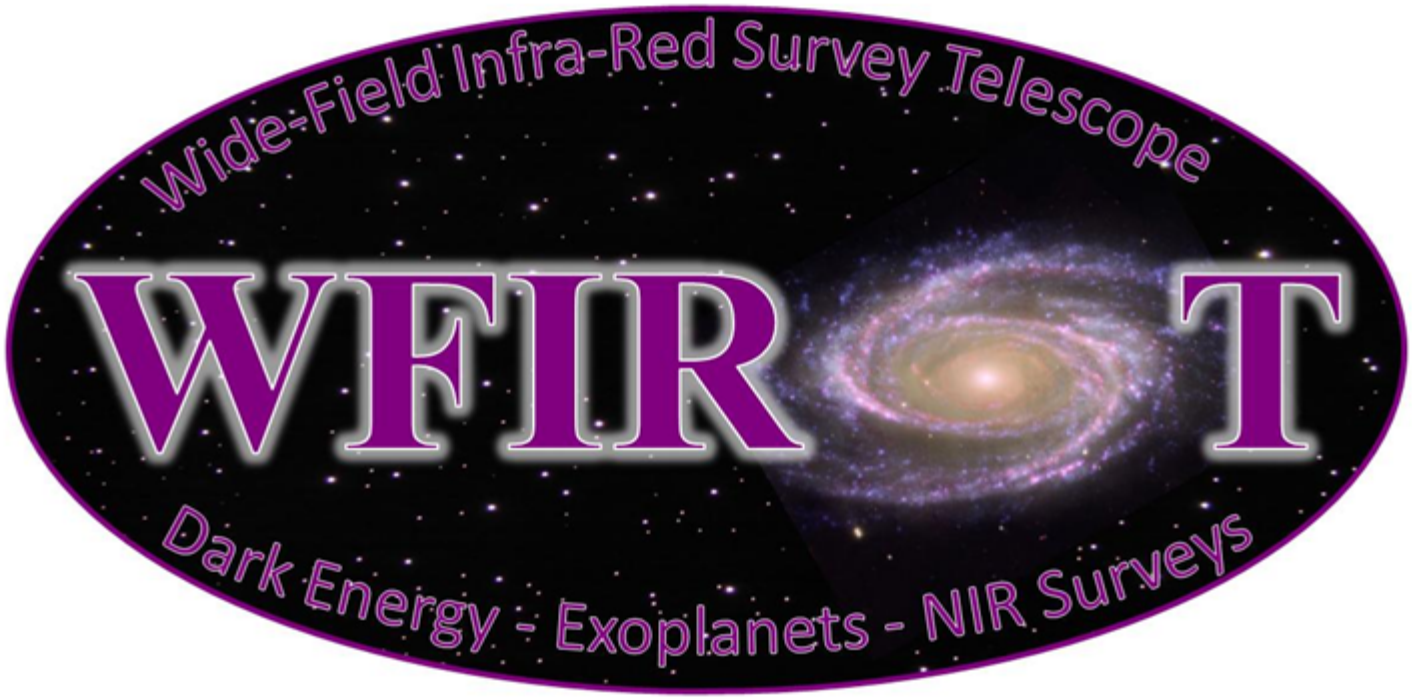
DRM1 design description



SDT 5/17/12

WFIRST DRM candidate design summary

- At SDT6 2/2-3/2012 consensus for full-up mission, aka "DRM1" was:
  - 1.3m aperture, unobscured three mirror anastigmat telescope
  - Single channel instrument
    - Imaging with filter wheel
    - Prisms with 1-2 prism assemblies for single or counter-dispersed galaxy redshift survey respectively plus SN 1a spectroscopy prism assembly
    - Extend to 2.4um cutoff
  - No requirement to fit on Falcon9 launch vehicle
  - ±36 degree pitch range [relative to 90 degrees from sun to center of FOV]
- Two options for this design are given some initial documentation here:
  - [baseline] DRM1 is based on a 9x4 H2RG layout focal plane array
  - DRM1a [requires H4RG(-10) at TRL6] is based on a 6x3 H4RG(-10) layout FPA

WFIRST DRM1 design summary

- DRM1 is based on a 9x4 H2RG layout focal plane array
  - 0.18”/pixel, ie same focal length and f/# as ImC on IDRM1
  - Same detector and pixel count as IDRM1
  - 0.356 sq deg active pixels, 20% gaps
  - Auxiliary fine guider for guiding during spectroscopy modes
  - Outrigger fine guider for guiding during imaging modes
  - 0.387 IDRM ImC AΩ < this AΩ < 0.690 IDRM SpC AΩ [m^2deg^2]

title	DRM1 H2D3 1.3m 9x4 single channel			
filled		ImC/SpC	outrigger FGS	Aux FGS
npix		2040	2040	2040
pixel size	mm	0.018	0.018	0.018
pixel scale	"/p	0.180	0.18	0.208
nx		9	1	1
ny		4	1	1
total x	deg	1.081	0.102	0.118
total y	deg	0.469	0.102	0.118
total area/channel	deg^2	0.507	0.010	0.014
total active area	deg^2	0.375	0.021	0.014
focal length	m	20.62664	20.62664	17.84997
aperture	m	1.3	1.3	1.3
system f/#		15.867	15.867	13.731
obscured fraction		0.000	0.000	0.000
A	m^2	1.327	1.327	1.327
A - omega est.	m2deg2	0.497	0.028	0.018
Mpix		149.8	8.3	4.2
field size x	mm	389.232	36.72	36.72
field size y	mm	168.912	36.72	36.72
x gap angle	deg	0.0204	0.0204	0.0236
y gap angle	deg	0.0204	0.0204	0.0236
chip size	mm	36.72	36.72	36.72
chip angle	deg	0.102	0.102	0.118
# science SCA	36			

WFIRST DRM1a candidate design summary

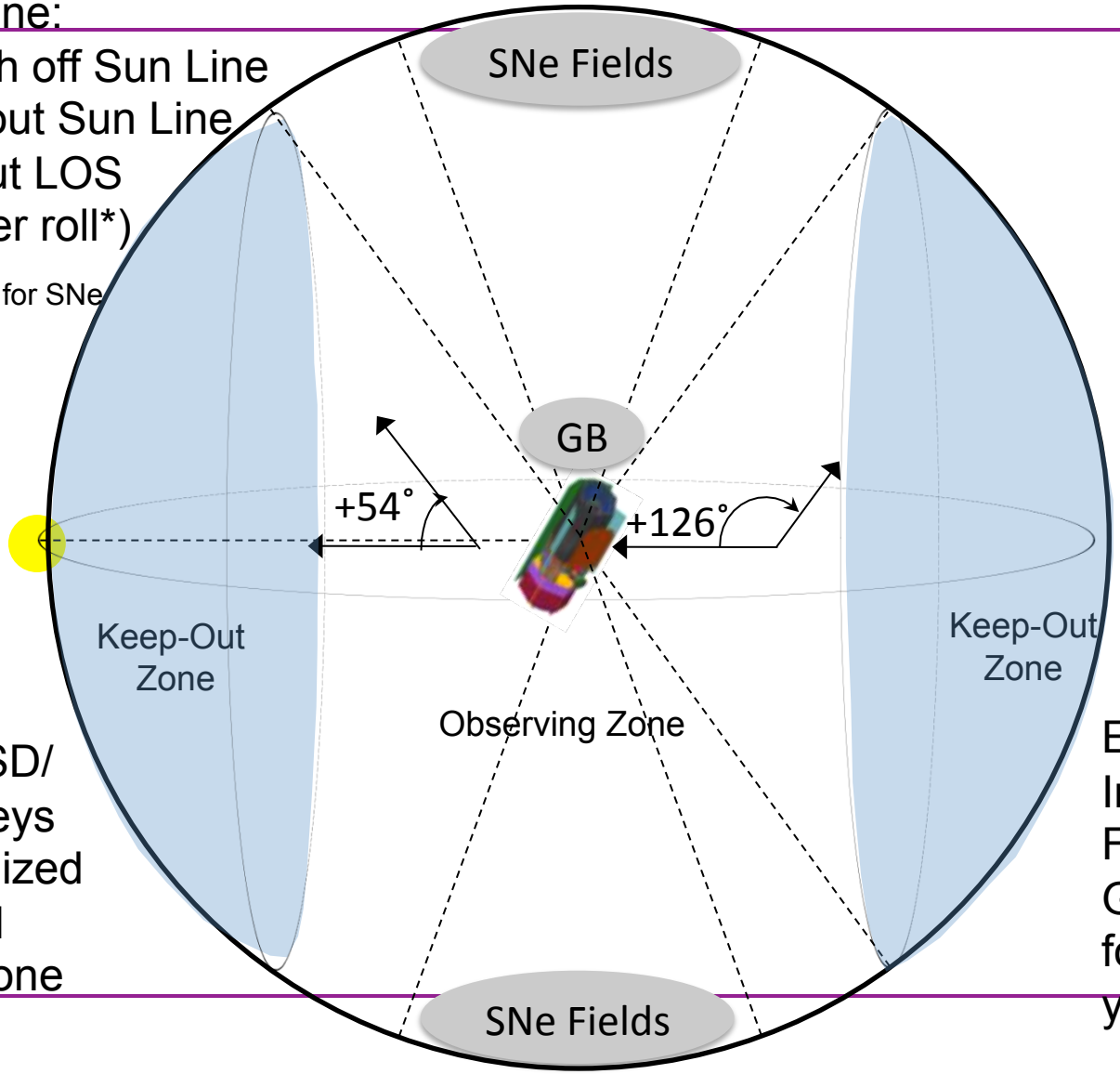
- DRM1a is based on a 6x3 H4RG(-10) layout focal plane array
  - 0.17”/pixel, f/9.33, 12.13m focal length
  - Fewer detector arrays, larger pixel count as compared to IDRM1
  - 0.671 sq deg active pixels, 300 Mpix
    - May be descoped for cost when cost guidance is received
    - 20% gaps
  - Auxiliary fine guider will be added for guiding during spectroscopy modes
  - Outrigger fine guider will be added for guiding during imaging modes
  - 0.387 IDRM ImC AΩ < 0.690 IDRM SpC AΩ [m^2deg^2] < this AΩ

title	DRM1 H4D3 sngl chnnl 6x3			
filled		AuxFGS	FGS outrigger	ImC/SpC
npix		2040	2040	4088
pixel size	mm	0.018	0.018	0.01
pixel scale	"/p	0.251	0.306	0.170
nx		1	1	6
ny		2	2	3
total x	deg	0.142	0.173	1.351
total y	deg	0.310	0.361	0.656
active area	deg^2	0.040	0.060	0.671
total area/channel	deg^2	0.044	0.063	0.887
focal length	m	14.80086	12.13332	12.13332
aperture	m	1.3	1.3	1.3
system f/#		11.385	9.333	9.333
obscured fraction		0.000	0.000	0.000
A	m^2	1.327	1.327	1.327
A - omega est.	m2deg2	0.054	0.080	0.890
Mpix		16.6	16.6	300.8
field size x	mm	36.72	36.72	286.16
field size y	mm	80.03	76.44	138.992
x gap angle	deg	0.0203	0.0142	0.0386
y gap angle	deg	0.0255	0.0142	0.0386
chip size	mm	36.72	36.72	40.88
chip angle	deg	0.142	0.173	0.193
# science SCA	18			

WFIRST's Central Line of Sight (LOS) Field of Regard (FOR)

Observing Zone:
54°-126° Pitch off Sun Line
360° Yaw about Sun Line
±10° roll about LOS
(off max power roll*)

* Larger roll allowed for SNe

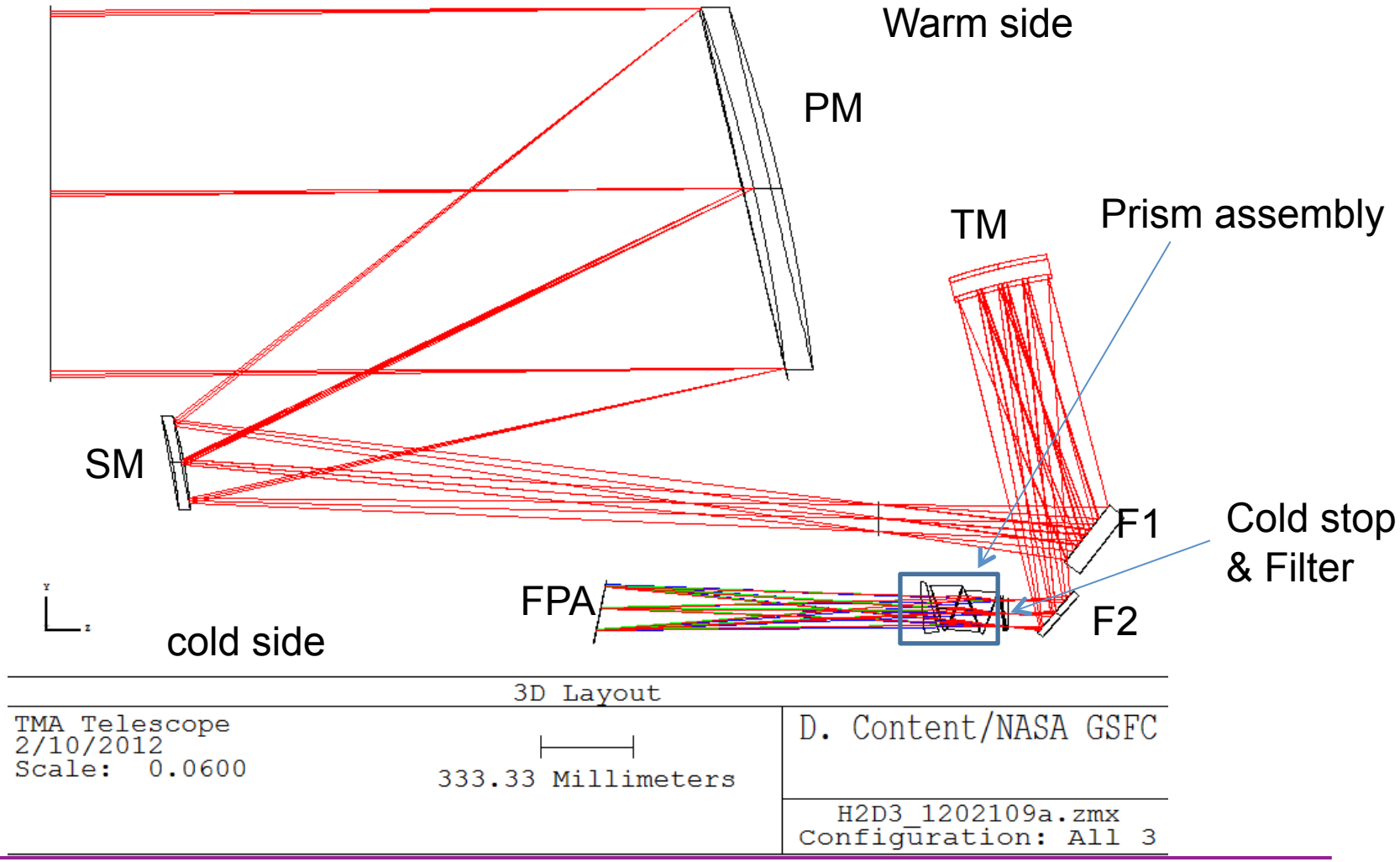


SNe Inertially Fixed Fields must be within 20° of one of the Ecliptic Poles, and can be rotated every ~45 days

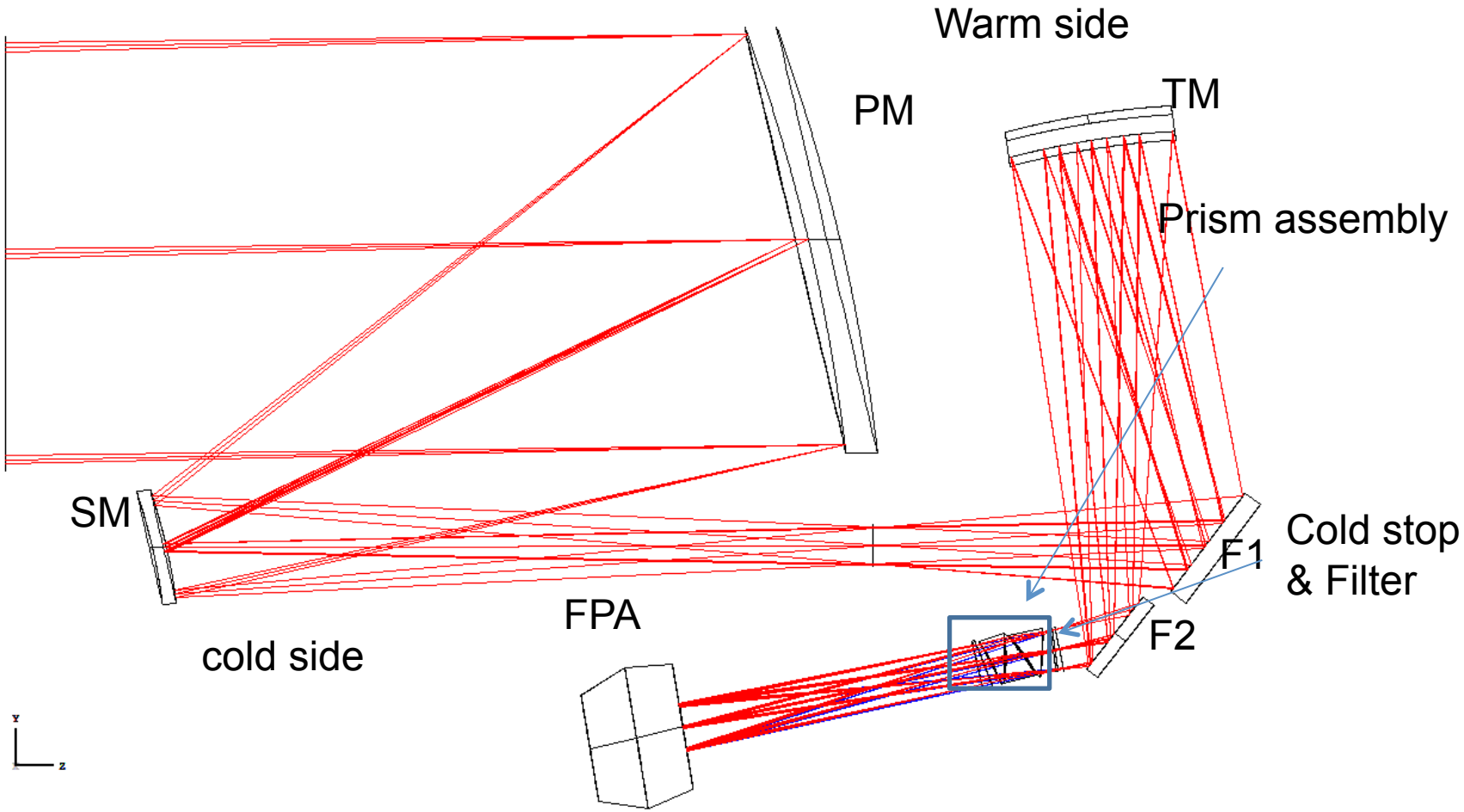
WL/ BAO-RSD/ GI/ GP Surveys can be optimized within the full Observing Zone

ExP can observe Inertially Fixed Fields in the Galactic Bulge (GB) for 72 days twice a year

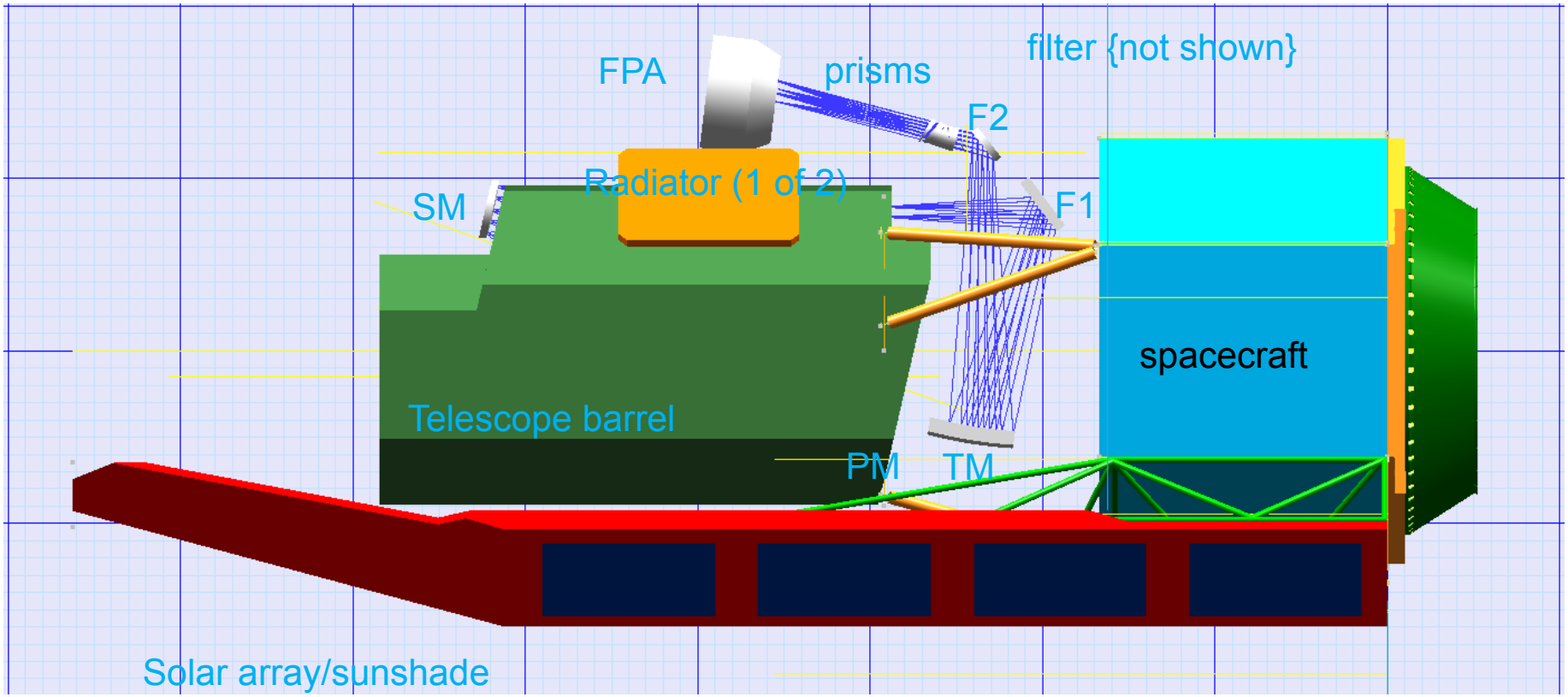
DRM1 ray trace



DRM1a ray trace



DRM1 CAD views

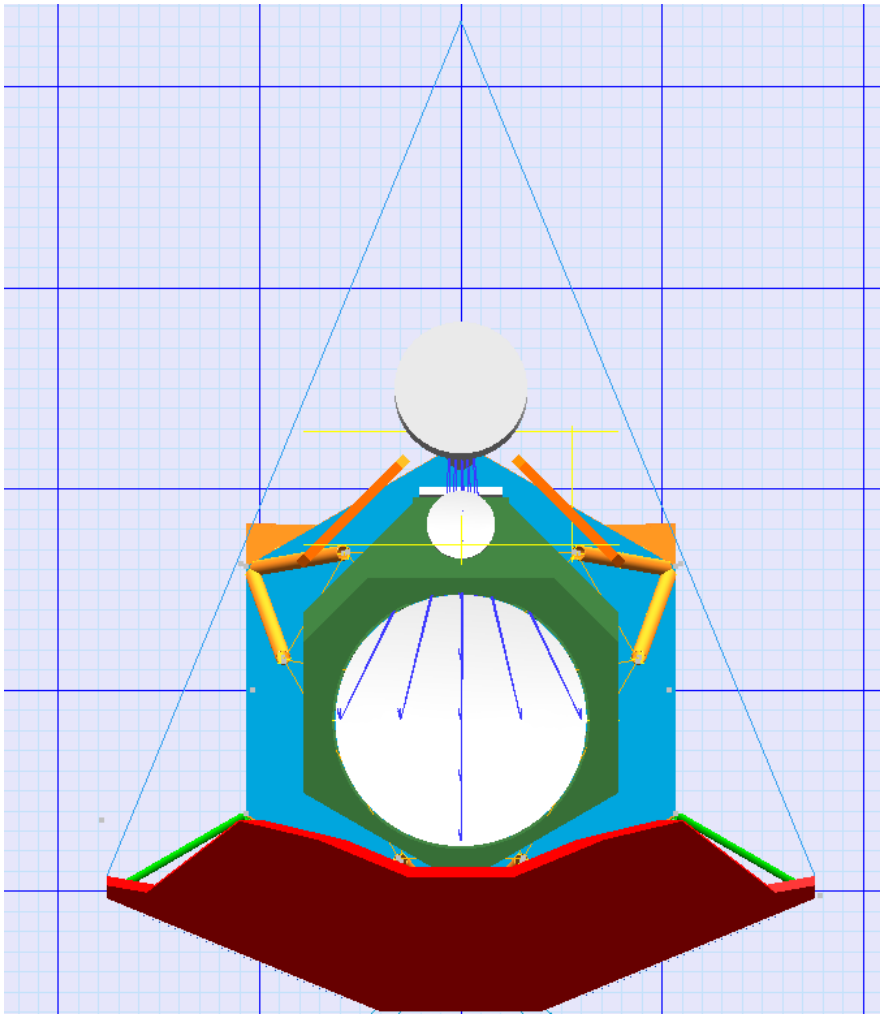


Grid is 1m

Front view showing shadowing of SAS

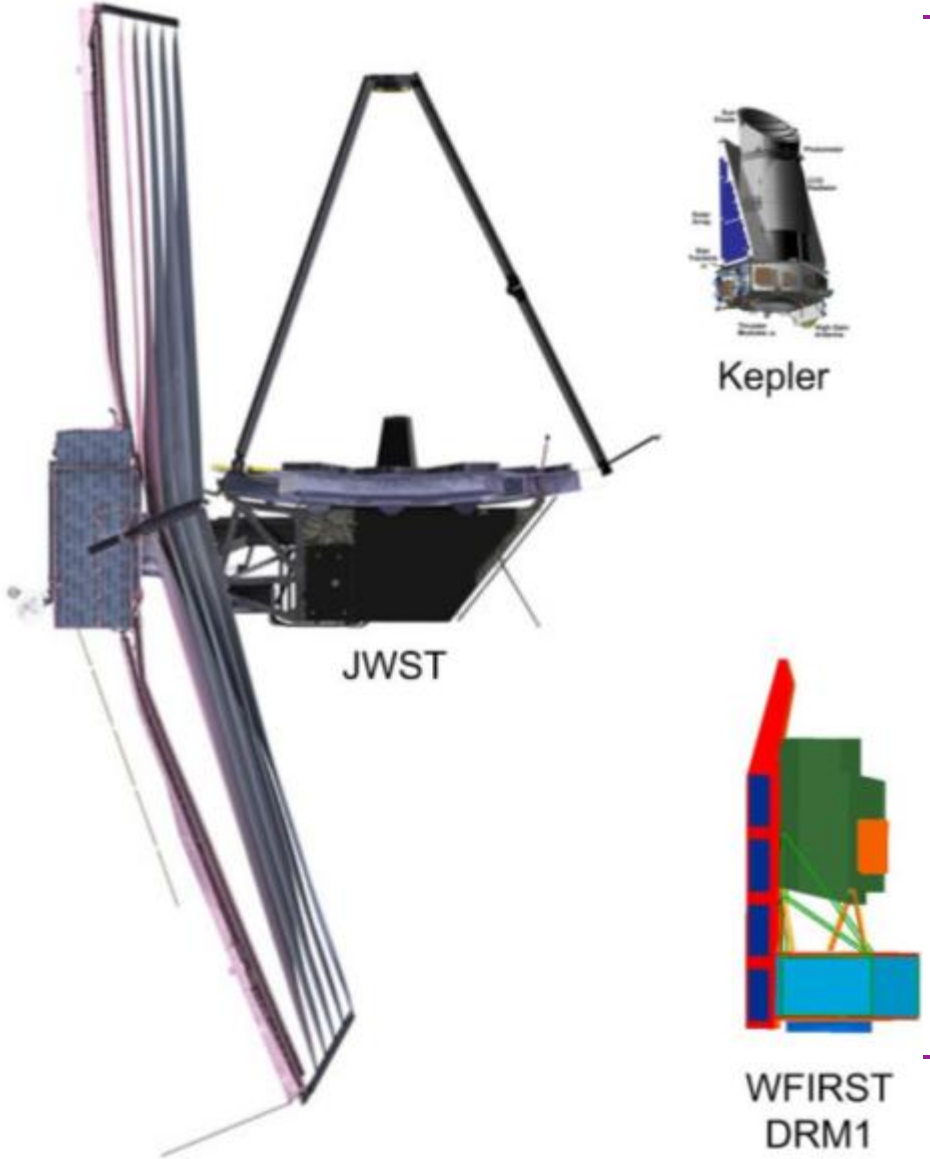
- Payload is shadowed over entire Field of regard
- Mass summary:

N. Armani 5/16/2012	DRM1 1.3m 1-Channel mass (kg)	% of SC
Payload Mass	761.3	39.46
SC Mass	1056.0	54.73
Propellant Mass	112	5.81
Observatory Wet Mass Total (CBE)	1929.3	100.0
Falcon-9 LV to C3 Capability		
Falcon 9 LV mass margin (against wet CBE)		31.14
Atlas V to C3 Capability		
ATLAS V LV mass margin (against wet CBE)		58.87



JWST, Kepler, WFIRST DRM1 to same scale

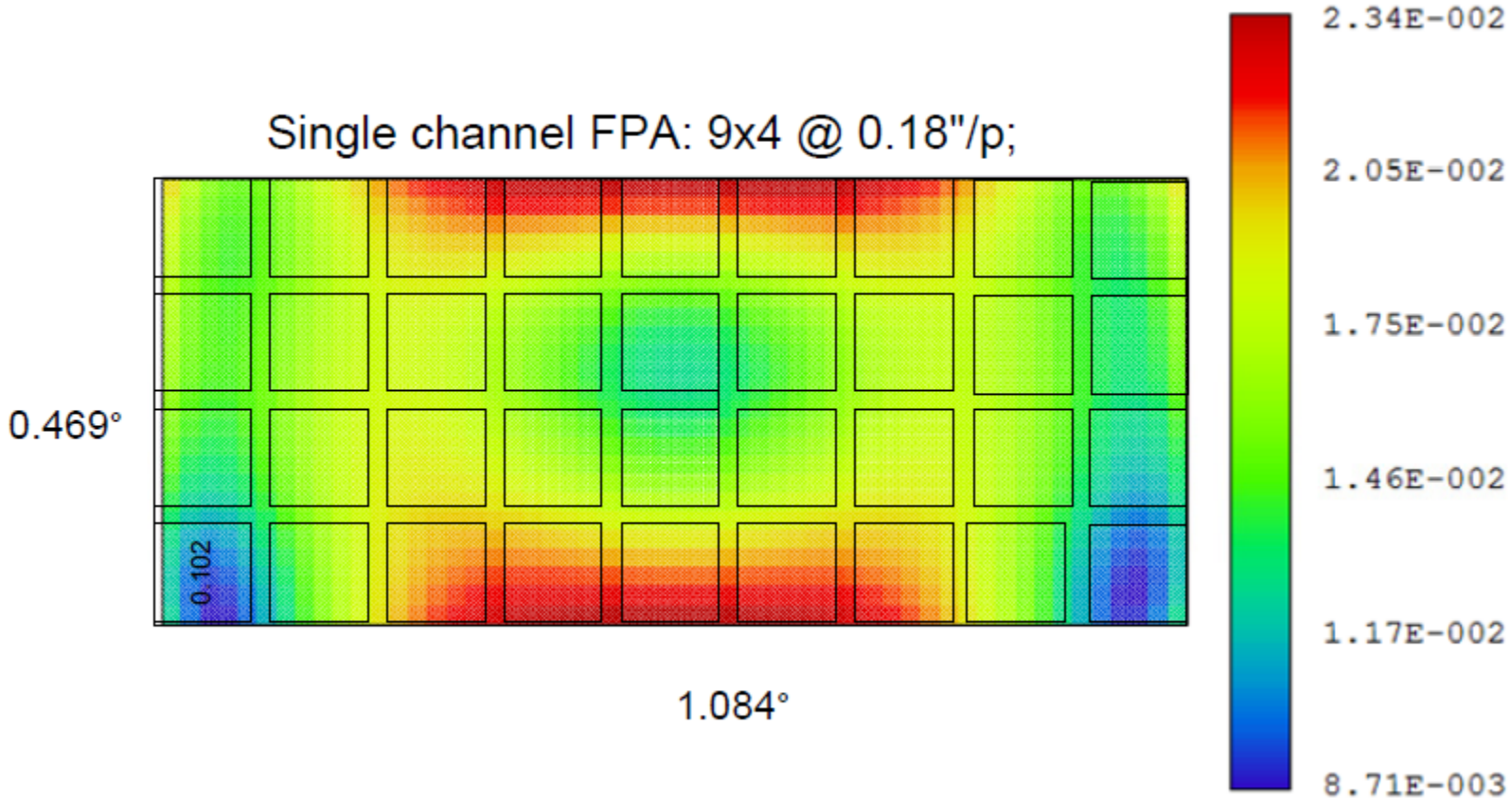
- All shown on orbit, with field of view up and sun to left



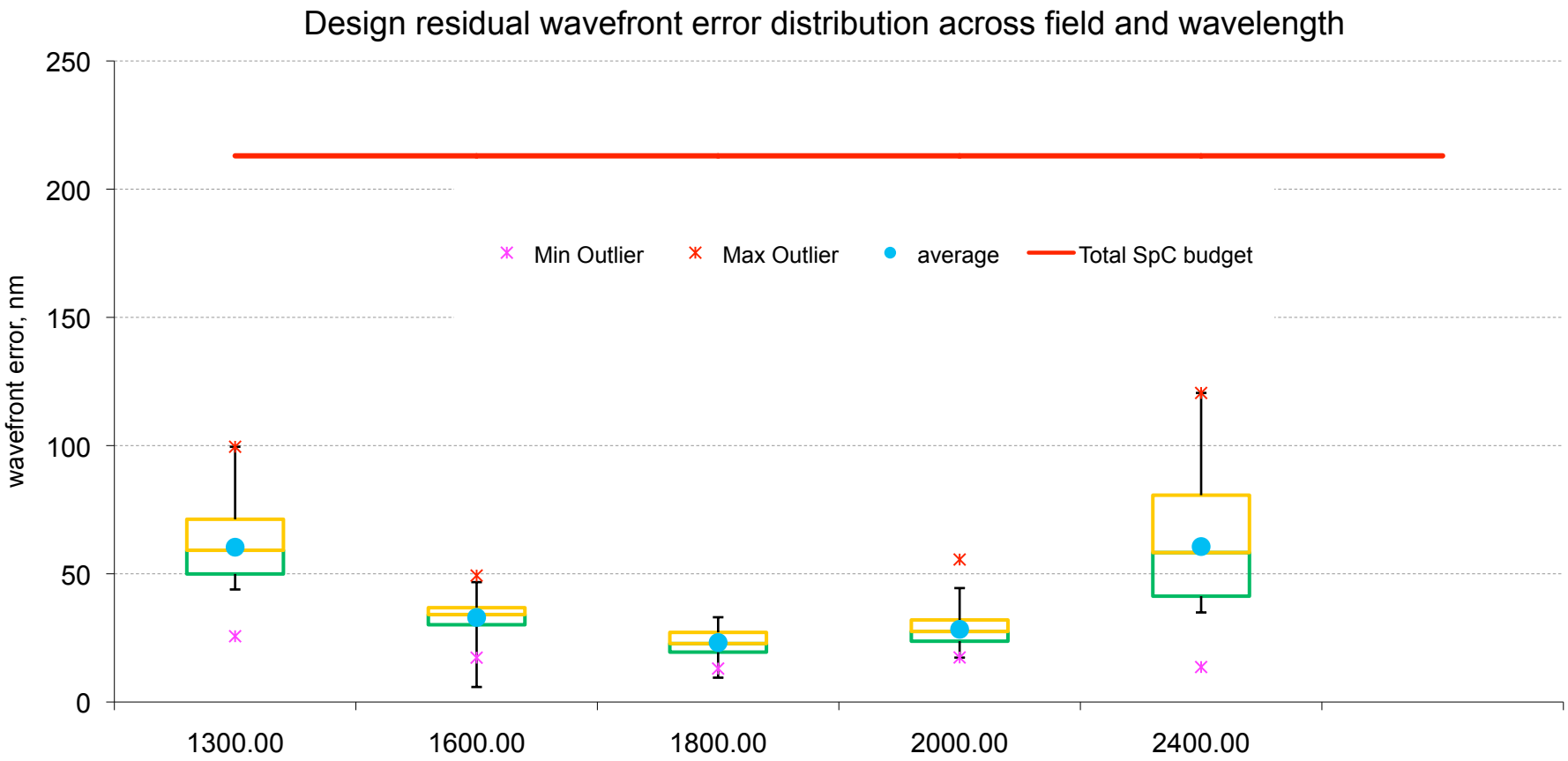
Backup charts – performance for DRM1, DRM1a

- Ray trace
- ImC mode design residual map
- SpC mode design residual box plot
- Spot diagrams
- Distortion plot
- SpC prism $D_\theta(\lambda)$ curves {preliminary}
- Prism complexity table
- Throughput estimate

DRM1 ImC error residual map, 1um



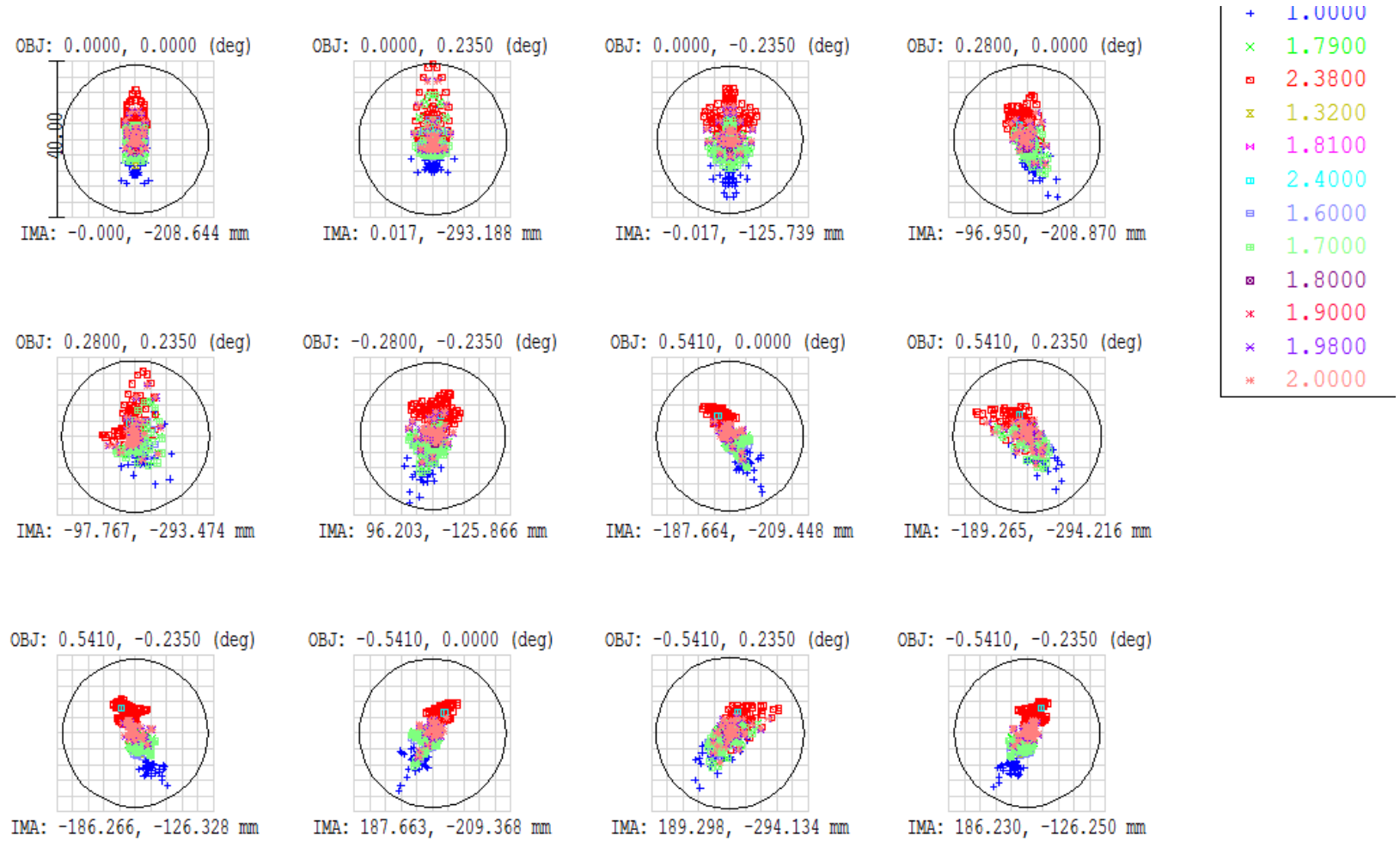
DRM1 SpC residual error distribution



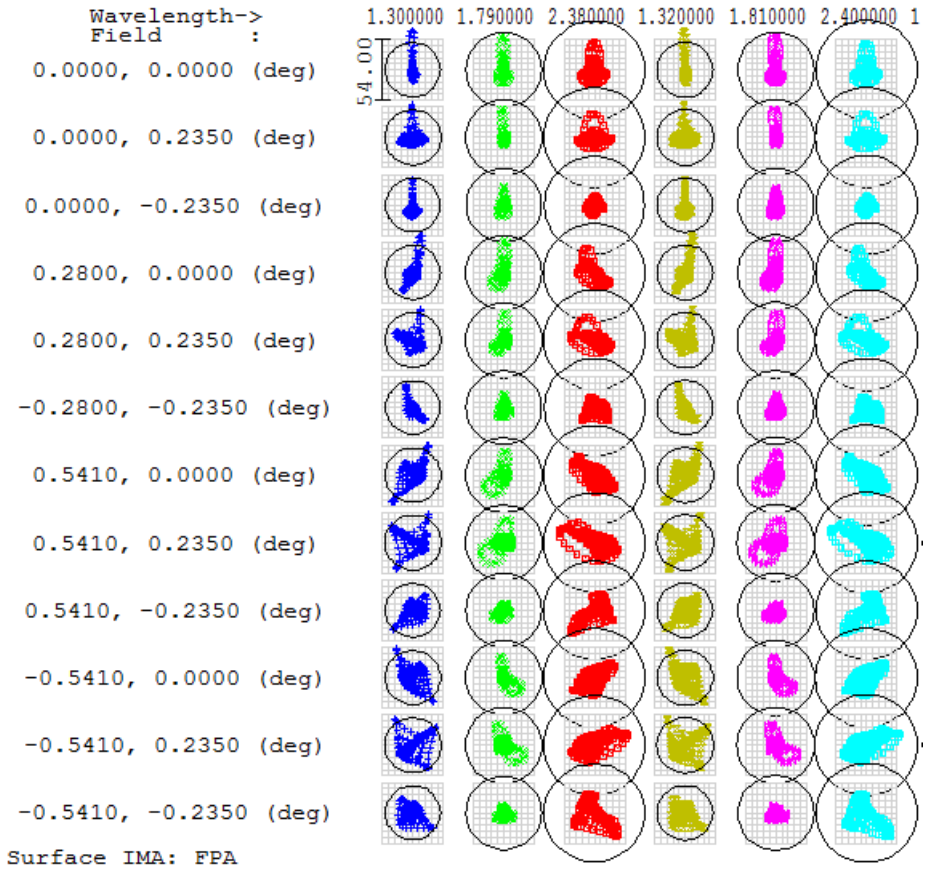
Spectrometer wavefront error distribution at wavelength (nm) shown

Much slower SpC (f/13.7) than previous, improved residuals

DRM1 ImC spot diagram

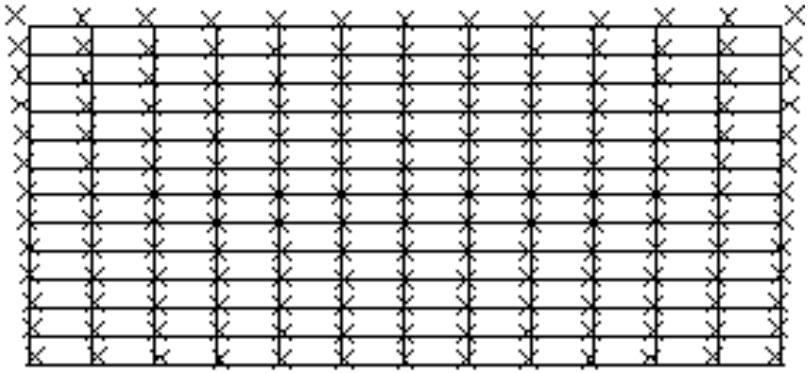


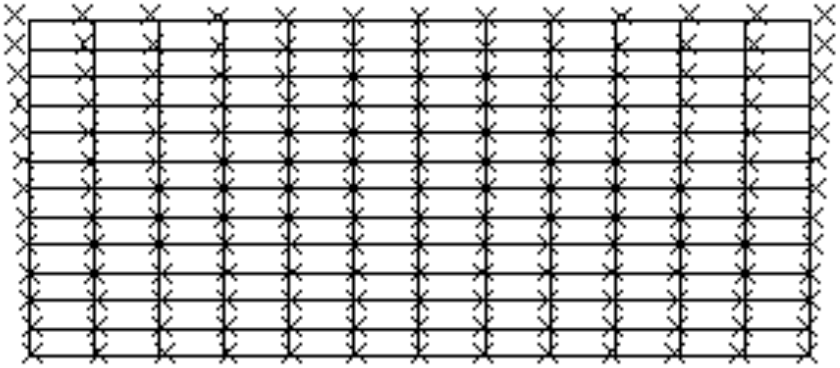
DRM1 SpC mode matrix spot diagram



DRM1 Grid distortion

- L ImC, R SpC



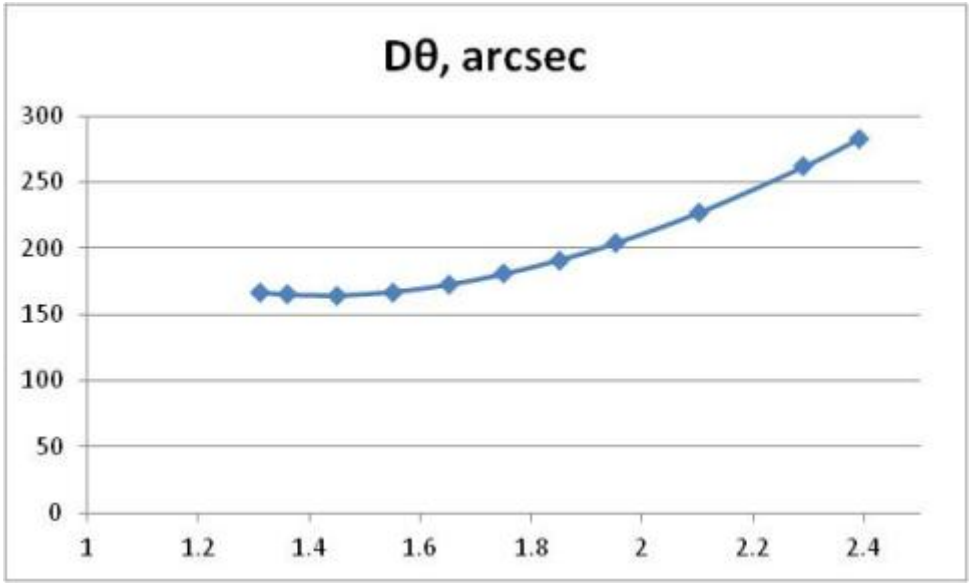


Grid Distortion	
TMA Telescope 2/10/2012 Field: 1.0810 w 0.4690 h Degrees Image: 374.05 w 167.02 h Millimeters Maximum distortion: 1.3547% Scale: 3.000X, Wavelength: 1.0000 µm	D. Content/NASA GSFC H2D3_1202109a.zmx Configuration 1 of 3

Grid Distortion	
TMA Telescope 2/10/2012 Field: 1.0810 w 0.4690 h Degrees Image: 377.44 w 162.23 h Millimeters Maximum distortion: 1.3146% Scale: 3.000X, Wavelength: 1.3000 µm	D. Content/NASA GSFC H2D3_1202109a.zmx Configuration 2 of 3

DRM1 D_θ – preliminary dispersion

- Bandpass (TBR) is 1.3-2.4um [z range 1-2.6]
- ADEPT requirement on D_θ == λ/{dλ/da} where a is sky angle was range 200-240 over 1.3-2.0um
- ISWG requirement was D_θ >100 λ
- New materials being investigated

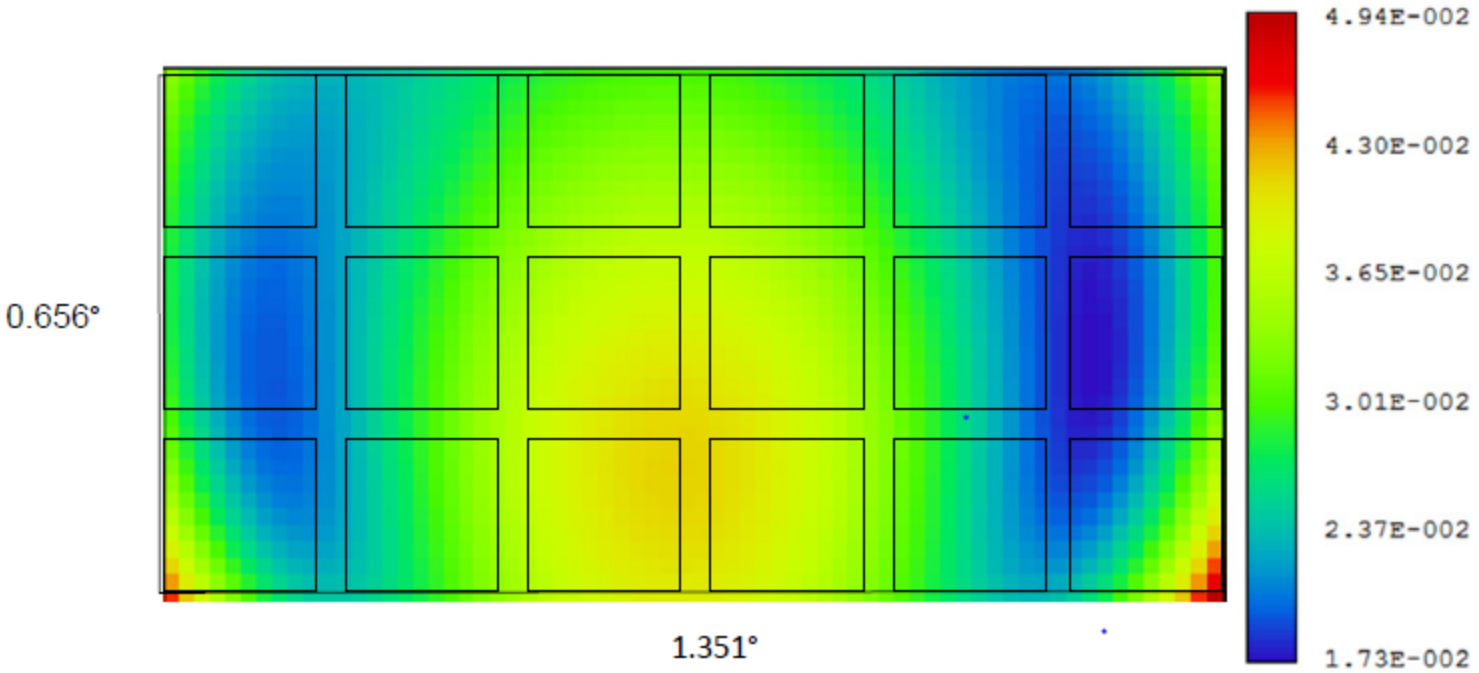


Prism complexity

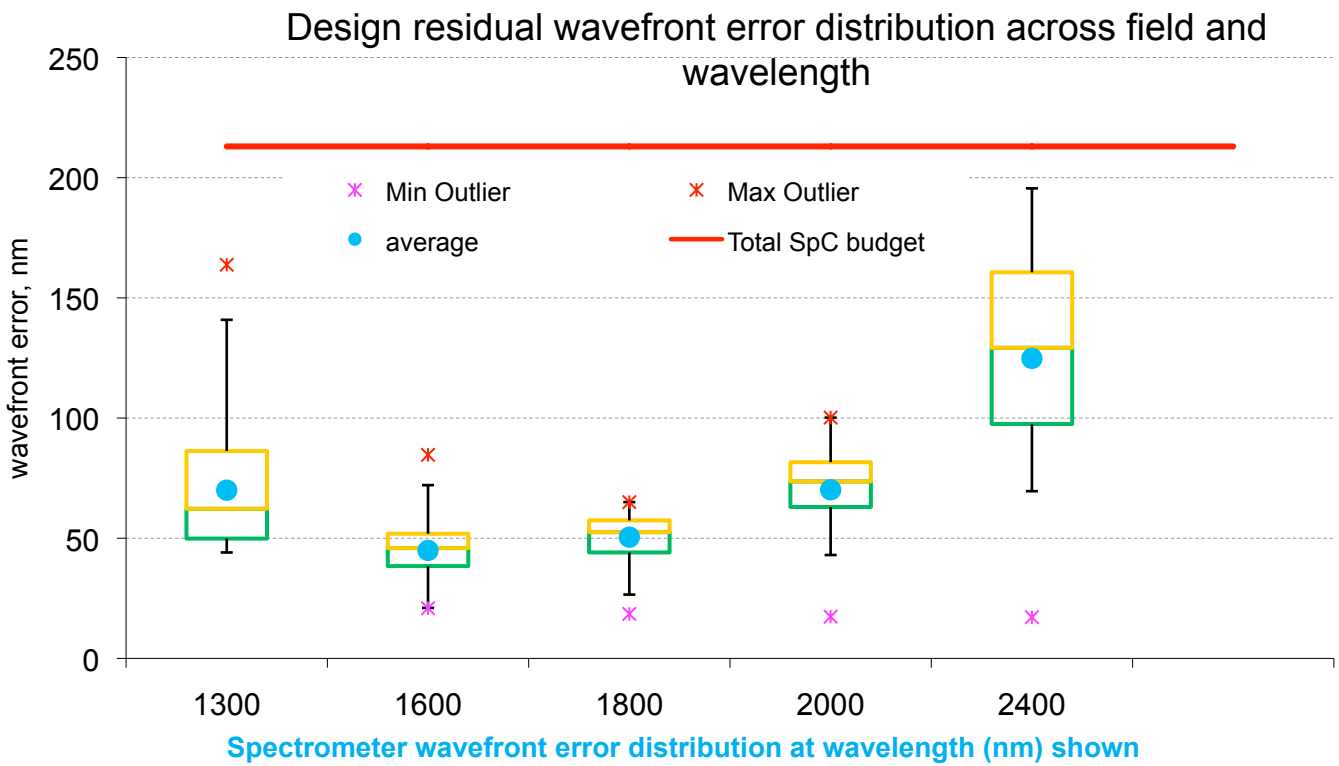
- Conic is axisymmetric surface with conic constant 1
- Zernike15 is a general freeform asphere described by up to 15 Zernike terms
- Biconic is surface with differing x, y radii and conic constants
- Cylinder has either x or y curvature but other axis is flat
- All prism sets have P2 made from S-TIH1 and rest at CaF2

Design	IDRM	H2D3	H4D3
pixel scale, "	0.45	0.18	0.17
# prisms	3	4	4
# lenses	4	0	0
# mechanisms	0	1	1
f/#	6.35	15.9	9.3
P1 S1	sphere	sphere	biconic
P1 S2	sphere	sphere	sphere
P2 S1	sphere	sphere	sphere
P2 S2	sphere	sphere	sphere
P3 S1	sphere	sphere	sphere
P3 S2	conic	sphere	biconic
P4 S1	n/a	Zernike15	Zernike15
P4 S2	n/a	cylinder	sphere

DRM1a ImC error residual map, 1um

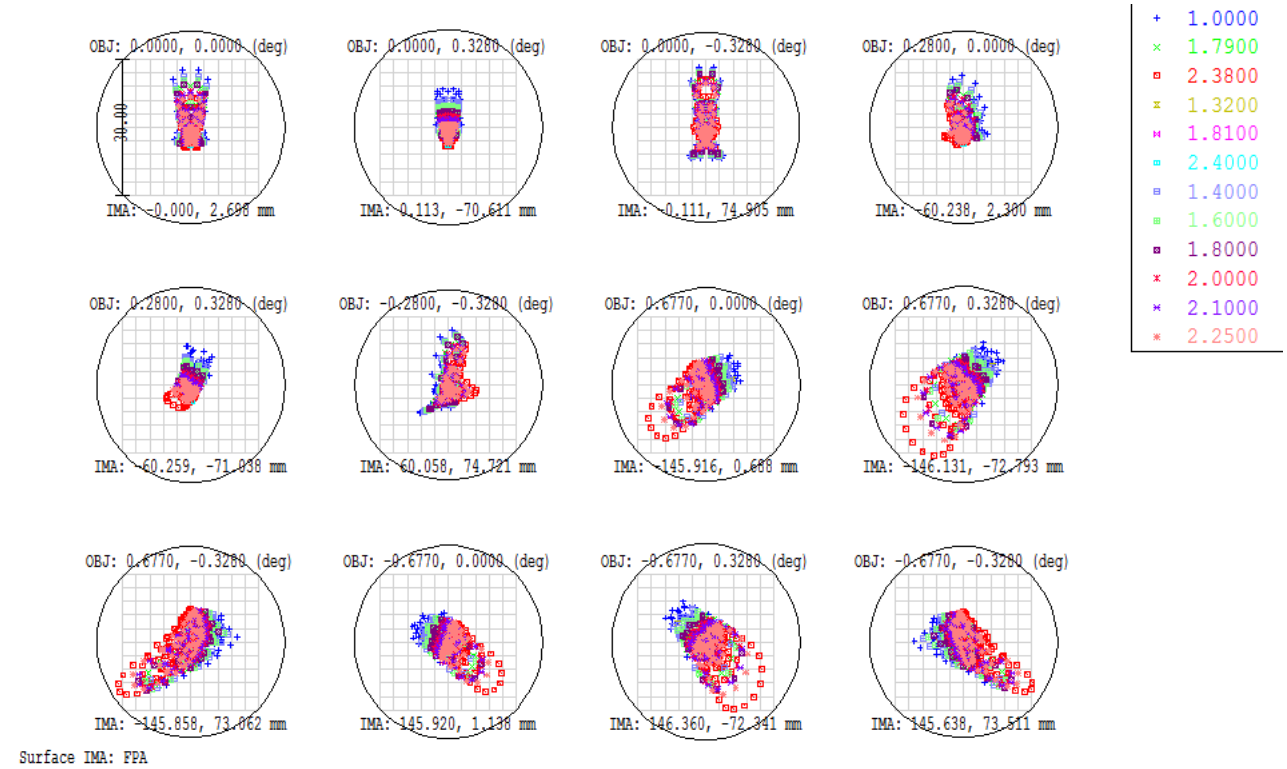


DRM1a SpC residual error distribution

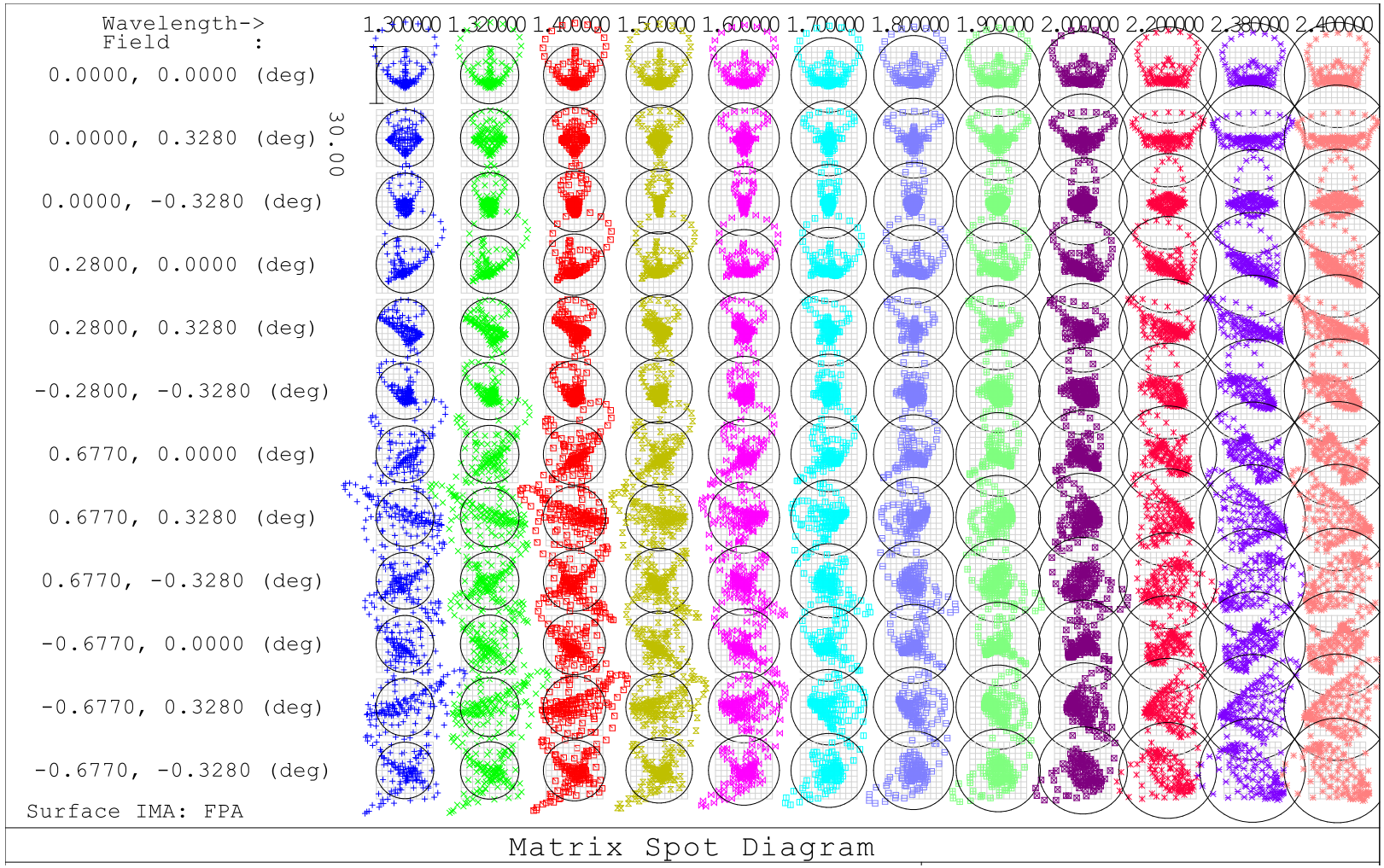


A bit slower SpC (f/13.7) than previous, but larger field; mixed result

DRM1a ImC spot diagram

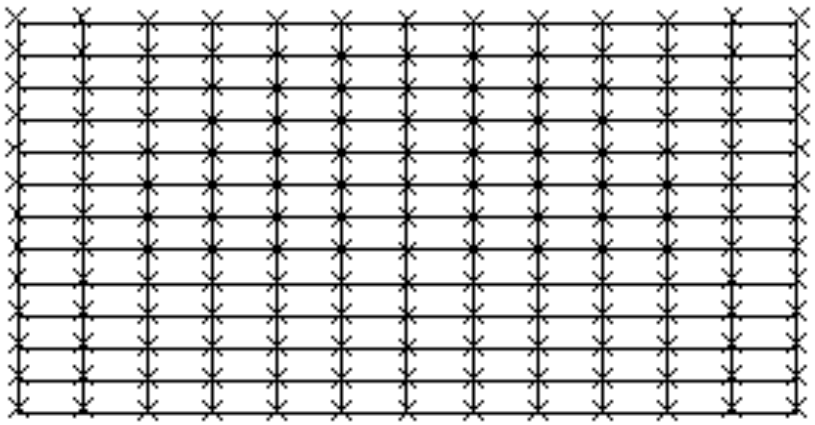


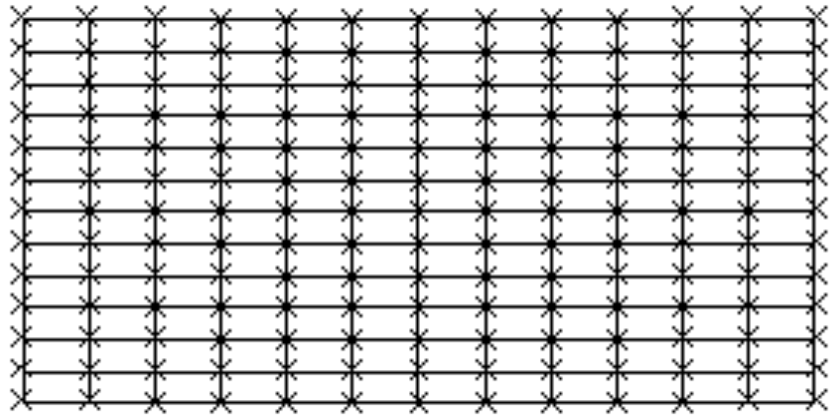
DRM1a SpC mode matrix spot diagram



DRM1a Grid distortion

- L ImC, R SpC



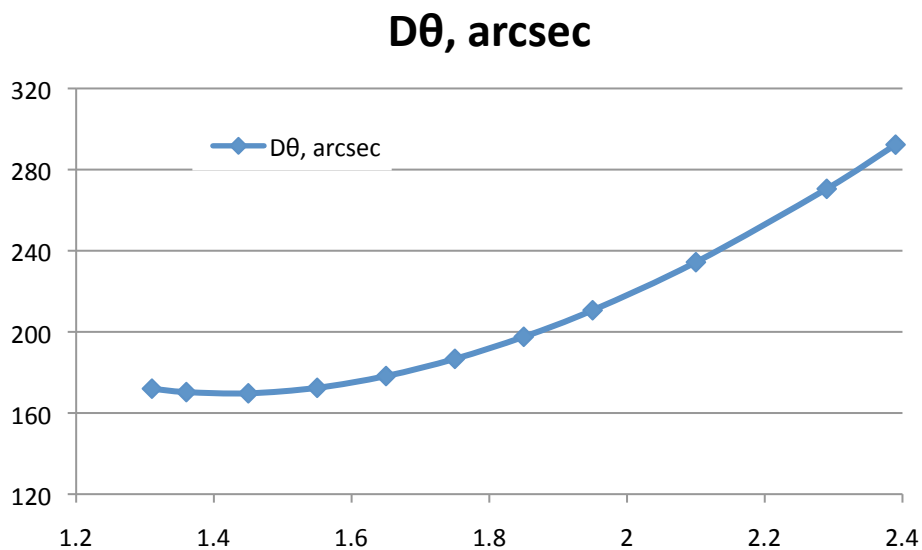


Grid Distortion	
TMA Telescope 2/13/2012 Field: 1.3510 w 0.6560 h Degrees Image: 290.54 w 145.43 h Millimeters Maximum distortion: 1.6114% Scale: 1.000X, Wavelength: 1.0000 µm	D. Content/NASA GSFC H4d3_120211dv.zmx Configuration 1 of 3

Grid Distortion	
TMA Telescope 2/13/2012 Field: 1.3510 w 0.6560 h Degrees Image: 292.39 w 140.93 h Millimeters Maximum distortion: 1.3042% Scale: 1.000X, Wavelength: 1.3000 µm	D. Content/NASA GSFC H4d3_120211dv.zmx Configuration 3 of 3

DRM1a D_θ -- preliminary

- Bandpass (TBR) is 1.3-2.4um [z range 1-2.6]
- ADEPT requirement on D_θ == λ/{dλ/da} where a is sky angle was range 200-240 asec over 1.3-2.0um
- ISWG requirement was D_θ >100 λ
- New materials being investigated



Throughput comments

- QE estimated updated, again
  - Now includes "internal trap inefficiency" model which degrades short wavelength response somewhat
  - Net result is less effective area below ~1.5um
    - Similar average (81%) 0.6-2.0 to IDRM1 baseline and prior results
- Retained gold mirror coatings
- SpC mode improves, 4 instead of 3 prisms but 4 focal reducer lenses are not used
- ImC mode optical throughput nearly unchanged; 1 fewer fold mirror

Throughput summary table

Mode	units	ImC	SpC	Sn Spec.
bandpass blue edge	um	0.79	1.3	0.6
bandpass red edge	um	2.4	2.4	2.4
Average Aeff	m^2	0.9644	0.9208	0.7675
min Aeff	m^2	0.6956	0.7216	0.3617
max Aeff	m^2	1.0653	0.9857	0.9303

ImC throughput – note, applies for DRM1 & DRM1a

Effective Area Analysis

configuration title: ImC [sig] chnl imag

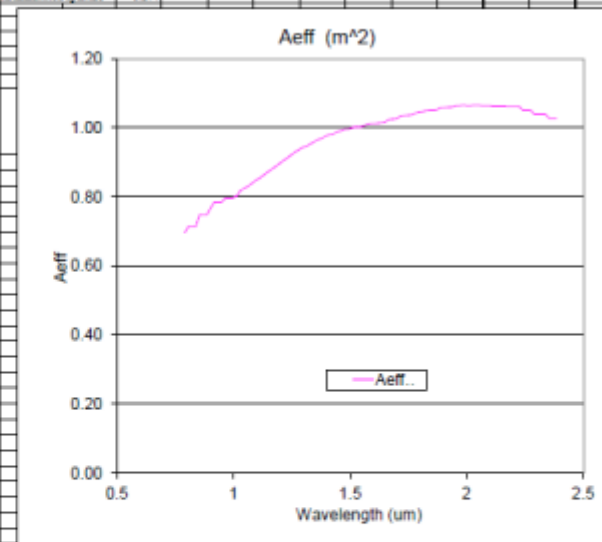
D. Cassell

Min wavelength	um	0.79	
Max wavelength	um	2.4	
Mirror coating	pAg or pAl	pAl	
filter name			
bandpass filter center, wl	um	n/a	
fraction width of bandpass, R		n/a	
wavelength spacing	um	0.01501	
Eff. bandpass		1.0094	
assumed max bandpass efficiency		0.9500	

Mirror diameter	m	1.2	mirror geometric area
# mirrors		5	Area (m^2) 1.327
# refractive elements (lens/prism)		1	Illuminated aperture 1.274
linear obscuration ratio (HST=0.33)		0	
area fraction lost to SM vanes		0	
area fraction lost to pupil mask		0.049	
Contamination loss at EOL		0.03	
Dichroic T/R, #	R	0	
		m^2	

wavelength (um)	Mirror reflectivity (Protected Ag)	Anti-Antireflection coating transmission, per surface	Bandpass filter transmission	Dichroic	Optical Throughput	combined reflectivity of mirrors	combined transmission of lenses & prisms	Contamination loss	detector QE	Aeff (m^2)
0.79	0.9750	0.9500	1	1.0000	0.7952	0.8811	0.9026	0.98	0.701	0.696
0.8059	0.9800	0.9500	1	1.0000	0.8158	0.9039	0.9026	0.98	0.700	0.713
0.8219	0.9800	0.9500	1	1.0000	0.8158	0.9039	0.9026	0.98	0.700	0.713
0.8378	0.9800	0.9500	1	1.0000	0.8158	0.9039	0.9026	0.98	0.700	0.713
0.8538	0.9850	0.9607	1	1.0000	0.8558	0.9272	0.9230	0.98	0.700	0.748
0.8697	0.9850	0.9607	1	1.0000	0.8558	0.9272	0.9230	0.98	0.700	0.748
0.8856	0.9850	0.9607	1	1.0000	0.8558	0.9272	0.9230	0.98	0.700	0.748
0.9016	0.9900	0.9607	1	1.0000	0.8778	0.9510	0.9230	0.98	0.700	0.787
0.9175	0.9900	0.9714	1	1.0000	0.8975	0.9510	0.9437	0.98	0.700	0.784
0.9335	0.9900	0.9714	1	1.0000	0.8975	0.9510	0.9437	0.98	0.700	0.784
0.9494	0.9900	0.9714	1	1.0000	0.8975	0.9510	0.9437	0.98	0.700	0.784
0.9653	0.9900	0.9786	1	1.0000	0.9107	0.9510	0.9576	0.98	0.700	0.796
0.9813	0.9900	0.9786	1	1.0000	0.9107	0.9510	0.9576	0.98	0.700	0.796
0.9972	0.9900	0.9786	1	1.0000	0.9107	0.9510	0.9576	0.98	0.700	0.796
1.0132	0.9900	0.9786	1	1.0000	0.9107	0.9510	0.9576	0.98	0.704	0.800
1.0291	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.709	0.818
1.0450	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.714	0.824
1.0610	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.720	0.830
1.0769	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.725	0.837
1.0929	0.9900	0.9886	1	1.0000	0.9257	0.9510	0.9734	0.98	0.731	0.845
1.1088	0.9900	0.9886	1	1.0000	0.9257	0.9510	0.9734	0.98	0.738	0.853
1.1248	0.9900	0.9886	1	1.0000	0.9257	0.9510	0.9734	0.98	0.744	0.860
1.1407	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.750	0.869
1.1566	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.757	0.876
1.1726	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.763	0.884
1.1885	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.769	0.891
1.2045	0.9900	0.9884	1	1.0000	0.9291	0.9510	0.9769	0.98	0.776	0.900
1.2204	0.9900	0.9884	1	1.0000	0.9291	0.9510	0.9769	0.98	0.782	0.907
1.2363	0.9900	0.9884	1	1.0000	0.9291	0.9510	0.9769	0.98	0.788	0.915
1.2523	0.9900	0.9893	1	1.0000	0.9307	0.9510	0.9787	0.98	0.794	0.923
1.2682	0.9900	0.9893	1	1.0000	0.9307	0.9510	0.9787	0.98	0.801	0.930
1.2842	0.9900	0.9893	1	1.0000	0.9307	0.9510	0.9787	0.98	0.806	0.937
1.3001	0.9900	0.9893	1	1.0000	0.9307	0.9510	0.9787	0.98	0.812	0.944
1.3160	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.818	0.947
1.3320	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.823	0.954
1.3479	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.829	0.960
1.3639	0.9900	0.9875	1	1.0000	0.9274	0.9510	0.9752	0.98	0.834	0.966
1.3798	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.840	0.969
1.3957	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.845	0.975
1.4117	0.9900	0.9857	1	1.0000	0.9240	0.9510	0.9717	0.98	0.849	0.980
1.4276	0.9900	0.9839	1	1.0000	0.9207	0.9510	0.9681	0.98	0.854	0.982
1.4436	0.9900	0.9839	1	1.0000	0.9207	0.9510	0.9681	0.98	0.858	0.987
1.4595	0.9900	0.9839	1	1.0000	0.9207	0.9510	0.9681	0.98	0.862	0.991
1.4754	0.9900	0.9839	1	1.0000	0.9207	0.9510	0.9681	0.98	0.866	0.995
1.4914	0.9900	0.9822	1	1.0000	0.9174	0.9510	0.9646	0.98	0.869	0.996
1.5073	0.9900	0.9822	1	1.0000	0.9174	0.9510	0.9646	0.98	0.872	0.999
1.5233	0.9900	0.9822	1	1.0000	0.9174	0.9510	0.9646	0.98	0.875	1.003

average	0.9894	0.9812	1.0000		0.9131	0.9482	0.9628	0.9800	0.8447	0.9644
RMS	0.0024	0.0092	0.0000		0.0256	0.0111	0.0179	0.0000	0.0840	0.1082
min	0.9750	0.9500	1.0000		0.7952	0.8811	0.9026	0.9800	0.7000	0.6956
max	0.9900	0.9893	1.0000		0.9307	0.9510	0.9787	0.9800	0.9209	1.0653



SpC Throughput – note, applies for DRM1 & DRM1a

Effective Area Analysis

configuration title: SpC

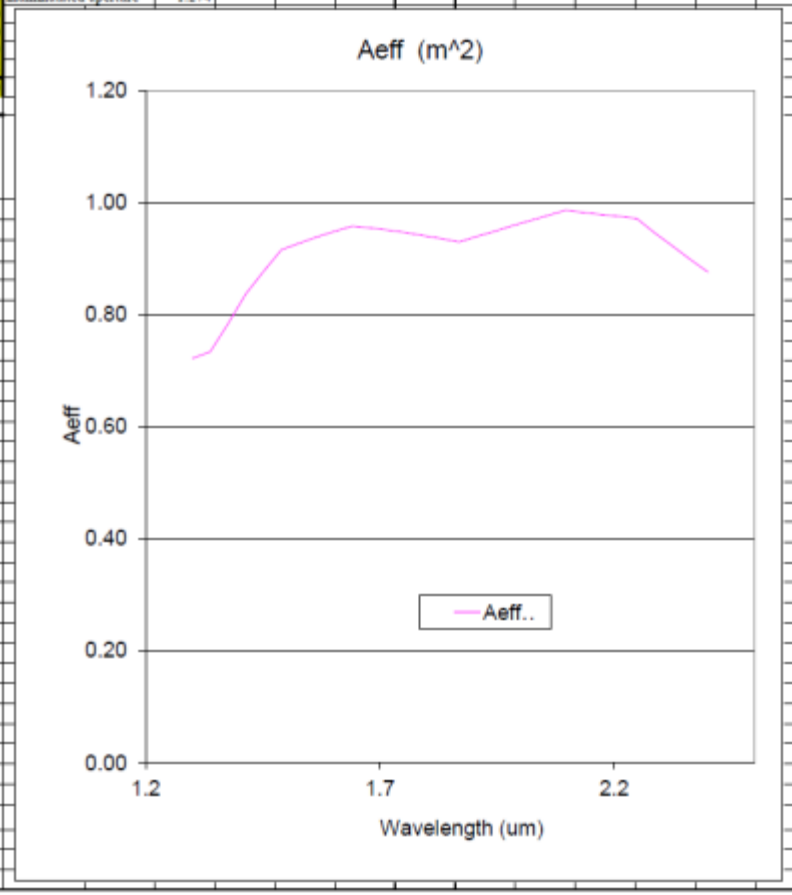
D. Content

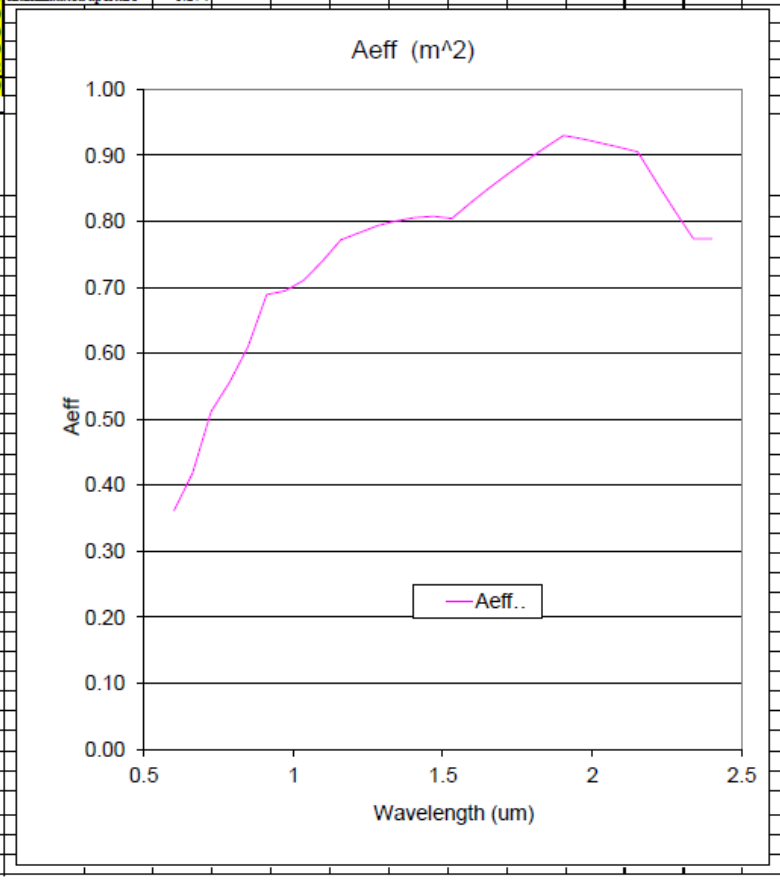
Min wavelength	um	1.3	Mirror diameter	m	1.3
Max wavelength	um	2.4	# mirrors		5
Mirror coating	pAg or pAu	pAu	# refractive elements (lens/prism/dichroic))		4
filter name			linear obscuration ratio (HST=0.33)		0
bandpass filter center, w0	um	1.85	area fraction lost to SM vanes		0
fraction width of bandpass, R		0.5946	area fraction lost to pupil mask		0.040
wavelength spacing	um	0.0579	Contamination loss at EOL		0.02
Rel. bandpass		0.5946	Dichroic T/R, #	T	0
assumed max bandpass efficiency		0.9500			m^2

mirror geometric area

Area (m^2)	1.327
illuminatated aperture	1.274

wavelength (um)	Mirror reflectivity (Protected Au)	Lens Antireflection coating transmission, per surface	Bandpass filter transmission	Dichroic	Optical Throughput	combined reflectivity of mirrors	combined transmission of lenses & prisms	Contamination loss	detector QE	Aeff (m^2)
1.3	0.9900	0.9706	0.95	1.0000	0.7114	0.9510	0.7480	0.98	0.812	0.722
1.3379	0.9900	0.9706	0.95	1.0000	0.7114	0.9510	0.7480	0.98	0.826	0.733
1.3759	0.9900	0.9769	0.95	1.0000	0.7492	0.9510	0.7878	0.98	0.838	0.784
1.4138	0.9900	0.9832	0.95	1.0000	0.7888	0.9510	0.8295	0.98	0.849	0.837
1.4517	0.9900	0.9874	0.95	1.0000	0.8162	0.9510	0.8583	0.98	0.860	0.876
1.4897	0.9900	0.9916	0.95	1.0000	0.8444	0.9510	0.8879	0.98	0.868	0.916
1.5276	0.9900	0.9921	0.95	1.0000	0.8480	0.9510	0.8917	0.98	0.876	0.927
1.5655	0.9900	0.9926	0.95	1.0000	0.8516	0.9510	0.8955	0.98	0.882	0.938
1.6034	0.9900	0.9932	0.95	1.0000	0.8552	0.9510	0.8993	0.98	0.888	0.948
1.6414	0.9900	0.9937	0.95	1.0000	0.8589	0.9510	0.9031	0.98	0.893	0.958
1.6793	0.9900	0.9926	0.95	1.0000	0.8516	0.9510	0.8955	0.98	0.898	0.954
1.7172	0.9900	0.9916	0.95	1.0000	0.8444	0.9510	0.8879	0.98	0.901	0.950
1.7552	0.9900	0.9905	0.95	1.0000	0.8373	0.9510	0.8804	0.98	0.905	0.946
1.7931	0.9900	0.9895	0.95	1.0000	0.8302	0.9510	0.8730	0.98	0.908	0.941
1.8310	0.9900	0.9884	0.95	1.0000	0.8232	0.9510	0.8656	0.98	0.910	0.935
1.8690	0.9900	0.9874	0.95	1.0000	0.8162	0.9510	0.8583	0.98	0.912	0.930
1.9069	0.9900	0.9884	0.95	1.0000	0.8232	0.9510	0.8656	0.98	0.914	0.939
1.9448	0.9900	0.9895	0.95	1.0000	0.8302	0.9510	0.8730	0.98	0.915	0.949
1.9828	0.9900	0.9905	0.95	1.0000	0.8373	0.9510	0.8804	0.98	0.916	0.958
2.0207	0.9900	0.9916	0.95	1.0000	0.8444	0.9510	0.8879	0.98	0.918	0.967
2.0586	0.9900	0.9926	0.95	1.0000	0.8516	0.9510	0.8955	0.98	0.918	0.977
2.0966	0.9900	0.9937	0.95	1.0000	0.8589	0.9510	0.9031	0.98	0.919	0.986
2.1345	0.9900	0.9932	0.95	1.0000	0.8552	0.9510	0.8993	0.98	0.920	0.982
2.1724	0.9900	0.9926	0.95	1.0000	0.8516	0.9510	0.8955	0.98	0.920	0.979
2.2103	0.9900	0.9921	0.95	1.0000	0.8480	0.9510	0.8917	0.98	0.921	0.975
2.2483	0.9900	0.9916	0.95	1.0000	0.8444	0.9510	0.8879	0.98	0.921	0.971
2.2862	0.9900	0.9884	0.95	1.0000	0.8232	0.9510	0.8656	0.98	0.921	0.946
2.3241	0.9900	0.9853	0.95	1.0000	0.8024	0.9510	0.8438	0.98	0.921	0.922
2.3621	0.9900	0.9821	0.95	1.0000	0.7821	0.9510	0.8224	0.98	0.920	0.899
2.4	0.9900	0.9790	0.95	1.0000	0.7622	0.9510	0.8015	0.98	0.920	0.876
average	0.9900	0.9881	0.9500		0.8218	0.9510	0.8641	0.9800	0.8963	0.9208
RMS	0.0000	0.0064	0.0000		0.0411	0.0000	0.0432	0.0000	0.0312	0.0685
min	0.9900	0.9706	0.9500		0.7114	0.9510	0.7480	0.9800	0.8123	0.7216
max	0.9900	0.9937	0.9500		0.8589	0.9510	0.9031	0.9800	0.9209	0.9857



SN spectroscopy throughput – note, applies for DRM1 & DRM1a

Effective Area Analysis					configuration title:	SN spec							
D. Content													
Min wavelength		um	0.6			Mirror diameter		m	1.3	mirror geometric area			
Max wavelength		um	2.4			# mirrors			5		Area (m^2)	1.327	
Mirror coating		pAg or pAu	pAu			# refractive elements (lens/prism/dichroic))			4	illuminatated aperture		1.274	
filter name						linear obscuration ratio (HST=0.33)			0				
bandpass filter center, w0		um	1.5			area fraction lost to SM vanes			0				
fraction width of bandpass, R			1.2000			area fraction lost to pupil mask			0.040				
wavelength spacing		um	0.0621			Contamination loss at EOL			0.02				
Rel. bandpass			1.2000			Dichroic T/R, #		T	0				
assumed max bandpass efficiency			0.9500						m^2				
wavelength (um)	Mirror reflectivity (Protected Au)	Lens Antireflection coating transmission, per surface	Bandpass filter trans-mission	Dichroic	Optical Through-put	combined reflectivity of mirrors	combined transmission of lenses & prisms	Contami-nation loss	detector QE	Aeff (m^2)			
0.6	0.9200	0.9406	0.95	1.0000	0.3836	0.6591	0.5821	0.98	0.755	0.362			
0.6621	0.9450	0.9406	0.95	1.0000	0.4387	0.7536	0.5821	0.98	0.764	0.418			
0.7241	0.9700	0.9533	0.95	1.0000	0.5566	0.8587	0.6481	0.98	0.736	0.511			
0.7862	0.9750	0.9661	0.95	1.0000	0.6350	0.8811	0.7207	0.98	0.702	0.556			
0.8483	0.9800	0.9745	0.95	1.0000	0.6987	0.9039	0.7729	0.98	0.700	0.611			
0.9103	0.9900	0.9830	0.95	1.0000	0.7878	0.9510	0.8284	0.98	0.700	0.689			
0.9724	0.9900	0.9841	0.95	1.0000	0.7946	0.9510	0.8356	0.98	0.700	0.695			
1.0345	0.9900	0.9852	0.95	1.0000	0.8015	0.9510	0.8428	0.98	0.710	0.710			
1.0966	0.9900	0.9862	0.95	1.0000	0.8085	0.9510	0.8501	0.98	0.733	0.740			
1.1586	0.9900	0.9873	0.95	1.0000	0.8154	0.9510	0.8575	0.98	0.758	0.772			
1.2207	0.9900	0.9852	0.95	1.0000	0.8015	0.9510	0.8428	0.98	0.782	0.783			
1.2828	0.9900	0.9830	0.95	1.0000	0.7878	0.9510	0.8284	0.98	0.806	0.793			
1.3448	0.9900	0.9809	0.95	1.0000	0.7743	0.9510	0.8142	0.98	0.828	0.800			
1.4069	0.9900	0.9788	0.95	1.0000	0.7610	0.9510	0.8002	0.98	0.848	0.805			
1.4690	0.9900	0.9767	0.95	1.0000	0.7479	0.9510	0.7865	0.98	0.864	0.807			
1.5310	0.9900	0.9745	0.95	1.0000	0.7350	0.9510	0.7729	0.98	0.876	0.804			
1.5931	0.9900	0.9767	0.95	1.0000	0.7479	0.9510	0.7865	0.98	0.887	0.828			
1.6552	0.9900	0.9788	0.95	1.0000	0.7610	0.9510	0.8002	0.98	0.895	0.851			
1.7172	0.9900	0.9809	0.95	1.0000	0.7743	0.9510	0.8142	0.98	0.901	0.872			
1.7793	0.9900	0.9830	0.95	1.0000	0.7878	0.9510	0.8284	0.98	0.907	0.892			
1.8414	0.9900	0.9852	0.95	1.0000	0.8015	0.9510	0.8428	0.98	0.911	0.911			
1.9034	0.9900	0.9873	0.95	1.0000	0.8154	0.9510	0.8575	0.98	0.914	0.930			
1.9655	0.9900	0.9862	0.95	1.0000	0.8085	0.9510	0.8501	0.98	0.916	0.925			
2.0276	0.9900	0.9852	0.95	1.0000	0.8015	0.9510	0.8428	0.98	0.918	0.918			
2.0897	0.9900	0.9841	0.95	1.0000	0.7946	0.9510	0.8356	0.98	0.919	0.912			
2.1517	0.9900	0.9830	0.95	1.0000	0.7878	0.9510	0.8284	0.98	0.920	0.905			
2.2138	0.9900	0.9767	0.95	1.0000	0.7479	0.9510	0.7865	0.98	0.921	0.860			
2.2759	0.9900	0.9703	0.95	1.0000	0.7098	0.9510	0.7464	0.98	0.921	0.816			
2.3379	0.9900	0.9639	0.95	1.0000	0.6734	0.9510	0.7081	0.98	0.920	0.774			
2.4	0.9900	0.9639	0.95	1.0000	0.6734	0.9510	0.7081	0.98	0.920	0.774			
average	0.9847	0.9762	0.9500		0.7338	0.9277	0.7867	0.9800	0.8343	0.7675			
RMS	0.0153	0.0126	0.0000		0.1062	0.0653	0.0757	0.0000	0.0865	0.1469			
min	0.9200	0.9406	0.9500		0.3836	0.6591	0.5821	0.9800	0.7000	0.3617			
max	0.9900	0.9873	0.9500		0.8154	0.9510	0.8575	0.9800	0.9208	0.9303