"CHAI-12U: A Constellation of Schmidt-Dyson Imaging Spectrometers based on the 12U CubeSat Form Factor"
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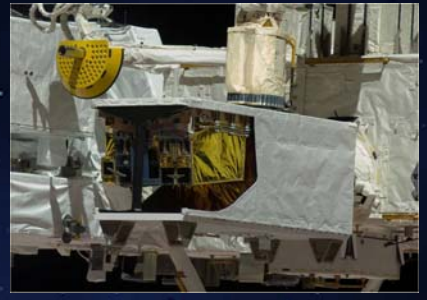
[#] In Memoriam to Robert Lucke, Naval Research Laboratory as Originator of the Schmidt-Dyson Optical Design

CHAI
COMPACT
HYPERSPECTRAL
ADVANCED
IMAGER

CHAI VNIR-2048



HICO
Spectrograph & Telescope

VIS-SWIR PICARD

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CHAI VNIR-640

CHAI LWIR-320

CHAI SWIR -640

CHAI VNIR-1

CHAI-12U Mission Concept

Develop a low-cost constellation of Eight 12U CubeSats to test components, subsystems, algorithms, and mission concepts for addressing HySpiri technology needs and science objectives

<u>Key Advantages of a 12U Constellation</u>

Low-cost, Daily Revisit, Cross-calibration, In-flight Spares, Easier Scheduling, Formation Flying (adjacent, fore/aft for BRDF)

Mission of Opportunity on Hosted Payload or Rideshare, Band selectable. Rapid turn around of data products.

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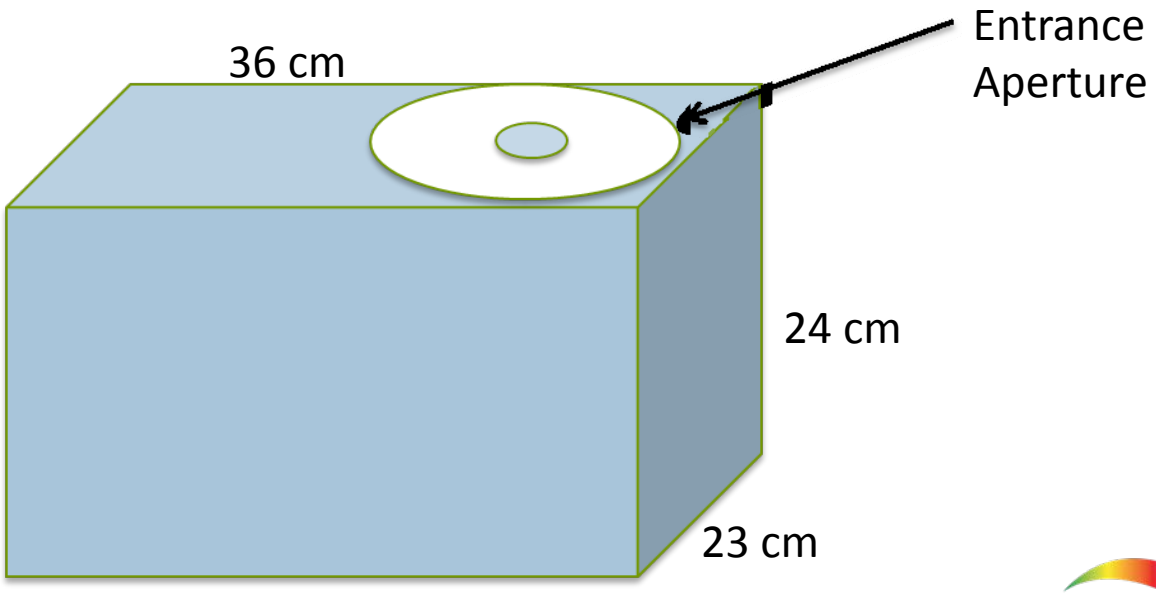
Why 12U CubeSat?

- Enables large aperture without need for deployable telescope
- Easier thermal control than 6U
- Canisters for deployment coming on line within next two years
- Sufficient power for covering VIS-SWIR with cryocooler
- Estmated Cost per Observatory < $2M to Class-D requirements



12U CubeSat Format
Mass < 24 kg

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CHAI-12U System Specifications

- Focal length: 225 mm, F/1.1, 205 mm aperture, 1500 pixels
- 5.5 degrees FOV, 40 m GSD, 37 km swath width
- Forward Motion Compensation not included in SNR, but could be available (5X improvement in signal)
- Spectral Range 350-1050 nm, 5 nm sampling (140 bands)
- Band selectable by dropping lines during acquisition

- Satellite Estimated SWAP
  - 6 - 10 Kg
  - 25 Watts
  - Fills the 12U form factor 23 cm x 24 cm x 36 cm
  - CHREC 1U Processor (Dan Mandl)
  - X-band transmitter

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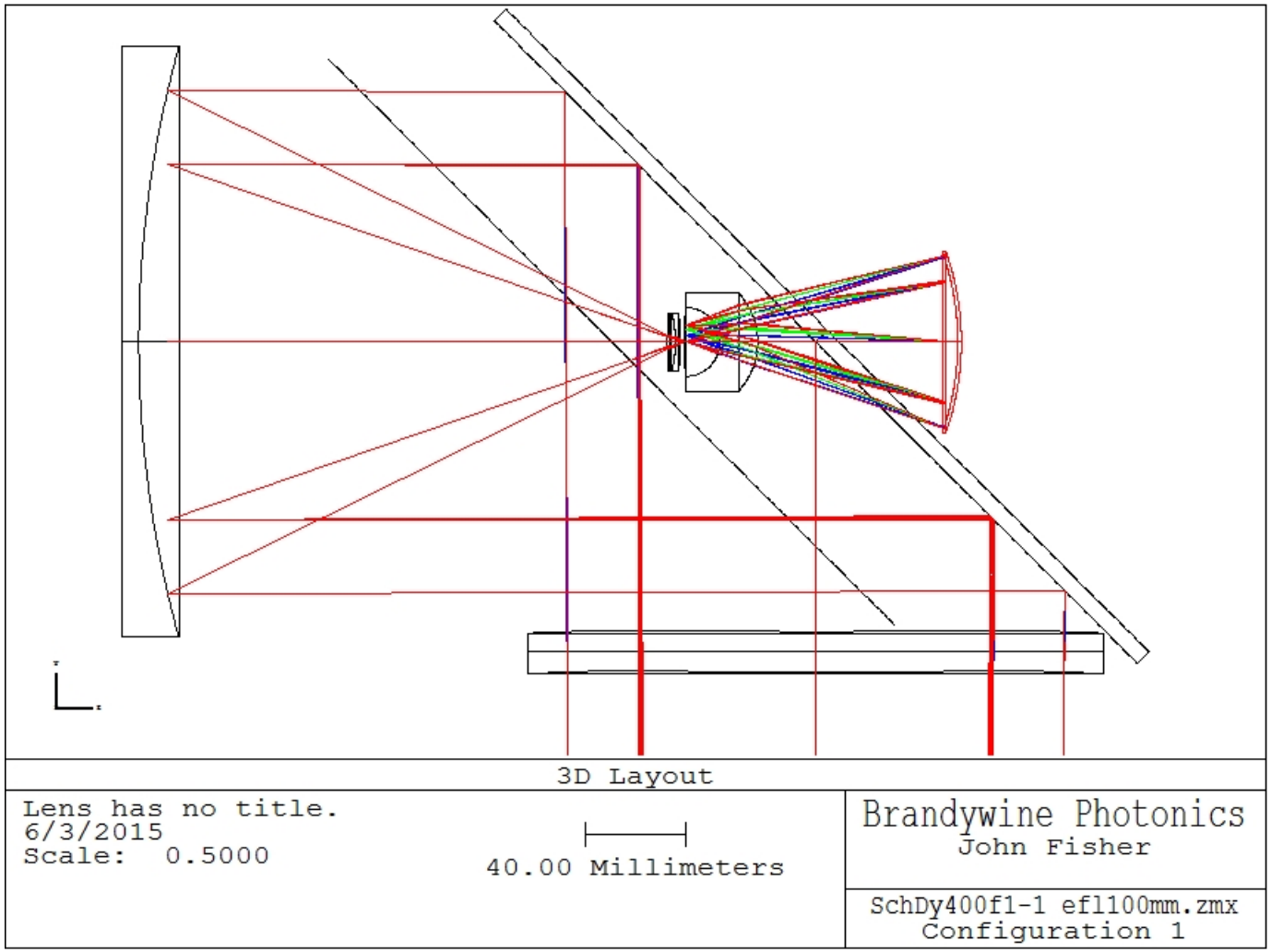
Optical System Layout



1. Schmidt Corrector
2. Fold Mirror
3. Primary Mirror
4. Corrector lens
5. Slit
6. Dyson Refractive Element
7. Grating
8. FPA

Based on optical design from : R. Lucke and J. Fisher, “The Schmidt-Dyson: a fast space-borne wide-field hyperspectral imager,” Proc. SPIE7812, 78120M, 78120M-13 (2010).

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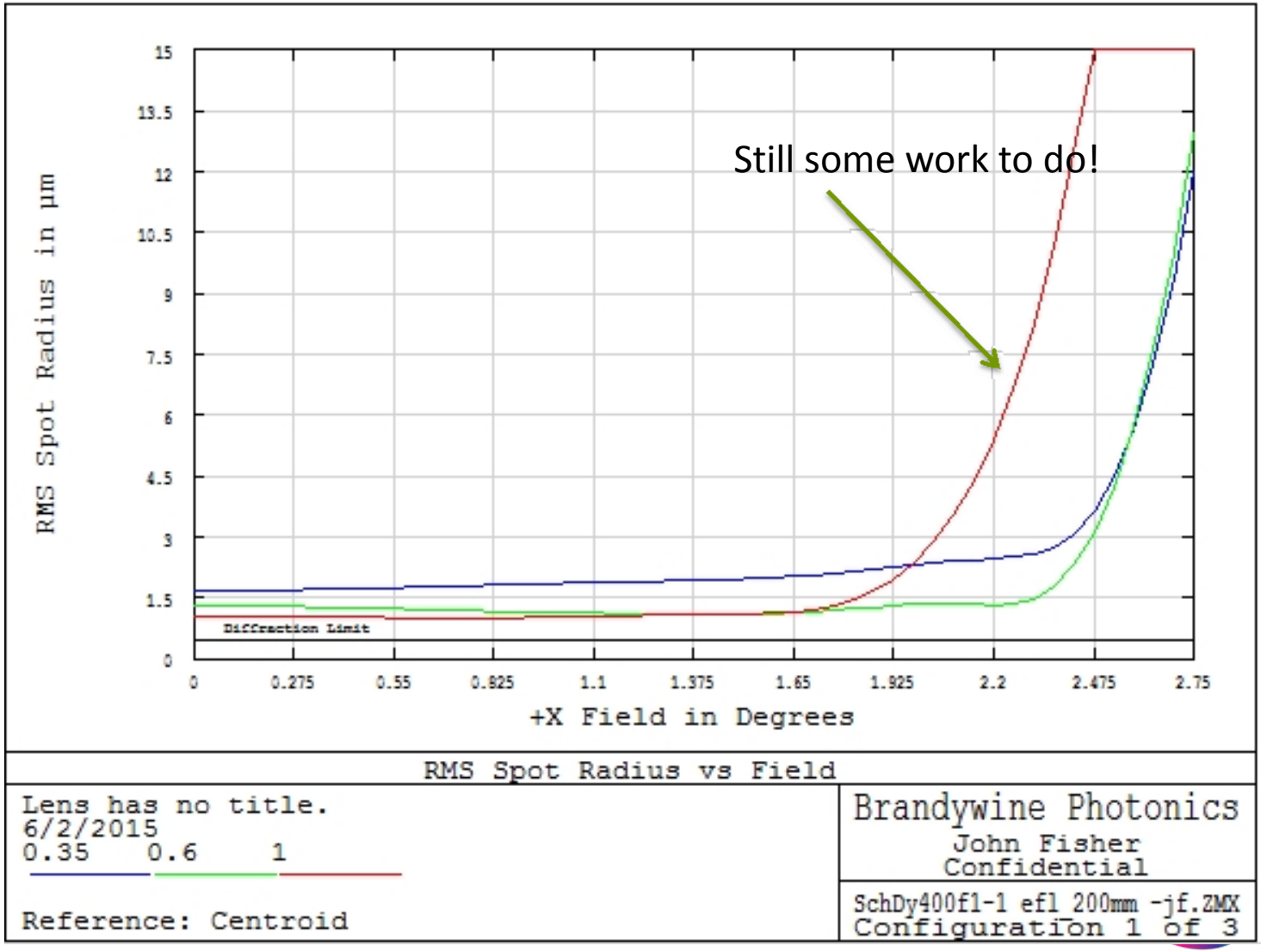
RMS Spot Radius vs. Field



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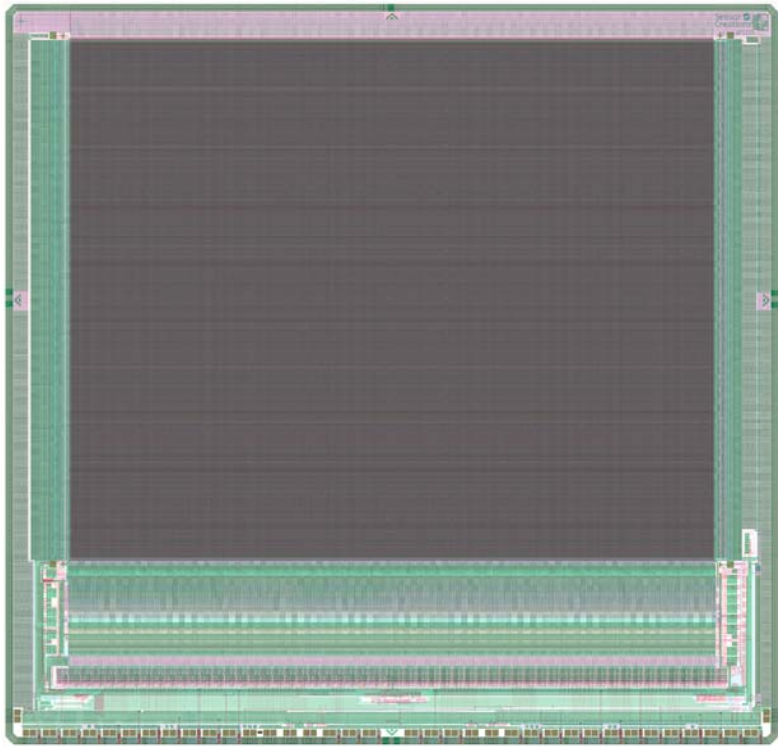
FBX – 640x512 CMOS Image Sensor

Summary of design specifications of fully depleted backside illuminated CMOS VGA sensor imager	
Parameter	**Value**
Array Format	640 x 512
Pixel Size	15mm
Die Size	12 x 12 mm^2
Frame Rate	30Hz, 60Hz, 500Hz
Shutter type	IWR/ITR/NDR
Exposure Time	200nsec to 30msec
Charge Capacity	500ke, 60ke, 10ke
Minimum Noise	< 10e
QE at 1050nm	> 35% for 300nm thick Si
Binning	2x2, 1x2, 2x1
Master Clock	5 Mhz
Number of analog outputs	1, 2, 4
Power	60 mW @ 30Hz frame rate
Supply Voltages	1.8V/3.3V/10V
Serial Interface	3 wire



Other High TRL FPAs available (Teledyne Chroma)

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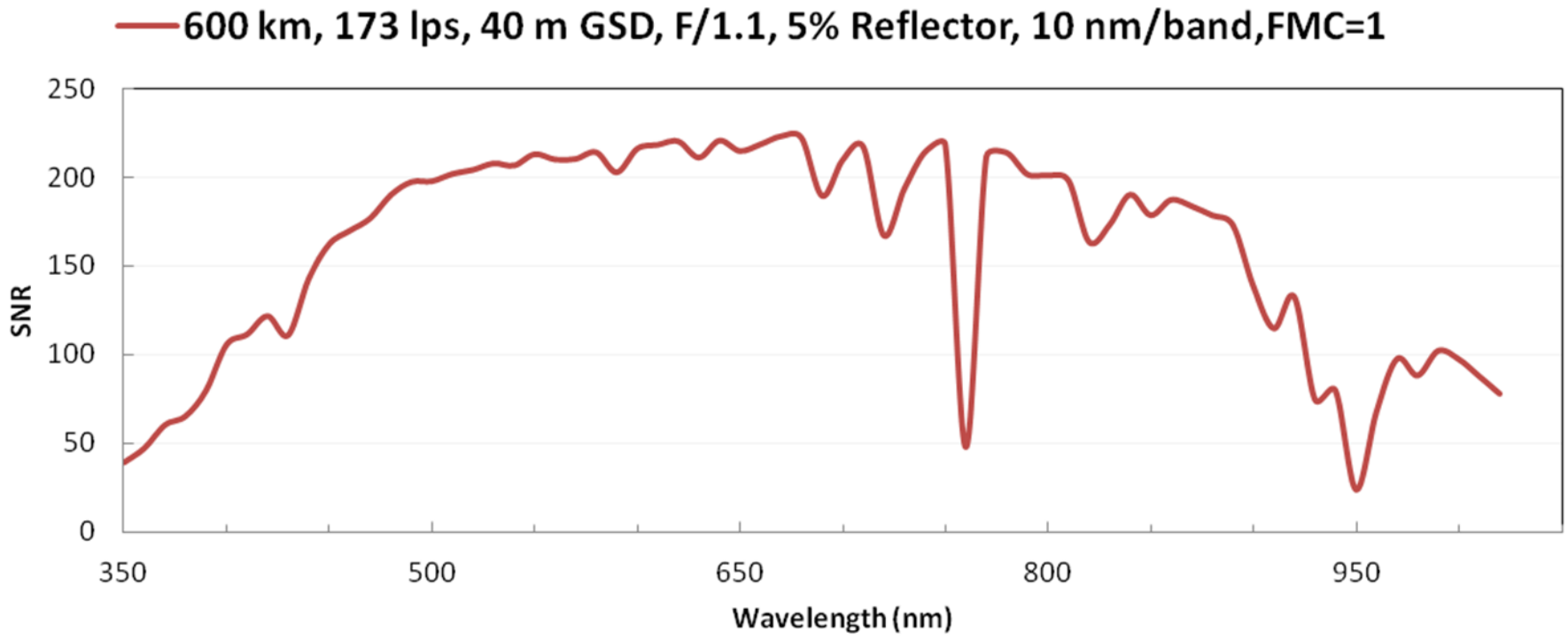
SNR 5% Albedo



Increase in SNR performance with FMC=5, higher albedo scenes (vegetation), and wider bands.

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CHAI-12U Constellation Advantages

- *Daily revisit, catching major temporal events.*
- *Cross-calibration*
- *Formation Flying (wider swath, 1-hour separation, fore-aft BRDF measurements without nodding)*
- *Greater global coverage*
- *Single launch or satellite failure does not jeopardize the mission*

Thanks to colleagues and NRL, NASA Goddard, and NASA Ames for many fruitful discussions!

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System Design Parameters (Back up slide)

Platform

600.0	(km) Altitude
372.8	(mi) Altitude
324.0	(nmi) Altitude
600000	(m) Altitude
circular	(type) Orbit
6.38E+06	(m) Approx Radius of Earth
6.98E+06	(m) Radius of Orbit
8.19	(m/s2) Gravitational Acceleration at Altitude
7561.1	(m/s) velocity of satellite perpendicular to ground
5798.7	(s) Orbit Time
96.6	(min) Orbit Time
6910.9	(m/s) Velocity of Satellite nadir point across earth surface
40	(m) Static GSD
172.8	(lines per second)
1	Forward-motion compensation over-sampling factor

Telescope

6.7E-05	(rad) Needed IFOV
66.7	(uRad) Needed IFOV
1.1	(#) F/# of System
0.225	(m) Effective Focal Length
0.2045	(m) Minimum aperture for F-number, signal
8.05	(in) Aperture
5.7	(deg) FOV
0.031	(m) Minimum aperture for spatial resolution

Spectrometer

350	(nm) Shortest Wavelength
2500	(nm) Longest Wavelength
215	(#) Number of Bands
10.00	(nm/band) Dispersion
500	(nm) Blaze Wavelength

Collection

60000	(m) Swath Width (first order)
37.3	(mi) Swath Width
415	(km^2/s) Area collection rate
6.69E+08	(bits/s) Data Collection Rate
80	(Mbytes/s) Data Collection Rate *(uncompressed)*
4.01E+07	(m) Circumference of earth
24,902	(mi) Circumference of earth
668	(#) Number of orbits to completely cover equator
1076	(hours) Time to completely cover equator
45	(days) Time to completely cover equator
90	(days) Time to completely cover equator - 1/2 sunlight

Scene

5.0%	(refl) Reflectance of Target

Detector

1500	(#) Spatial Channels

Detector

15	(um) Detector Pitch
0.000015	(m) Detector Pitch
0.0058	(s) Integration Time
5	(# e-) Read-out Noise
200000	(# e-) Quantum Well
12	(#) bits per pixel
173	(fps) Frame rate

Title:
600 km, 173 lps, 40 m GSD, F/1.1, 5% Reflector, 10 nm/band,FMC=1

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