High Performance Optical Imaging Payloads for Smallsat Missions

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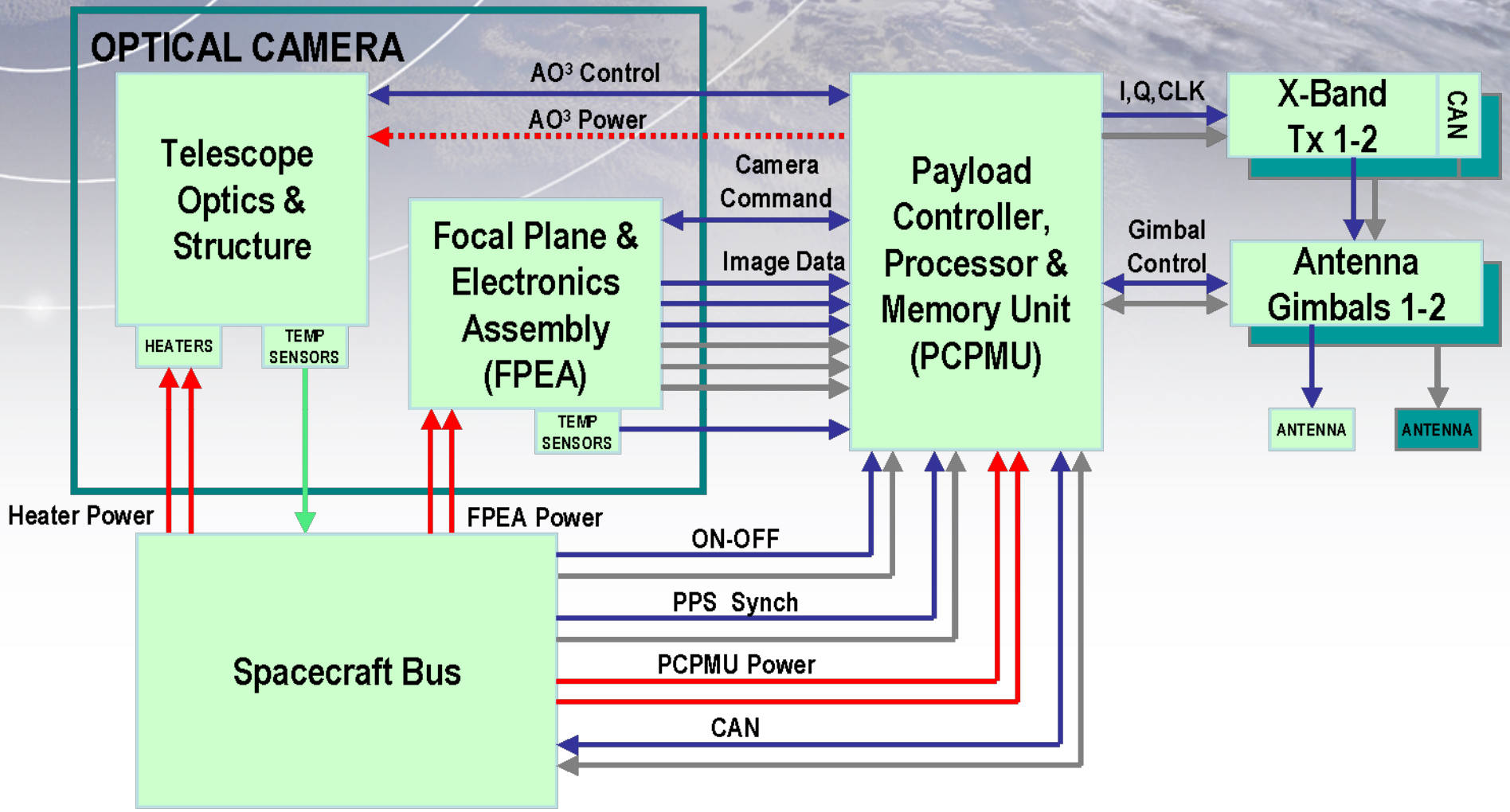
Outline

- Camera & Spacecraft Dev't Program Overview
- Optical Camera Design
- Camera Hardware Testing
- Payload Controller, Processor & Memory Unit (PCPMU)
- Camera System Performance
- Hi-Res Optical Spacecraft Design
- Summary

Development Program Overview

- Two classes of Hi-Res Camera in development
  - RALCam-4: 1.0 m GSD @ 600 km altitude
  - RALCam-5: 0.5 m GSD @ 500 km altitude
- Camera's designed together to share same technology
  - Telescope optics & structure identical BUT RALCam-5 is scaled up in size to increase aperture
  - Focal Plane & Electronics Assembly (FPEA) is same for both
- PCPMU is MDA's re-configurable payload electronics
  - performs all payload control & data handling for future MDA missions
  - Both classes of optical camera, radar missions & Comms missions
- Developed MDA's next-generation Hi-Res mission offering
  - Leveraged elements of the RapidEye spacecraft design

Payload Architecture



RALCam-4 Optical Camera

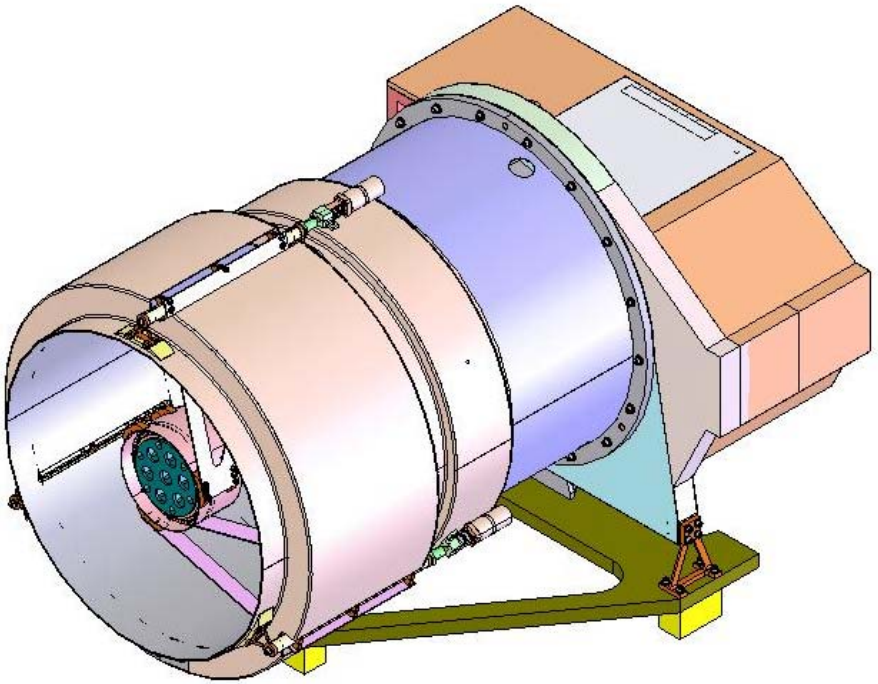
Key Parameters

- Mass: 76 kg
- Power 60 W

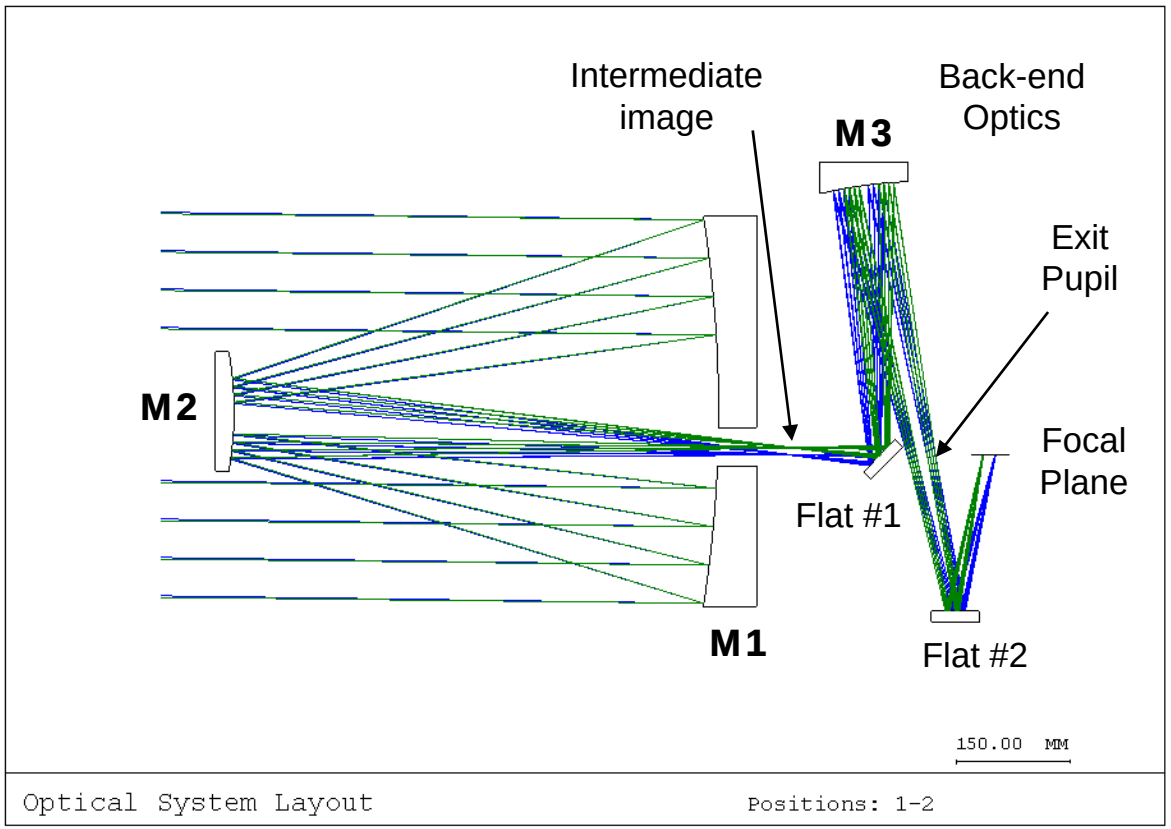
- Length 1.17 m
- Height 0.75 m
- Width 0.83 m

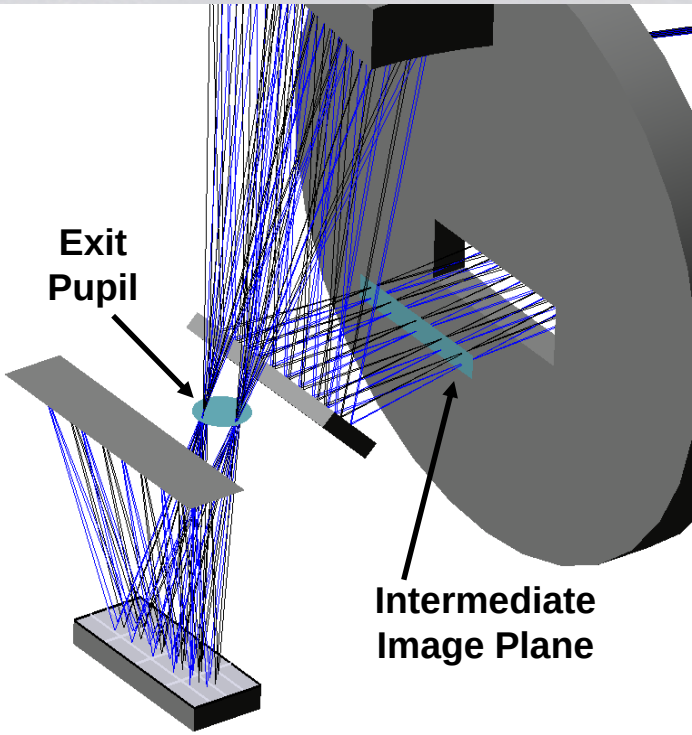
- Focal Length 6000 mm
- Aperture 480 mm

- Near-zero CTE materials used (CFRP & Zerodur)

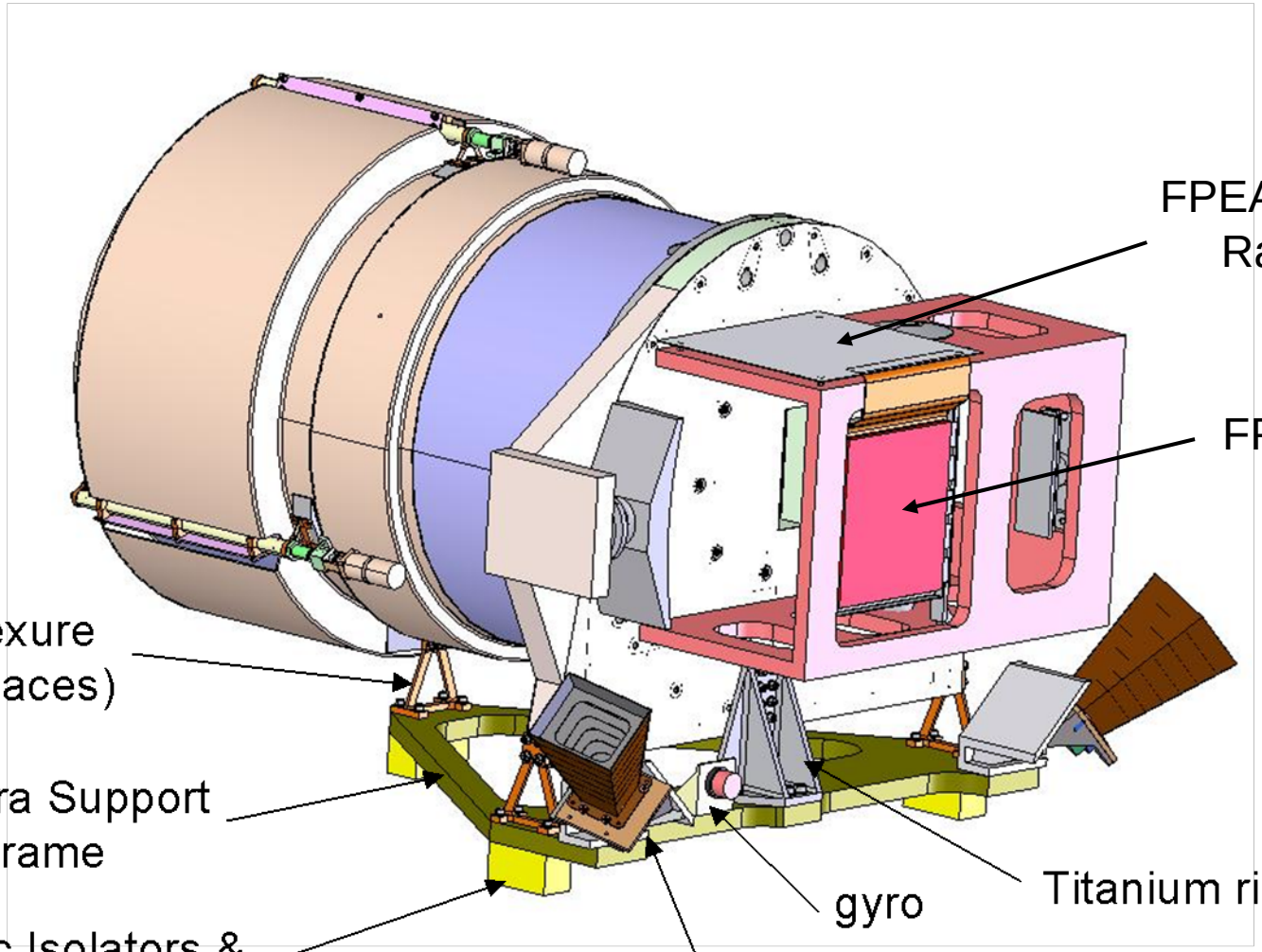


RALCam-4 & 5 Optical Layout





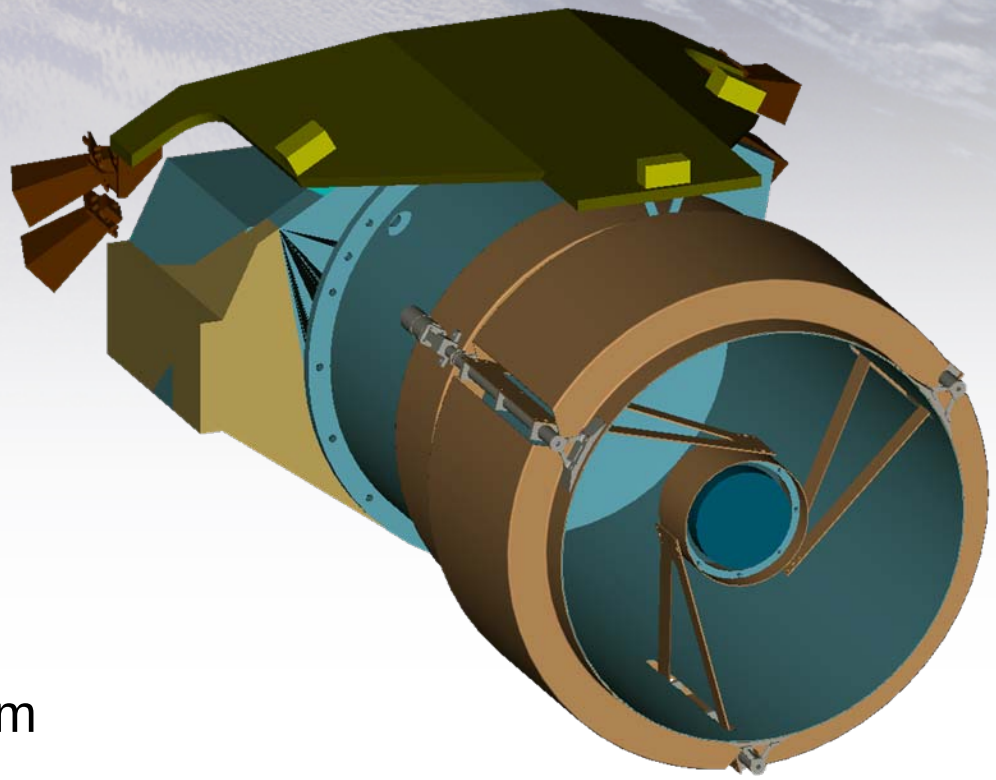
RALCam-4 Optical Camera



RALCam-5 Optical Camera

The following are changes from RALCam-4:

- **scaled up in size to increase aperture**
- **increased detectors in focal plane**
- **“wrap around” camera frame**



Key Parameters

– Mass:	220 kg
– Power	120 W
– Length	1.95 m
– Height	1.25 m
– Width	1.38 m
– Focal Length	10,000 mm
– Aperture	800 mm

– Same materials as RALCam-4

RALCam 4 & 5 Focal Plane

5 spectral bands:

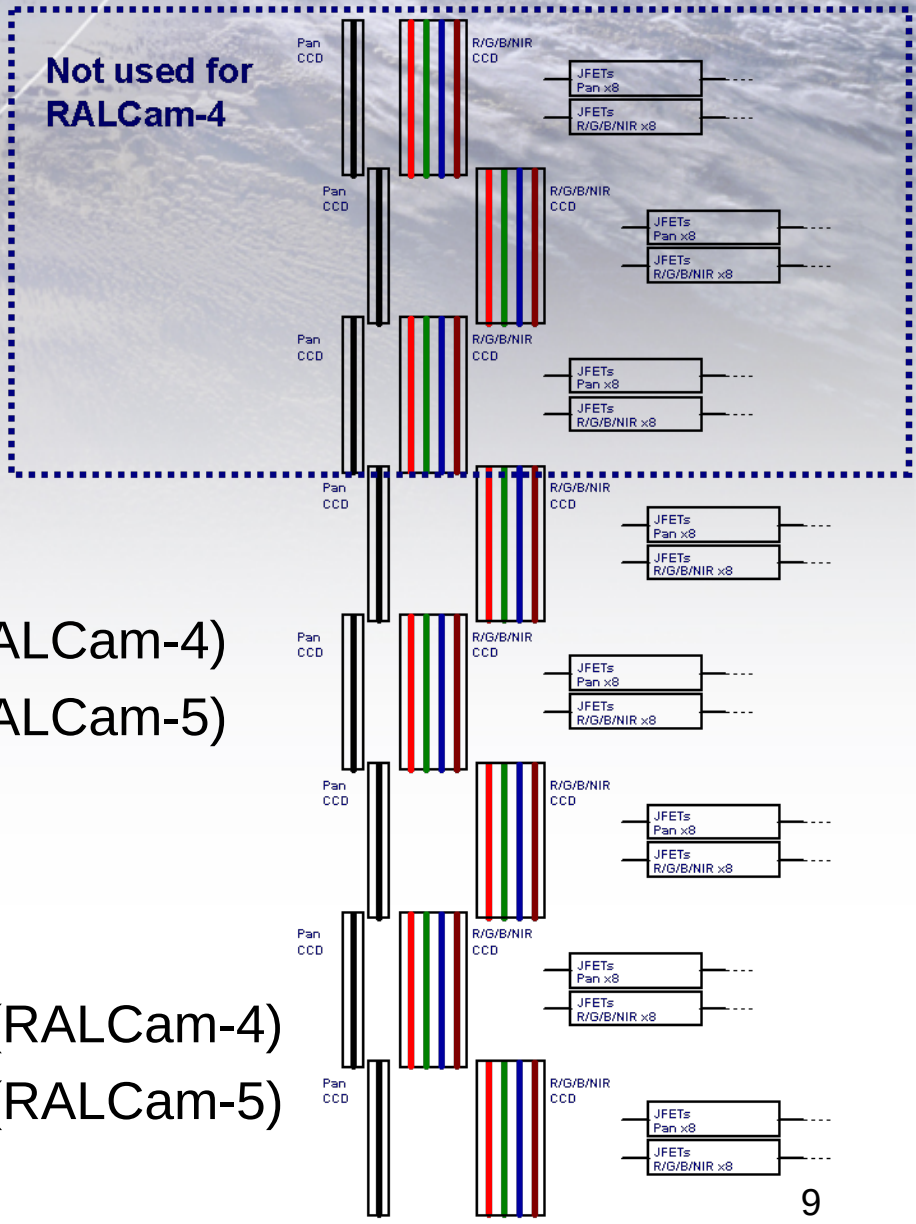
PAN	450 – 700 nm
Blue	450 – 520 nm
Green	520 – 600 nm
Red	630 – 690 nm
NIR	760 – 900 nm

PAN Sensor

pixel size:	10µm
number of pixels:	20,580 (RALCam-4)
	32,868 (RALCam-5)
number of TDI stages:	96

MS Sensor

pixel size:	40µm
number of pixels:	4 x 5,145 (RALCam-4)
	4 x 8,217 (RALCam-5)
number of TDI stages:	16



Optical Camera Key Features

- Active On-Orbit Optics (AO^3) System
  - Telescope optics re-aligned in space using a proprietary approach
  - Removes need to maintain very high optical component stability from Lab to on-orbit - a significant cost driver
  - Maintains high image quality
- FPEA
  - Custom CCD's (Pan and MS) developed with e2v (UK) from ground up together with Front End Electronics (RAL)
  - Leverage heritage processes & technology for ultra-high data quality
  - Designed to allow for low recurring costs – optimized to reduce price point
- Telescope
  - CFRP telescope structure & zerodur mirrors – provide near-zero CTE and remain low cost
- Camera Structural and Thermal Isolation from Bus
  - Elastomeric isolators used (with launch locks) for jitter suppression
  - Also provide thermal & structural isolation (e.g., bus distortion or non-flatness a non-issue)

Optical Camera Dev't Status

- The camera design is based significantly on the technology developed and proven on the RALcam-1 camera
  - in-orbit on the Topsat Mission since 2005

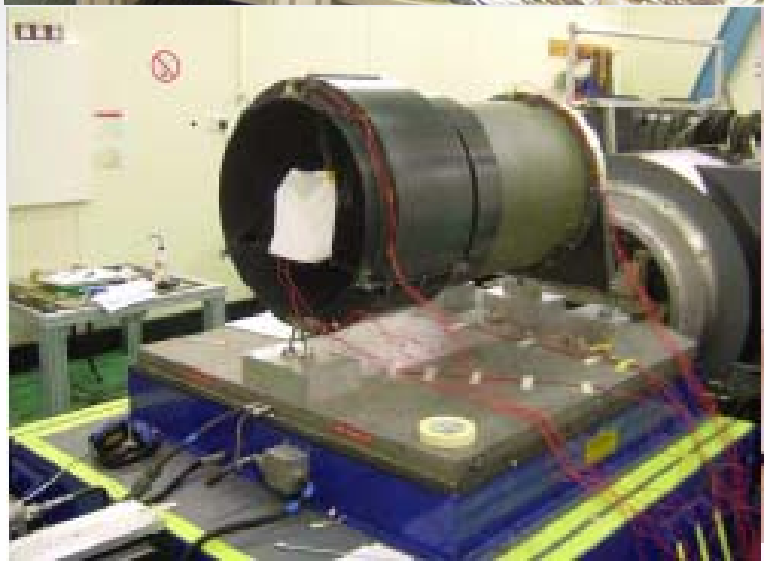
- The camera design is well advanced and hardware procurement is in process (long lead items)
  - Key design elements based on proven well understood technologies & processes (e.g., AO^3 actuators, CCD detector)
  - Key Suppliers identified
  - Mirror procurement in process
  - Focal plane layout and CCD designs are defined
  - Key components identified, risk-reduction test program in process

- Significant risk reduction work has already been undertaken
  - Structural engineering model built and tested to confirm structural design and optical element stability under loads (a key risk)
  - Detailed optical design and analysis performed that assesses tolerancing and other manufacturing related elements

Testing Status

Structural qualification model of telescope underwent environmental test campaign

- Vibration
- Thermal-Vacuum

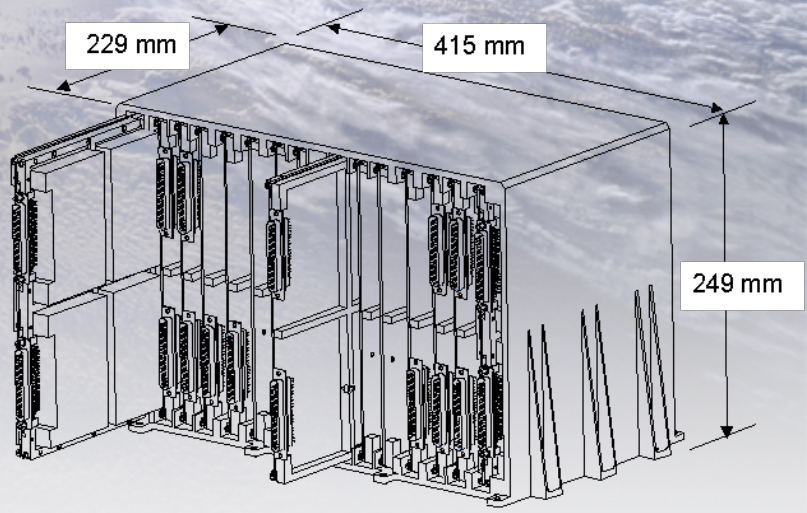


Key Test Results:

1. Telescope survived the typical launch environments.
2. Natural frequency meets requirements.
3. Optical alignment stability during vibration is well within the correction capability using the AO^3 system (with ample margin).
4. CTE of the telescope tube was measured and found to be 0.2×10^{-6} /ºC.
5. Qualified primary mirror mounting technique to the bulkhead panel (used dummy optics).

PCPMU

- Provides Instrument Control
- Drive electronics
  - X-band antenna gimbals
  - Camera AO^3 alignment system
- JPEG2000 compression (real-time)
- Large On-board data storage capacity
  - Non-volatile memory (Flash)
  - 0.5 to 4 Tbits at EOL
- Data formatting (e.g., CCSDS, RS encoding)
- Data Encryption (triple DES or AES)
- Instrument high speed data interface
  - up to 8 Gbps
- interface to X-Band Tx (up to 800 Mbps)
- Power conditioning
- Fully redundant architecture
  - RALCam-4: 12 boards (8 powered)
  - RALCam-5: 16 boards (11 powered)



RALCam-4:

Mass = 21 kg

Power = 58 W (imaging)

82 W (Imaging & DL)

0 W (data retention)

RALCam-5:

Mass = 27 kg

Power = 87 W (imaging)

95 W (Imaging & DL)

0 W (data retention)

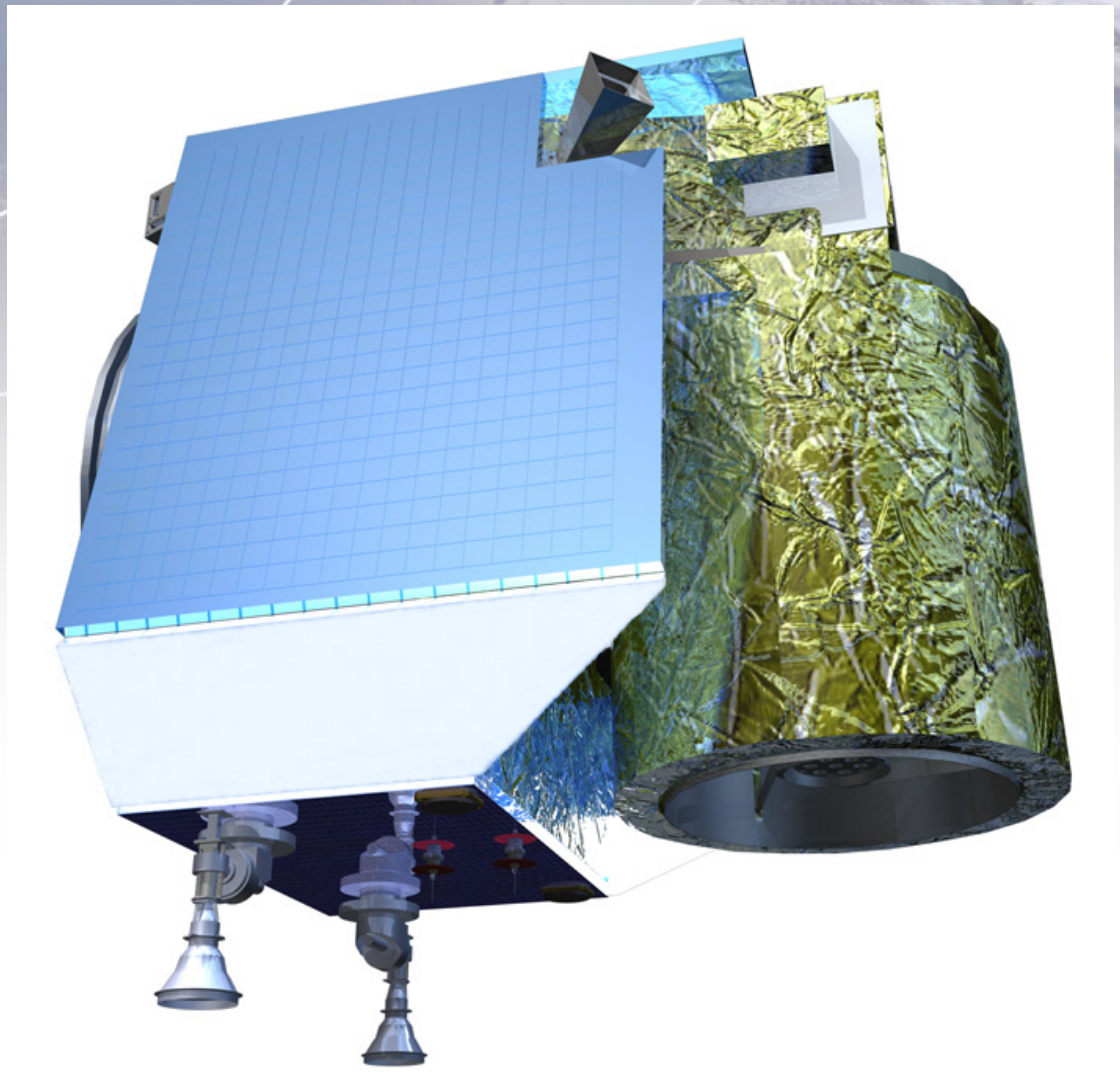
RALCam-4 Performance Spec

GSD	Pan band (@ 600 km)	1.0 m
	MS bands	4.0 m
Swath Width	Pan & MS bands (@ 600 km)	20.6 km
MTF	Pan band - across track	>16.1%
	Pan band - along track	>10.8%
SNR	Pan band sun angle = 67.3 deg, TDI = 24	> 146
TDI levels	Pan / MS bands	96 / 16
Resolution	Pan & MS bands	12 bits

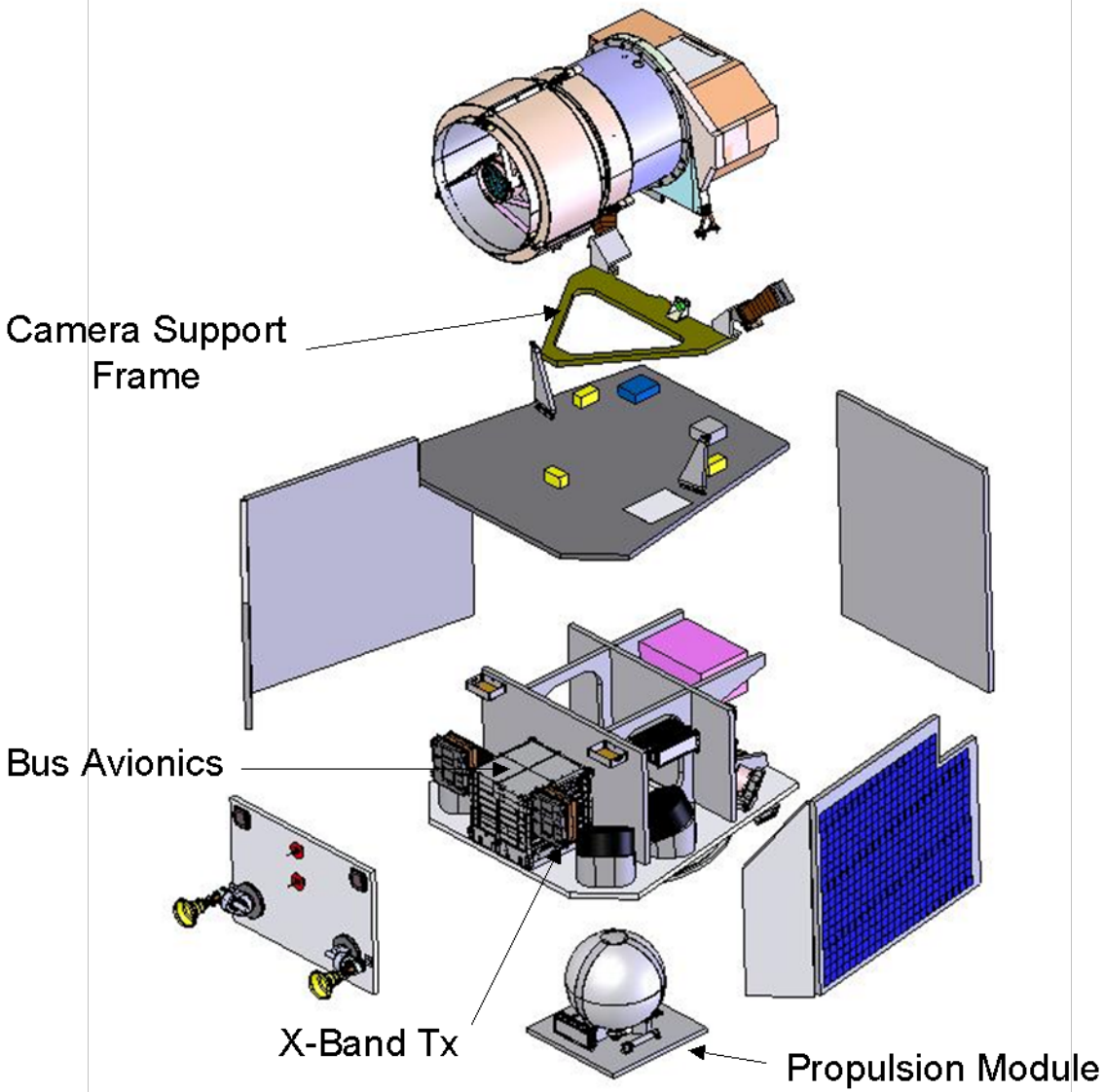
RALCam-5 Performance Spec

GSD	Pan band (@ 600 km)	0.5 m
	MS bands	2.0 m
Swath Width	Pan & MS bands (@ 600 km)	16.4 km
MTF	Pan band - across track	>16.1%
	Pan band - along track	>10.8%
SNR	Pan band sun angle = 80.1 deg, TDI = 96	> 98
TDI levels	Pan / MS bands	96 / 16
Resolution	Pan & MS bands	12 bits

0.8 m / 1.0 m Class Spacecraft



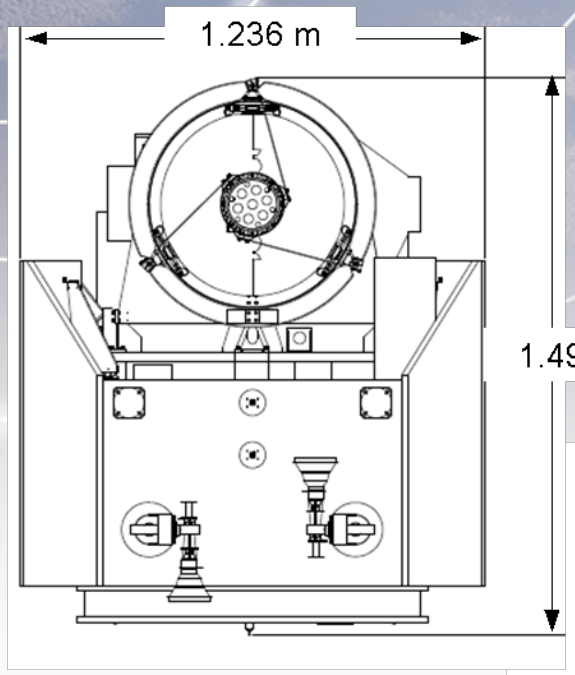
Spacecraft Configuration

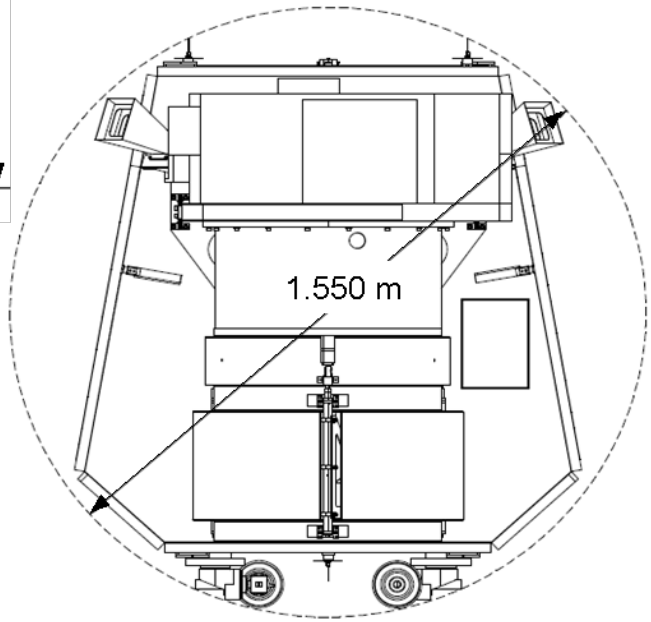


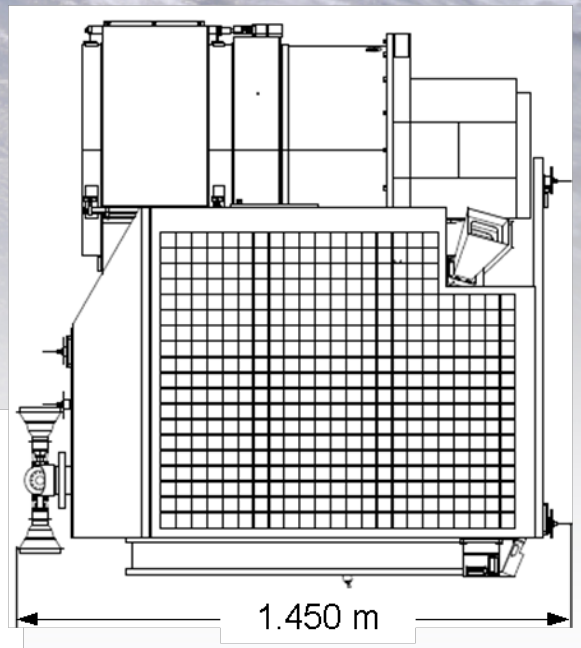
Spacecraft Configuration

Spacecraft Mass: 366 kg

Power generation: 132 W (Orbit average)





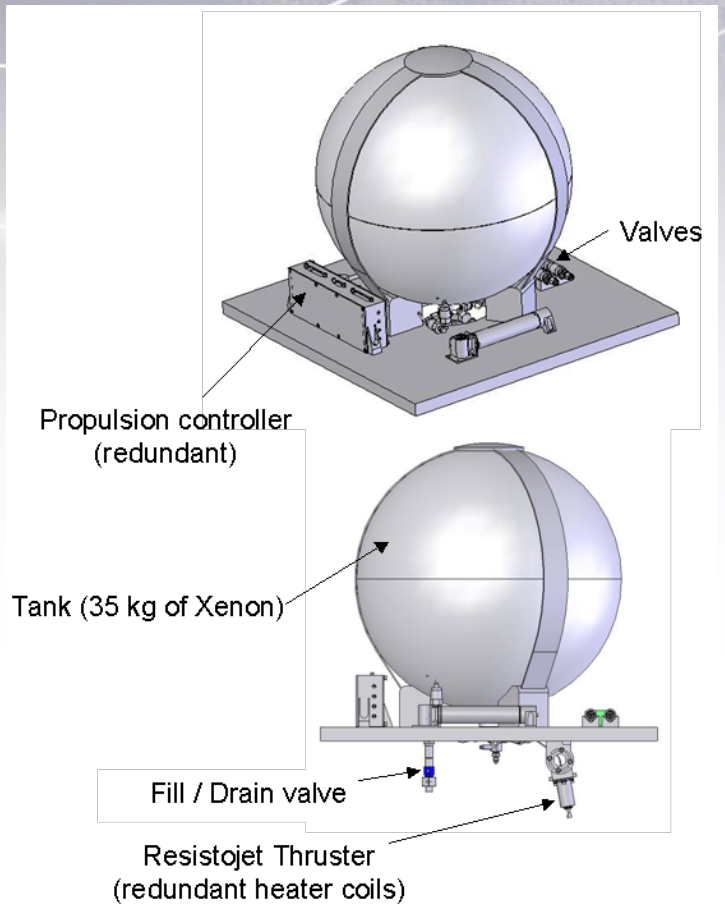


Propulsion Module

Cold Gas Prop System Baseline

Delta V = 35 m/s

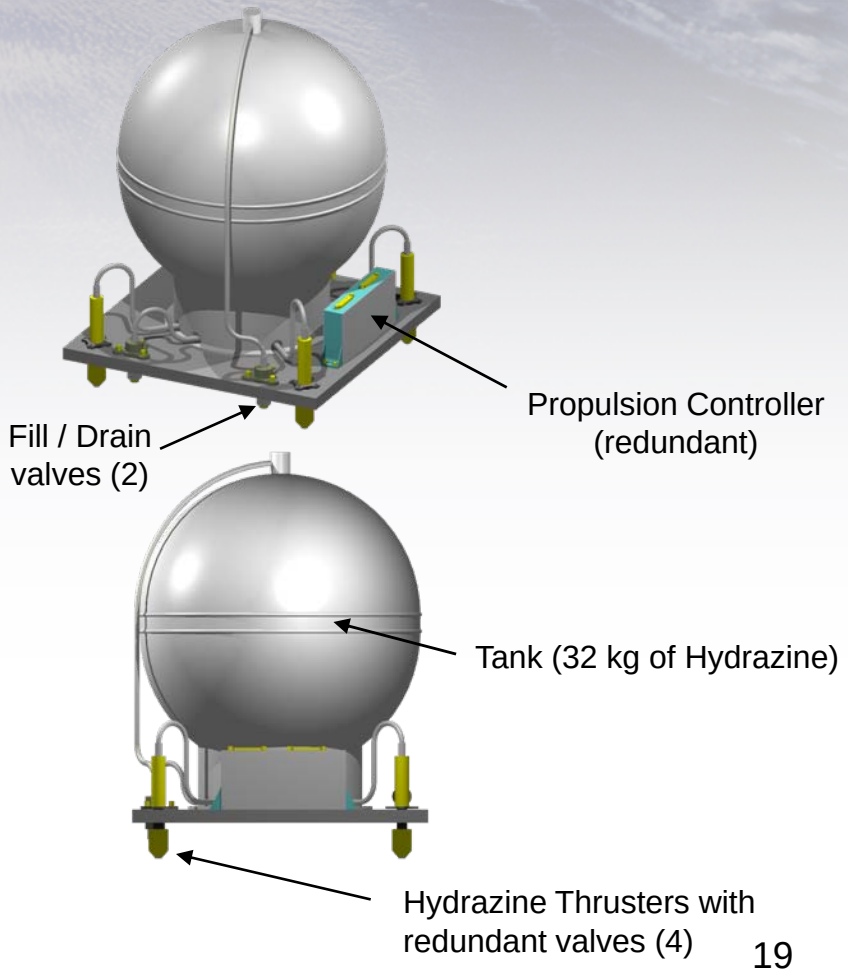
Altitude = 600 km (gives 1 m GSD)



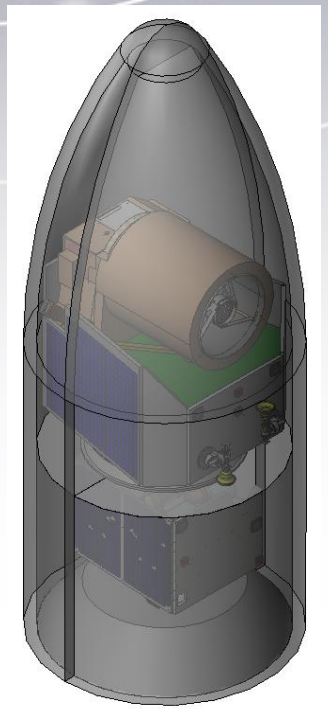
Hydrazine Prop System Option

Delta V = 165 m/s

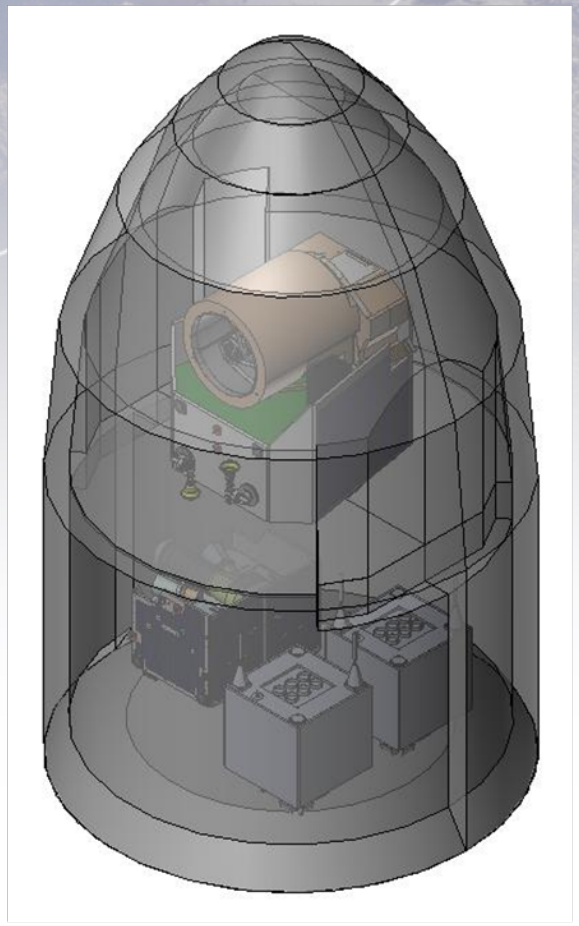
Altitude = 480 km (gives 0.8 m GSD)



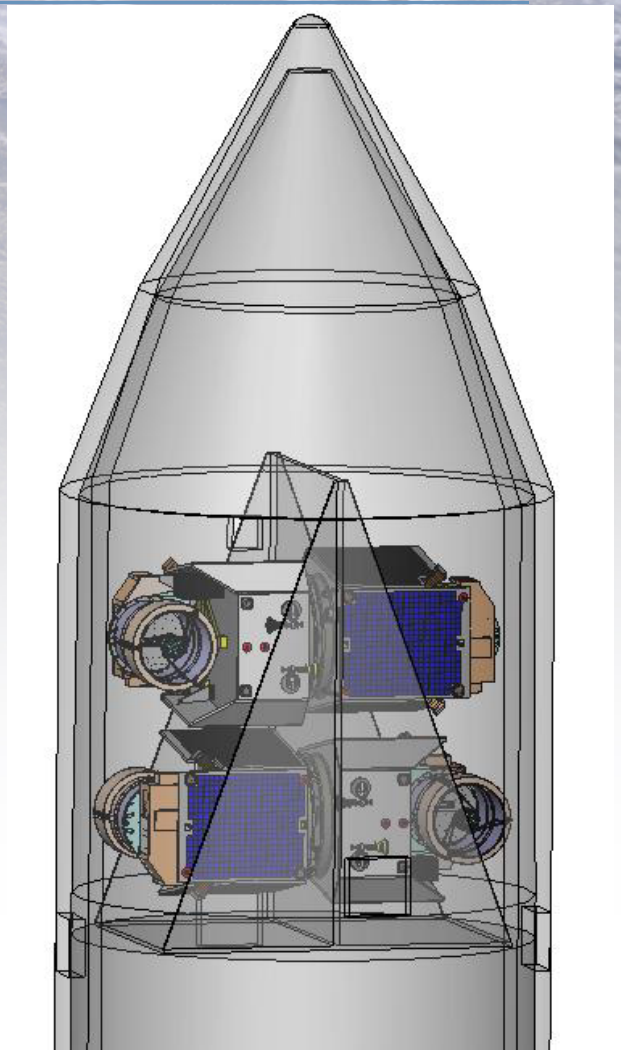
Low Cost Launch Options



Falcon 1E
launch vehicle

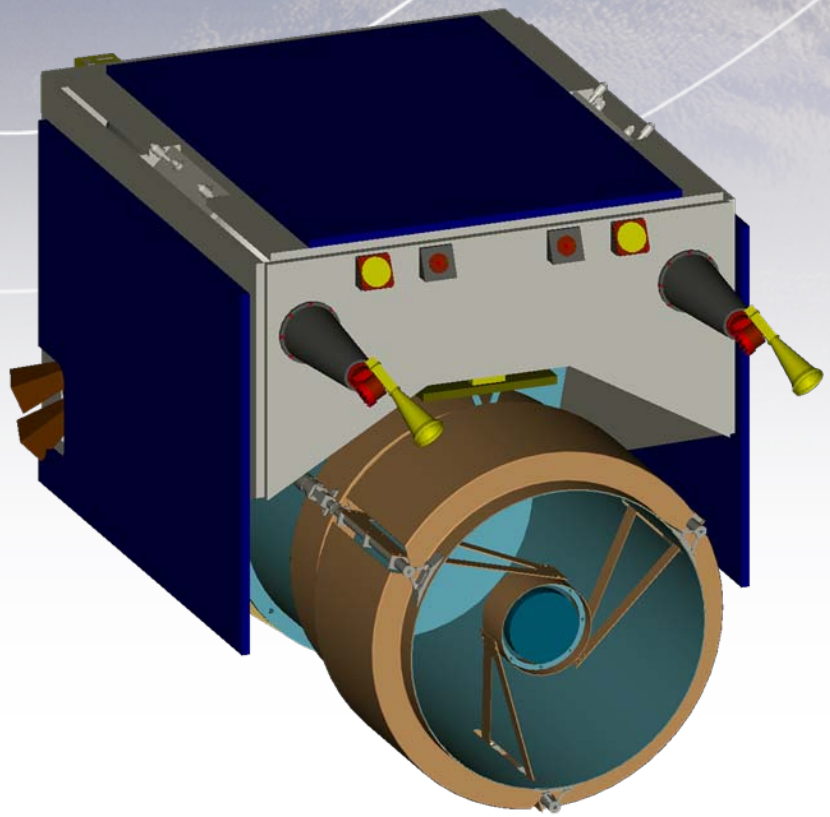


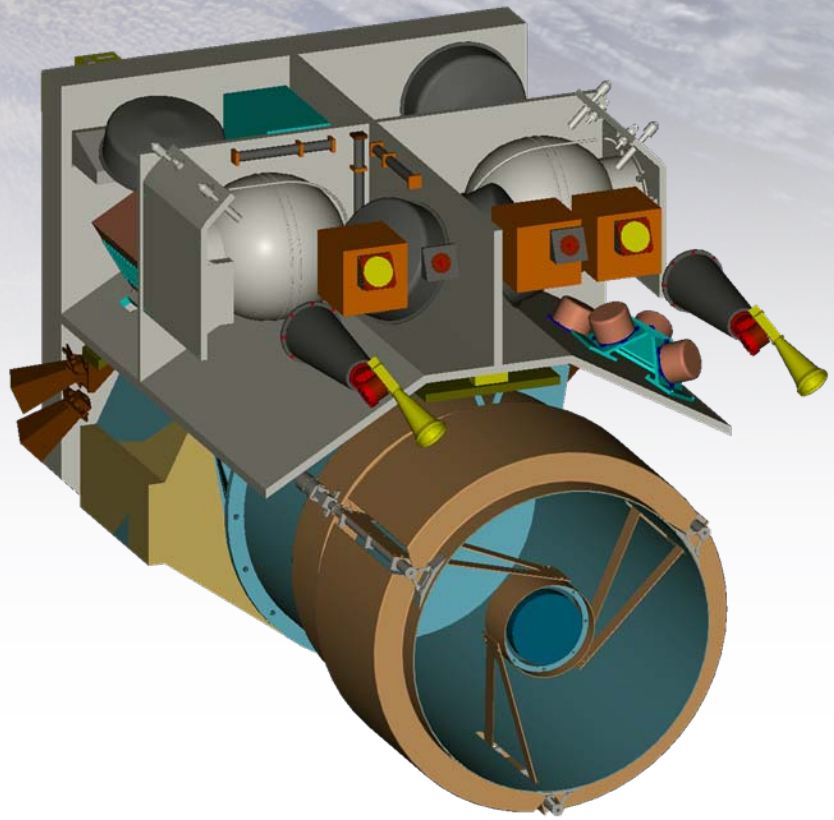
DNEPR launch
vehicle



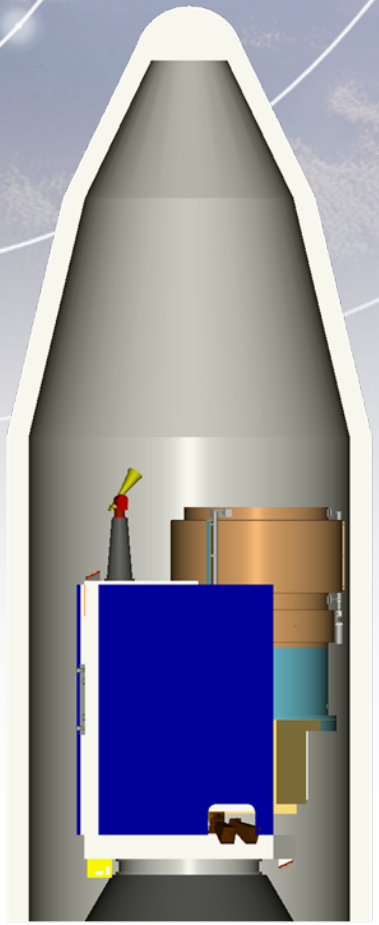
Soyuz
launch vehicle

0.5 m Class Spacecraft

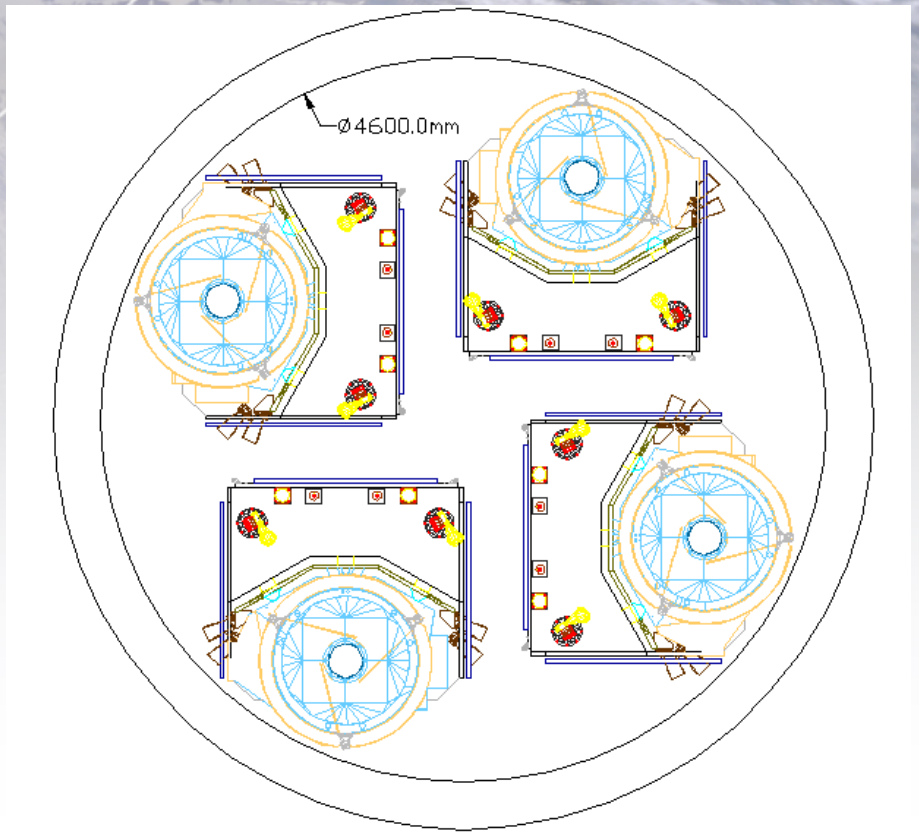




Low Cost Launch Options



Minotaur IV launch vehicle



Falcon-9 launch vehicle

Summary

- MDA's Hi-Res optical cameras and spacecraft
  - designed to provide very high image quality at highly competitive price points
  - S/C price point enables launching small constellations to provide unprecedented coverage and performance
  - High Reliability & Lifetime (> 7 years)

- Key Price Point Enablers
  - AO^3 system
  - Integrated Focal Plane & FEE in the FPEA
  - PCPMU
  - Proven Processes for use of commercial EEE parts
  - Highly compact S/C design requiring low power
    - deployed solar panels not required, high agility, low cost launch options