BIRDS Bus Open-Source Webinar

LOW GSD IMAGING SYSTEM PAYLOAD FOR ASEANSAT 1U-SIZED CUBESAT APPLICATION

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BACKGROUND OF CAM MISSION

CAM Mission Statement:

- CubeSat provides low ground resolution imageries due to limitation in selecting suitable imaging sensor.
- With the technology advancement in optical design, ground resolution can be improved.

CAM Mission Objective:

- To capture optimal ground resolution image, store the image onboard and transmit it to ground station.

MISSION REQUIREMENT

Functional Requirements:

- Performance: *The satellite shall obtain optimal ground resolution imagery.*
- Coverage: *The coverage size depends on the amount of viewing angle.*
- Timeliness: *Satellite shall downlink image packets for every available pass.*

Mission Mode:

- Single shot

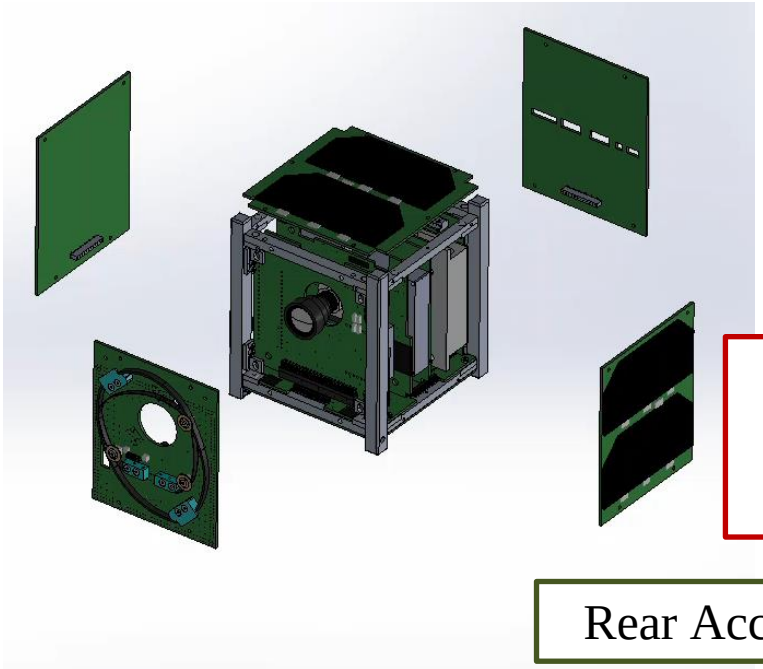
Mission Executions:

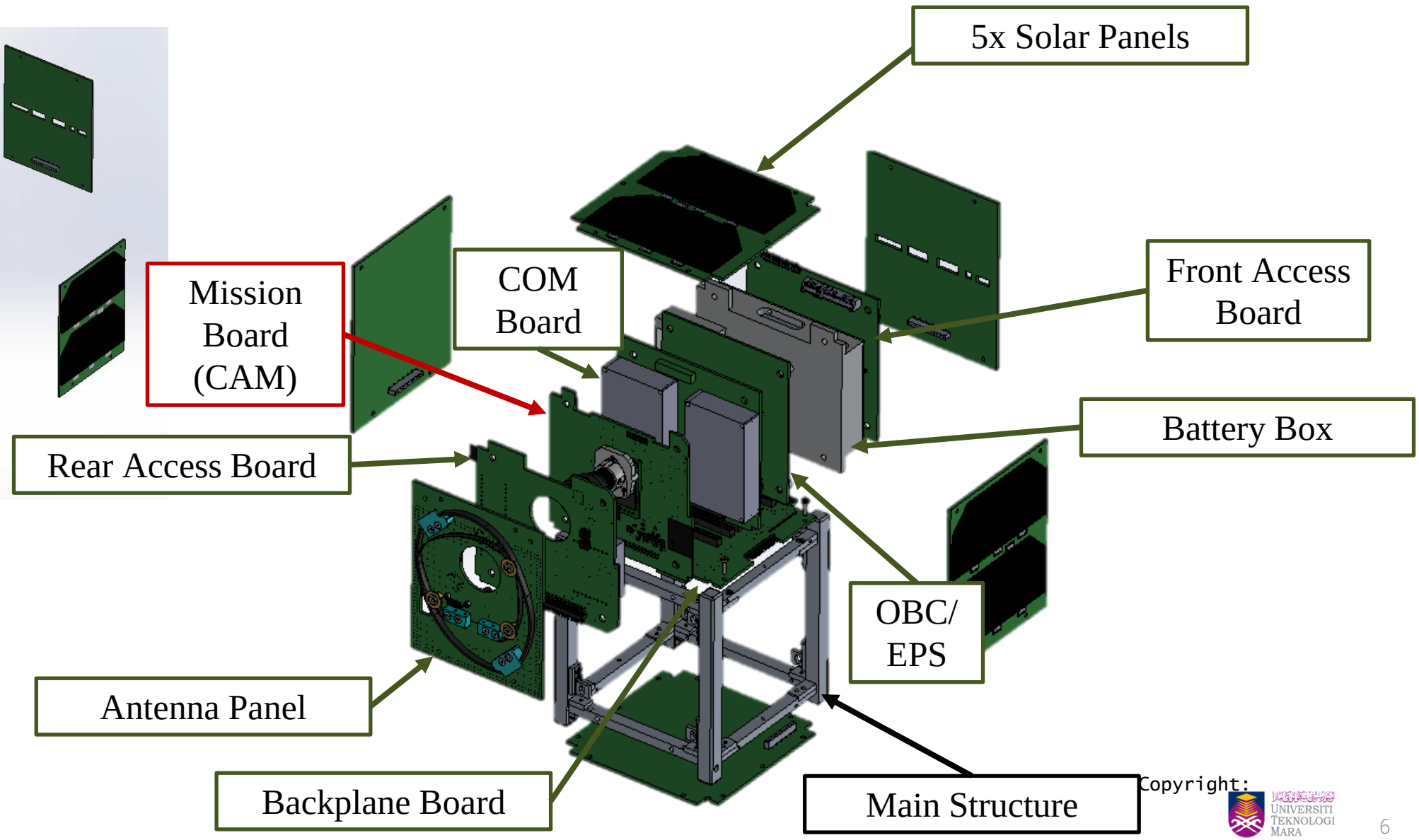
- Upon command image capturing

STAGING GOALS

SUCCESS LEVEL	CRITERIONS
Minimum	Takes image(s).
Medium	Takes image(s) of Earth.
Full	Takes image(s) of Earth with optimal ground resolution.
Extra	Takes image(s) of each of the participating countries with optimal ground resolution.

ASEANSAT CUBESAT





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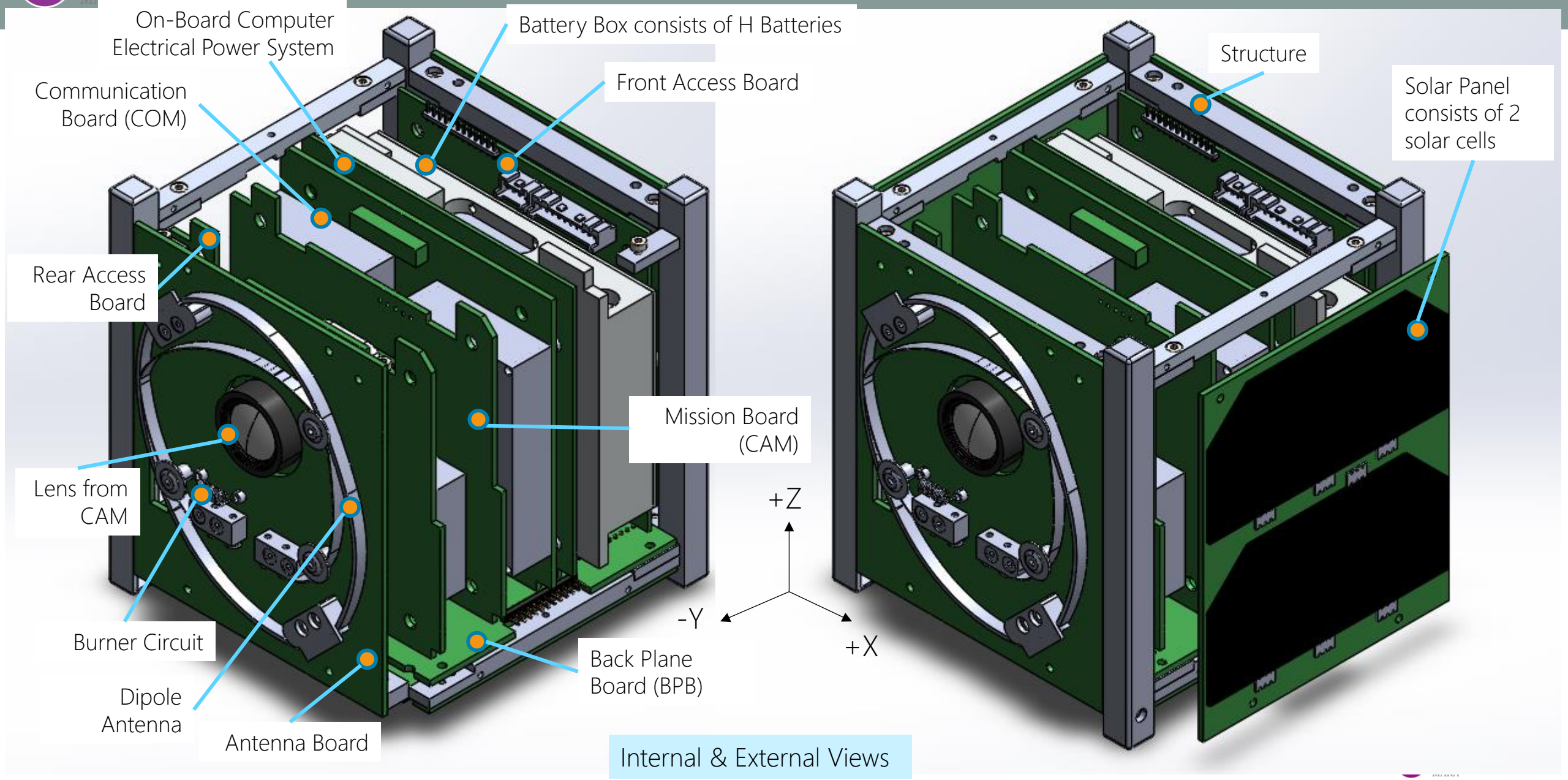
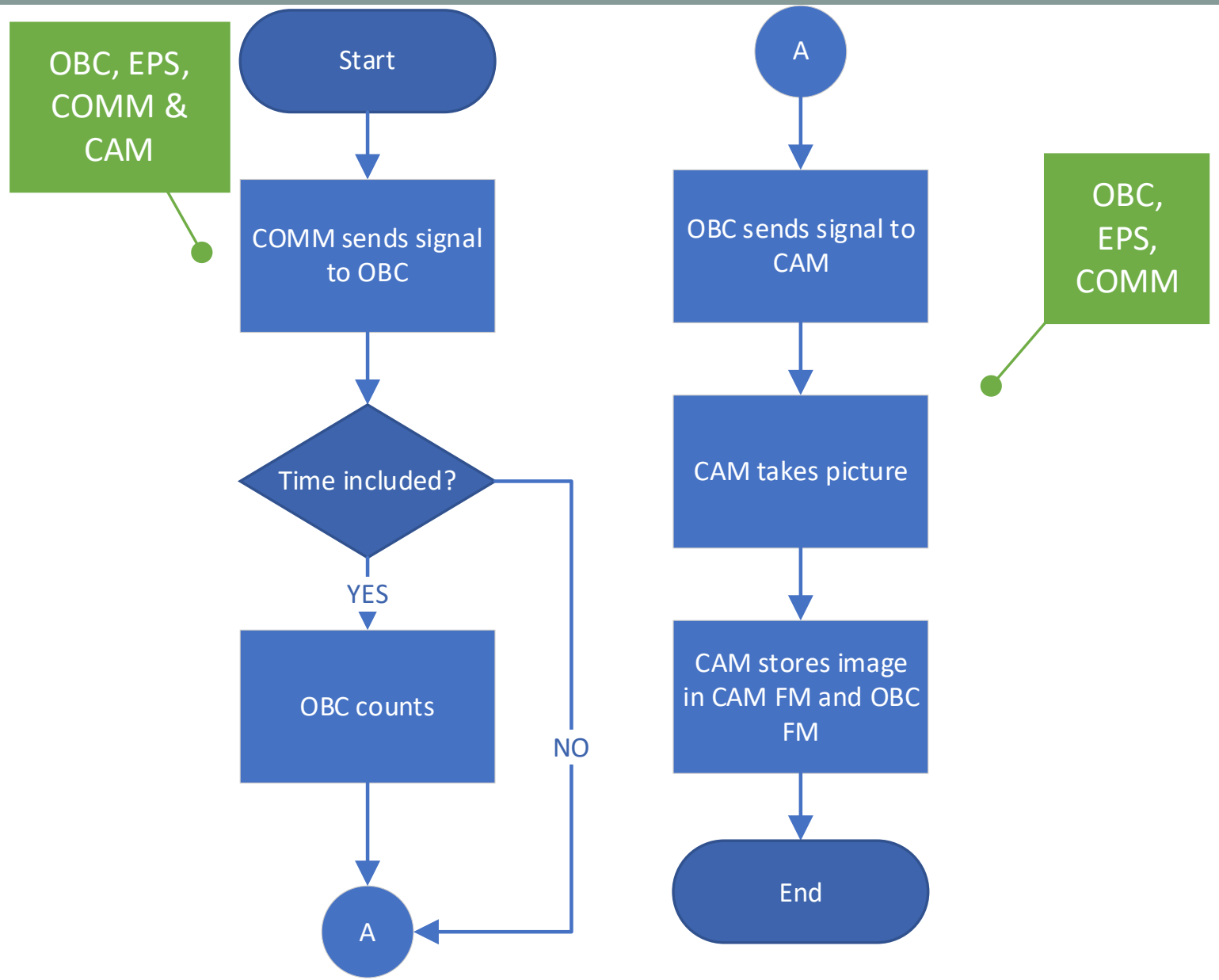
CUBESAT STRUCTURE



Internal & External Views

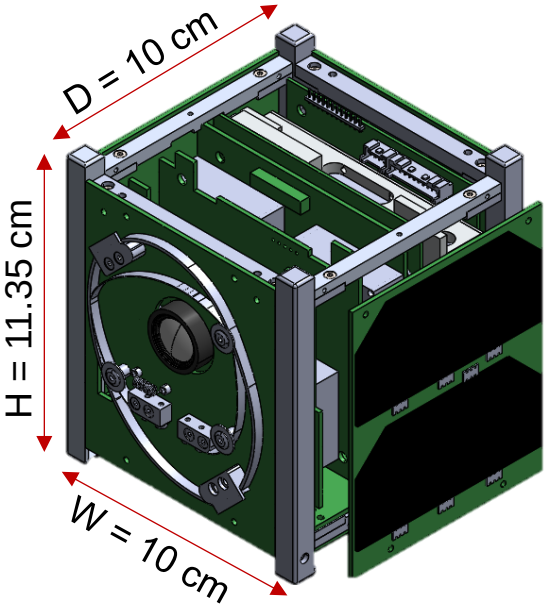
CAMERA OPERATIONS

COMMAND MODE



CAMERA MISSION CHARACTERISTICS

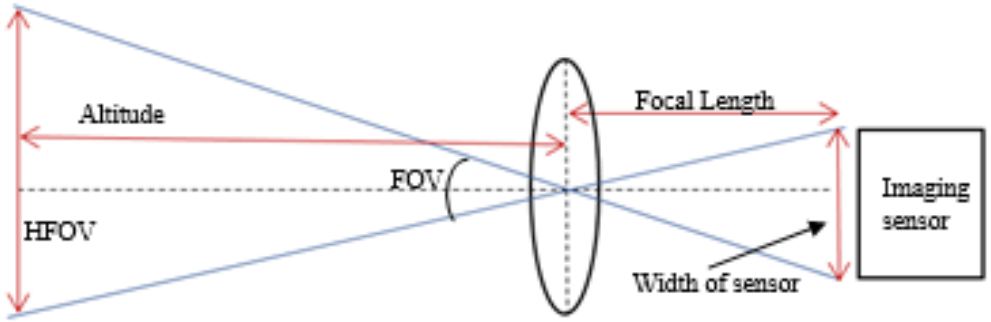
		CubeSat
Mass	≤ 50 – 66.5 g (5% lighter) [23] ≤ 100 – 133 g (10% lighter) (BIRDS)	1 – 1.33 kg
Size (W x D x H)	≤ 5 mm x 5 mm x 5.675 mm (5% smaller) ≤ 10 mm x 10 mm x 11.35 mm (10% smaller)	10 cm x 10 cm x 11.35 cm
Power Consumption	0.1 – 0.25 W [32] (depends on power budget calculation)	1 – 2.5 W [16]
Interface	SPI, UART, I2C	UWE-3



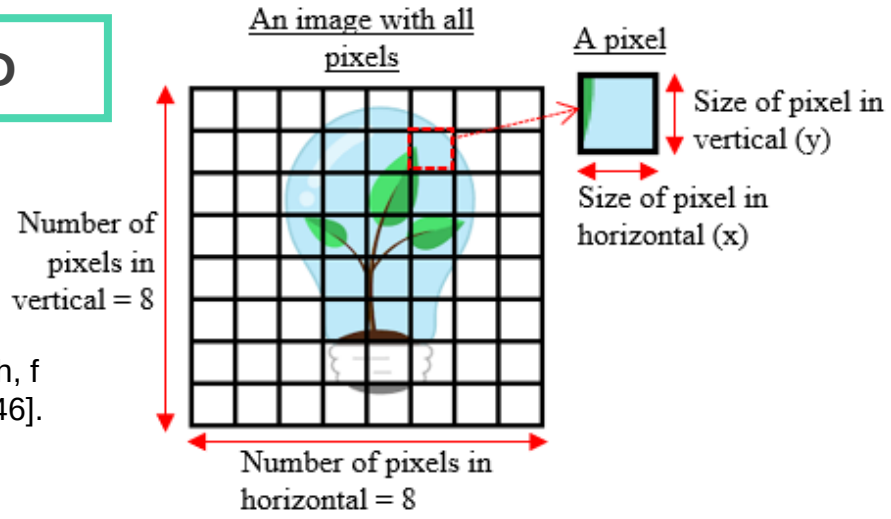
Other technical requirement:

- Temperature range: -40 °C to +50 °C
- Compatible interface
- Operating Voltage: 3.3 – 5 V
- Compatible & convenience features

THEORITICAL CALCULATION



GSD



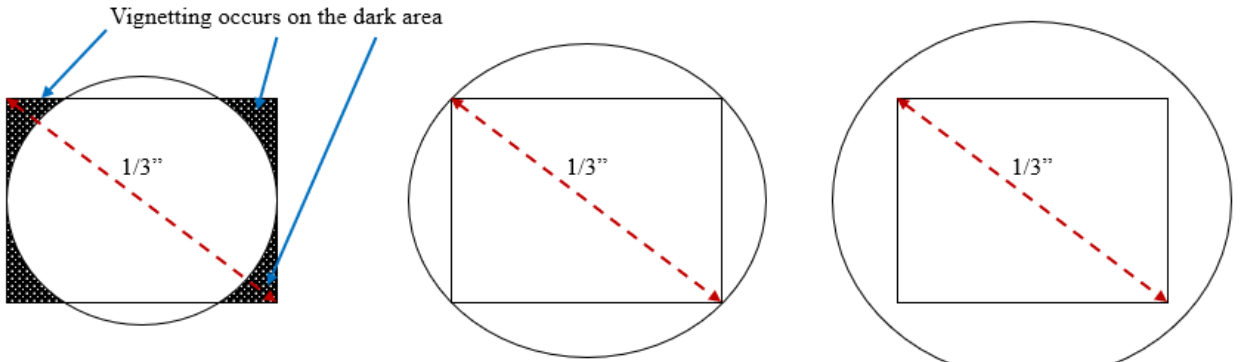
$$GSD = \frac{H}{f}(d) \quad ...(2.1)$$

GSD (in m) may be improved by varying focal length, f (in mm), altitude, H (in m), or pixel size, d (in mm) [46].

$$Field\ of\ View, FOV = 2 \times tan^{-1}\left(\frac{width\ of\ sensor}{2 \times focal\ length}\right)$$

$$Horizontal\ Field\ of\ View, HFOV = 2 \times altitude \times tan\left(\frac{FOV}{2}\right) \quad ...(3.2)$$

Lens:
- Mount type
- Optical format



1/4" optical lens mounted on 1/3" imaging sensor

1/3" optical lens mounted on 1/3" imaging sensor

1/2" optical lens mounted on 1/3" imaging sensor

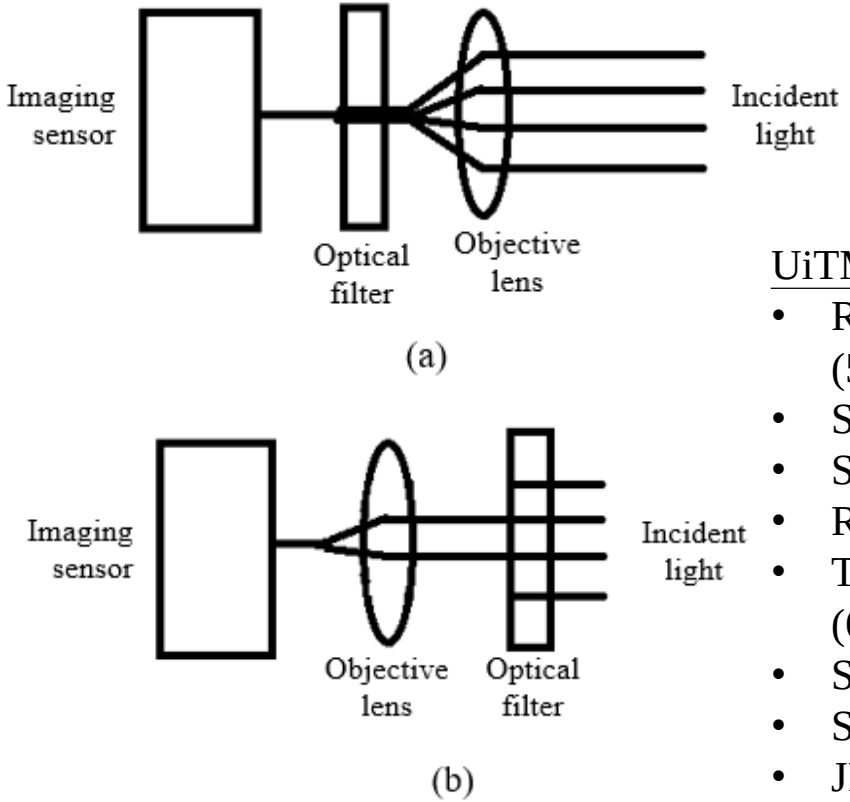
Example of Imagery with Vignetting Effect. Source from [32]

IR FILTER

Filter:
VIS = 465 nm to 630 nm
IR = 700 nm to 1 mm

(a) (b)

Source from furulevi



UiTMSAT-2:

- Resolution: 2592x1944 pixels array (5 MP)
- Spatial: GSD ~16 m @ 400 km
- Spectral: RGB (λ: 0.4 – 0.7 nm)
- Radiometric: 8 – 10 bits image data
- Temporal: 4 ~ 6 times/day (6~8 minutes/pass)
- Swath: FOV ~6° (41.5 x 31 km)
- Size ~1.152 MB
- JPEG compression

Image Data

$$Image\ Size\ (in\ bytes, B) = Array\ Size \times Bit\ Depth \times Channel \quad ...(3.6)$$

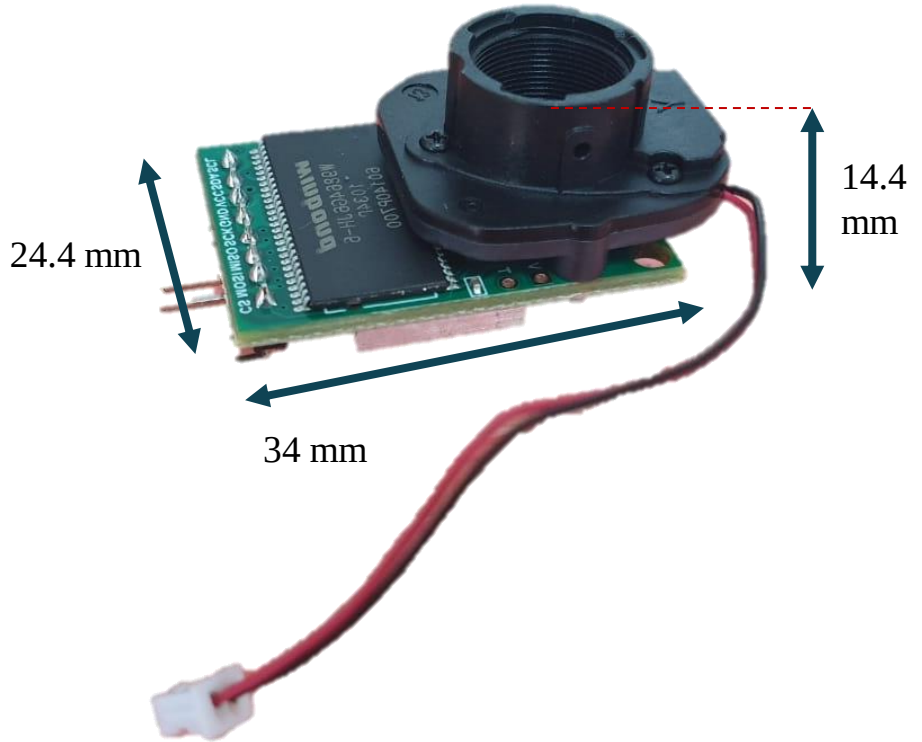
$$Data\ Rate\ \left(in\ {}^{bytes}/_{sec}, Bps\right) = Clock\ Rate\ (MHz) \times \sum bytes \quad ...(3.9)$$

SENSOR SELECTION

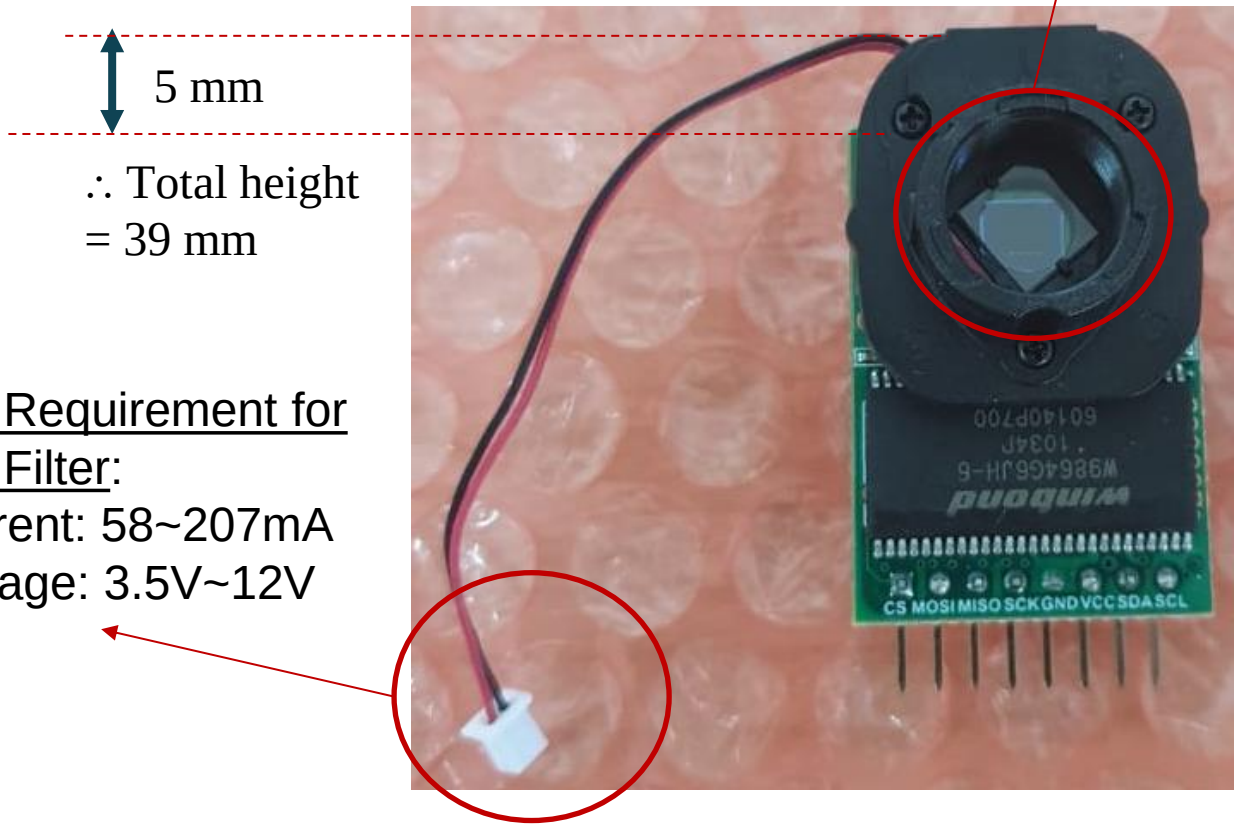
ArduCam OV5642 5MP

- Optical format
  - Lens format = ¼”
  - Lens mount = CS or M12

IR Cut Filter
Material: Glass



Mass = 8.1g (without lens)



Power Requirement for IR Cut Filter:

- Current: 58~207mA
- Voltage: 3.5V~12V

SENSOR SELECTION

Model	CMS-V	FFS-U3-16S2M-S /FFS-U3-16S2M-S(SONY IMX296)	FFY-U3-16S2C-S (SONY IMX296)	OV5642
Company	SILIOS Tech	FLIR	FLIR	ArduCam
Spectral Range	Color bands	Monochrome	Color	RGB
Spatial Resolution	-			
Array size (MP)	1.3	**1.58/1.6**	1.6	**5**
Power (W)	4.5	1.5/2.2	2.2	1
Size (mm) W x D x H	52 x 52 x 22	27x27x14	27x27x14.5	34x24x30
Volume (mm^3)	**59488**	**10206**	**10570.5**	**24480**
Weight (g)	**59**	**20**	**20**	**20**
Interface	USB 3.0	USB3.1	USB3.1	SPI,UART

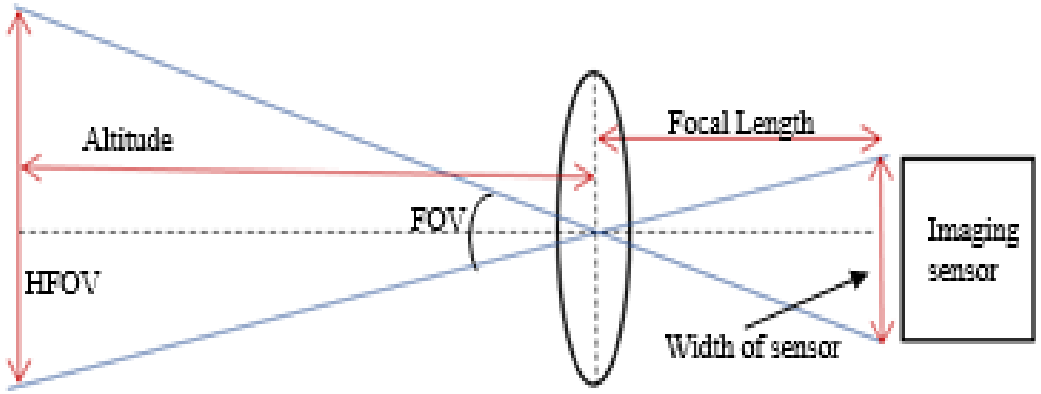
LENS SELECTION

ArduCam Lens

- Lens format = 1/1.7”
- Lens mount = M12
- FL = 35 mm
- FOV = 8° (H)
- Dimension: Φ22×29.3mm
- Weight: 15.4g (measured using scale)

CAMERA ATTRIBUTES

Parameter	VGA	HD	5 MP
Altitude, H		400 km	
Sensor Size (W x H)		3.6 x 2.7 mm	
Pixel Size, d (W x H)		1.4 x 1.4 μm	
Focal length, f		35 mm	
GSD*	16 m	16 m	16 m
Effective FOV (Viewing Angle)*	1.5°	4.5°	6°
HFOV x VFOV*	10.24 x 7.68 km	30.71 x 17.28 km	41.47 x 31.10 km



Acronym:

VGA – Video Graphics Array
HD – High definition
GSD – Ground Sampling Distance
FOV – Field of View
HFOV – Horizontal FOV
VFOV – Vertical FOV

LENS ATTRIBUTES

Focal Length	35 mm	25 mm	4.9 mm
Altitude, H		400 km	
Sensor Size (W x H)		3.6 x 2.7 mm	
Pixel Size, d (W x H)		1.4 x 1.4 μm	
GSD*	16 m	22.4 m	114.29 m
FOV*	5.94°	8.30°	40.64°
HFOV x VFOV*	41.47 x 31.10 km	58.01 x 43.55 km	296.23 x 222.17 km
Weight of Lens	15.4 g	8.2 g	1.2 g
Total Weight (with sensor)	23.5 g	16.3 g	6.7 g
Mechanical Size	Φ22×29.3mm	Φ17×21mm	Φ13.8×12.73mm

CAM BOARD

Mission Board 1 (Optional: additional missic

Battery Box

On-Board Computer (OBC)
Electrical Power System (EPS)

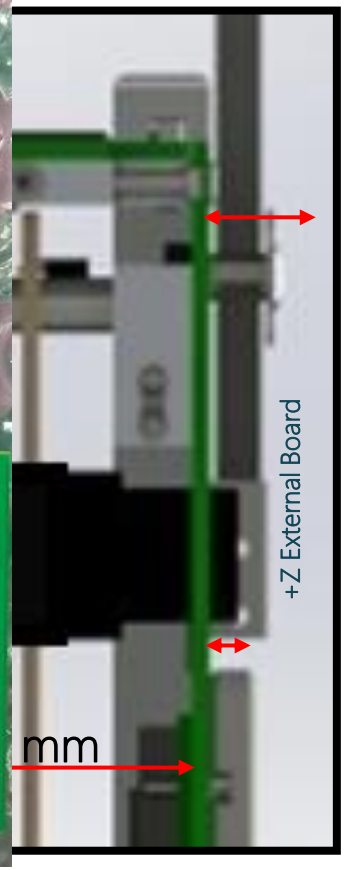
Communication Board (COM)

Mission Board 2 (ADCS, SFWARD & CAM)

+Z

-X

Board (RAB)



6.5mm (allowable absolute maximum extrusion)

2.5mm (nominal extrusion for camera lens)

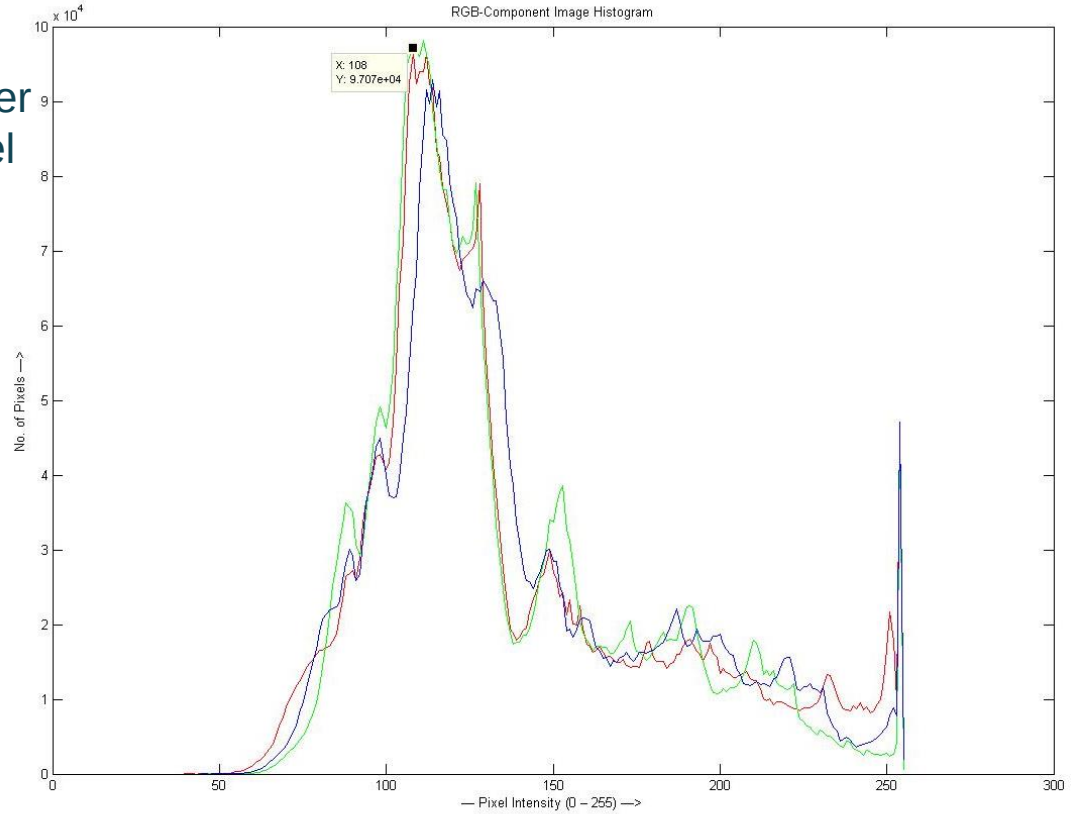
(Mission board to external board)

CAM MISSION TEST

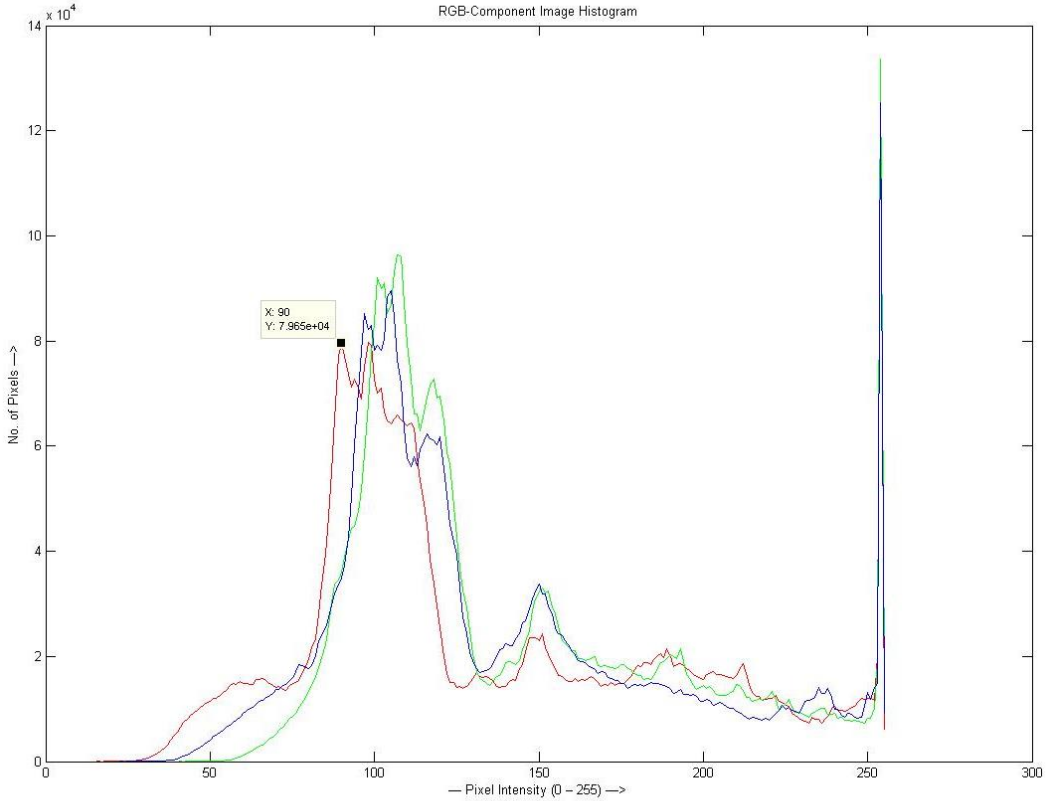
Before IR filter is turned on.

After IR filter is turned on.

CAM MISSION TEST



Before filter is turned on.



After filter is turned on.

Number of pixel

Brightness level

CAM MISSION TEST

SNR Measurement

$$SNR = \frac{\mu}{\sigma}$$

μ: average value of the brightness level

σ: standard deviation of the brightness

Without IR Cut Filter

SNR = 29.4216 dB

With IR Cut Filter

SNR = 31.5173 dB

SNR improved with application of IR Cut Filter. IR ray has become the noise to the image and reduced the accuracy of RGB color distributions.

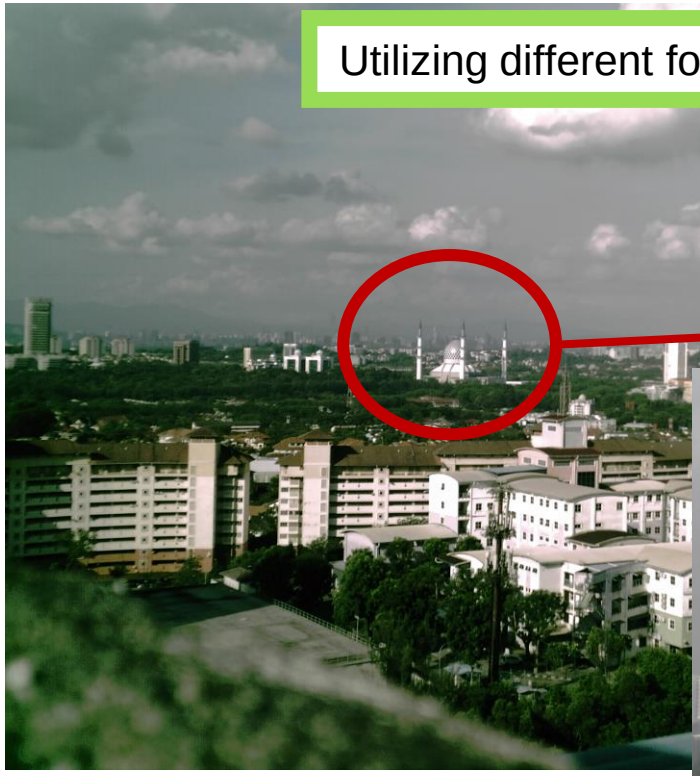
CAM MISSION TEST

OV5642 with 4.9 mm EFL default lens.

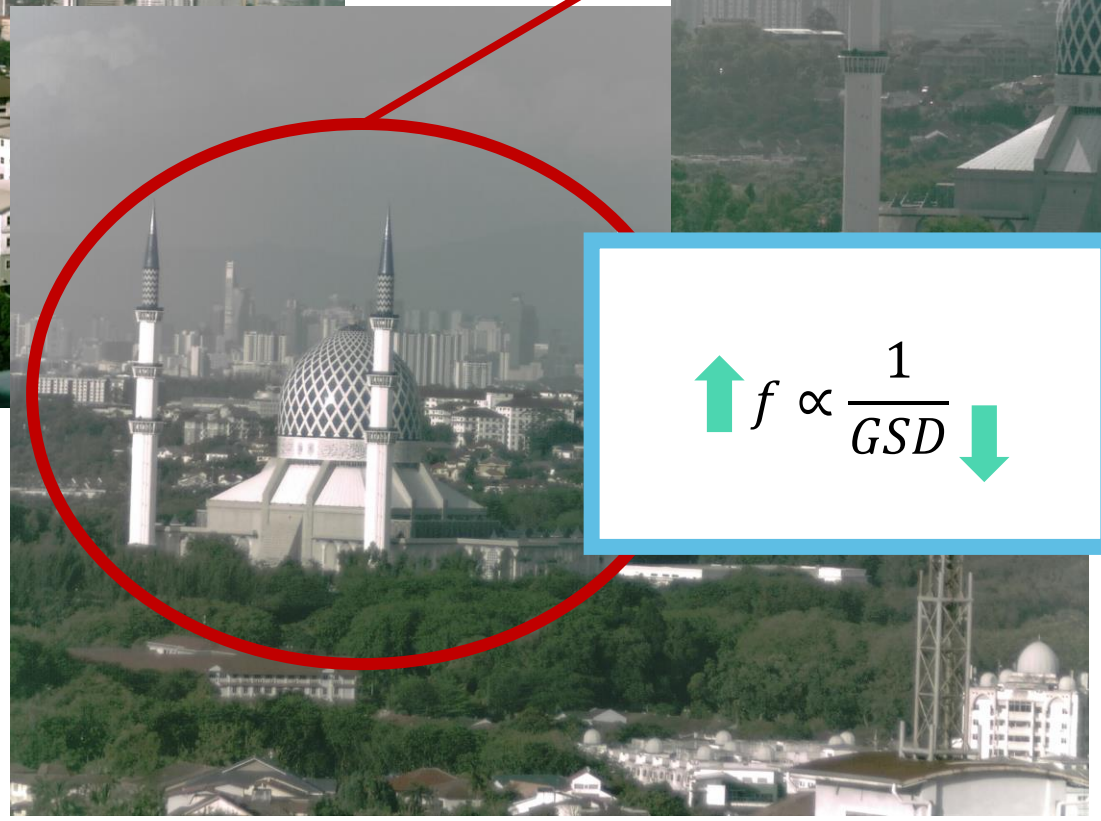
OV5642 with 35 mm EFL lens.

CAM MISSION TEST

Utilizing different focal length lenses produced different GSD and FOV at similar working distance, 2.7 km

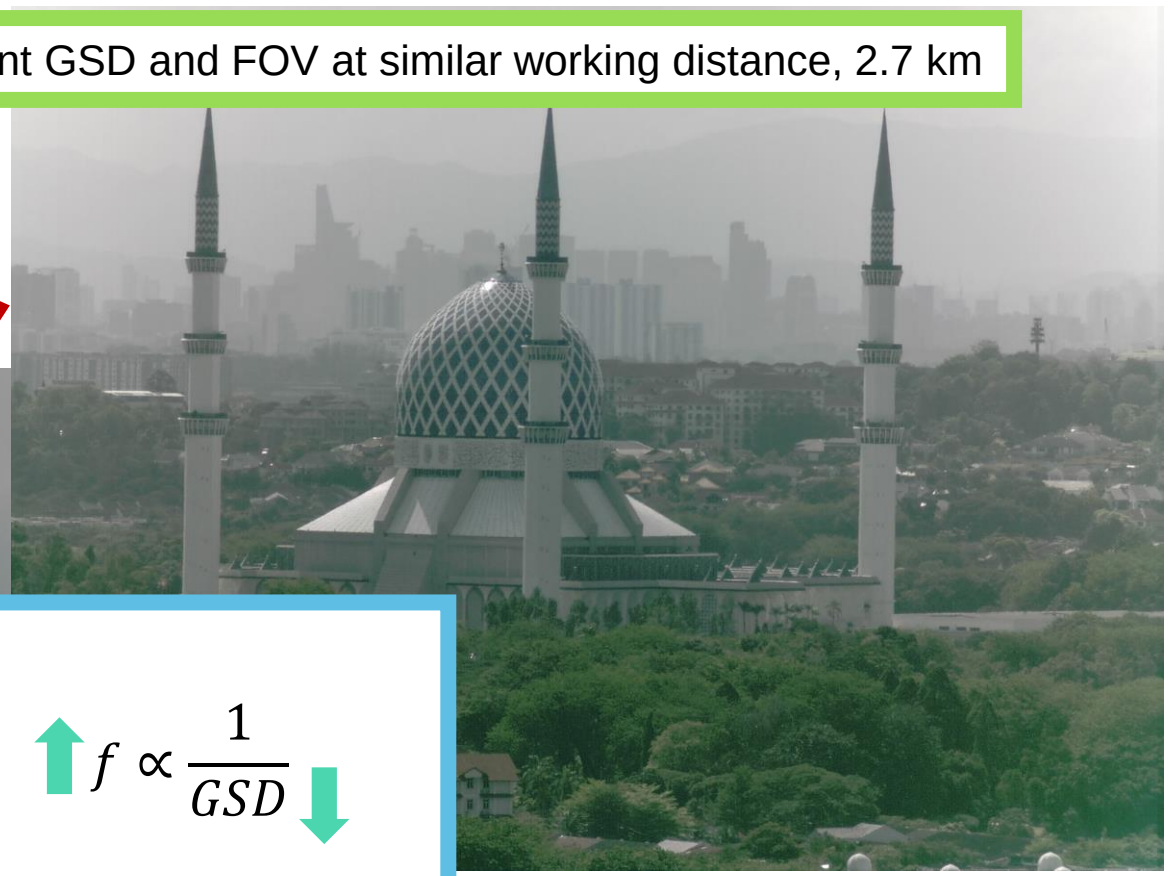


Focal Length : 4.9 mm
Size: 604 kB
GSD: 0.7714 m



Focal Length : 25 mm
Size: 548 kB
GSD: 0.1512 m

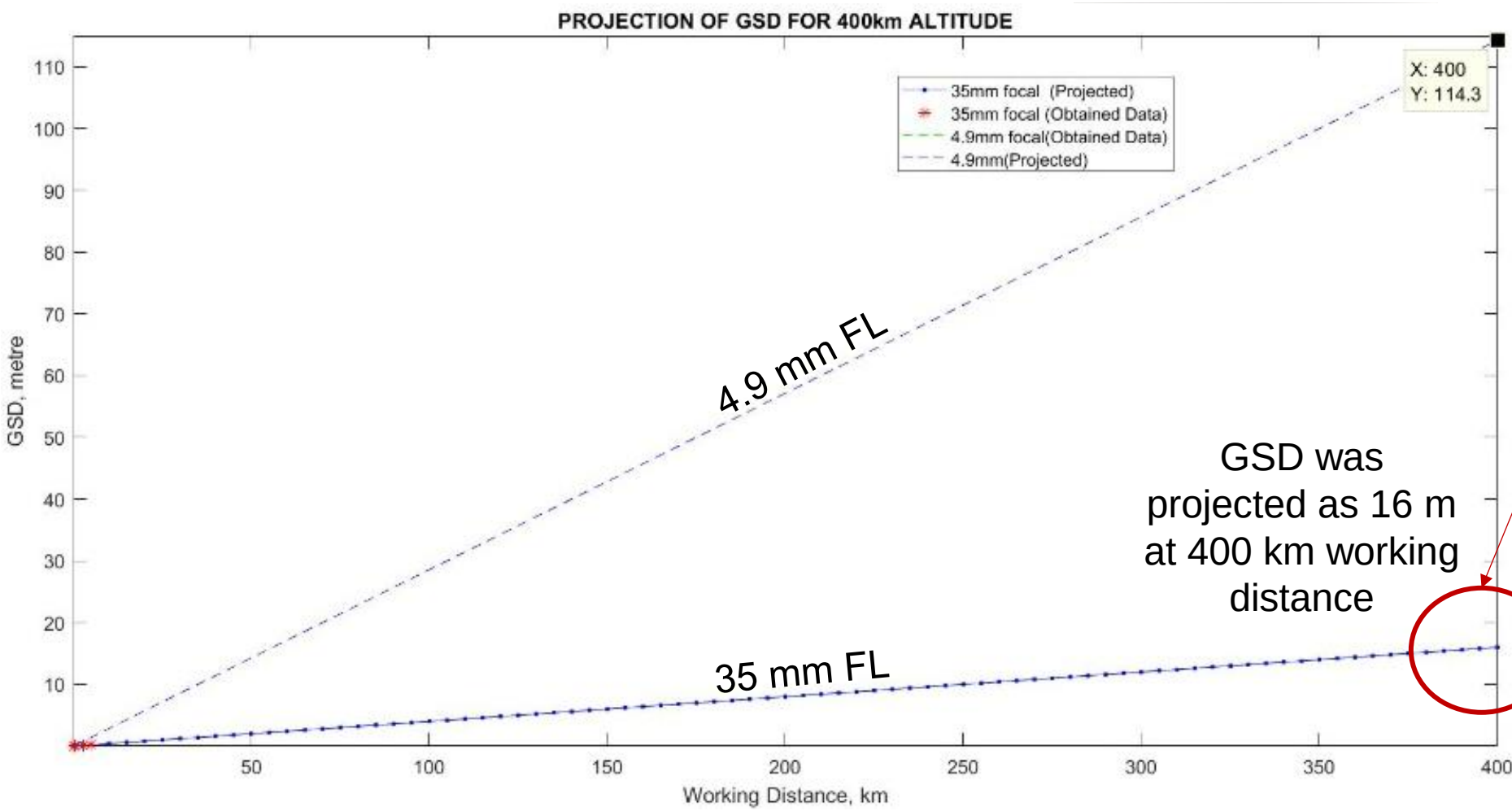
$$\uparrow f \propto \frac{1}{GSD} \downarrow$$



Focal Length : 35 mm
Size: 540 kB
GSD: 0.108 m

CAM MISSION TEST

35 mm FL at various working distance, H



GSD was projected as 16 m at 400 km working distance

$H \propto GSD$

$H = 4.9$ m

$GSD = 0$

High ground/ spatial resolution

THANK YOU

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