University Space Engineering Consortium

Overview of Aoba VELOX-IV Missions; Pulsed Plasma Thruster Attitude and Orbit Control and Earth-rim Night Image Capture for A Future Lunar Mission

Presented by:

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  - Mission overview
- System requirements
  - Camera module
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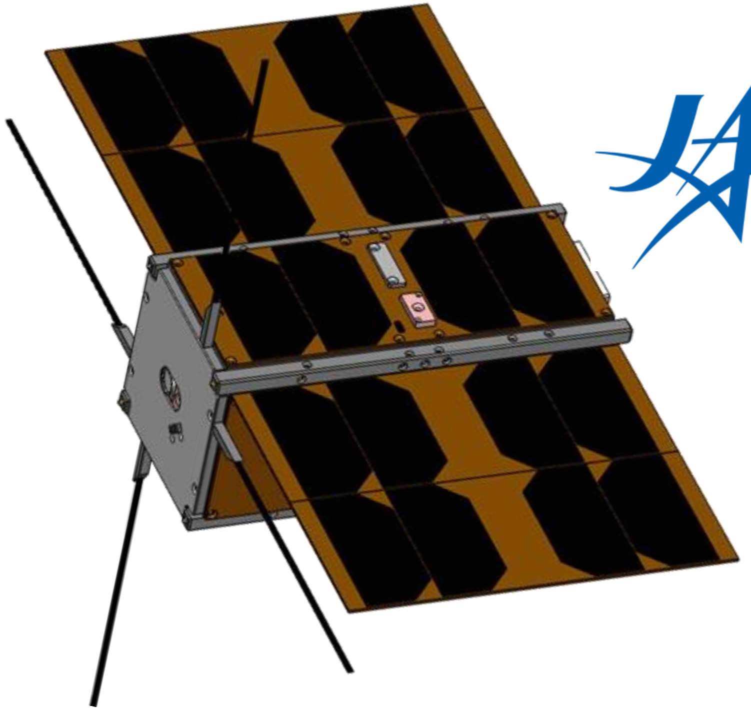
Aoba VELOX-IV

- A **two-unit CubeSat** developed in collaboration with **Nanyang Technological University**, Singapore and **Kyushu Institute of Technology**, Japan.
- **Technology demonstration satellite** for a future **lunar mission in LEO**.
- AV4 will be **launched by JAXA in 2018** (to be confirmed), and AV4 mission will be supported by a ground station network placed in Japan, Taiwan, Singapore and Mongolia.



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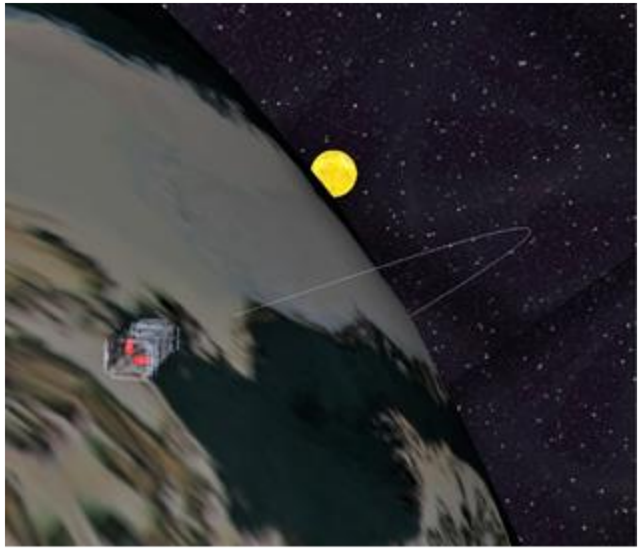

PURPOSE:

TECHNOLOGY DEMONSTRATION IN LEO ORBIT

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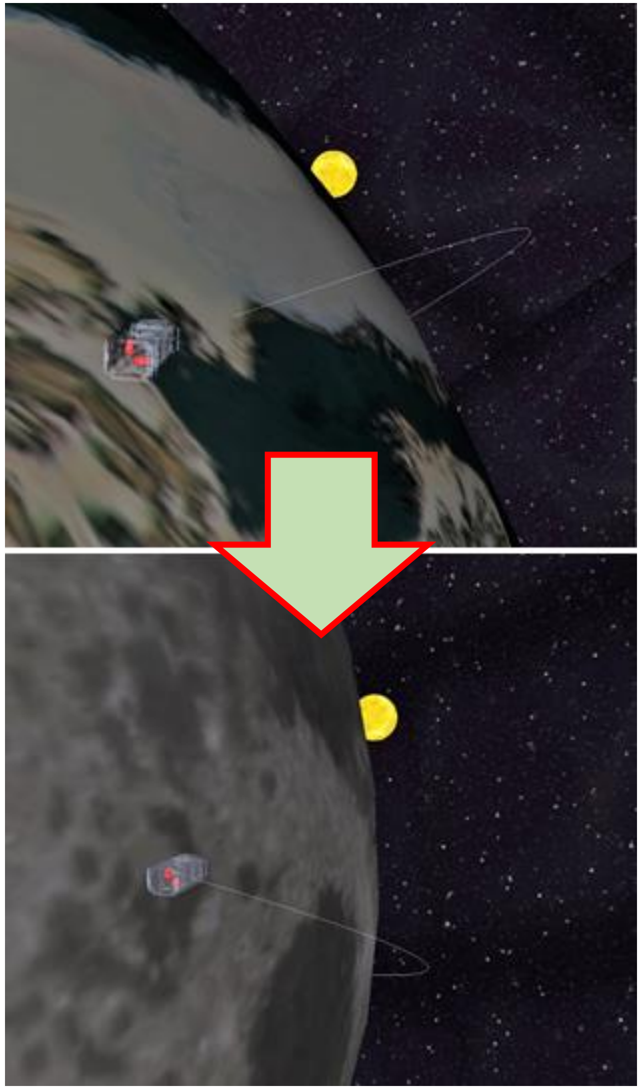

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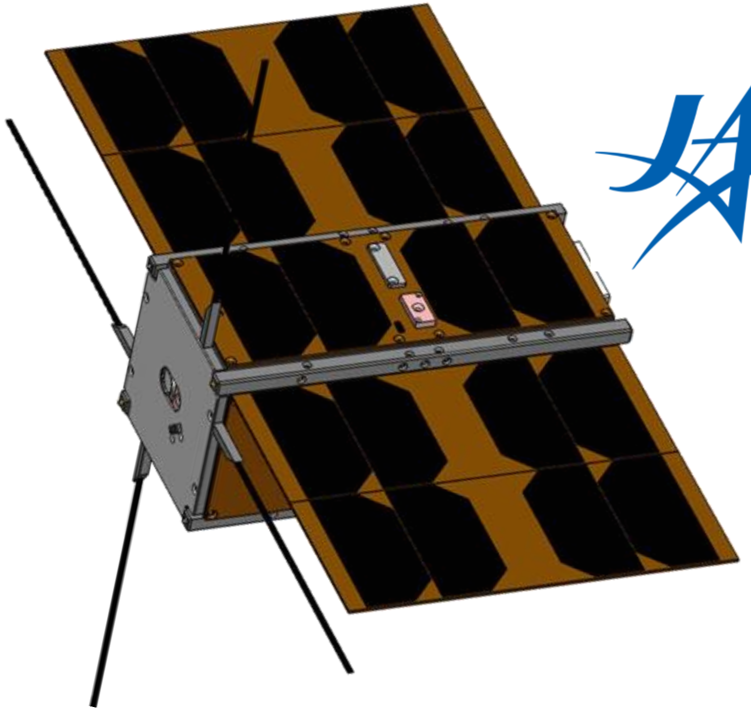
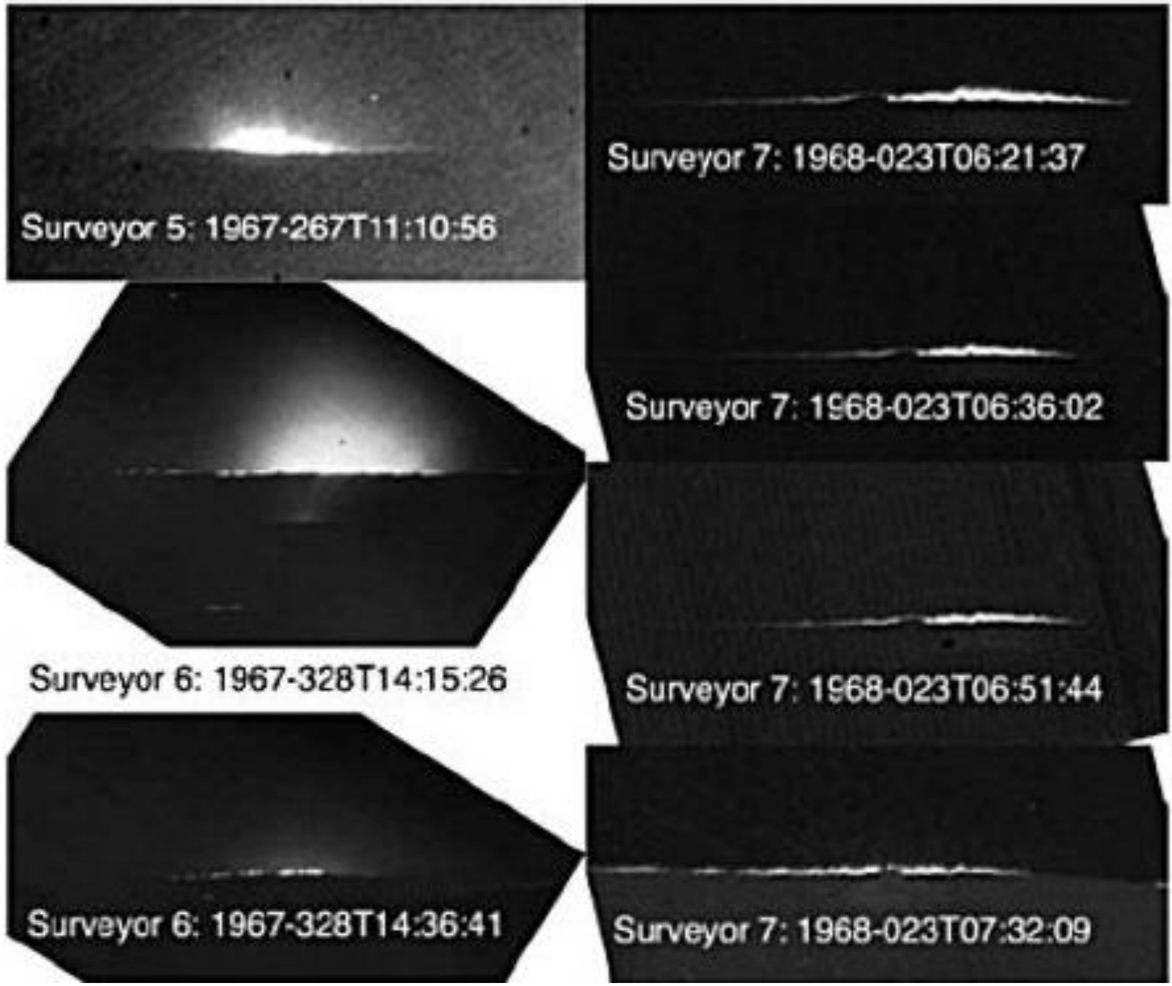


Aoba VELOX-IV and the future lunar mission

- Detection of the lunar horizon glow (LHG).
  - **First spotted in 1966 and 1968** by on-board cameras on **Surveyor missions**.
  - **Apollo astronauts saw it** and made drawings from their observations.
  - The **Lunokhod-II** astrophotometer **detected a brighter twilight** as expected.
  - **High-varying phenomena** different levels of luminosity reported from further lunar missions
  - **LHG causes are still investigated**



NASA photos, Criswell, 1973; Rennilson and Criswell, 1974; Colwell et.al.,2007

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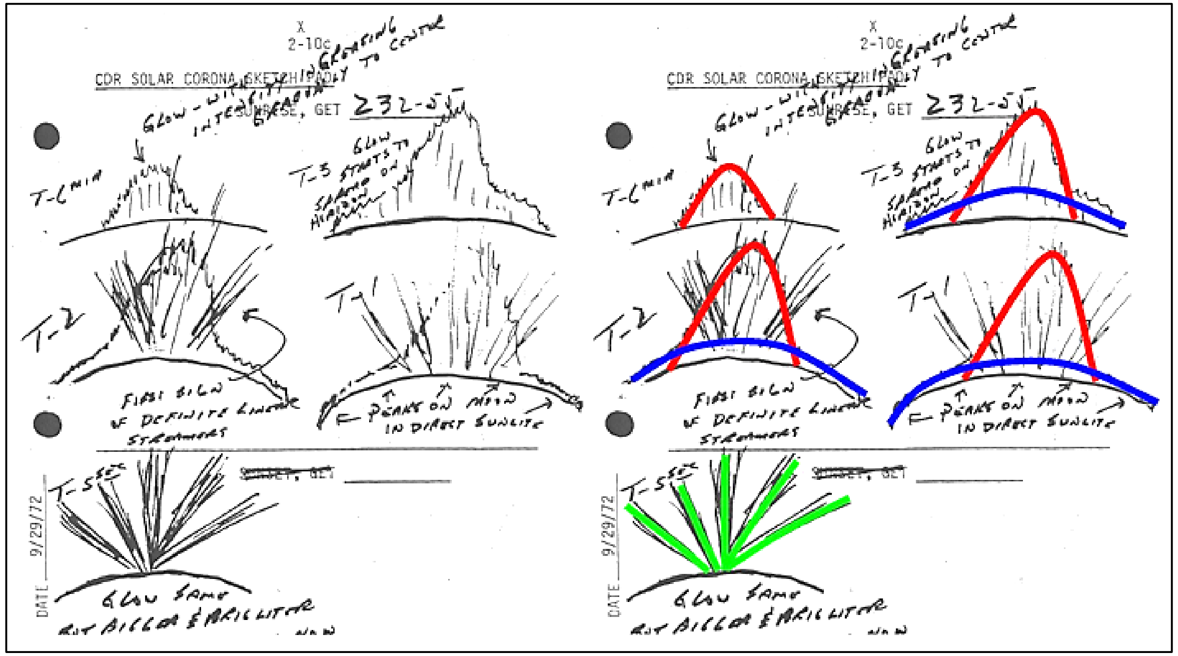

Stubbs, T. J. et.al. 2007. A sketch by Apollo 17 astronaut Eugene Cernan. Coronal and Zodiacal Glow in Red Line (CZG), Lunar Horizon Glow (LHG) in blue line, crepuscular rays in green lines formed by shadowing and scattered light.

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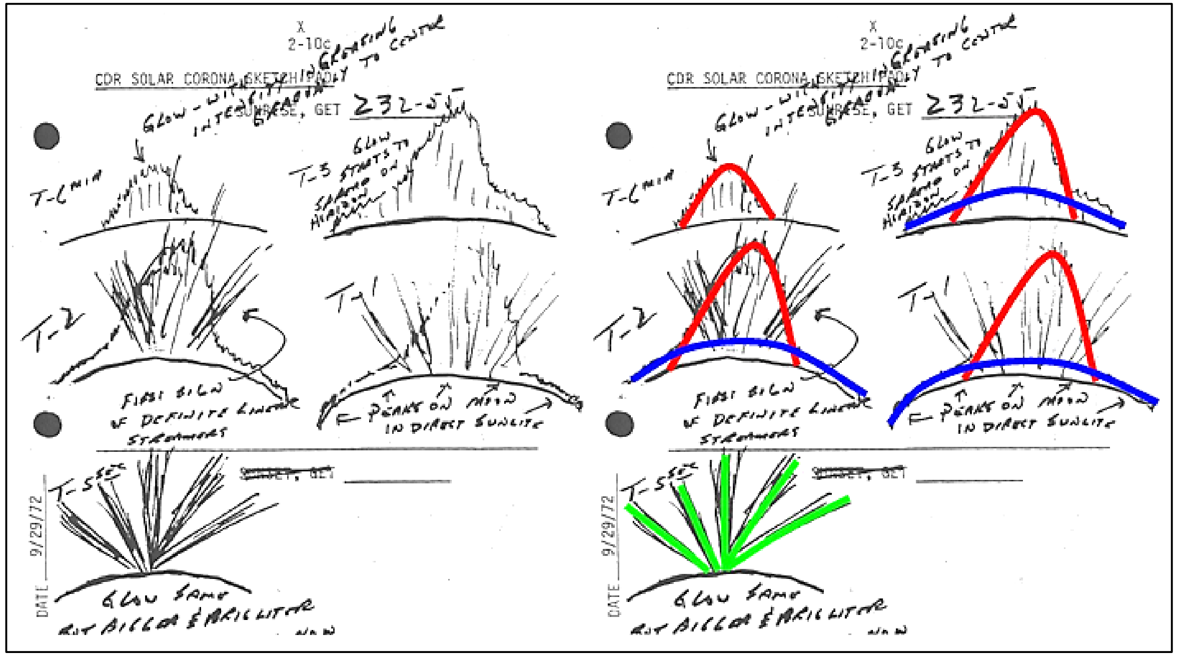

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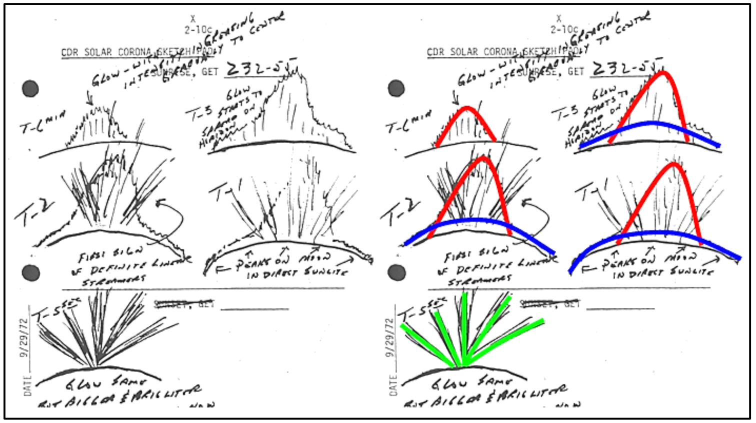
Aoba VELOX-IV as technology demonstration satellite

- LHG different intensity levels:
  - Apollo: 0.2-20 lux
  - Surveyor: 60-2600 lux



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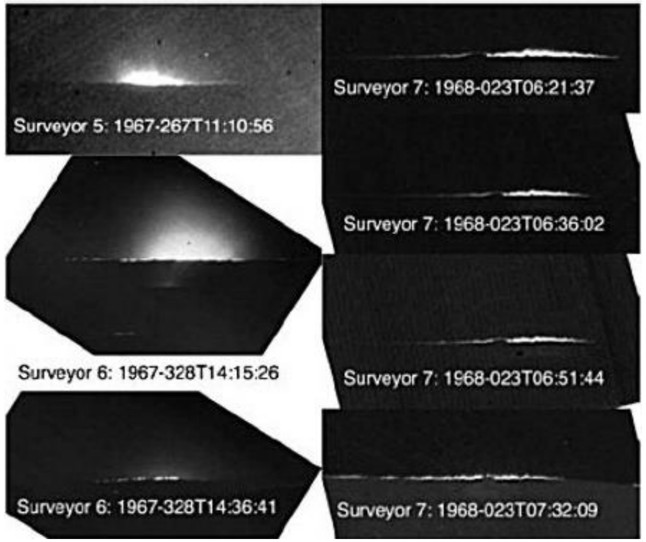

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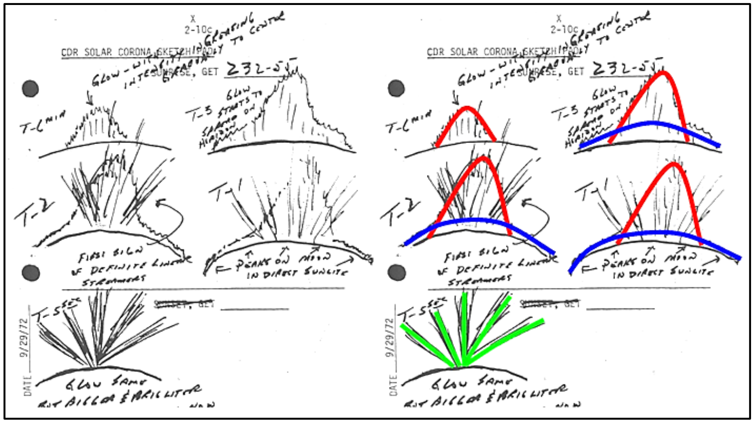
- Choose of a low-light camera



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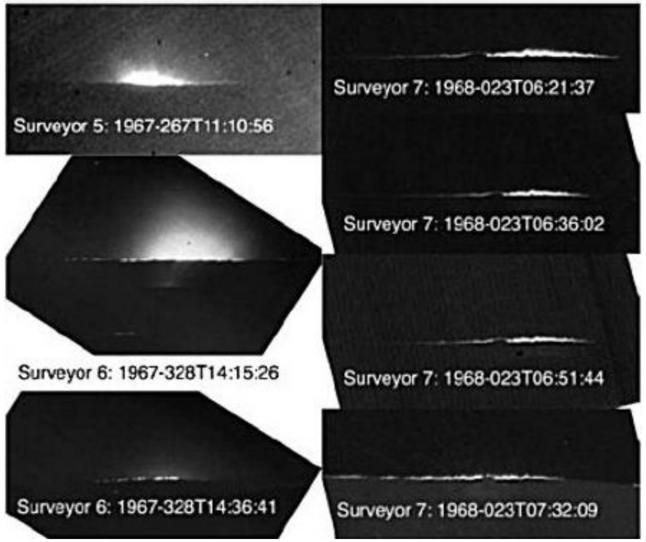

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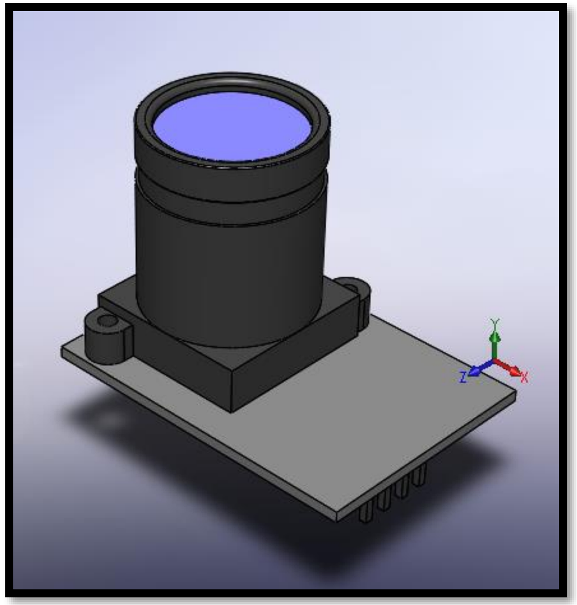
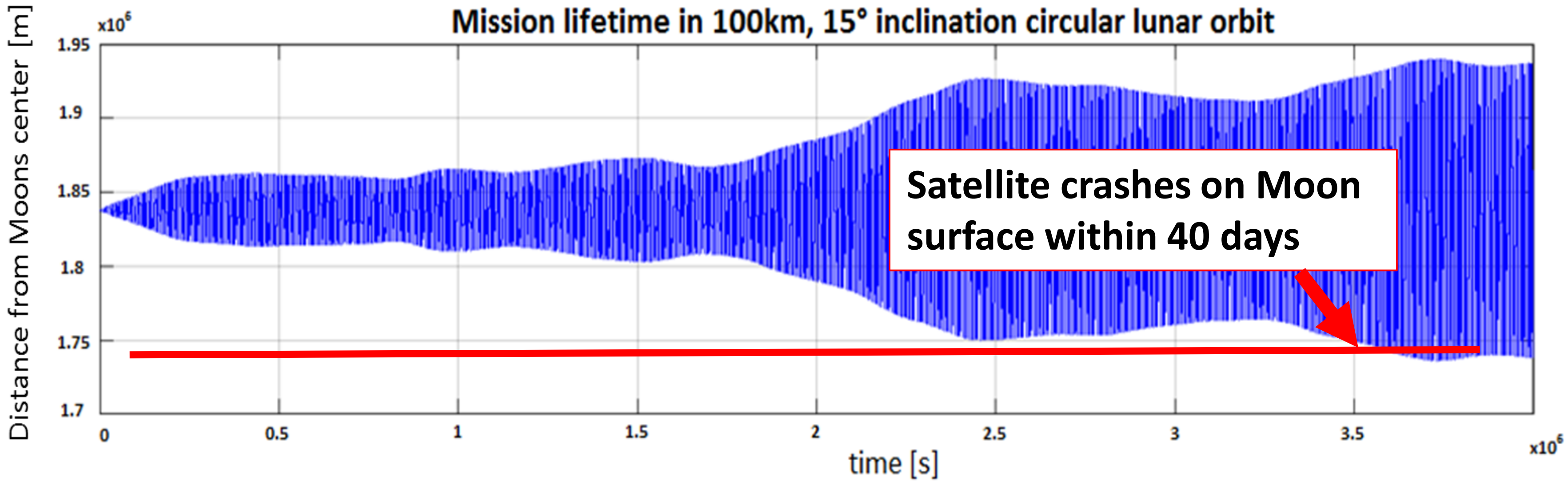


CAD Drawing of the Camera Module (Kyutech).

Aoba VELOX-IV as technology demonstration satellite

- Irregular lunar gravity field, orbit maintenance required to extend its mission lifetime



Mission lifetime analysis without orbit maintenance (Kyutech)

Aoba VELOX-IV as technology demonstration satellite

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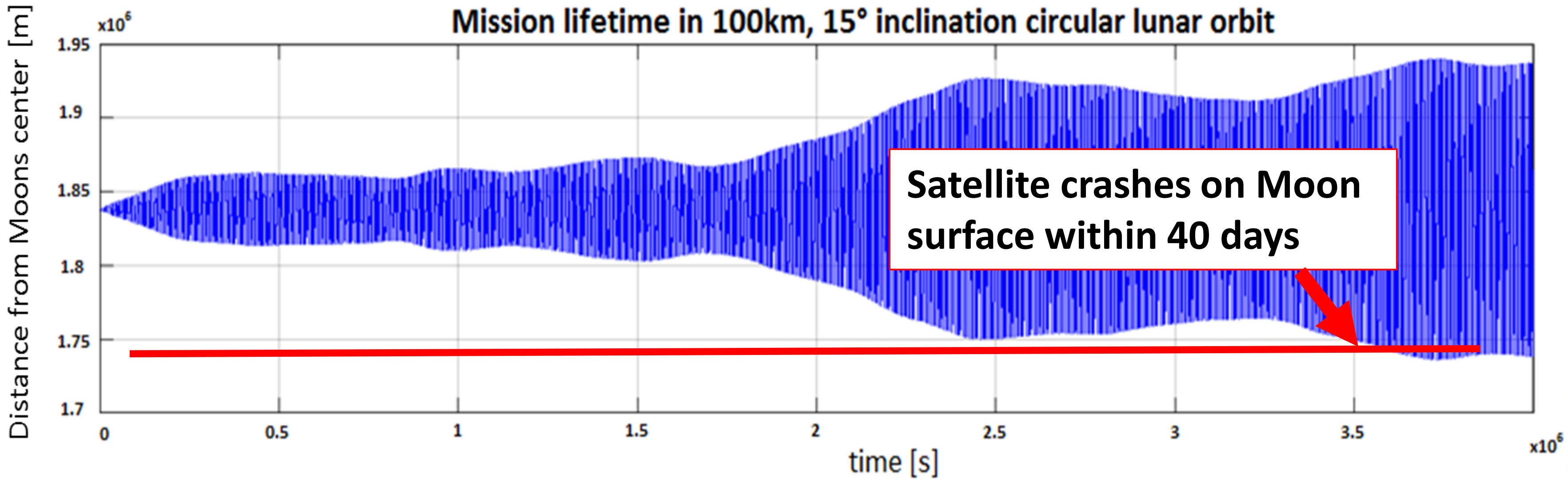
- Pulsed plasma thrusters developed by NTU
- AOCS software developed by Kyutech



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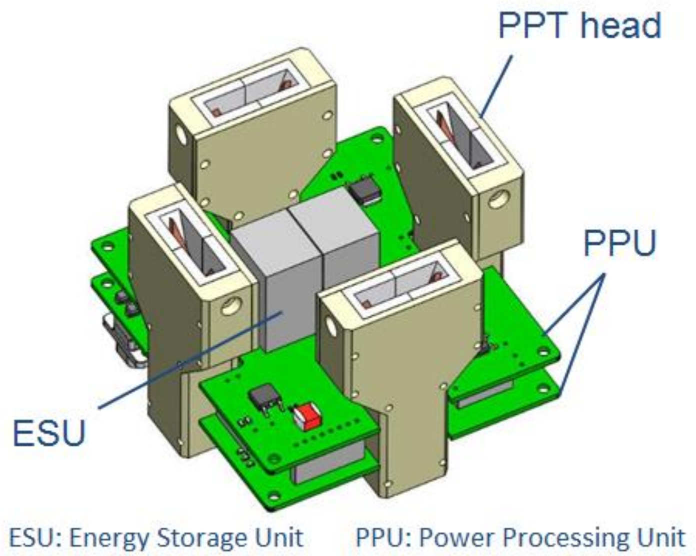


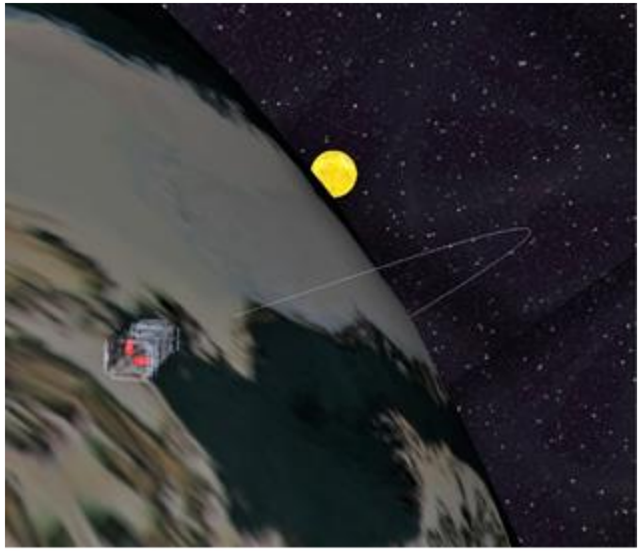
CAD Drawing of the PPT (NTU).

Camera requirements

- The objective of camera payload can be given as:

Earth Mission:

- Earth-rim
- Night view and aurora
- Horizon detection



PURPOSE:

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- Payload requires
  - a small size and mass
  - a circuitry to compress raw images to JPEG format
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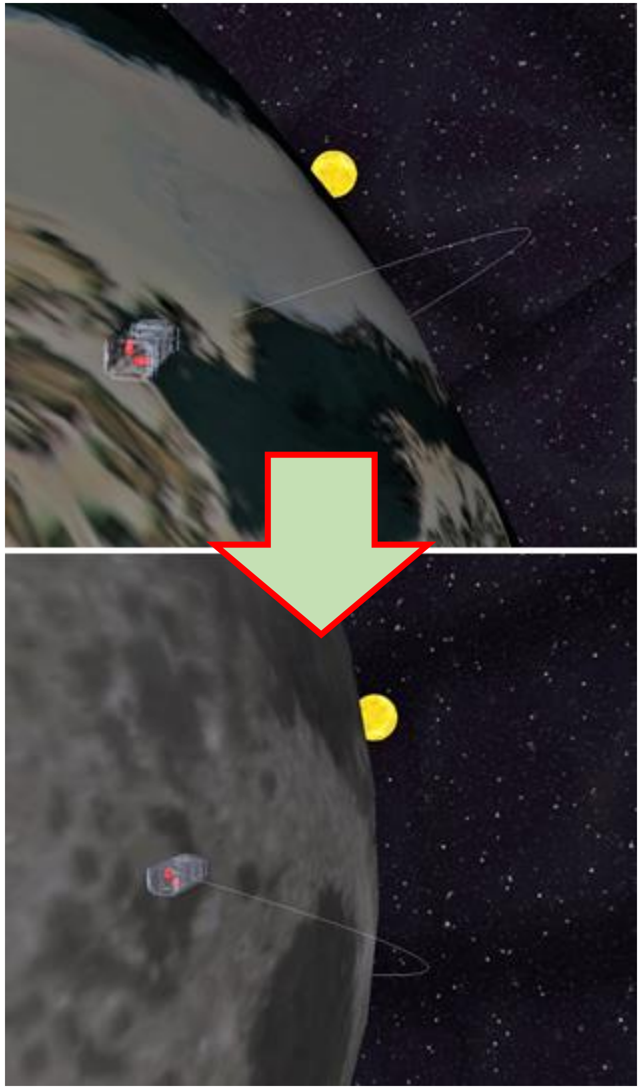

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Specifications	Requirements
Mass	< 0.2 kg
Volume	< 0.1U
Maximum Resolution	VGA
Sensor Type	CMOS or CCD
Field of View	>40^o
Minimum Luminosity	0. 015 Lux
Sensitivity	3.0 V/Lux-sec and higher
Exposure Time	0.033 sec
Operation Temperature Range	-10 to 50 ^oC
Interfaces	UART, SPI, I2C
Possible Secondary Operation	Horizon Detection

AOCS requirements

- Pointing towards horizon
  - Images from Sunset
  - Images from Earth rim in night side
- Orbit maintenance capabilities
  - Demonstrate orbit maintenance capabilities
  - About 60m/s as Δv orbiting maneuvering.
- Momentum dumping by PPT
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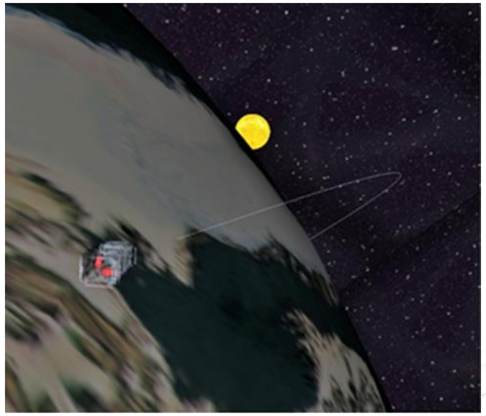
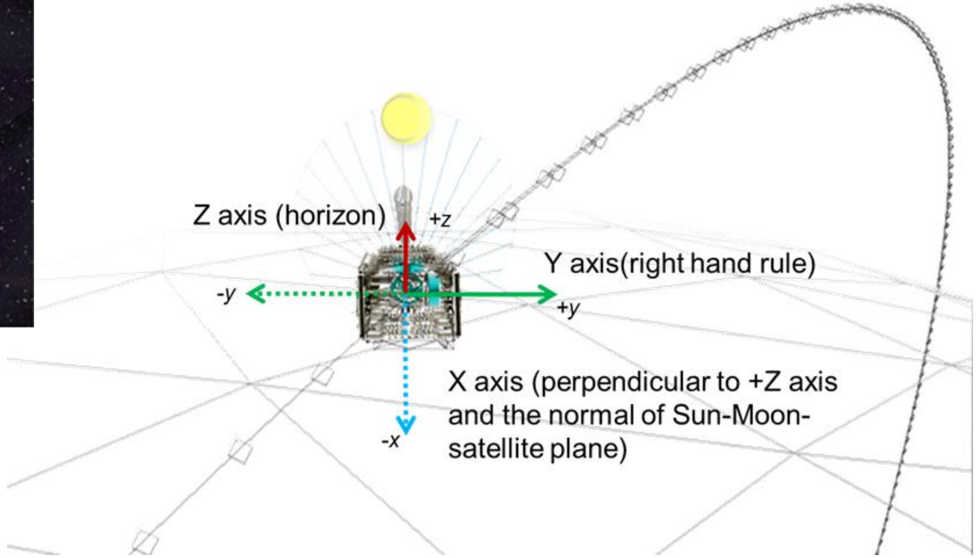
  - 0.0001Nms angular momentum reduction via PPT
- Desaturation of reaction wheels by PPT



Earth rim / sunrise /sunset reference frame



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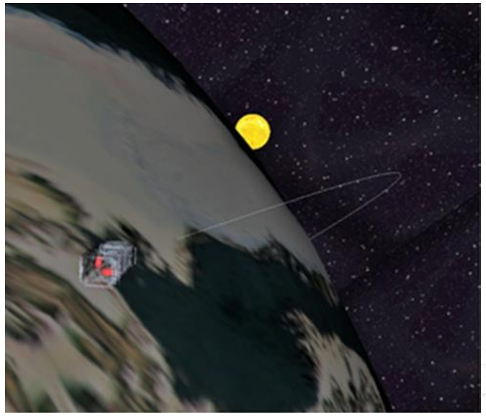

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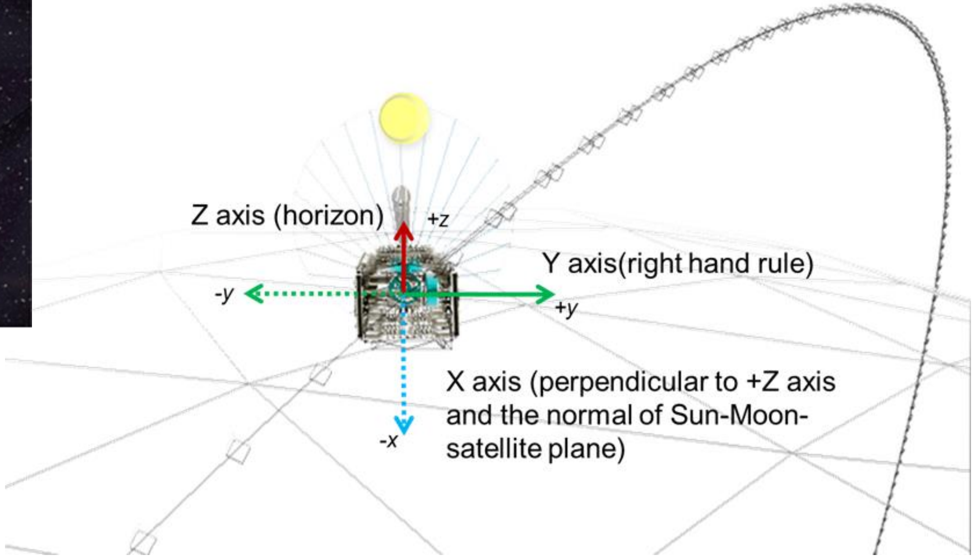

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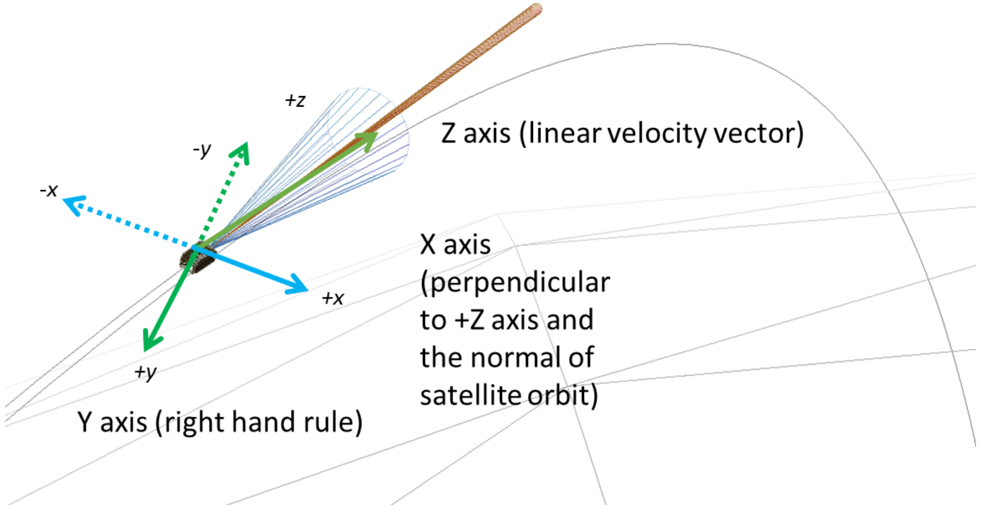

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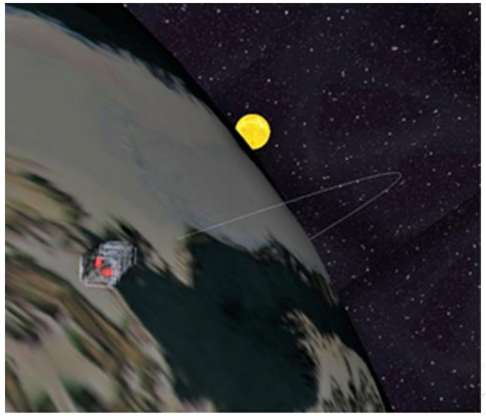

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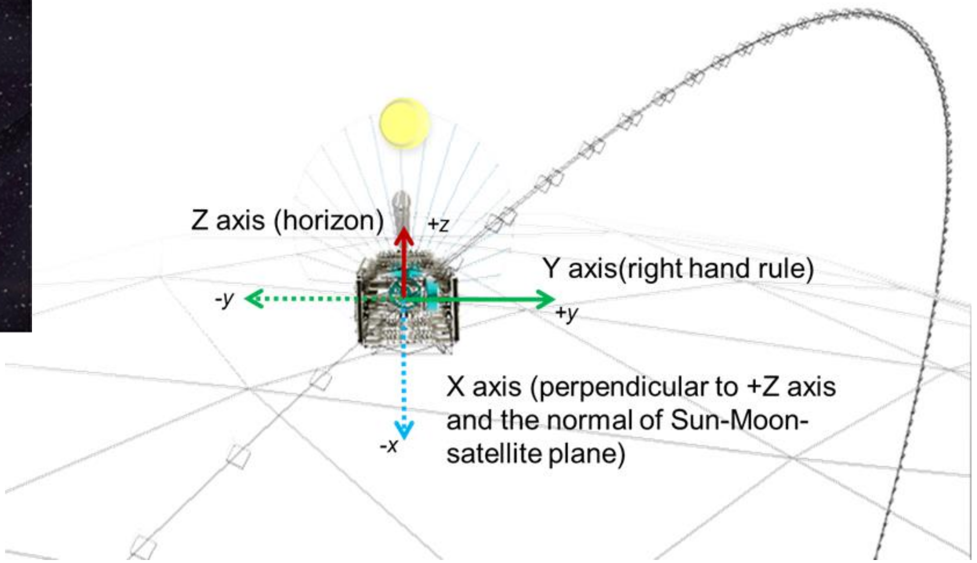

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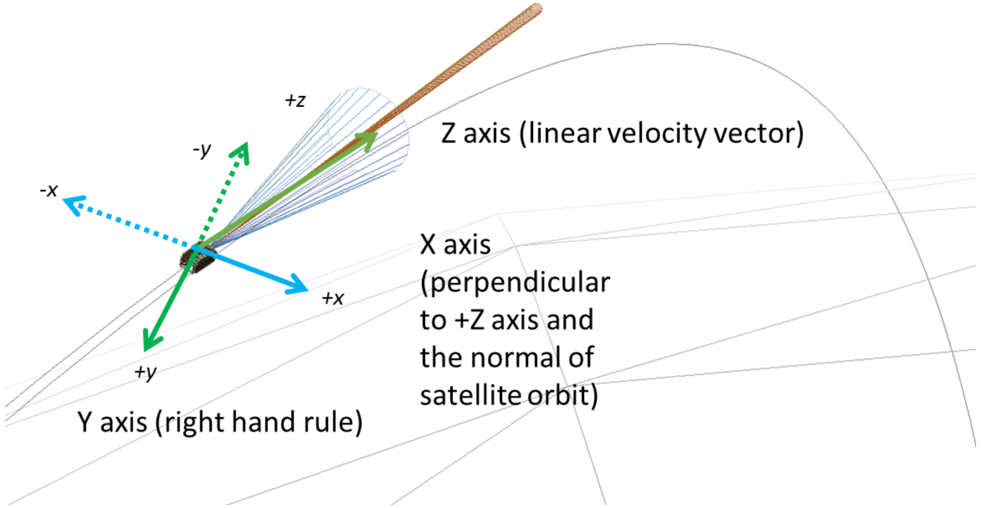

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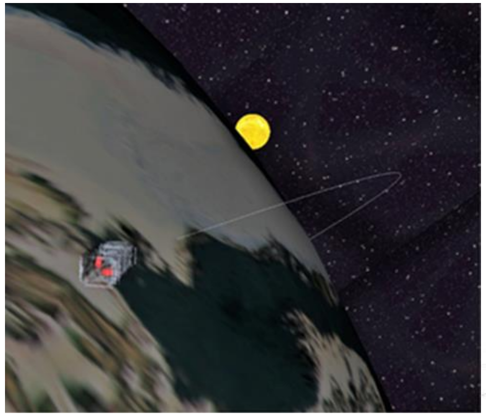

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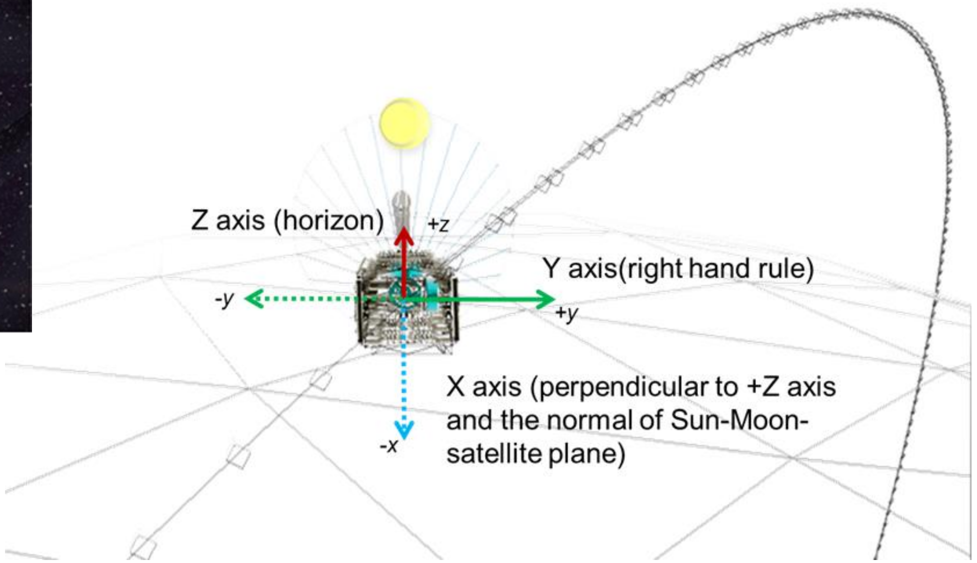

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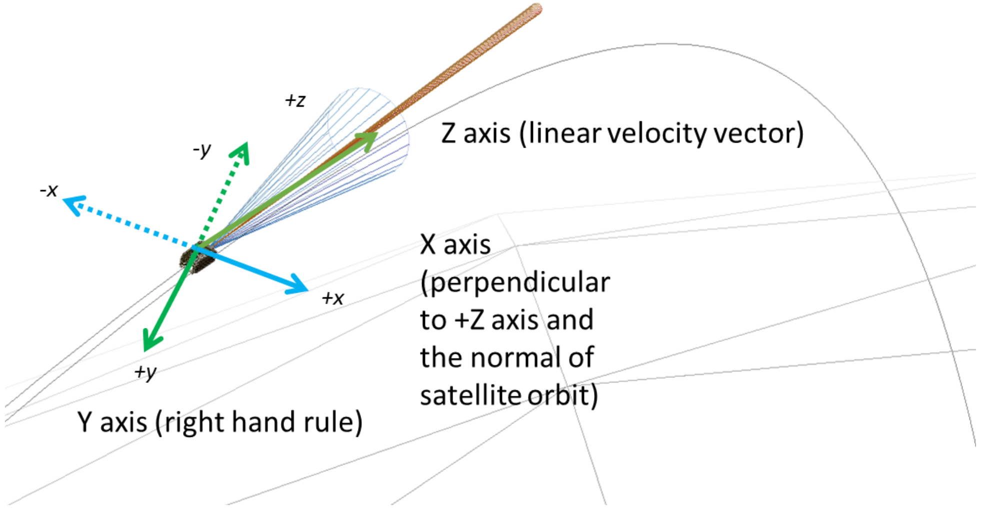


Camera system overview

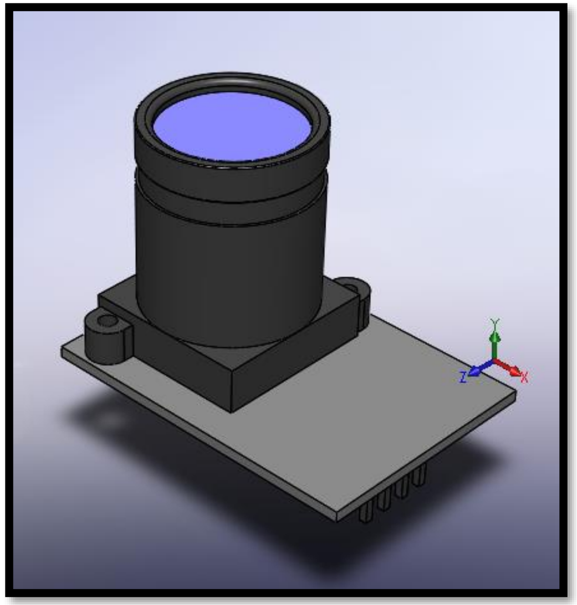
A high number of COTS cameras has been considered.

- ***the interface and light sensitivity requirements*** eliminated most of the candidates.
- the ***power consumption and size requirements*** were effective for the selection as well.

The payload has been determined as C329BW camera module.

Camera Specifications.

Camera	**C329BW**
Resolution	640x480
Sensor Type	1/4" OmniVision VGA sensor
Sensitivity	3.8 V/lux-sec
Power Consumption	264 mW
Mass	6 g
Size	20 x 28 x 25 mm
Interface	UART
Sensor S/N Ratio	50 dB
Dynamic Range	60 dB



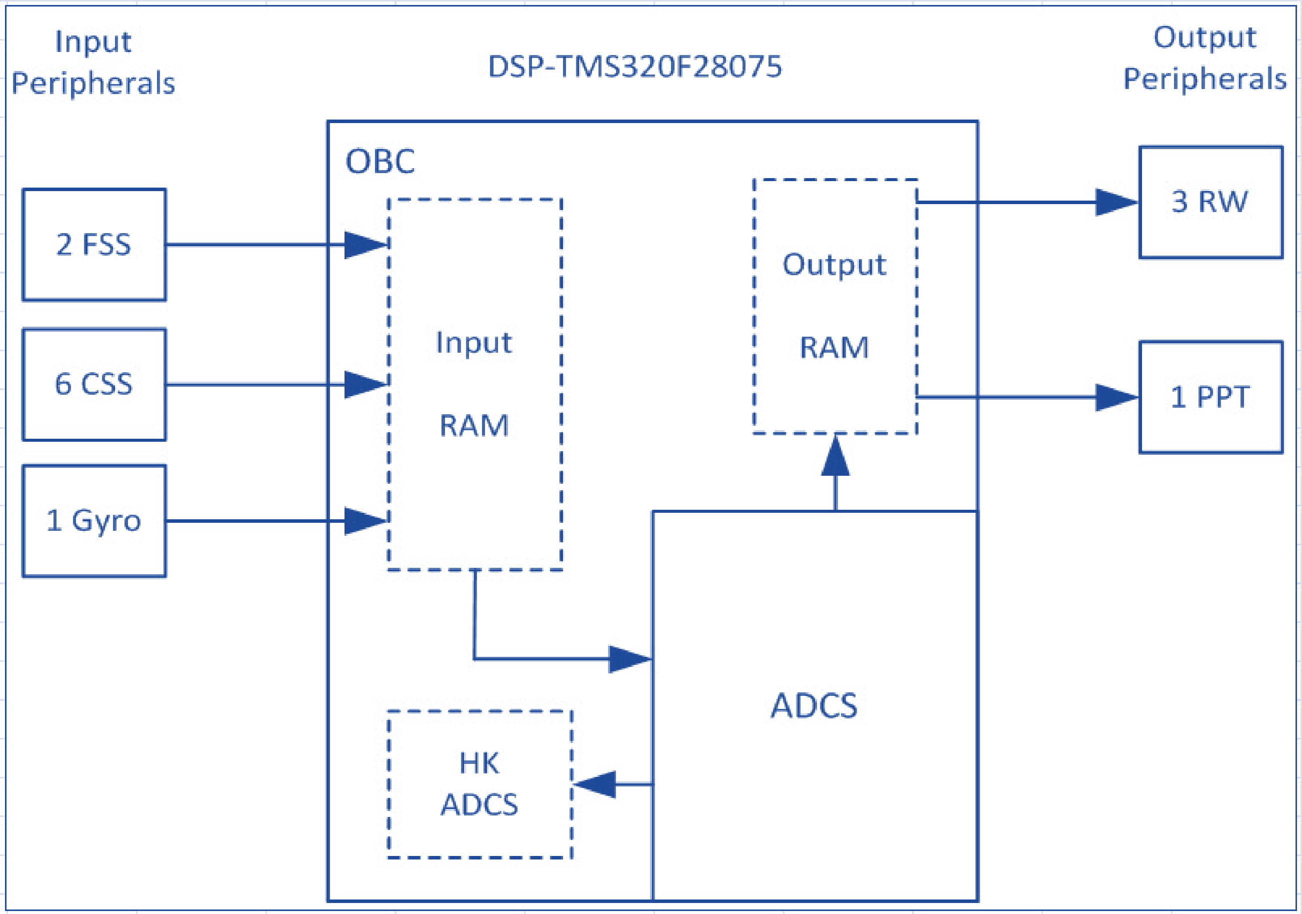
CAD Drawing of the Camera Module (Kyutech).

AOCS overview

Due to mass restrictions, minimum required hardware for two-axis stabilized satellite will be used

AOCS software will be embedded into a DSP based on-board computer

Hardware	Features
Coarse sun sensors	**Six SLCD-71N8** coarse sun sensors distributed along the satellite body. 60° half angle.
Fine sun sensors	**Two GOM Space NanoSense FSS-4** fine sun sensors placed in -z and -x axis. 60° half angle.
Gyroscope	**One three-axis gyroscope ICG20330** from inventsense, with a noise of 5 mdps/√Hz.
Reaction Wheels	**Three reaction wheels aligned with x, y and z axis**, angular momentum 2gm2s-1 at 4800 rpm.
Pulsed Plasma Thrusters	Four heads placed in +z satellite face, operation frequency at **1 Hz**, **25.20322 μNs as impulse bit and 60[m/sec] as maximum Δv**.



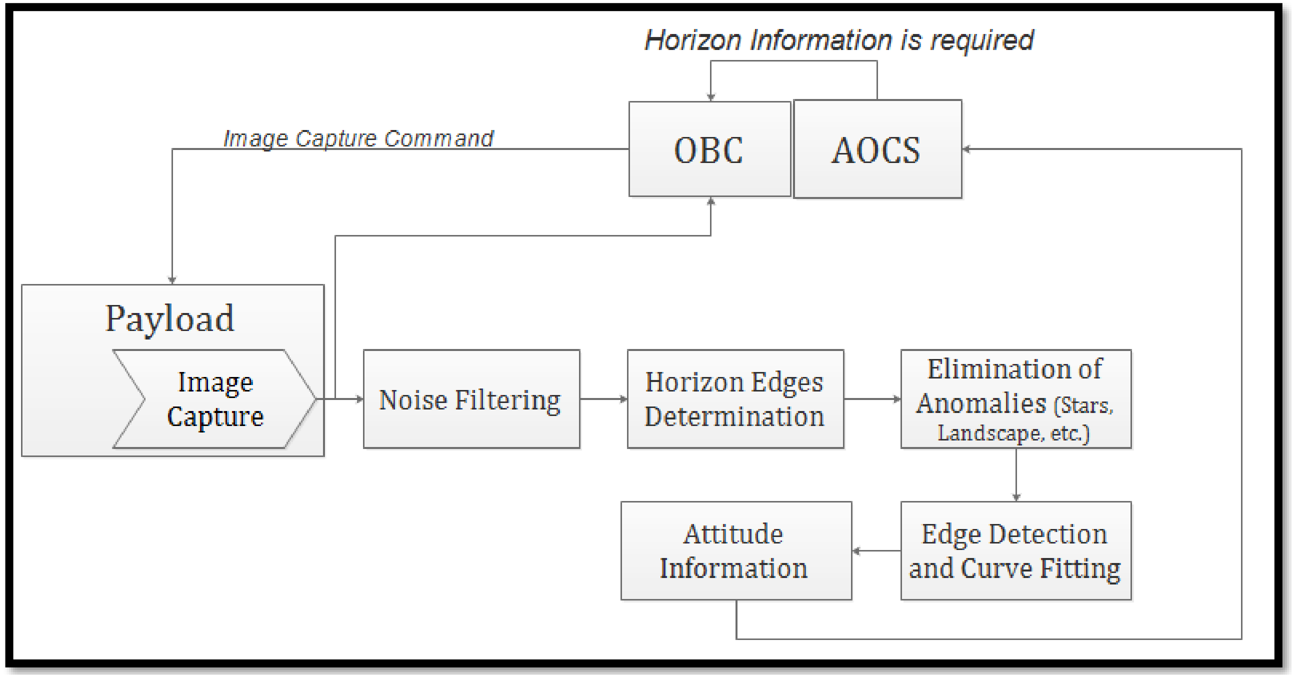
Camera system software

Image acquisition

Time period: less than 2 sec
- 25 msec SYNC x 2
- 33 msec Transfer
- 33 msec Exposure
- Less than 1 sec for compression + ACK

Software Size: ~10 KB
Image Size: ~ 307 KB (Raw) / 30 KB (JPEG)

Horizon Detection Algorithm



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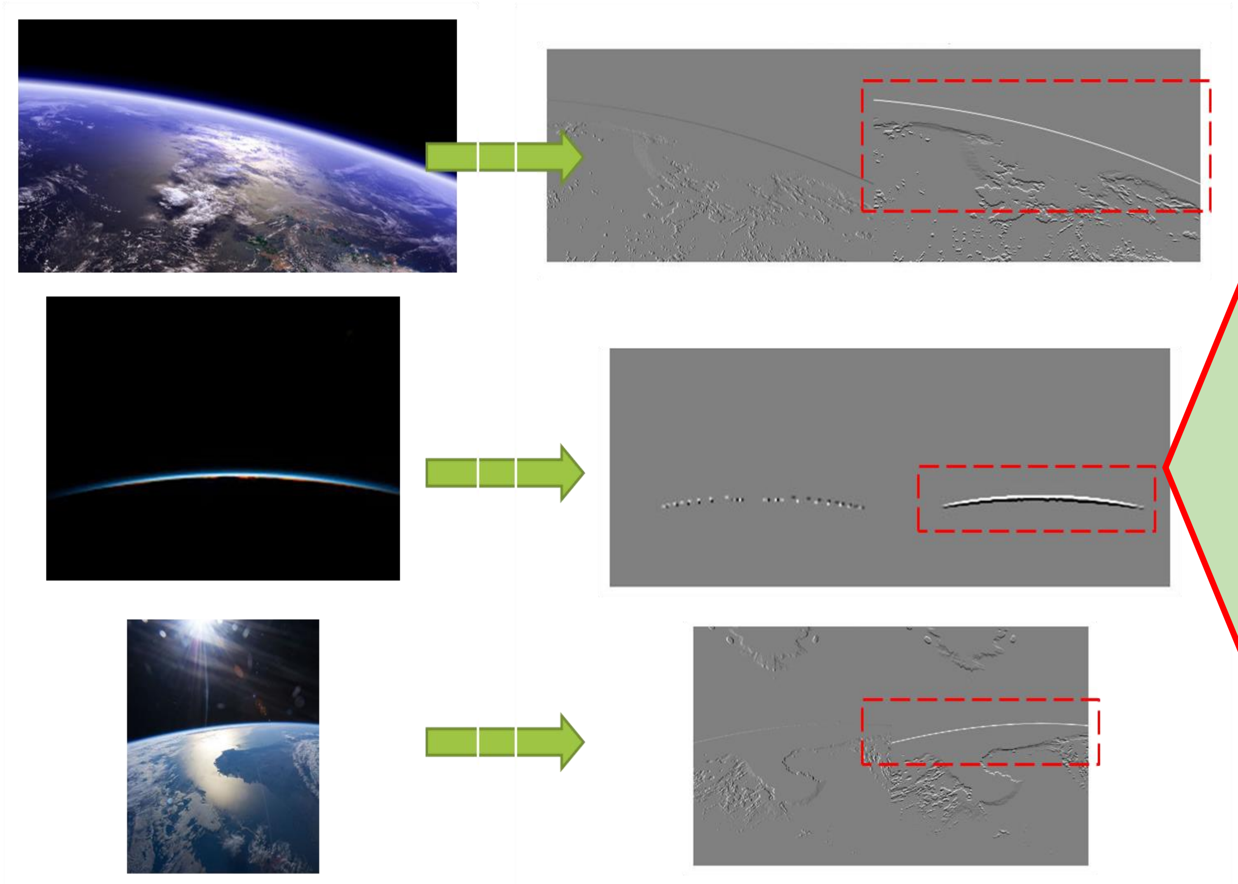

Sample images taken from Google.

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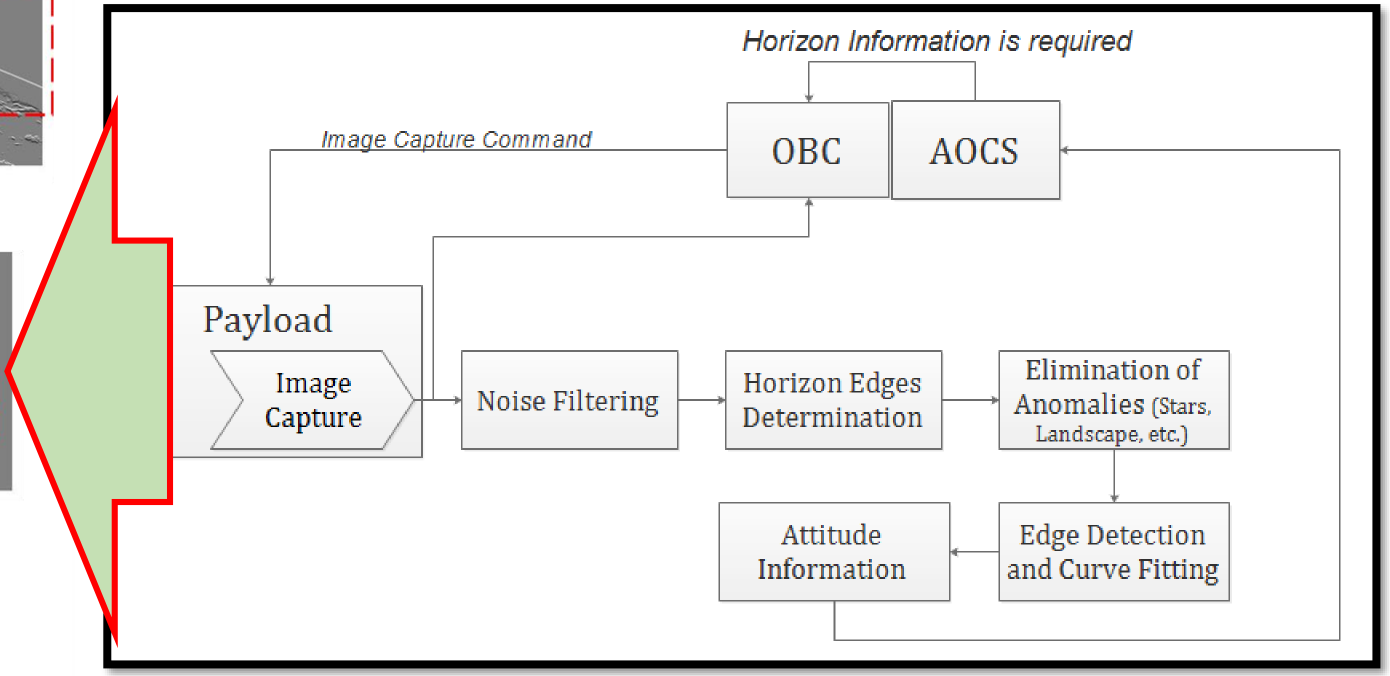
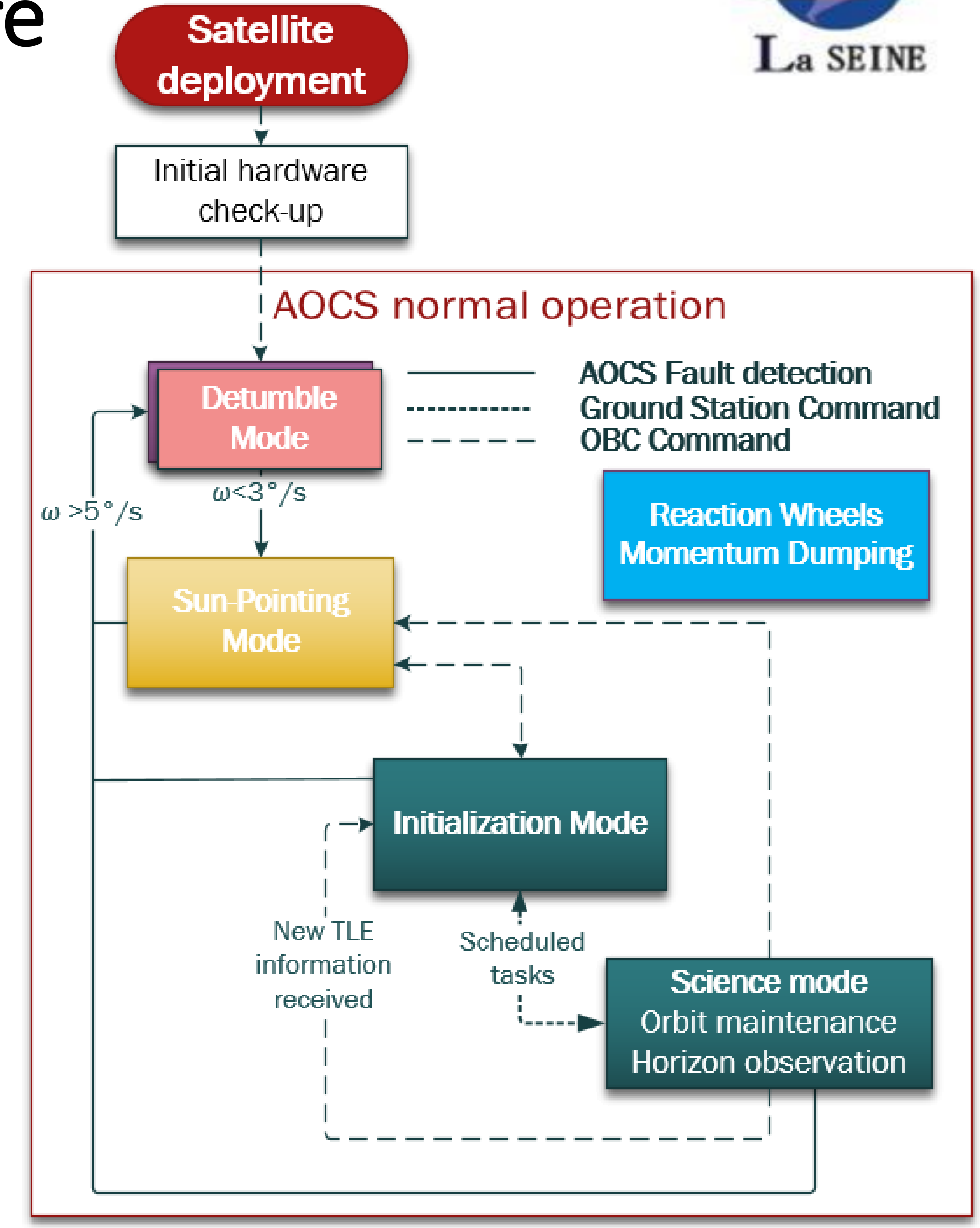


AOCS software

Operation mode	Features	Hardware required
Detumble mode	Reduction of angular rate via reaction wheels	RWs, gyroscope
Sun-pointing mode	The solar paddles alignment to the sun for optimal solar energy collection.	Coarse sun sensors, RWs, gyroscope
Initialization mode	Initialization of orbit propagator and EKF. Solar paddles aim to the Sun by z axis angle control.	Coarse and fine sun sensors, gyroscope, RWs
Science mode	Satellite control its attitude to the target. Orbit maintenance and horizon observation.	Coarse and fine sun sensors, gyroscope, RWs and PPT
Momentum dumping mode	Desaturation of RW via PPT.	Gyroscope, RWs and PPT



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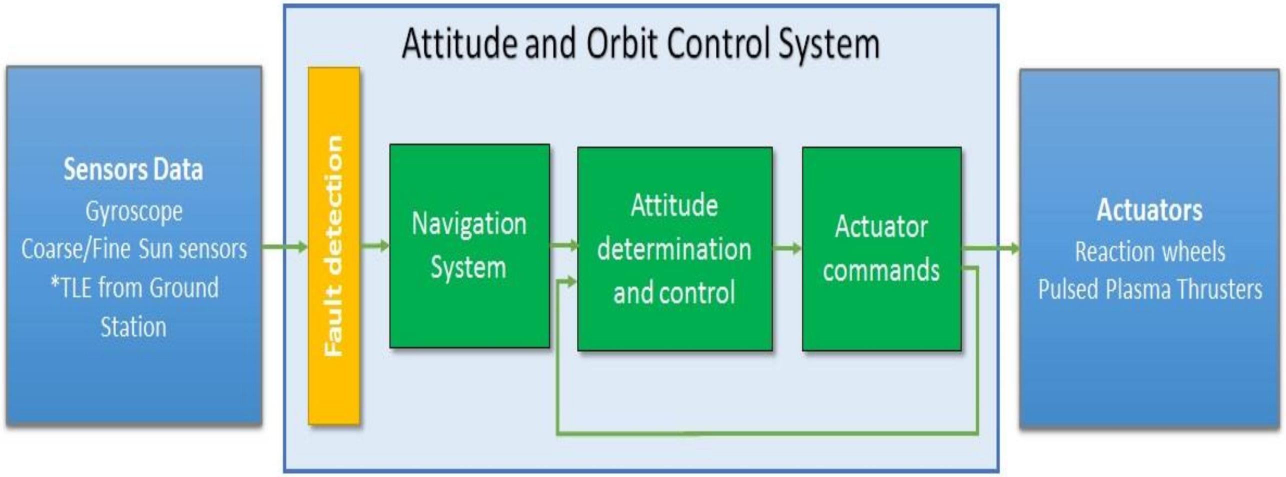

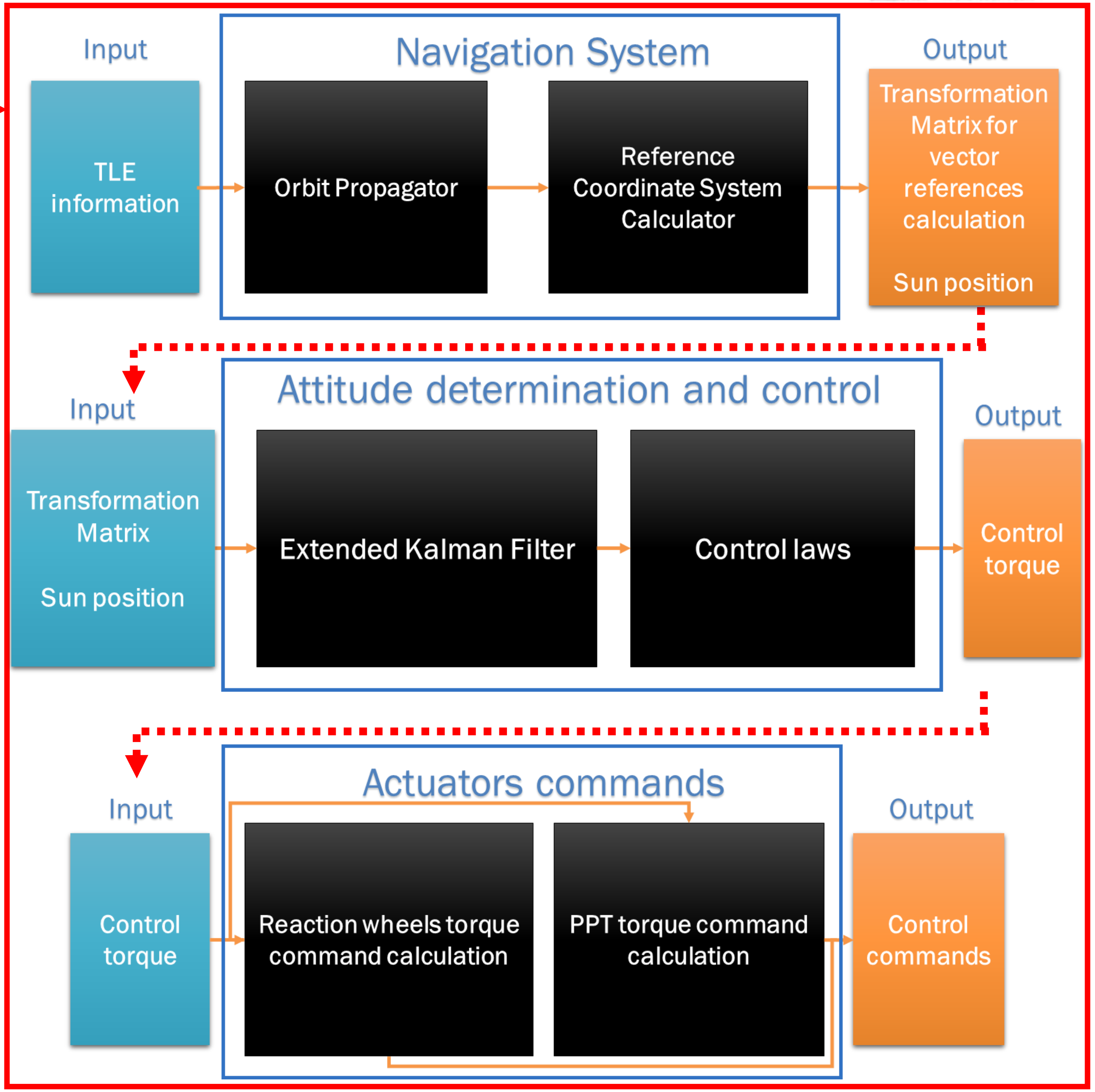

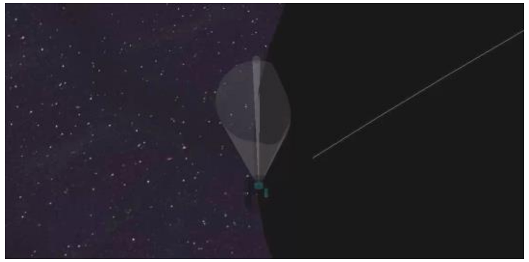

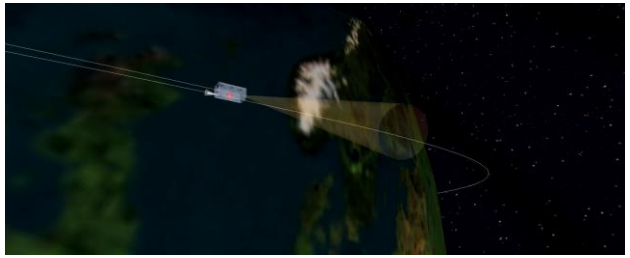

Conclusions

- Camera module was selected for the observation of low-light images from either Earth or Moon.
- Regarding AOCS, pointing towards horizon and orbit maintenance are the main objectives to be met in both Earth and Moon orbit cases.
    - A reliable orbit propagation and attitude determination algorithm is required to be implemented into AOCS software.
    - PPTs can be used for both orbit maintenance and desaturation of reaction wheels.
- To improve the reliability of AOCS, the camera module can serve as horizon sensor to increase the accuracy of attitude knowledge with the development of horizon detection algorithms.

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