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System Architecture for a CubeSat DTE Laser Communication Terminal

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Introduction

Small satellites and CubeSats are playing an increasingly larger role in technology demonstrations, research, and obtaining data for commercial use from space. As these use cases and applications for CubeSats increase and expand the need to get fast, secure and reliable access to the data gathered by the payloads on these space-craft also increases. To support these developments AAC Hyperion together with TNO has developed a down-to-earth laser communication module for small satellites and CubeSats with a downlink capability of 1 Gbit/s, namely CubeCAT.

One of the challenges that needed to be solved to ensure success was how to deal with the pointing of the unit both for up-link and down-link purposes. Once this could be achieved the next challenge was the stability of the pointing mechanism since the pointing accuracy and stability of the laser link directly affect the link budget and achievable data rate. In other words rejection of mechanical vibrations and other disturbances. The goal of the development project was to develop such a system with a form factor and mass suitable for implementation on CubeSats. This meant that a maximum volume of 1U was set as a requirement and a maximum mass of <2 kg.

Architecture

The relatively small form factor requirement necessitated the implementation of a *novel* architecture for the system. The DTE laser communication terminal in question can be broken down into the following subassemblies:

- Structure
- Fine Pointing System
- Optomechanical Assembly
- Laser

Each plays a key role in the operation and performance of the system. For this publication, emphasis is placed on the Fine Pointing System.

Fine Pointing System

In order to solve the pointing challenge within the volume requirements whilst adhering to pointing stability and accuracy requirements decision was taken to rely on the Space Craft for coarse pointing. Current ADCS technology is capable of achieving pointing accuracies of down to ~0.5 deg. This is well within the requirements to be able to close the link.

In combination with coarse pointing a fine steering mechanism had to be incorporated into the architecture. The development of this Fine Steering Mirror (FSM), see Figure 2, was done in parallel to this project. The FMS in question has a range of 1.5 degrees which means that the FSM has more than enough range to correct for the coarse pointing error.

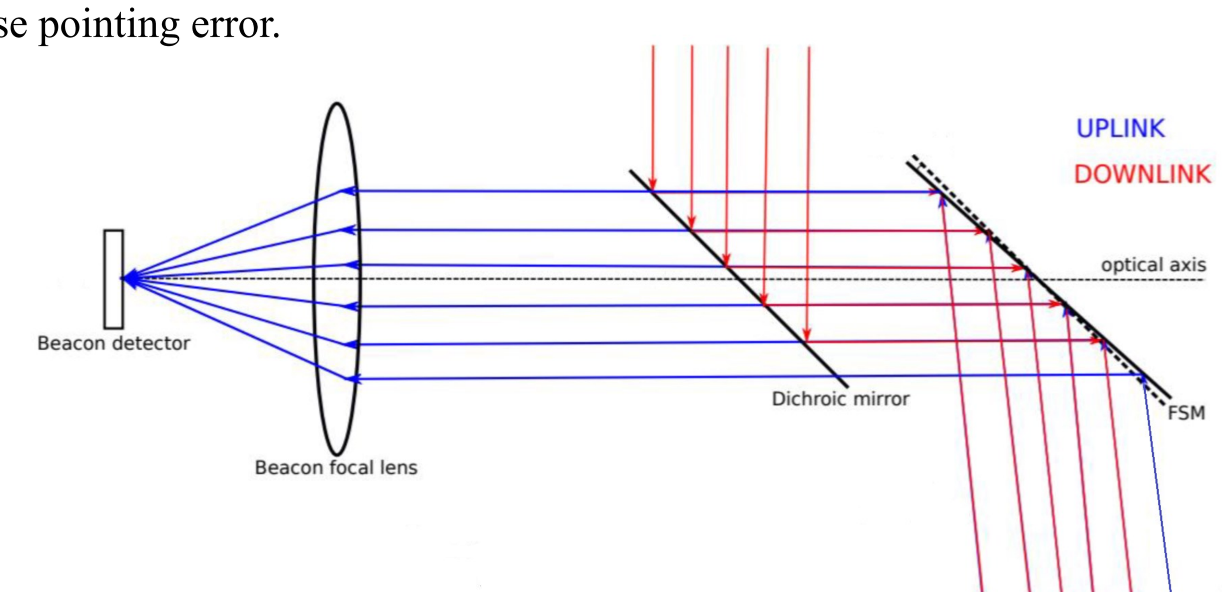

Figure 3: Diagram of the CubeCAT fine pointing system.

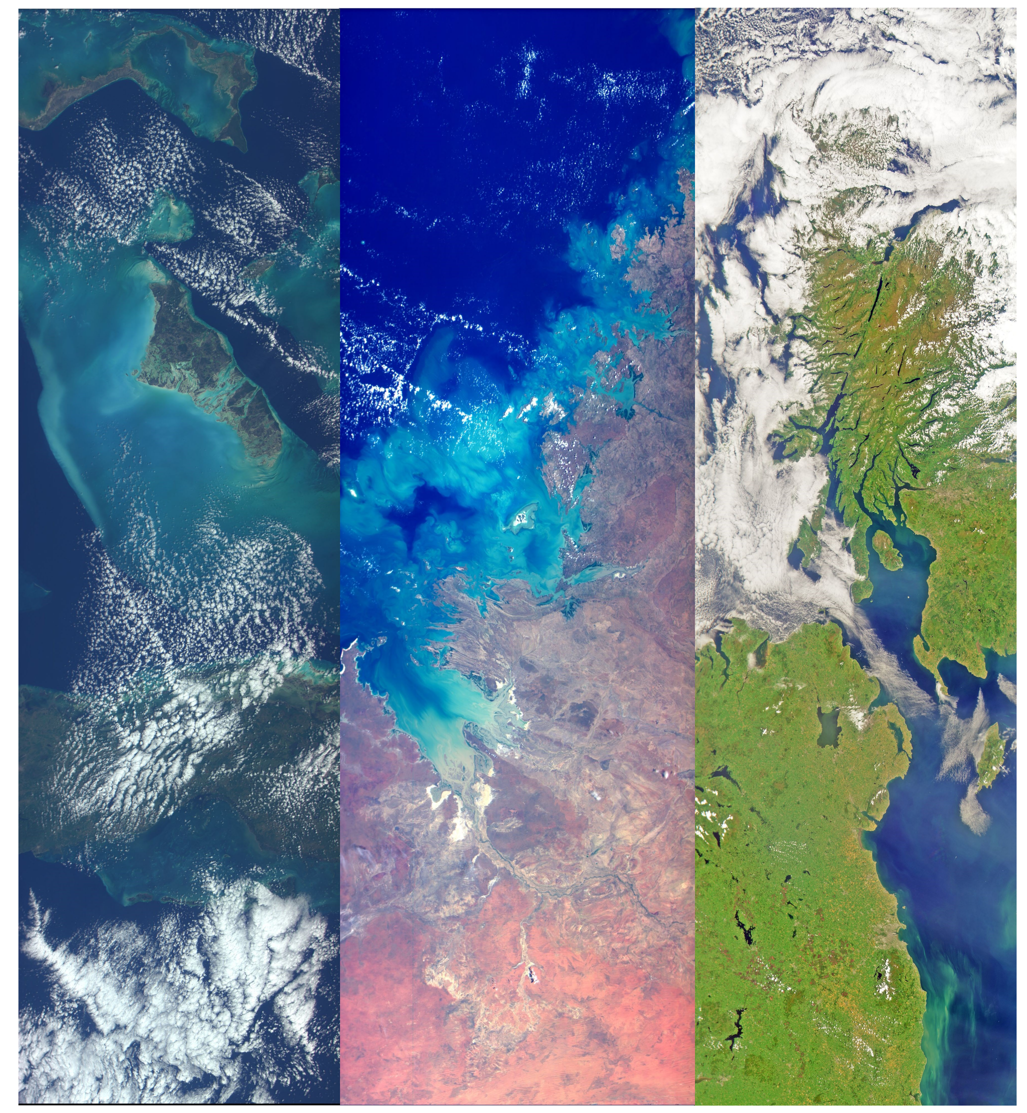

Figure 1: Example of Earth Observation data typically downloaded from satellites.

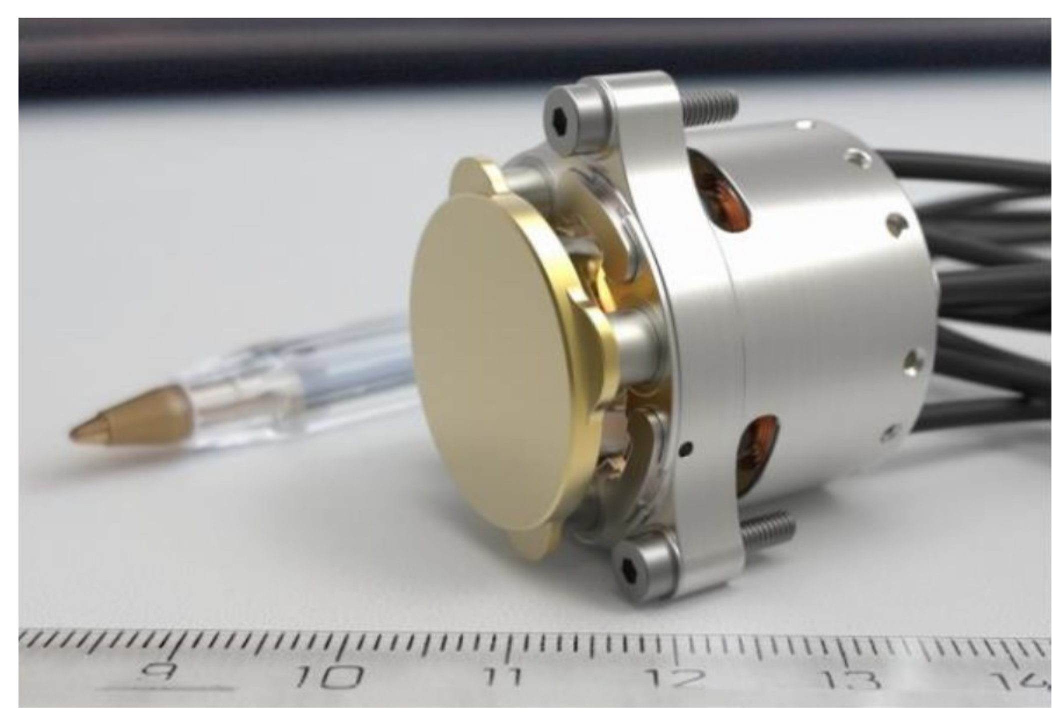

Figure 2: Render of Fine Steering Mirror with pen for reference.

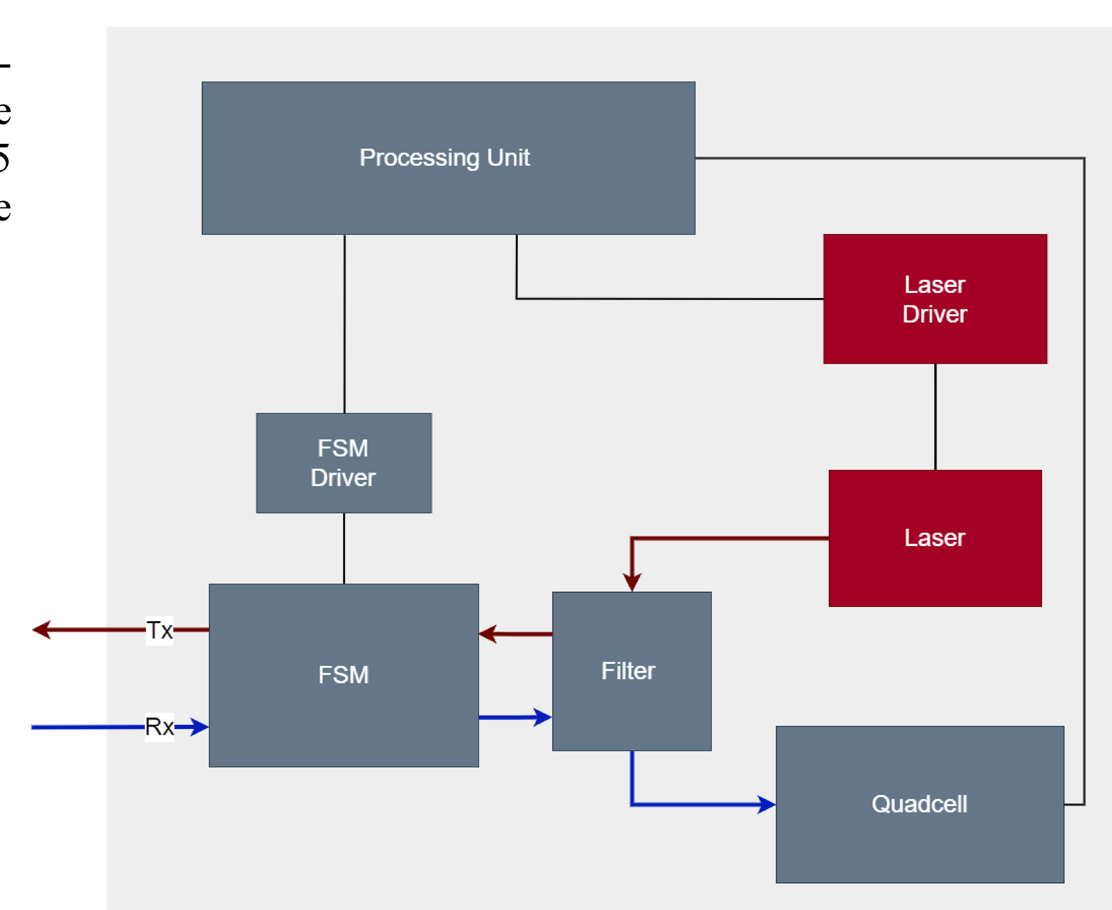

Figure 4: Basic Architecture of the CubeCAT fine pointing assembly design

Fine Pointing Continued

The high-level representation of the architecture employed for the pointing system is presented in Figures 3 and 4. The main subsystems for the fine pointing system are, as previously mentioned, the Fine Steering Mirror (FSM), the Laser, the Quadrant detector and the processing unit. The laser and the FSM each have their respective drivers as well.

In order to establish a link, a beacon light is transmitted from the ground station. The beacon light coming from the ground station is captured using the Quadcell. The readout from the Quadcell can be used to obtain tip/tilt knowledge of the pointing error of the spacecraft. From this the required corrections the FSM has to make can be calculated. This is done using the processing unit.

The FSM is then used to make corrections using this tip/tilt information obtained from the Rx beam. The design leverages a paired common path for the Tx and Rx beams, meaning that corrections made for the Rx beam lead to corrections for the Tx beam as well.

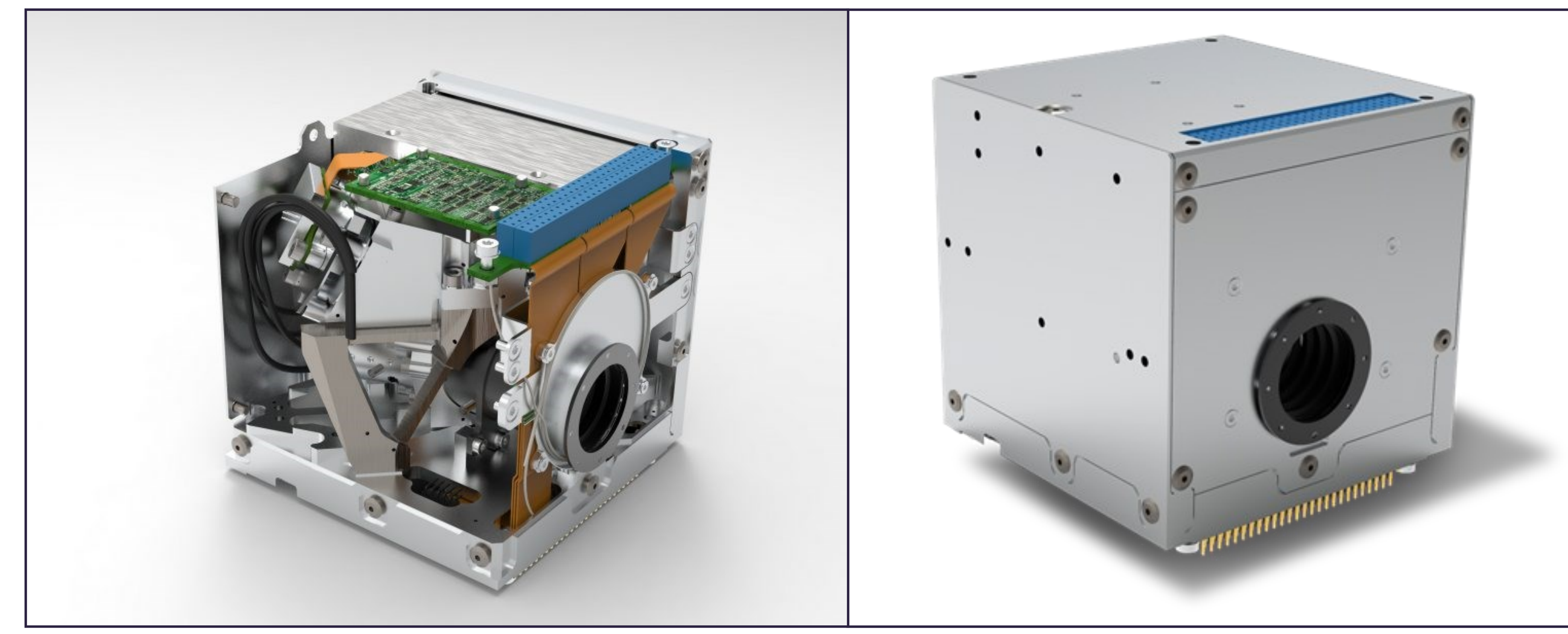

Figure 4: CubeCAT DTE Laser Communication Terminal

In Orbit Demonstration and Next Steps

The final proof of what was achieved will be provided by an In-orbit demonstration. The unit is planned on a mission which is scheduled to launch in Q1 2023. The mounting of the unit has been modified for this mission to accommodate environmental loads specific to the satellite bus in question showing the versatility achievable with this laser communication terminal.

The CubeCAT unit will provide much improved bandwidths for downlinks on small and nano satellites. The next challenge will be to increase the bandwidth of such a system while maintaining the current form factor and also without increasing the power consumption drastically. Another consideration is to remove the reliance of the system on the body pointing of the space craft. Doing this without drastically increasing the formfactor and mass of the system will be the challenge.

Table 1: CubeCAT system performance and characteristics.

Performance		
Raw Data rate (downlink)	100/300/1000	Mbps
Raw Data rate (uplink)	200	kbps
On-board buffer	>64	GB
Host Satellite Constraints		
Pointing accuracy	< 8.7 / 0.5 / 1800	mrad/deg/arcsec (3-sigma)
Low frequency vibration velocity1 (<20Hz)	< 2.445	mrad/s (3-sigma)
High frequency vibration/jitter amplitude (>20Hz)	< 15 / 0.86 / 3.1	µrad/mdeg/arcsec (3-sigma)
Pointing knowledge[2] error	< 0.3 / 17.2 / 61.9	mrad/mdeg/arcsec (3-sigma)
Physical Characteristics		
Outer Dimensions	96 x 96 x 96	mm
Mass	<1.33	Kg
Temperature Range	-20 to 40	°C

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