Optics Payload System for 12U Sun Monitoring CubeSat

Thomas Burghardt | Katrina Ternus | Sarah Ketchersid | Michael Daven | Kiana Zarandi

Embry-Riddle Aeronautical University | American Institute of Aeronautics and Astronautics

Abstract

- Overall objective: Real-time monitoring of solar activity
- Science Payload:
  - White light coronagraph to monitor coronal behavior
  - Extreme ultraviolet (EUV) imager to analyze solar disk for increased activity
- Rotating gear wheel system to transition between EUV filters and coronagraph
- Telescope aligned with active filter and CMOS camera
- CubeSat design intended for constellation in heliocentric orbit

Background and Mission

As space agencies plan to establish a long-term human presence in deep space, it is crucial to understand risk associated with solar activity. Solar behaviors, including active regions, flares, coronal holes, and coronal mass ejections affect the electronics of spacecraft and expose astronauts to high levels of radiation. Satellites can provide early warning of increased activity for missions not protected by Earth's magnetic field. The research and design of this payload system was informed by needs of NASA and experience from heritage missions:

- Response to NASA Strategic Knowledge Gap II-A, "Define active regions that are potential Solar Energetic Particles/Coronal Mass Ejection sites over the 1/2 of a solar rotation"
- Design informed by NOAA's GOES and NASA and ESA's SOHO heritage missions
- Operate in heliocentric orbit, beyond Earth's magnetic field, in order to inform missions on the Moon and Mars
- Initial flight as a technology demonstration, then deployed as a constellation of satellites for redundancy and increased amounts of data
- This subsystem is part of a larger design for the Solar and Coronal Observation of Radiation and Catastrophic events to Humans (SCORCH) CubeSat design by Embry-Riddle's AIAA chapter

Methodology

To accomplish SCORCH's science goals, observation time must be split between EUV imaging and the coronagraph. This is accomplished using a filter wheel containing the three EUV filters and the occulter. Light enters the sun-pointing satellite, flowing through the system described in Figure 1.

Figure 1: How the light flows through the payload subsystem.

Several components are used to accomplish the goals of SCORCH's mission, as detailed in Table 1. Table 2 specifies the size and specs of the gears made in house. Assemblies are pictured in Figures 2 and 3.

Component	Supplier	Description
Camera	Imperx	25 MP C5180 CMOS Camera
Filter Wheel	In-house	80 mm diameter gear wheel housing EUV filters and occulter; aluminum 7075
Motor Gears	In-house	32 mm diameter gears connecting filter wheel to motors; aluminum 7075
Motors	Empire Magnetics	RH-U17-1 Radiation Hardened Stepper Motor
EUV Filters	NTT AT	30.4, 28.4, and 17.1 nm wavelengths

Table 1: Component list, including supplier and description of each component used in the payload.

Variable	Filter Wheel	Motor Gear
z	25	10
d_{RF}	80.0 mm	32.0 mm
d_{TP}	86.4 mm	38.4 mm
d_{RF}	72.0 mm	24.0 mm

Table 2: Gear variable components and sizes for the filter wheel and motor gear.

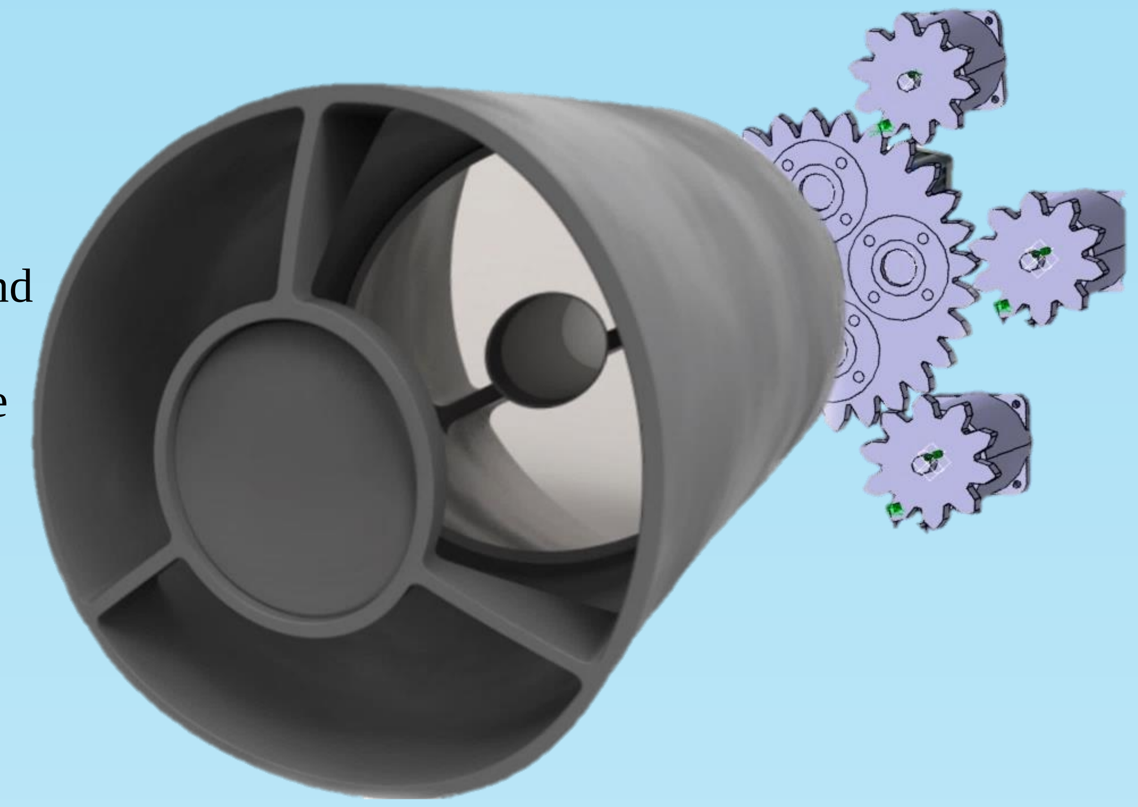

Figure 2: Full payload assembly, including the telescope, three motors and gears, the filter wheel, four lenses, and camera. Note that the camera, telescope and lenses are in-line features.

Figure 3: Motor and gear assembly. Each motor has a small gear wheel that interfaces with the filter wheel to rotate the lenses to the appropriate position.

Conclusions

In summary, the science payload is equipped with:

- Ritchey Chretien Telescope
- Filter Wheel
- Three EUV filters
- Occulter
- Three motorized gears
- C5180 CMOS Camera

The entire data cycle is 15 seconds with 1.5s exposure for each EUV filter, 5s exposure for the coronagraph, and 1s rotation of the filter wheel between experiments.

Based on the capability of the system design and experience from heritage vehicles, this payload is fully functionable and capable of capturing solar images for real-time monitoring of solar activity.

Further areas of research include:

- Pointing accuracy required for level of data quality and monitoring capability
- Error associated with aberration and alignment
- Integration with data handling for activity recognition and reporting system

References

Hill, S. M., et al. "The NOAA Goes-12 solar X-ray imager (SXI) 1. Instrument, operations, and data." *Solar Physics* 226.2 (2005): 255-281.

Delaboudiniere, J-P., et al. "EIT: extreme-ultraviolet imaging telescope for the SOHO mission." *The SOHO Mission*. Springer, Dordrecht, 1995. 291-312.

Shah, Neerav, et al. "Next-Generation Formation Flying Solar Coronagraph." 3rd Interplanetary CubeSat Workshop. iCubeSat, 27 May 2014, Pasadena, California, icubesat.files.wordpress.com/2014/05/icubesat-org_2014_b-3-2-coronagraph_shah_201405281756.pdf.