THE RAPIDEYE SPACECRAFT

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ABSTRACT

The RapidEye satellite constellation consists of five identical satellites. These satellites will be launched in a sun synchronous 620 Km orbit. Each satellite is equipped with an identical 5 band multi-spectral optical camera. The RapidEye spacecraft are unique as they are small (less than 0.8 m a side), low mass (~150 kg), and highly cost effective, while being capable of a very advanced imaging performance and long mission lifetime (i.e., >7 years).

The technical characteristics of the RapidEye spacecraft are described. In particular, the architecture and configuration of the spacecraft is given and a short description is provided for each of the key bus subsystems. The subsystems include a full 3-axis agile high accuracy pointing system, propulsion, power, S-band TT&C communications system and an X-band data downlink. A description of the optical payload design is also provided which includes the optics, the detector and focal plane assembly, and the digital processing electronics. It is shown that while being highly cost effective, the RapidEye system provides both high performance and a high degree of reliability through the extensive use of flight proven systems in the spacecraft and the use of several layers of redundancy.

1. INTRODUCTION

RapidEye is a commercial mission being undertaken by the German company *RapidEye AG* who intend to offer a land information service to a variety of customers. The key business requirements for RapidEye are as follows:

- Provide high quality ortho-rectified imagery is required in 5 spectral bands.
- Have daily revisit capability anywhere on the Earth.
- Provide large area coverage in less than 6 days in primary regions of interest (i.e., Europe and North America).
- Provide a significant ortho-image data download capacity to allow building up and maintaining an extensive database of information for large areas of interest

To meet these business needs, a constellation of five identical satellites will be used in a sun-synchronous 620 km orbit, where each spacecraft will be equi-spaced around a single orbit plane. The satellites are very small weighing only approximately 150 kg allowing all 5 to be launched on a single launcher. Each satellite carries a pushbroom optical imager that provides a swath width on the ground of approximately 80 km. To achieve the coverage and daily revisit requirements, the spacecraft can be maneuvered in the across track direction by up to +/-25 degrees. Spacecraft Telemetry, Tracking and Command (TT&C) functions are provided through a dedicated Spacecraft Control Centre using an S-band TT&C station. The data downlink uses commercial data receive stations operating in the X-band.

The following provides a description of the overall spacecraft with a summary of the key characteristics of the spacecraft bus and the optical payload.

2. SPACECRAFT DESCRIPTION

The RapidEye Spacecraft is shown in Figure 1. The overall spacecraft mass is approximately 150 kg which includes about 35 kg for the Payload.

The spacecraft bus will be developed by Surrey Satellite Technologies Limited (SSTL) and will be based heavily on a flight proven design. The general spacecraft layout has the spacecraft divided into three separate functional volumes. At the base of the spacecraft is the launch vehicle separation system which is baselined as a 4 point release system with integral deployment springs. Four reaction wheels and associated interface electronics are located in the volume between the 4 separation system bolts. Then, in the middle are the majority of the bus subsystems plus the Payload Electronics Unit, while the optical imager is located at the top of the spacecraft as shown in Figure 1.

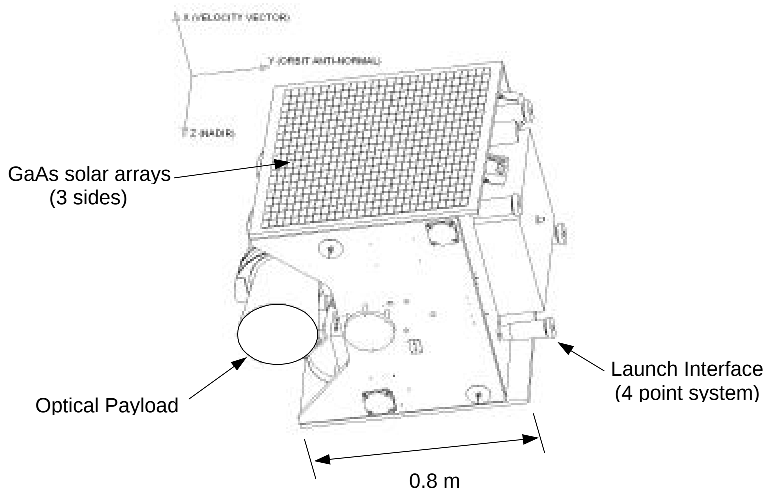

Figure 1 The RapidEye Spacecraft

The architecture of the spacecraft is shown in Figure 2. Redundant spacecraft onboard computers (OBC's) are used to perform all bus housekeeping functions. A dual redundant CAN bus architecture provides communication between the OBC's and the other spacecraft subsystems including the Payload. This provides a reliable means for controlling the spacecraft subsystems and to manage the onboard redundant systems. The power system consists of three GaAs solar panels located on the +X, -Z, and –X faces of the spacecraft. This provides about 100 W of power generation capability when in the sun. The battery uses two NiCd battery packs charged by 6 battery charge regulators (2 per panel). The attitude control system relies on 4 reaction wheels for 3-axis control with redundant magnetic torques for momentum management. Redundant sun sensors and magnetometers provide the coarse attitude knowledge with a star camera providing the high accuracy attitude information. To minimize alignment attitude knowledge errors, the star camera is mounted directly to the payload optical bench. The propulsion system is based on a cold gas blow down system utilizing a resistojet thruster with a single propellant tank and associated plumbing located in the middle section of the bus. On-board GPS is used to provide accurate orbit knowledge and also to provide timing synchronization with the payload. The TT&C uplink and downlink utilizes redundant S-band transmitters and receivers, while the data downlink utilizes a dedicated X-band transmitter providing a data rate > 60 Mbps. A fully redundant transmitter and antenna chain is provided as shown in Figure 2.

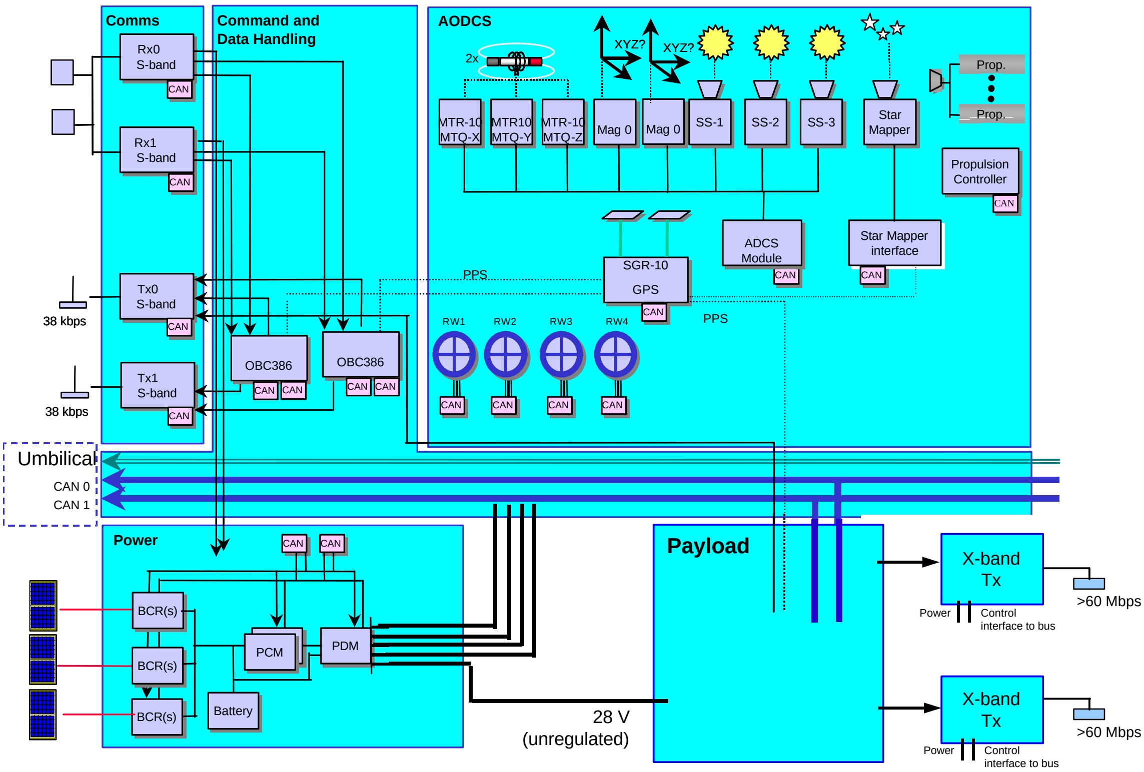

Figure 2 Spacecraft Block Diagram and Architecture

3. PAYLOAD DESCRIPTION

The RapidEye payload on each spacecraft is comprised of 2 separate units, a Multi Spectral Imager (MSI), and a Payload Electronics Unit (PEU) as shown in Figure 3.

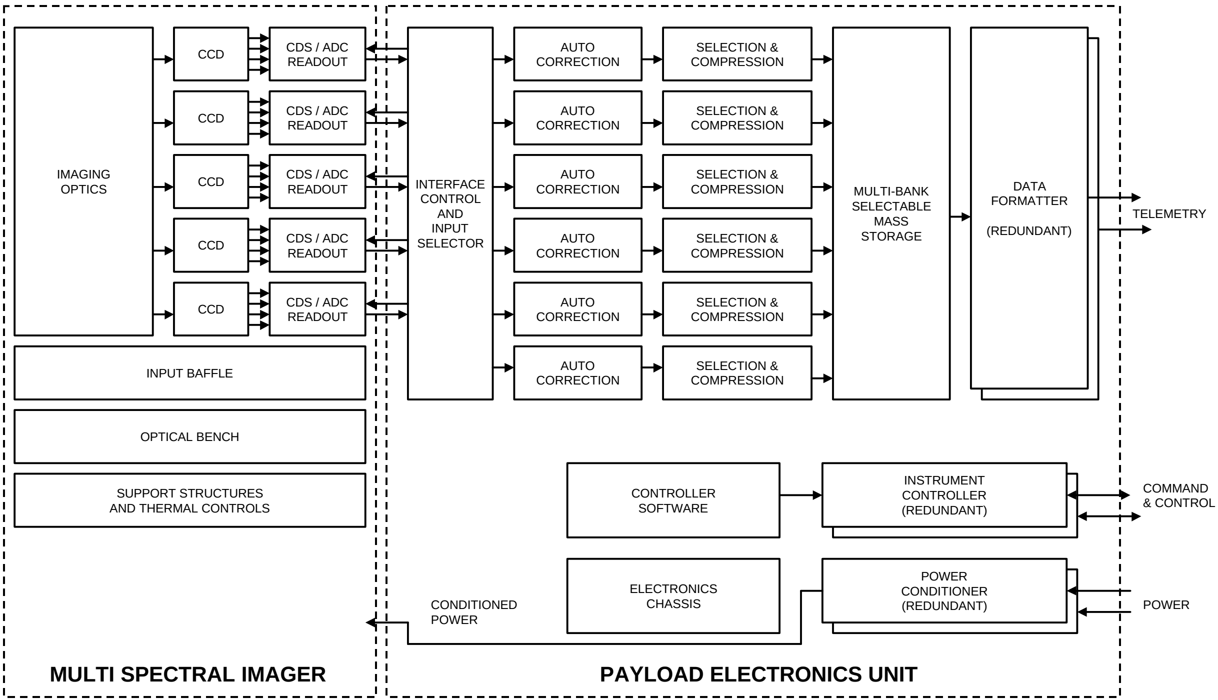

Figure 3: Payload Block Diagram

The MSI is a pushbroom style imager which images the earth in 5 spectral bands over a 80 km swath at 6.5 m resolution (at nadir). The collector optics image onto five parallel linear 12K pixel CCD detectors. Options for the collector optics include both three mirror anastigmat (TMA) and catadioptric designs. The design requirements for the optical camera are well within what has already been demonstrated for similar systems. The required aperture is approximately 150 mm. The CCD will be selected from 3 candidate manufacturers, where this is a heritage product for each manufacturer. Filters, placed in close proximity to each CCD, separate the spectral imaging bands. The five spectral bands are as follows:

Channel	Spectral Band Name	Spectral Range (nm)
1	Blue	440 – 510
2	Green	520 – 590
3	Red	630 – 685
4	Red edge	690 – 730
5	Near IR	760 – 850

Each CCD produces 4 outputs, which are synchronously clocked out by the detector readout electronics at a rate of approximately 3.2 MHz, which is sufficiently slow to allow for 12 bit digitisation with low readout noise. The raw pixel data, totalling nearly 765 Mbps, is transferred to the PEU via a set of high speed serial interfaces.

The PEU provides a separate processing chain for each CCD, with a redundant chain cross-strapped to the others. The first step in the processing chain is to correct CCD data, in real time, for gain and offset non-uniformities using a programmable table of coefficients. This must be done prior to data compression to prevent image defects from biasing the compressed data. CCD correction coefficients, derived from imaging of ground calibration sites, are periodically uploaded from the ground station.

The corrected image data can be processed in a variety of ways to reduce data volume prior to transmission. Pixel binning in 2x2 or 3x3 sizes provides the most rudimentary data compression method (one axis is binned directly on the CCD to reduce readout noise). The PEU also supports both selectable lossless 2:1 compression and lossy (up to 10:1) compression ratios based upon direct cosine transform (DCT) or wavelet algorithms.

The compressed data, together with spacecraft GPS and attitude information, is stored in mass memory, which provides sufficient storage for a 5-band imaging swath length of up to 1500 km at 2.5 bits/pixel (>45 Gbits). The final stage of processing is performed by the data formatter, which encodes the data for error correction and encryption and sends it directly to the spacecraft X-band transmitters.

The PEU provides overall control of the imaging process. Each imaging segment can be individually configured for different compression schemes, allowing multiple user data requirements to be met

4. CONCLUSIONS

The RapidEye constellation of 5 small satellites provides a highly capable remote sensing system which has very high performance in terms of image quality, repeat coverage and data throughput capacity. The system also provides a high degree of reliability through the extensive use of flight proven systems in the spacecraft and the use of several layers of redundancy including a redundant satellite as the RapidEye business requirements can still be satisfied with only a 4 satellite constellation. The payload design also is based on proven optical design approaches, uses proven hardware for critical items, and includes redundancy in critical areas. Hence, the RapidEye system of 5 small satellites offers a highly cost effective and unique capability that is not available from current remote sensing systems.