Singapore's satellite mission X-Sat

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SINGAPORE’S SATELLITE MISSION X-SAT

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ABSTRACT

X-Sat is a mini-satellite project undertaken as a collaboration among the Nanyang Technological University and different organisations within Singapore. The mission objectives are imaging over Singapore as well as surrounding regions and satellite-based advanced data acquisition and messaging over the Indian and Pacific Ocean. The main focus is the provision of a technology demonstration for future missions. Therefore the satellite bus with its on-board computer, mass storage system, bus-oriented communication, transmission system etc. was designed to cater for a variety of different future mission objectives.

1. OBJECTIVES AND MISSION

The X-Sat mission is a technology capability demonstration project. The main purpose of the project is to develop the capability within Singapore to design, build, test, and operate a mini-satellite bus with multi-mission support capability. The primary payload on-board of the first X-Sat is the camera IRIS, which will provide multispectral imagery in the visible and near-infrared wavelength range. The instrument shall image over Singapore and surrounding regions and transmit the data to the receiving station in Singapore within the same orbit. The advanced data acquisition and messaging (ADAM) instrument is the secondary payload and aims for the communication with remote mobile terminals. The third payload is a technology demonstration for the parallel processing unit (PPU), which will make on-board image processing available.

2. PLATFORM

X-Sat is a low earth orbit (LEO) mini-satellite and designed to fly on a sun-synchronous orbit at a nominal altitude of 685 km. This leads at an inclination of 98.13° to a repeat cycle of 409 orbits in 28 days with an orbit period of 98.58 min. The piggyback launch on a PSLV-C2 rocket from Madras, India, is scheduled for 2006. The satellite’s mass is less than 120 kg at a size of 600 mm × 600 mm × 800 mm. The box design is made of a honeycomb panel structure, which carries the individual components mounted on the respective panels. In addition to the six body panels a central shelf is provided.

The satellite differs between the bus sub-systems and the actual payloads. This concept can be found throughout the entire design and is most obvious in the connectivity

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diagram provided in Figure 1. The central component is the on-board computer (OBC), which provides two separate controller area networks (CAN) to both groups. Only one bus on either side is operational at a given moment in time while the second bus acts as a backup. The choice of using CAN is driven by the requirement to reduce mass and therefore the number of hard-wired connections. Dedicated connections are preferred for high reliability, broad bandwidth, and power connections.

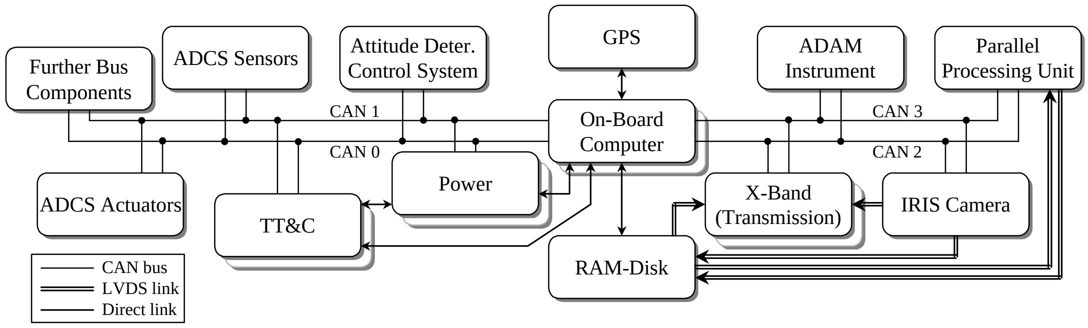

Figure 1: Connectivity diagram of X-Sat

2.1 Communication

The design of the X-Sat provides X-band (~8 GHz, image downlink) and S-band (~2 GHz, command uplink and telemetry downlink) communication links with the ground station. The X-band transmitter supports for an elevation angle of more than 10° the four different transmission rates of 12.5 Mbps, 25 Mbps, 50 Mbps, and 100 Mbps with a 3 dB margin. The unit is connected to a multiple patch antenna whose individual patches are mounted on the surface of a cut-through octahedron facing different directions. Therefore the number of required manoeuvres to establish a communication with the ground receiving station is reduced [1].

The S-band communication has three receivers and three transmitter antennas, whereby for both types two antennas are mounted on the same side as the camera aperture and the remaining ones on the opposite side. Hence at all times a communication can be established if the satellite is within ground station visibility. The achievable transmission rates for the up- and downlink are 2 kbps and 4 Mbps, respectively.

2.2 On-Board Data Handling

The on-board data handling system (OBHD) system consists of the OBC and the directly attached RAM-Disk. The tasks performed by the OBC include classical functionality of housekeeping and monitoring but also embrace functionality such as the failure detection, identification, and recovery. The RAM-Disk provides additional data storage for the payloads while all the bus specific data, e.g. telemetry data, is stored within the memory of the on-board computer [2]. The heart of the OBC is the space-proven radiation-hardened ERC32 with a clock speed of 25 MHz. In this configuration the 32-bit processor archives up to 25 MIPS, which was found to be sufficient for the mission since the burdensome orbit computation is carried out by the additional attitude determination and control system (ADCS). The OBC is equipped with 64 MByte of memory and uses error detection and correction (EDAC) to maintain program and data validity.

The RAM-Disk is a solid-state bulk memory storage consisting of 2 GByte SDRAM made from 8-bit wide 128 Mbit modules. For high bandwidth data transfer it is connected via dedicated 100 Mbps LVDS links with the camera, the X-band transmitter, and the PPU, while the connection with the OBC is through a direct interface for address, data, and control signals.

2.3 Attitude Determination and Control System

The design of the ADCS is based on dual-redundant StrongARM 1110 processors, which provide the computational power for the orbit determination and control of the satellite. A special software scheme for EDAC ensures that all calculations are accurate and correct. In case of any failures the OBC will act as a backup system. The required data for the ADCS is provided by three sun sensors, one star sensor, three rate sensors, and two 3-axis vector magnetometers. Only the GPS receiver is directly connected to the OBC, which provides the positioning information not just to the ADCS but also to the payloads. On the actuator side the satellite possesses four reaction wheels (three orthogonal and one spare) and three magnetic torquers.

2.4 Power System

The power system comprises the charging and control hardware, two Li-ion batteries that provide a capacity of 6 Ahr, and three GaAs solar panels covering a total area of $1.14m^2$. The central panel is body-mounted while the outer ones are deployed after injection from the launcher [3]. The system provides a voltage range of 22-34 V and has an expected end-of-life power of 175 W. Each sub-system and payload is connected separately to the power system, which enables the individual isolation of faulty components.

3. PAYLOADS

The satellite carries three payloads, namely the imaging system IRIS, the communication platform ADAM, and the parallel computer PPU for image processing. Further research experiments using the communication and navigation instruments on-board will be conducted to investigate atmospheric question and communication related issues.

3.1 IRIS

The camera is built by SatReC*i* and designed as a push-broom scanner with three individual scan lines in the green (520 nm – 600 nm), red (630 nm – 690 nm), and near-infrared (760 nm – 890 nm) wavelength range. The three linear detectors consists each of 5000 active elements, which were all manufactured on the same wafer and subsequently coated with different interference filters to select the appropriate spectral characteristic. The design provides a high degree of band-to-band alignment, i.e. 0.1 pixels. The provided spatial resolution will be 10 m for the nominal altitude of 685 km, thus enabling a swath width of 50 km. The optics were designed as a variant of the Mangin telescope with a primary and secondary mirror as well as two correction lenses and has an aperture diameter of 120 mm. Internally the IRIS is equipped with a redundant signal processing and control module, which pre-processes the image data for the storage in the 8 Gbit large memory module. Note that this bulk storage module is entirely under the control of the IRIS and independent from the earlier mentioned RAM-Disk.

3.2 ADAM

The instrument is a two-way low data rate communication link using UHF [4] to acquire oceanographic data, e.g. temperature, salinity, and water pressure from autonomous, operating buoys that drift in the open sea. Further applications are in aeronautics, search and rescue missions as well as in land-based data collection. For the downlink of the gathered information to the individual ground receiving station the satellite’s S-band transmitter is utilised.

3.3 Parallel Processing Unit

The third payload is the PPU that will provide processing of acquired imagery on a parallel architecture. The objective is to increase the mission’s benefits by enabling unsupervised data processing in space and therefore easing the bottleneck of transmission to the ground receiving station. The computer consists of four fully connected radiation-hardened Xilinx Vertex FPGAs with each of it hosting four processing nodes (PN). In addition, spare processor nodes are kept available in case a regular PN will become inoperative due to the environmental conditions. Every node comprises a StrongArm processor that is clocked at 100 MHz and 64 MByte of local memory (SDRAM). The choice for this processor was determined through its 0.35 μm manufacturing process, i.e. the relatively small sensitivity to radiation, and the provided performance energy ration of 115 MIPS / 200 mW.

4. CONCLUSIONS

The X-Sat provides a multi-purpose bus architecture for mini-satellite missions. The main technological features were reviewed along with the payloads of the first X-Sat. The successful launch and operation of the satellite will verify the designed system and will provide the foundation for future developments.

6. REFERENCES

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