The FedSat Microsatellite

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Abstract

In mid-1997, the Australian Government approved the setting up of a Cooperative Research Centre for Satellite Systems (CRCSS) to promote indigenous space research and development activities. A key part of the research activities is the launching of a research microsatellite - FedSat - by the year 2001, the centenary year of Australian Federation. It will be the first Australian built satellite since 1970. This paper briefly describe the FedSat project and the basic features of the FedSat spacecraft.

1. The Objectives

The scientific aims of FedSat are to obtain pure and applied knowledge in the field of space science and atmospheric sounding by carrying out experiments in space, to disseminate the knowledge throughout the research community, and to pass it on to the education curricula.

The engineering aims of the project are to gain capabilities in small satellite technology through the designing, developing, assembling, integrating, testing and commissioning of a small, innovative research satellite, and to establish the infrastructure, know-how and intelectual properties for the benefit of Australian space industry.

Another objective for FedSat is to provide a space vehicle for many research and application activities such as precise orbit determination and positioning, high performance reconfigurable computing, space-born trials for advanced Ka-band technologies, satellite propagation studies, mobile communication and remote data collection.

2. The Mission

FedSat will be launched at the end of the year 2000, into an 800km nearly sun-synchronous orbit at an inclination of 98.6 degrees. The local time of the ascending node is 10.30 pm [1], [2].

FedSat is an experimental microsatellite, cubical in shape with dimensions of 50cms x 50 cms x 50 cms. It has a 2.5 m deployable boom used to support a 3-axis fluxgate magnetometer. The mass of the satellite is 50 kg. The satellite uses 3-axis stabilisation.

The satellite will autonomously acquire Earth pointing after launch, while retaining sufficient power to run the basic systems. After radio contact with ground control, the boom will be deployed, and payloads brought into operation.

Data and housekeeping information will be acquired by the satellite platform and payloads during operations, and stored for later transmission to ground. The spacecraft will be capable of operating autonomously for at least two days and will have sufficient memory storage capacity available to accommodate two days of payload, housekeeping and timing data.

There will be one main TT&C ground station located at the University of South Australia in Adelaide. Other fixed, transportable and mobile terminals will be used at various locations in Australia and the surrounding oceans.

3. The Platform

The FedSat structure is a variant of the standard MicroSIL^{TM} structure, adapted to interface with the NASDA H-IIA launcher. The design is based around six honeycomb outer panels, and an interior double shelf dividing the platform equipment from the payloads. This arrangement simplifies the interface between the platform and payload equipment [3]. The main components of the platform are given in Figure 1

Communication System
The platform communications link is based on the SIL (Space Innovations Ltd) series of standard S-band

equipment. The subsystem will provide down-link data rates of up to 1 Mbps, and an output power of 2W. Suppressed carrier, binary phase shift keyed (BPSK) modulation is employed, conforming to European and NASA standards.

The on-board receiver is a flexible, low-cost, and high performance device, with a sophisticated all digital sub-carrier demodulator. The receiver accepts telecommand data BPSK modulated on to a sub-carrier, with up-link rates of between 8 bps and 4 kbps. Redundancy will be provided through the experimental communications payload, with a UHF up-link at 4 kbps, and a Ka-band down-link with 125 kbps or 250 kbps capability.

Data Handling System

The Data Handling System provides real time and time-tagged tele-command processing, monitoring and telemetry of systems, data, and payload status; as well as the facility to perform essential autonomous control functions. A block diagram of the DHS is given in Figure 2. The main components of the Data Handling System are:

- Direct Memory Access (DMA) bus
- Signal Processing Unit (SPU)
- Data Acquisition Unit (DAU) Board
- Packet Telecommand Decoder (PTD)
- Command Pulse Distribution Unit (CPDU) Board
- Telemetry Processor Unit (TPU)
- General Purpose Interface (GPIF) and Telemetry System Board
- Mass Memory Unit (MMU)

Attitude Control System

The Spacecraft Attitude Control Electronics (SACE) unit consists of a PCB located within the DHS enclosure. A block diagram of the SACE configuration is shown in Figure 3

Attitude knowledge is derived from a series of sun-sensors. Each sensor consists of a linear array of 256 photodiodes. The sun sensor has a 120° field of view with an illuminated width of at least 2 pixels, resulting in a resolution of at least 0.5°.

As well as the sun-sensors, a 3-axis fluxgate magnetometer is used to provide attitude knowledge. It ensures the requirements of 2° attitude accuracy at all times are satisfied, even during eclipse.

Attitude control is provided by 3 precision reaction wheels mounted on orthogonal axes. These wheels were designed by the Canadian company Dynacon, for astrometric quality pointing, in excess of the requirements for the FedSat experiments. The reaction wheels provide initial attitude acquisition during Launch and Early Operations (LEOP), and maintain attitude during normal operations.

Power Sub-System

Figure 4 shows the FedSat power sub-system

The Power Conditioning System: FedSat is provided with a redundant power conditioning system with a fully regulated +28V ±2% power bus.

The system provides 12 switched power lines for normal sub-systems and 2 permanently powered unswitchable lines for essential units. The maximum power consumption of each line is set at 15W during manufacture, though limited operation above this level can be tolerated.

Battery: The battery used for FedSat is comprised of sixteen Nickel-Cadmium cells at a voltage of 20V, with a capacity of 6Ah. Upscreening of the cells ensures that a very accurately matched set of cells is used. The maximum depth of discharge is 25% as recommended for a three year mission at a nominal 800km altitude.

Solar Arrays: FedSat has body mounted solar panels on four of its sides, one panel with four strings, and three panels with five strings. The cells are space qualified flat panel Gallium Arsenide types, with Germanium substrates, and a minimum efficiency of 19.8%. The solar array provides a maximum power of around 60W.

4. The Payloads

To carry out its mission, the spacecraft is equiped with four payloads as shown in Figure 1.

NewMag

The magnetometer payload, called NewMag, is a project by the University of Newcastle. It is built in conjunction with the University of California, Los Angeles (UCLA).

The main purpose of the experiment is to improve modelling of the ionosphere and exosphere through satellite based magnetic field observations. The fluxgate magnetometer is capable of contributing high quality information on the dynamics of the magnetosphere. It is based on a UCLA proven design from the FAST mission, and consists of a three-axis orthogonal magnetometer with associated electronics. The sensors have a dynamic range of 65536 nT, with 16 bit precision, and a bandwidth of 10Hz.

GPS

The GPS receiver payload is a project by the Queensland University of Technology (QUT). It is built according to a design from the Jet Propulsion Laboratory (JPL). The hardware is being funded by NASA, with whom the CRCSS has a cooperative research agreement under which scientific data will be supplied to USA researchers.

There are two independent groups of experiments to be carried out using the GPS receiver. The first, led by QUT, is concerned with precise timing, position and attitude determinations of the spacecraft itself. The second, led by La Trobe University, uses the timing data and known positions of the GPS satellites to determine electron content of the atmosphere.

The GPS receiver will also be used to provide synchronisation for the On-Board Elapsed Time (OBET).

Communications

The communications payload consists of UHF, Ka-band and Baseband Processor (BBP) units. The UHF and BBP units are designed and built by the University of South Australia and DSpace Pty Ltd in Adelaide. The Ka-band unit is built by CTIP (CSIRO division of Telecommunication and Industrial Physics) in Sydney. More information on the Communications Payload is given in [4].

Potential applications of the UHF and BBP units include ARGO (Array for Real-time Geostrophic Oceanography) and mobile communication. The ARGO programme involves uploading data from a large number of floating buoys in the Southern Ocean, and forwarding the information to ground during the twice daily overpass of the ground station. Two-way capabilities allow control of the floats from the satellite, and greatly increase the efficiency of data up-link. Implementation of turbo-coding results in much larger messages per packet, and further savings in power. Mobile applications include communication with land-mobile, laptop and hand-held terminals in remote areas for data and messaging experiments.

The Ka-band unit will be used for bent-pipe and regenerative communications, and as a test bed to space-qualify the advanced MMIC technology developed by CTIP.

In case of failure of the S-band TT&C RF link, the Communications Payload can be reconfigured to carry TT&C traffic using UHF on the uplink and Ka-band on the downlink.

High Performance Computer Experiment (HPCE)

The HPCE is developed by the Queensland University of Technology in conjunction with Johns Hopkins University in USA.

The computer is built around modular reconfigurable Field Programmable Gate Array (FPGA) logic. The hardware configuration of wire connections are determined by downloading from memory a stream of configuration bits. These configurations can be loaded before launch, or up-linked during the mission. Each FPGA is capable of reconfiguration in a matter of seconds.

5. Conclusion

FedSat is a good project to focus the activities of CRCSS, to mobilise many different universities, research centres and industry partners, and to develop the infrastructure and know-how to revitalise Australian interest in space. The payloads have been specially designed to assist the CRCSS in its research activities and to develop commercially viable applications.

It is planned that the facilities currently provided on FedSat be duplicated and extended further by mounting Australian-made payloads on other satellites in the Asia Pacific region and on any future generations of FedSat. For example, duplicate FedSat UHF and BBP units will be flown on KAISTSAT-4 in 2002 as a Data Collection System (DCS) for Advanced Data Acquisition and Messaging (ADAM) applications.

Acknowledgements

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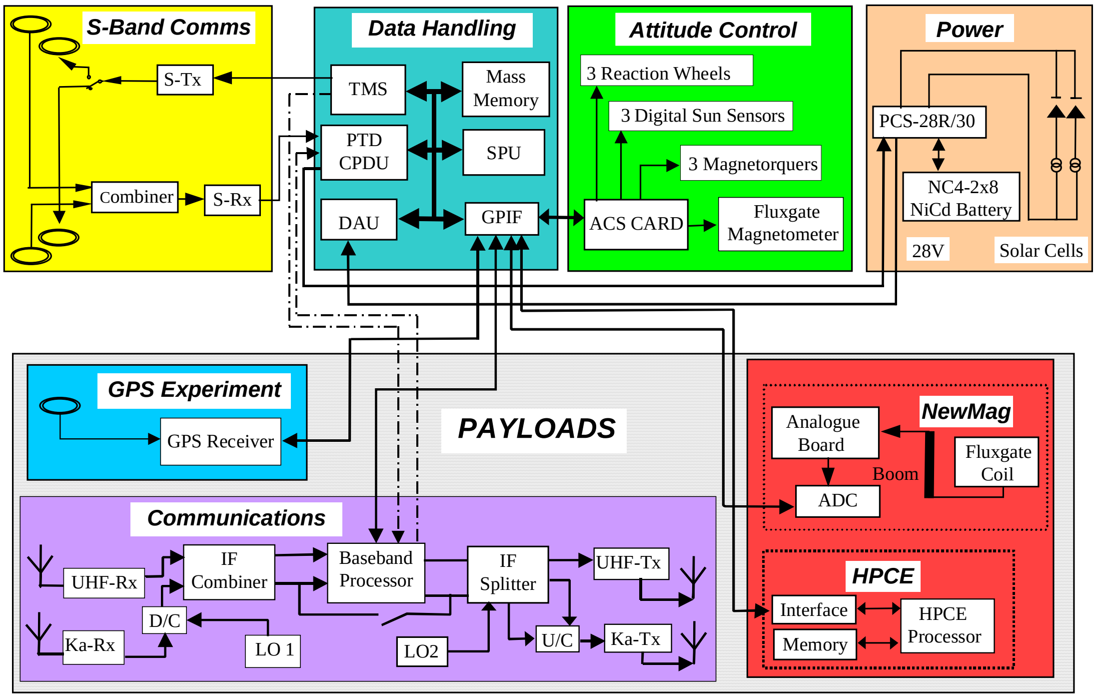
Figure 1 Spacecraft Block Diagram



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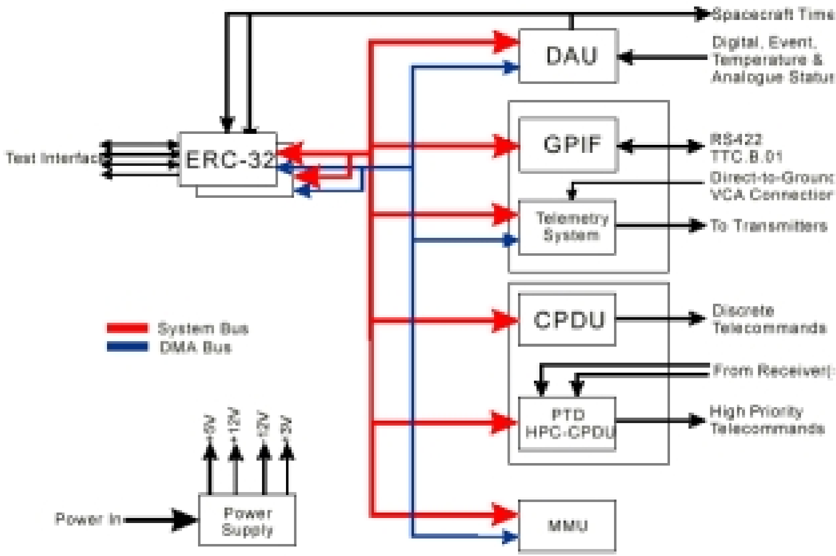

Figure 2 Data handling system (Source: Space Innovations Limited, 1999)

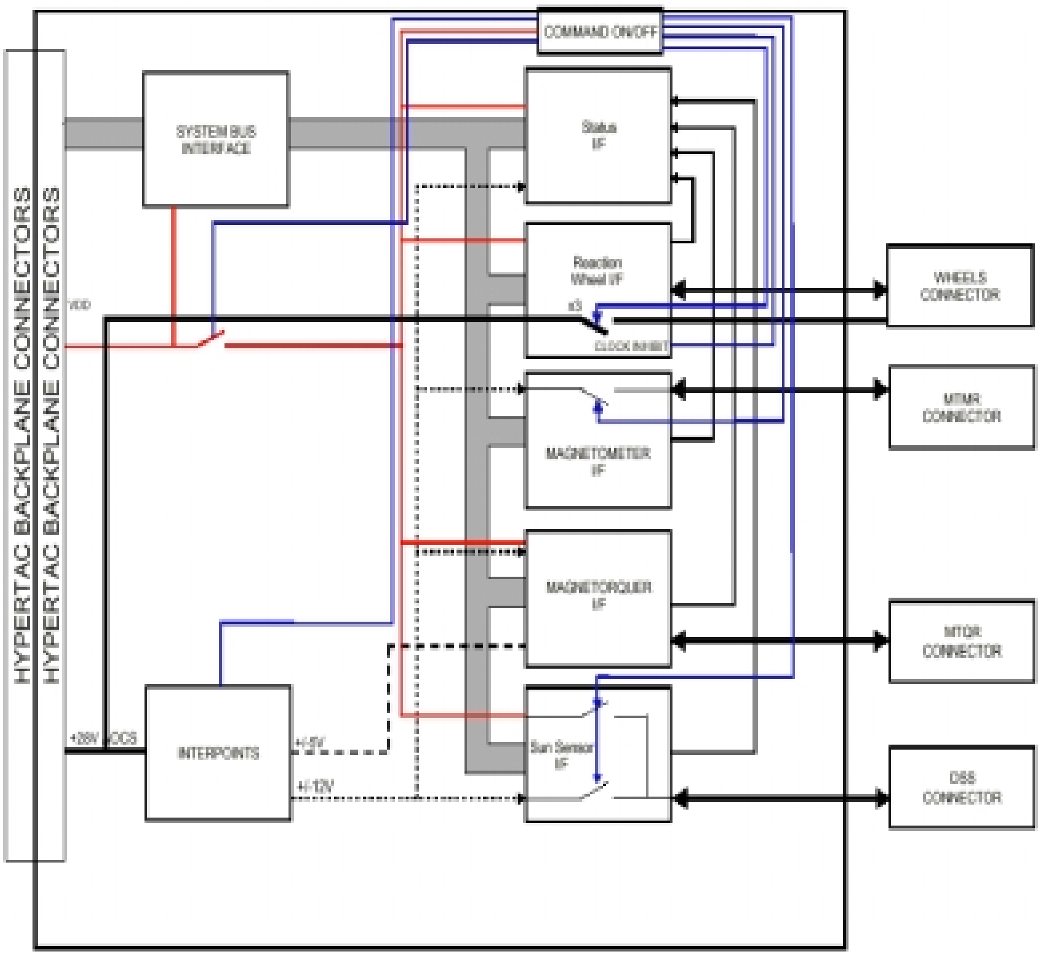

Figure 3 SACE card (Source: Space Innovation Limited, 1999)

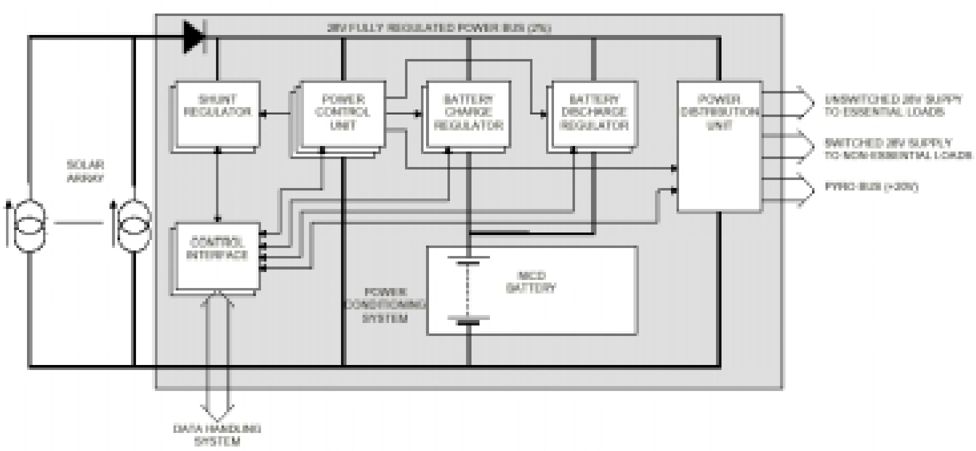

Figure 4 Power subsystem (Source: Space Innovations Limited, 1999)