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1996

NASA/ASEE Summer Faculty Fellowship Program

Marshall Space Flight Center

The University of Alabama

SEDSAT 1 Technologies

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Project Goals and Summary

The original goals of this project were to support the development of SEDSAT 1 for a tethered launch in July of 1997. This specifically required:

1. Monitoring development progress against a comprehensive delivery plan.
2. Incremental development and release of CDS and SEASIS software.
3. Supporting the integration of version 1.0 SEASIS software that will allow minimal autonomous operation without a software reload. These algorithms would include image quality evaluation, attitude determination, and autonomous earth imaging.
4. Developing software requirements and design for ground segment software, concentrating on command and data download capability; and interface to external development efforts for a more comprehensive software suite to be used after the initial mission.

Because of an unfavorable space shuttle safety review of the SEDS-3 tether deployer, and cost and schedule problems in upgrading the deployer, the mission was changed to an independent launch of SEDSAT. The original plan was to do a tether-less deployment from the space shuttle. Since this would have resulted in an unacceptable orbital lifetime, the mission was changed again to a tethered launch from a Delta II in June 1998. As a result of Marshall Space Flight Center's redirection of the SEDS-3 mission away from a tether launch, the whole question of a tether endmass had to be reconsidered.

The net result of these multiple changes was twofold. First, we completed work needed to define some aspects of ground software on SEDSAT 1 that would remain constant no matter the launch mode. Second, we developed a set of concepts for using SEDSAT-1 technology to support alternative endmass missions on SEDS-3. Both of these are included below.

SEDSAT Ground Software

One area of SEDSAT design that has been worked during the summer is the ground communications architecture. Figure 1 shows the basic hardware architecture for SEDSAT-ground communications. The hardware aspects are emphasized, though the schematic breakdown of the software is also shown. Figure 2 illustrates the architecture from a software perspective.

The communications link between the SEDSAT and the ground is a digital radio link. The basic rate is 9.6 Kbits/sec, though experiments at 57.6 kbits/sec are also planned. The link carries AX.25 frames, which encapsulate application data specific packets. Software routines, provided as part of SCOS, carry out the encapsulation and pass byte blocks to the hardware. The byte blocks go out over the serial port to the transponder which transmits them. On the ground side a Yaesu radio picks up the link and passes a lowpass signal to a modem The modem demodulates the bit stream and passes it to the TNC, which interprets the AX.25 packets internally. The data sections are re-encapsulated onto the PC serial port. The serial port is read by PC software drivers, which pass application level data to the labview front end. The labview front end interprets the packets and displays or archives the received data.

During the summer the basic ground communications system was built and tested. Configurations both with and without the transponder in place were tried. The transponder can be bypassed by connecting the serial port of the CDS board to a suitable tap point in the TNC, although not all of the TNC's will accept this.

Neither configuration has fully checked out in the lab. With the system wired directly the link is established in software and the packet stream can be observed on a monitor. However, packets containing executable program material cannot be passed so user tasks cannot be uploaded. The reason is not clear.

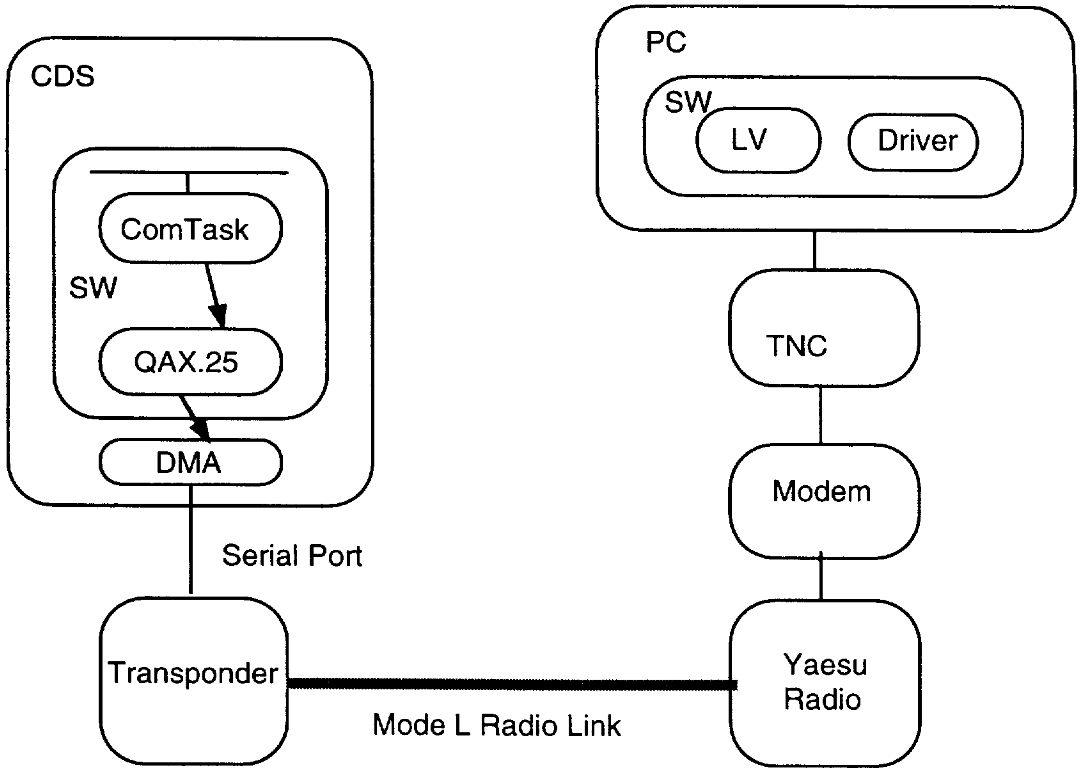

Figure 1: Hardware architecture diagram for SEDSAT ground communications

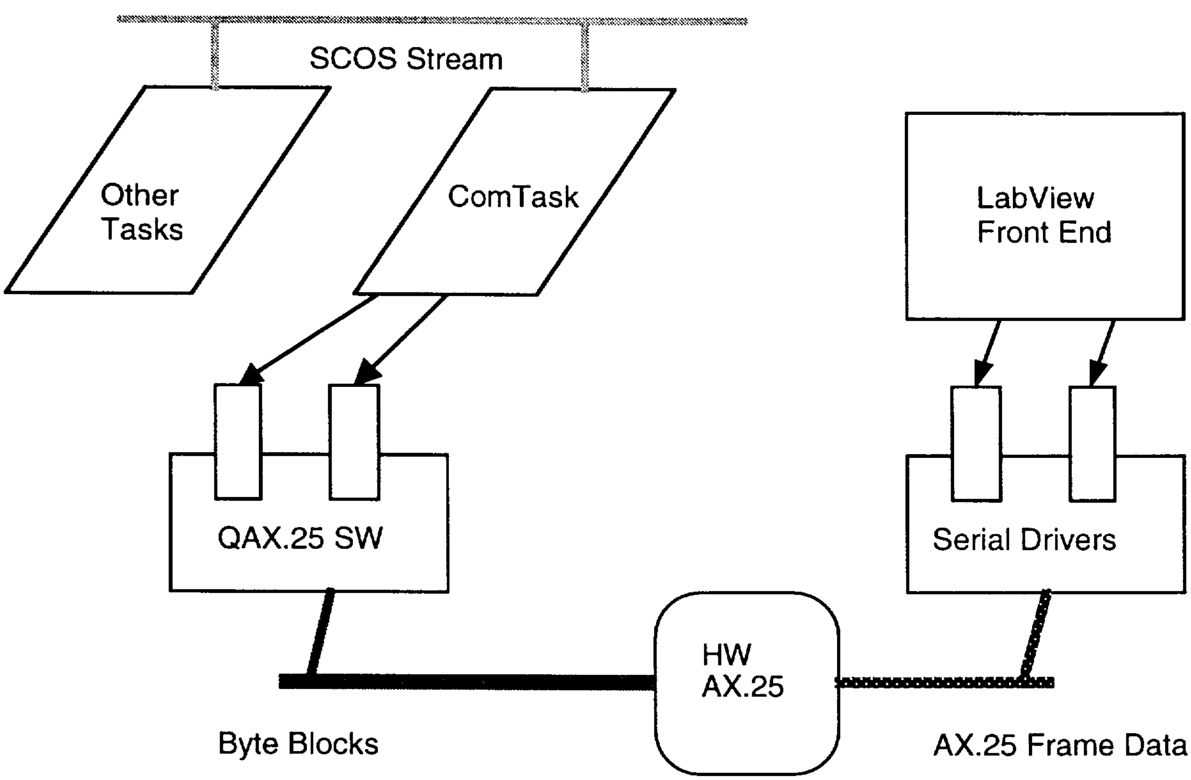

Figure 2: Software architecture diagram for SEDSAT ground communications

The transponder works and transmits when placed in the system chain. However, no data can be demodulated at the ground end. Based on laboratory measurements it appears that the transponder was stuck operating in 57.6 kbit/sec mode when the available ground station hardware can handle only 9.6 kbit/sec mode. This diagnosis was based on a spectrum analyzer display resembling ±17 Khz suppressed carrier FSK coming from the transponder, which corresponded to the specified modulation pattern for 57.6 kbit/sec transmission. The transponder was returned to the vendor for calibration and its correct operation confirmed. The most likely cause of the stuck condition is incorrect wiring in the CDS motherboard backplane.

From the software perspective, the SEDSAT software tasks read a communications data stream managed through ComTask. ComTask sends and receives data through calls to QAX.25 routines. On the ground end, a front end written in LabView sends and receives application level data packets through a set of serial drivers. The AX.25 protocol encapsulation and decoding is all done in the TNC.

SEDS-3 Mission Concepts

Technology developed between Marshall and UAH on SEDSAT can have wide application to potential SEDS-3 tether endmass missions. As examples the following sections examine possible missions, scenarios, and architectures for building a SEDS-3 endmass with maximum exploitation of SEDSAT 1 technologies.

Objectives

A new SEDS-3 endmass could address three principal scientific objectives:

1. Make a video record of deployment to determine the ability of astronauts to do visual discrimination of nominal and off-nominal deployment.
2. Record the three-dimensional dynamics of tether rebound during a hard snag event.
3. Record the three-dimensional dynamics of tether recoil during a simulated micrometeoroid tether cut.

A more advanced endmass concept is called a vertical, tethered camera array. This experiment would support one principal objective:

1. Demonstrate multi-camera stereo reconstructive imaging of atmospheric objects using a two dimensional image array. The horizontal dimension will be provided by satellite motion (as is conventional). The vertical dimension will be provided by the tethered endmass.

Mission Scenario

The proposed system is oriented around a mission scenario that deliberately introduces off nominal deployment to study tether dynamics. The scenario envisioned is:

1. On system power up the endmass is activated and prepares for separation. The imaging system powers up and begins transmitting real-time video before endmass deployment is commanded.
2. As the endmass separates its instruments record accelerations.
3. The video imaging system transmits real-time video of the tether deploying. Simultaneously, the stereo imaging subsystem is capturing and storing stereo stills to determine three-dimensional tether position.
4. After a desired length of tether is deployed the deployment is brought to a sharp halt to simulate a hard snag. The endmass records accelerations. The imaging system transmits and records the tether rebound. At the same time the other experiments would be

monitoring structural loads and the smart tether cutter would be firing (without actually cutting the tether).

5. After the tether has begun to swing, and tension has risen to a steady high, the endmass is commanded to release the tether. The imaging system records the recoil and subsequent redeployment under gravity gradient forces.
6. After the recoiling tether stabilizes the real-time video is commanded off. The stored digital stereo stills are now transmitted using the same transmitter. If an electrodynamic tether were deployed it would now operate. Optionally, the imaging system could continue to monitor the electrodynamic tether as desired.
7. The endmass continues to operate until the end of its battery life. Depending on the orbit, it will re-enter sometime later. Since the tether is not attached to the endmass it will most likely have significant orbital lifetime.

Requirements

Meeting these first set of objectives requires a deployment and endmass system capable of normal deployment, simulating a hard snag, and commanded release of the tether at the endmass at a suitable time. It would be desirable for the endmass to be able to record accelerations and attitude throughout deployment. A video/image recording system is required to capture video of deployment and stereo images at selected times. Of course, a data link system must be present to transfer all data to the ground as well as supporting power systems. vertical camera system requires orientable cameras in the endmass and on the deployer platform that can be coordinated.

SEDS-3 Endmass

The proposed endmass is derived from the SEDSAT project. It uses the SEDSAT structure, battery design, tether release mechanism, and accelerometers. It uses a new electronic design based on off-the-shelf components to facilitate early software development. A schematic of the proposed endmass is shown in Figure 3.

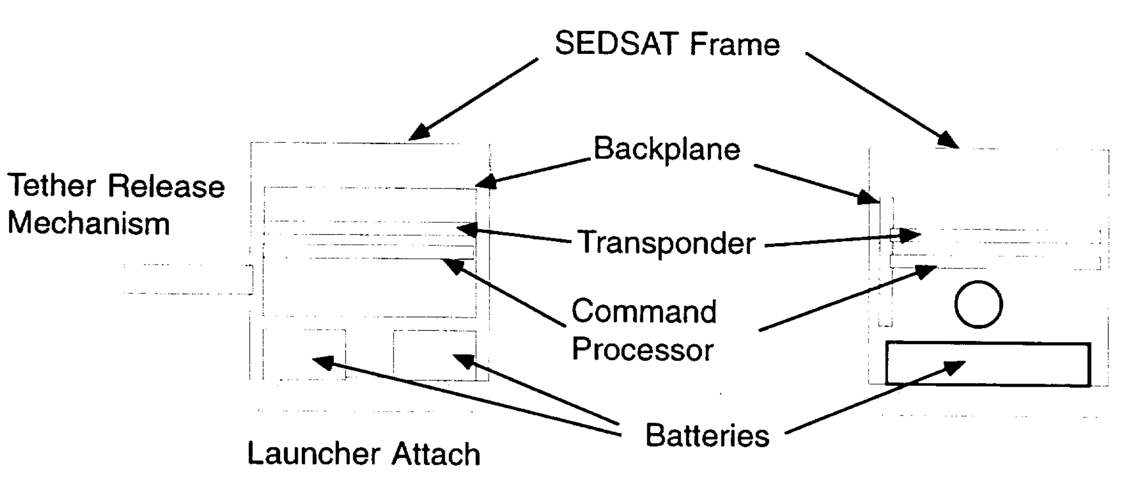

Figure 3: Schematic of proposed SEDS-3 endmass configuration. The system uses a simple structure with electronics supporting acceleration measurements and commanded tether release. There is an option for attitude measurement.

Making use of major portions of the SEDSAT design will carry important benefits. The SEDSAT structure is well characterized, with full production drawings immediately available. It can be produced quickly at known cost and has an existing history of structural characterization and flight paperwork. The tether release mechanism has not been built, but it has full drawings and the design has already been exposed to extensive review. The accelerometer package may be available without procurement from the existing SEDSAT project. The battery system has also been designed and a NASA Marshall procurement is in progress for SEDSAT.

The electronic design of the endmass should be reconsidered in light of the needs of the SEDS-3 mission. Assuming non-amateur frequencies are used for communications, the SEDSAT electronics can be replaced with higher capability, lower power designs. An off-the-shelf board solution will be considered to facilitate immediate development of a laboratory breadboard. The features and benefits of the proposed SEDS-3 endmass are shown in Table 1.

Table 1: SEDS-3 Endmass Features and Benefits

Feature	Benefit
SEDSAT derived structure	Known cost to construct, existing design reviews, designed for Delta secondary
SEDSAT proposed tether release mechanism	Existing design reviews, existing fabrication quotes
SEDSAT batteries	Existing designs, existing procurement paperwork, option for NiCAD for lower cost.
Accelerometers	Existing hardware, measures deployment accelerations
Off-the-shelf transponder	Moderate to high data rate available, known physical compatibility
COTS compatible electronics design	Rapid laboratory breadboard for software development
OPTION: PAL camera	Measures attitude during deployment
OPTION: Gyro package	Measures attitude during deployment, ring laser gyros very compact

Conclusions

Unfortunately, rapid program changes are to be expected. The technologies developed under SEDSAT can be applied to other small satellite projects, and seem particularly well suited to small tether experiments. In particular, the technologies could be used on a expendable booster mission to experimentally test dangerous dynamic conditions and, hopefully, alleviate some of the concerns for manned space flight that arose during SEDS-3 planning. The tethered satellite framework is an interesting one for earth observing missions, and future experiments seem worthy.