Session 2004-1880

EyasSAT:
Transforming the Way Students Experience Space Systems Engineering

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Abstract

The Department of Astronautics at the United States Air Force Academy has transformed the way spacecraft systems engineering is taught, and more importantly, the way it is experienced by students. This new development is called EyasSAT™—a miniaturized, fully functional satellite model that is "flown" in the classroom.

EyasSAT literally means "baby FalconSAT," where FalconSAT is the name of the flagship satellite program at USAFA. Students work as a team their senior year to design, build, launch, and/or operate a real satellite performing Department of Defense science. To prepare for this interdisciplinary experience, students take the prerequisite course titled "Spacecraft Systems Engineering." Students in this course work in small teams to build up an EyasSAT system, subsystem by subsystem, after the design issues are covered in the classroom.

The premise is simple: EyasSAT is composed of intelligent, stand-alone hardware modules built with commercial components that are integrated through a flexible data and power bus. Instead of designing and building each subsystem in detail, EyasSAT allows students the opportunity to perform acceptance and verification testing on the hardware as they learn about each subsystem in the classroom. This matches the spirit of the course, which is to broadly cover all spacecraft system and subsystem level issues and not to cover one subsystem in great detail. After each subsystem is tested and characterized in the lab, it is stacked up in an integrated fashion, ultimately producing a picosatellite-sized fully operational system by the end of the semester. A wireless link to a computer provides the command and telemetry interface. EyasSAT also can be easily expanded through additional payload or subsystem modules to support teaching or commercial objectives.

This paper outlines the system concept and design, as well as assembly, integration and testing basics. System characterization processes and data are likewise presented.

Introduction

The mission of the Department of Astronautics at the United States Air Force Academy (USAFA) is "to produce the world's finest officers who live the core values and understand space." (The core values that the cadets adopt are: Integrity first, Service before self, and Excellence in all we do). To support that mission, we firmly believe in "learning space by doing space." Every student graduating with an Astronautical Engineering degree completes a capstone design project, either a satellite design (FalconSAT) or rocket design (FalconLAUNCH) effort.

FalconSAT provides students an opportunity to participate in the design, build, test, and/or mission execution of real microsatellites that perform DoD missions. FalconLAUNCH provides an opportunity for students to design, build, test and launch payload-capable sounding rockets. Before students can participate in either of these capstone engineering design courses, space systems and rocket design issues must be well understood through prerequisite classroom experiences. The course that fulfills the space systems requirement is Astronautics 331, Space Systems Engineering.

EyasSAT Project Description and History

Due to USAFA-wide curriculum changes in the fall of 2002, our Space Systems Engineering course had to be re-scoped from two semesters to one. Upon a thorough review of the course curriculum, the opportunity arose to modernize the hands-on laboratory portion of the course. The vision of "students working in teams to build a micro-satellite over the course of a semester" was soon realized by a team of government and contractor engineers and given the project name of EyasSAT. The name EyasSAT was the logical choice, as "eyas" is the term for a baby falcon, implying that this experience prepares them for the FalconSAT capstone design experience the next year. It has truly revolutionized the way students understand space systems engineering.

The EyasSAT concept is not wholly unique. The CubeSat[2,3,4,5] effort at Stanford University provided the inspiration for building micro-satellites in a short period of time. However, unlike CubeSat, EyasSAT was designed purely to meet the educational needs of the classroom and not for spaceflight.

EyasSAT System Overview

EyasSAT is a microsatellite that demonstrates all six of the traditional satellite subsystems: Structural, Electrical Power (EPS), Data Handling, Communications (Comm), Attitude Determination and Control (ADCS), and Thermal subsystems as shown in the block diagram in Figure 1 and in the picture in Figure 2. It also has the capability to integrate other subsystems, such as propulsion and experimental payloads, which is discussed at the end of the paper.

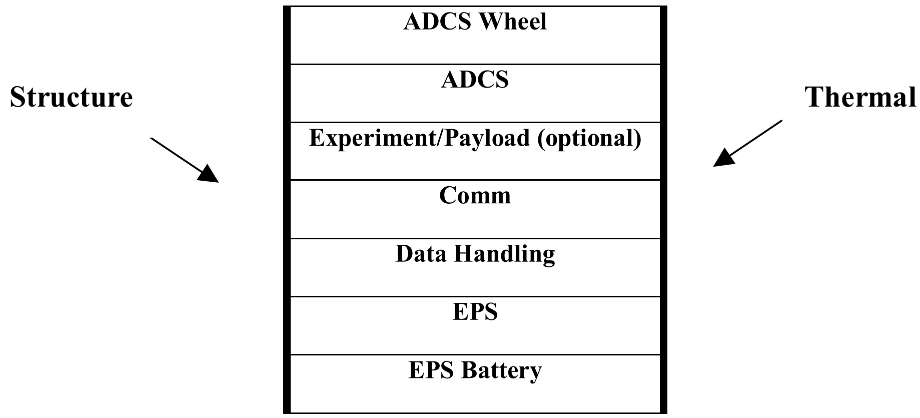

Figure 1. EyasSAT Subsystems Bock Diagram

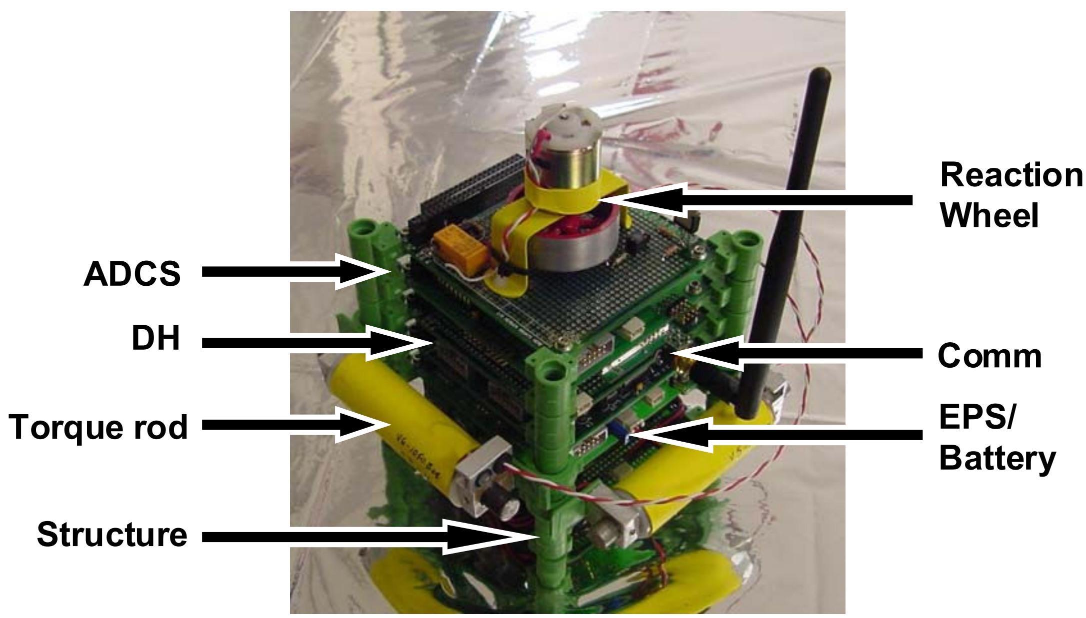

Figure 2. Photo of EyasSAT Subsystems

As students progress through the course exploring satellite subsystems, they literally build an EyasSAT from the ground up. After a block of two to three lessons on a particular subsystem, they spend an entire two-hour lab period reinforcing the concepts and design issues learned in class. During each phase, they act as the integrating contractors for the government. As each subsystem of the satellite is delivered, they perform an acceptance test of the subsystem and validate and/or characterize the performance of the subsystem and compare the results with the subsystem specifications. They do not design or build the subsystem modules themselves, as there is not enough time and that would be out of the courses' scope at the undergraduate level. The students then integrate the subsystem with the existing stack of EyasSAT modules and perform integrated checkout tests. A 74-page lab manual and 22-page workbook guide them through the process.

The following specifications for EyasSAT are the foundation of the project:

1.0 EyasSAT shall be an affordable and sustainable micro-satellite laboratory demonstration tool for the purpose of Space Systems Engineering instruction based on Space Mission Analysis and Design (SMAD)[1] principles.

2.0 EyasSAT shall demonstrate six satellite subsystems (Structural, Electrical Power, Data Handling, Communications, Attitude Determination and Control, and Thermal) and have the capability to optionally support additional subsystems such as propulsion and experimental payloads.

The remainder of the paper describes each EyasSAT subsystem and discusses how it is used to reinforce concepts learned in class.

Structural Subsystem

As in any satellite structure, the EyasSAT structure serves to enclose the module stack, mount solar panels, mount thermal panels, and provide a lifting point. It also serves as the external mount for the power switch, antenna, separation switch, battery charge port, and ADCS sensors. The subsystem module corners facilitate stacking of modules. See-through materials where chosen for the outer structure to literally eliminate student's "black box" thinking about satellite design. The final dimensions for EyasSAT are 7.5" L x 7.5" W x 8.5" H, giving a volume of 478 in^3. A picture of the structure is shown in Figure 3.

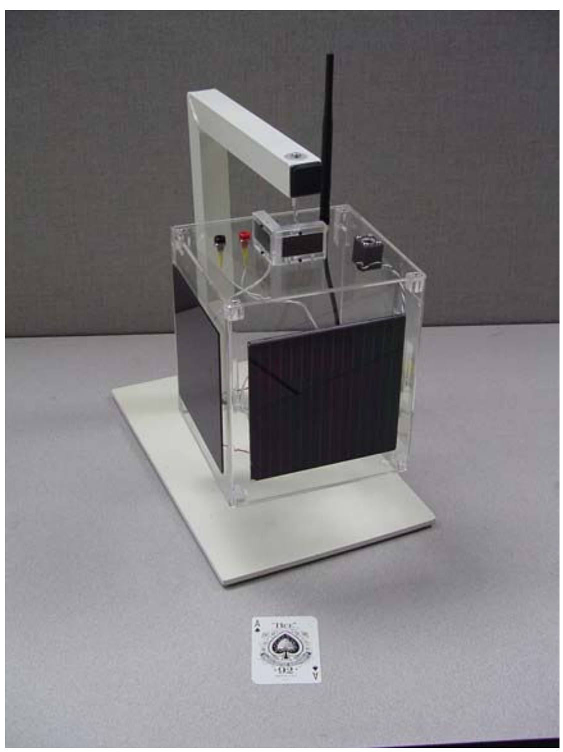

Figure 3. EyasSAT Structure

The structural subsystem specifications are as follows:

2.1 The EyasSAT Structural Subsystem shall provide structural support for all satellite modules and components.

2.1.1 The EyasSAT Structure shall enclose the EyasSAT stack and provide a platform for secondary structures.

2.1.2 The EyasSAT Structure shall have mounting locations for the EyasSAT Solar Array, EyasSAT Thermal Panel (Black), EyasSAT Thermal Panel (White), and provide one access hole.

2.1.3 The EyasSAT Structure shall be mounted on the EyasSAT Bottom Plate, which provides mounting for the EyasSAT Separation Switch, EyasSAT Sun Sensor (B), EyasSAT Stack Rods, and EyasSAT Mounting Feet.

2.1.4 The EyasSAT Structure shall be enclosed on top by the EyasSAT Top Plate, which provides mounting for the EyasSAT Sun Sensor (T), EyasSAT Yaw Attitude Sensor, EyasSAT Charge Port & Harness, EyasSAT Power Switch, EyasSAT Lifting Lug, and EyasSAT Antenna Cable.

2.1.5 The final assembled EyasSAT mass shall be no greater than 3.5 kg.

The first objective of the structures lab is to demonstrate the validation of a satellite's natural frequency by running sine sweep and random vibration tests. Students then compare the results with their predicted result from the natural frequency formula. Instead of using the EyasSAT hardware for these tests, we use a representative mass-spring model of EyasSAT so the students can clearly visualize the system and process.

The remainder of the lab is spent determining an as-built mass budget for EyasSAT. The students are issued their EyasSAT hardware. They then determine the mass of all the components and develop their mass budget. A sample mass budget is shown in Figure 4.

Subsystem	Mass (kg)	%
Structure	1.21	39%
EPS	1.03	33%
DH	0.08	3%
Comm	0.1	3%
ADCS	0.54	18%
Thermal	0.12	4%
Total	3.08	100%

Figure 4. EyasSAT Mass Budget

This lab follows a large block of systems design issues covered in chapters 1-3, 10, 11.6, and 12 in SMAD[1]. This lab experience reinforces the top-level aspects of systems design, introduces them to the concept of design budgets, and demonstrates simple structural verification tests. Students then complete a lab report that addresses sample structure data and conclusions, the actual mass budget for EyasSAT with a comparison with other micro-satellite missions, and they begin building an EyasSAT specification verification matrix. The purpose of this verification matrix is to introduce the students to the concept of validation loops performed in systems engineering to ensure the design meets the requirements.

Electrical Power Subsystem

The core of the EyasSAT electrical power subsystem (EPS) is a power regulation and conditioning module that provides regulated 5, 3.3, and unregulated 9 VDC. Telemetry data is initially observed through a direct RS-232 link from a laptop to the module and later through the data lines of the system bus, called EyaBUS™. The battery module provides 9 VDC, 1.6 Ah through NiMh technology batteries. A low-efficiency solar array provides V_{oc}=18 VDC, I_{sc}=120 mA in full sun. Due to the size and quality of the solar cells used, they can only be used to demonstrate the concept of primary power generation, but they cannot actually run the satellite. Power is distributed through the power lines of EyaBUS. Pictures of the EyasSAT EPS are shown in Figure 5 and Figure 6 below.

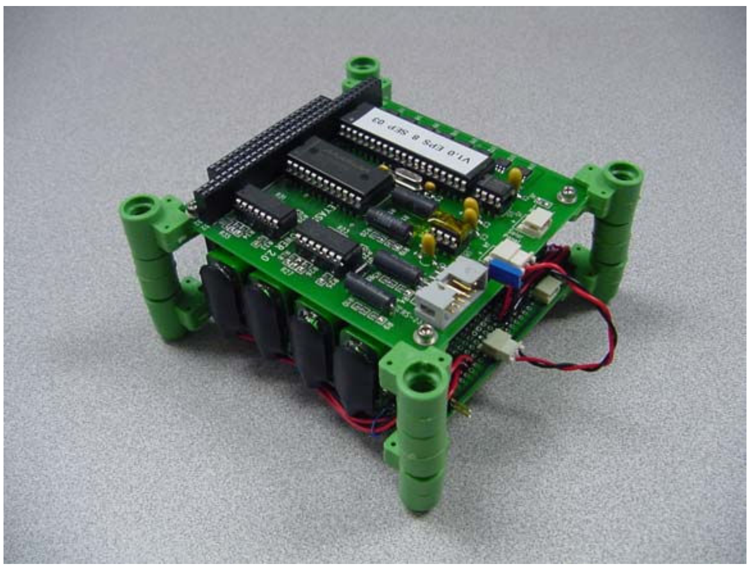

Figure 5. EyasSAT Power Module and Battery Module

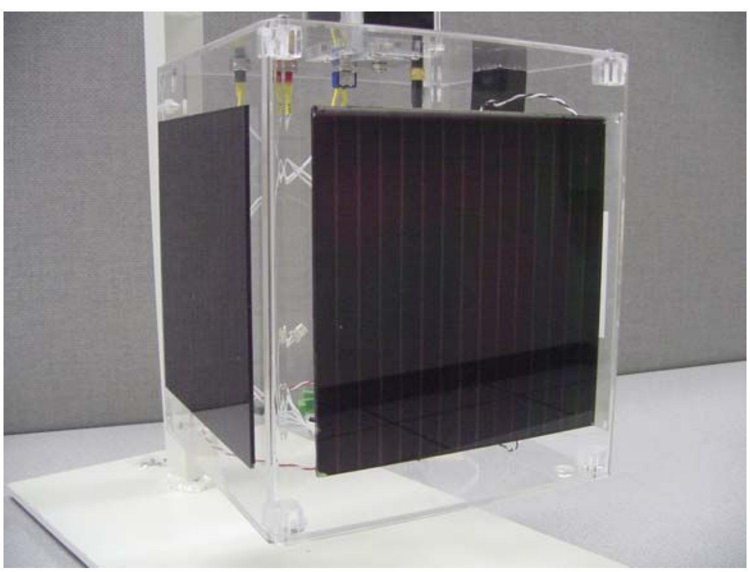

Figure 6. EyasSAT Solar Array

The electrical power subsystem specifications are as follows:

> 2.2 The EyasSAT Electrical Power Subsystem shall consist of a solar array for primary power generation, a rechargeable secondary battery, a power regulation and conditioning module, and provide for distribution of regulated power throughout the spacecraft.
>
> > 2.2.1 The EyasSAT Solar Array shall consist of two 9V COTS silicon-technology solar panels connected in series to demonstrate primary power generation.
> >
> > 2.2.2 The EyasSAT Battery Module shall consist of eight 9V Nickel Metal Hydride (NiMh) rechargeable batteries connected in parallel to provide a secondary battery power supply.
> >
> > 2.2.3 The EyasSAT power regulation and conditioning (EPS) module shall provide two regulated power supplies (5 and 3.3VDC). Each power supply shall be accessed through one fixed line and four switched lines for a total of 10 regulated power lines.
> >
> > 2.2.4 The EyasSAT EPS Module shall also provide real-time telemetry of the voltage and current levels of the battery, solar array, 5 VDC line, and the 3.3 VDC line. This information shall be available through a direct RS-232 umbilical connection to a PC or through a SPI connection on the EyaBUS.
> >
> > 2.2.5 The EyasSAT power bus shall distribute the regulated power described in specification 2.1.3 to all modules connected to the EyaBUS.

The first objective of the EPS lab is to perform acceptance and verification tests on the EyasSAT Battery Module. Students inspect the module and compare it with a known good module and pictures. They then perform an initial functional test on the module to confirm all the wiring is sound and that there is an initial charge on the battery. Finally, the batteries are charged for five minutes to determine the state of charge.

Next, acceptance and verification tests are performed on the on the EyasSAT Solar Array. As with the battery module, students inspect the array and verify initial functionality of the array and a thermistor used later in the thermal lab. Finally, the solar array is characterized by building an I-V curve, which highlights where the peak power point of the array lies as shown in Figure 7.

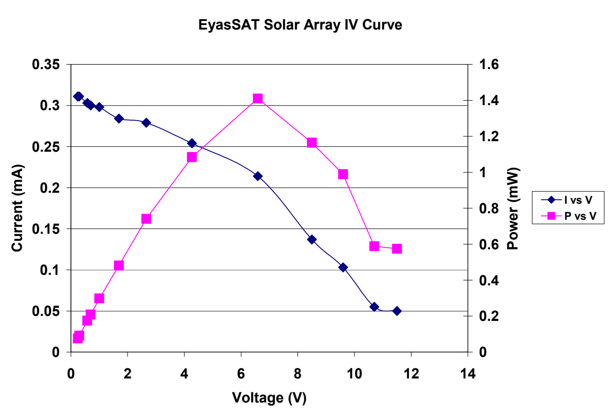

Figure 7. EyasSAT Solar Array I-V Curve

Then, acceptance and verification tests are performed on the EyasSAT EPS Module. As before, students inspect the module and confirm the module can supply regulated 3.3 and 5 VDC. The Atmel Mega8535[5] microcontroller software on the EyasSAT EPS Module is then tested to confirm that it can report telemetry data (current and voltage) of the battery, solar array, 3.3 VDC line, and 5 VDC line. The telemetry is observed through a RS-232 link and displayed using a terminal program, as shown in Figure 8. The additional four switched 3.3 and four switched 5 VDC lines are then tested. The last step is to characterize the efficiency of the EPS by determining the input and output power under load.

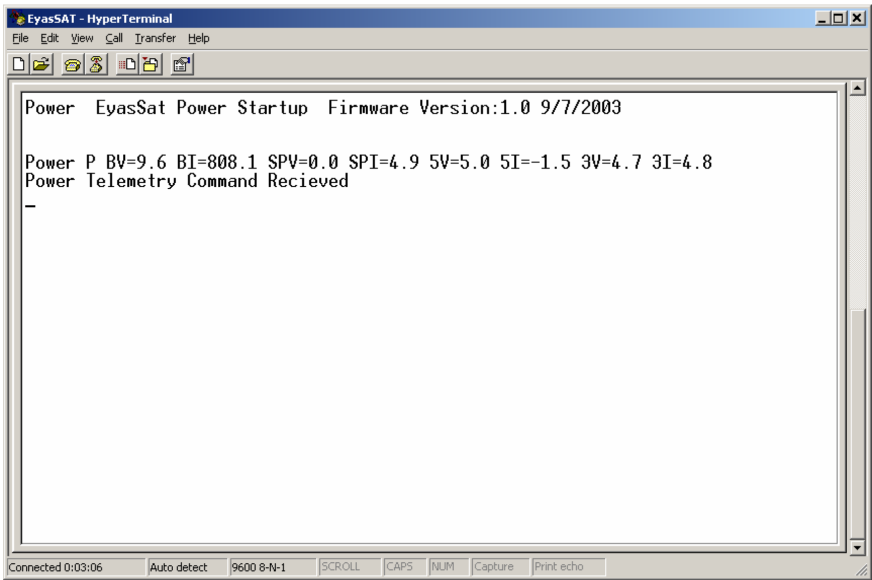

Figure 8. EyasSAT telemetry as observed through a PC terminal

Finally, the EyasSAT EPS Module, EyasSAT Battery Module, and EyasSAT Solar Array are integrated and verification tests performed to confirm integrated EPS operational status. Students then complete a lab report summarizing their results, conclusions, lessons learned and update their verification matrix. The lab reinforces the concepts learned in chapter 11.4 of SMAD[1], such as EPS architecture, efficiency, and functionality.

Data Handling Subsystem

The EyasSAT Integrated Housekeeping Unit (IHU) is powered by an Atmel Mega128 microcontroller serves as the system master control module. It collects and reports telemetry from all connected subsystems through the EyaBUS using the Serial Peripheral Interface (SPI) master-slave bus. It also receives commands sent to EyasSAT and sends them to the appropriate module for processing. A settable real-time clock provides data stamping. Eight direct analog inputs are configured for temperature data via external thermistors. A picture of the EyasSAT IHU is shown in Figure 9.

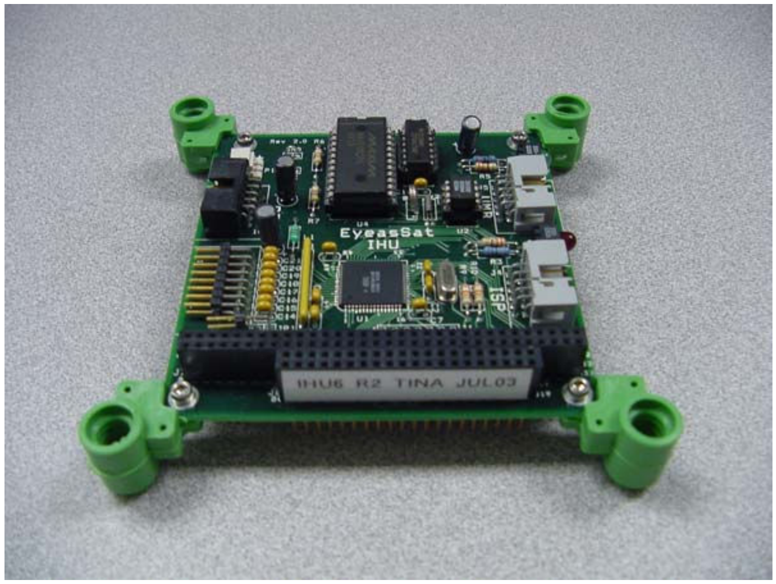

Figure 9. EyasSAT IHU

The data handling subsystem specifications are as follows:

> 2.3 The EyasSAT Integrated Housekeeping Unit (IHU) shall consist of a microcontroller with adequate capabilities to send commands to and collect telemetry from itself and up to eight additional "smart" modules in the EyasSAT stack.
>
> > 2.3.1 The EyasSAT IHU Module shall run on 5 VDC.
> > 2.3.2 The EyasSAT IHU Module shall provide an interface for wireless communications.
> > 2.3.3 The EyasSAT IHU Module shall provide three pulse width modulated outputs.
> > 2.3.4 The EyasSAT IHU Module shall provide eight general purpose digital I/O lines.
> > 2.3.5 The EyasSAT IHU Module shall provide eight analog inputs for the purpose of reading thermistor values for thermal telemetry.
> > 2.3.6 The EyasSAT IHU Module shall provide a settable real-time clock.
> > 2.3.7 The EyasSAT IHU Module shall accept commands as defined in the EyasSAT command list.
> > 2.3.8 The EyasSAT IHU Module shall report time-stamped telemetry as configured by the user.

The first objective of the data handling lab is to introduce the concept of calibrating telemetry channels. The EyasSAT EPS module is briefly revisited; one of the telemetry channels is calibrated by connecting it to instrumentation and determining the exact calibration coefficients for that set of hardware. Students realize that small variances in hardware due to manufacturer tolerances can lead to large discrepancies between telemetry and actual data.

The next objective is to inspect the EyasSAT IHU and perform a simple functional test to see if the module can be powered up. The software is then tested to ensure functions like time setting and refresh rates are working.

Finally, the EyasSAT IHU is integrated with the EPS. Integrated testing is performed to verify that the IHU can directly control the EPS. Students then complete a lab report summarizing their results, conclusions, lessons learned and update their verification matrix. The lab reinforces the concepts learned in chapter 11.3 and 16 of SMAD[1], such as data handling architecture and functionality.

Communications Subsystem

The EyasSAT Comm Module enables a wireless command and telemetry link through a Maxstream[6] OEM RS-232 communication module. It connects to the IHU through the EyaBUS using TTL level signals. The ground end interfaces directly through the PC's RS-232 serial port. The comm module communicates at 9600 baud and uses frequency hopping in the 900 MHz ISM band to communicate. The Maxstream modules are multi-channel configurable to facilitate multiple lab stations and have a selectable assured data delivery mode. A picture of the EyasSAT Comm Module and EyasSAT Radio Frequency Ground Support Equipment (RF GSE) is shown in Figure 10.

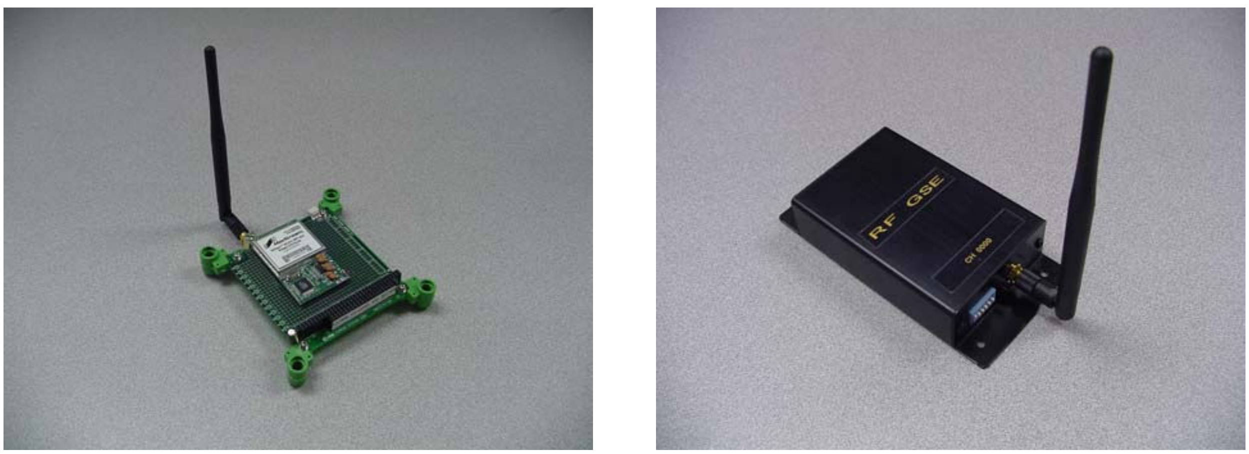

Figure 10. EyasSAT Comm Module and RF GSE

The communications specifications are as follows:

2.4 The EyasSAT Comm Module shall provide assured wireless communications between EyasSAT and a laptop.

- 2.4.1 The EyasSAT Comm Module shall run on unswitched 5 VDC.
- 2.4.2 The EyasSAT Comm Module shall interface directly to the EyasSAT IHU Module.
- 2.4.3 The EyasSAT Comm Module shall emulate the functionality of the RS-232 umbilical with a wireless connection by talking with a "ground" unit (EyasSAT RF GSE) connected to the laptop.
- 2.4.4 The EyasSAT Comm Module and EyasSAT RF GSE pair shall be programmed on the same channel, yet unique from other pairs in the room to avoid cross talk.
- 2.4.5 The EyasSAT Comm Module shall have an "assured delivery" mode to guarantee 100% delivery of data.

The first objective of the communications lab is to inspect and test the EyasSAT Comm Module. A simple loop back test is performed using vendor provided software. Since the module's software cannot be easily tested in a stand-alone mode, it is integrated with the EyasSAT stack, which at this point in the sequence is the EPS and IHU modules. Once integrated, the students enjoy wireless communications with their EyasSAT for the remainder of the labs. They confirm that they can change communications channels and verify the assured delivery mode can be set.

Students then complete a lab report summarizing their results, conclusions, lessons learned and update their verification matrix. The lab reinforces the concepts learned in chapter 13 of SMAD[1], such as comm architecture, functionality, modulation, data rates, and link margins.

Attitude Determination and Control Subsystem

The EyasSAT Attitude Determination and Control (ADCS) Module, powered by an Atmel Mega8535[5] microcontroller, controls actuators, collects sensor data, and reports telemetry through SPI on the EyaBUS. It regulates speed and controls direction of the EyasSAT Reaction Wheel Module. It also energizes and controls polarity of torque rods. The EyasSAT ADCS Module determines precise yaw orientation through differential solar cell sensors and rough sun location through top and bottom sun sensors built of photoresistors. A picture of the EyasSAT ADCS and Wheel Modules are shown in Figure 11. Pictures of the attitude sensor, sun sensor, and torque rods are shown in Figure 12.

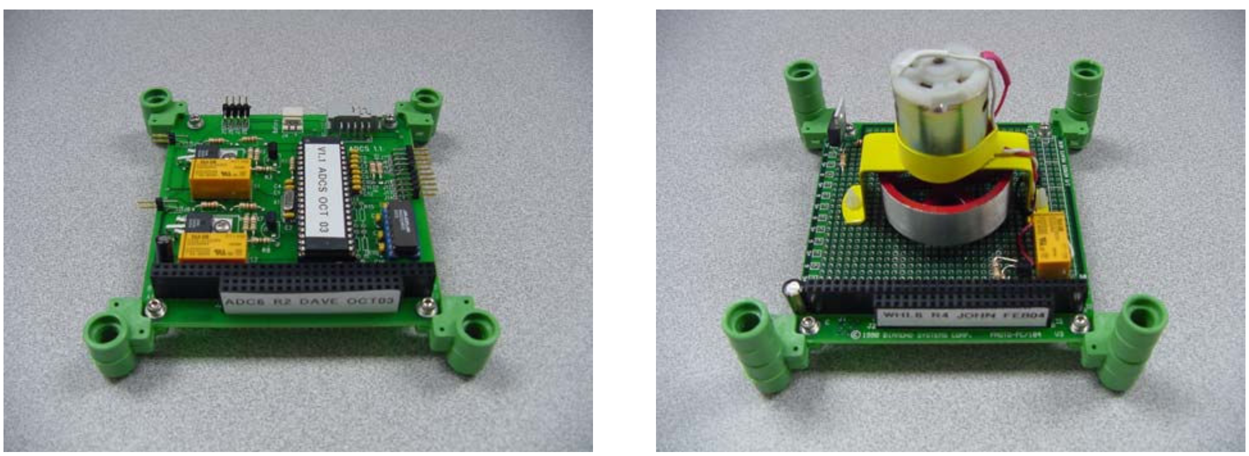

Figure 11. EyasSAT ADCS Module (left) and Wheel Module (right)

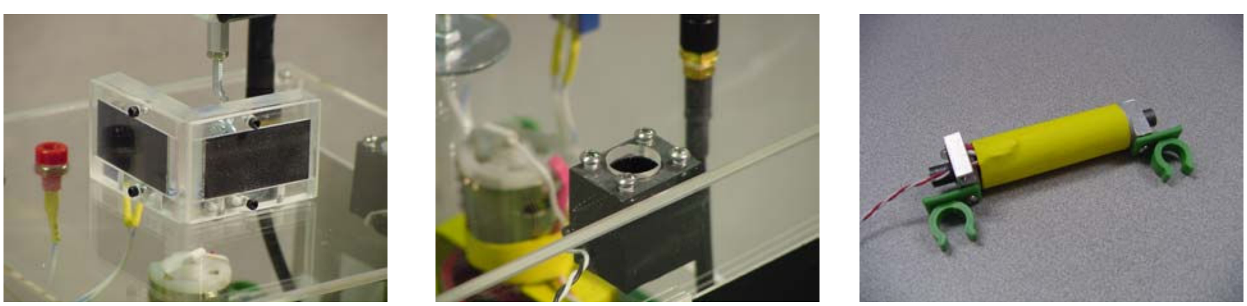

Figure 12. EyasSAT attitude sensor, sun sensor, and torque rods

The attitude determination and control subsystem specifications are as follows:

2.5 The EyasSAT ADCS Module shall provide one degree of freedom attitude determination and control to an accuracy suitable for classroom demonstration.

2.5.1 The EyasSAT ADCS Module shall run on switched 5 VDC for the logic functions and directly off the 9 VDC battery to power the actuators.

2.5.2 The EyasSAT ADCS Module shall be able to operate standalone through the EyasSAT RS-232 umbilical cable.

2.5.3 The EyasSAT ADCS Module shall interface with the EyasSAT IHU Module through the SPI bus.

2.5.4 The EyasSAT ADCS Module shall be able to independently control the EyasSAT Torque Rod (X) and the EyasSAT Torque Rod (Y), which are magnetorquers (actuators). The EyasSAT ADCS Module must be able to turn them on and off, plus reverse the polarity.

2.5.5 The EyasSAT ADCS Module shall be able to control the EyasSAT Wheel Module, which is a reaction wheel (an actuator) operating in either a zero or positive bias mode. The EyasSAT Wheel Module will provide a tachometer output and be reversible.

2.5.6 The EyasSAT ADCS Module shall have two inputs for a top EyasSAT Sun Sensor (T) and a bottom EyasSAT Sun Sensor (B) which are Cadmium Sulfide (CdS) type, which will detect light within a narrow range incident to the sensors.

2.5.7 The EyasSAT ADCS Module shall have two inputs for the EyasSAT Yaw Attitude Sensor, which is a differential Gallium Arsenide (GaAs) type sensor that can be used for attitude determination between +/- 90° from a center point.

The first objective of the ADCS lab is to inspect, test, and characterize the torque rods, reaction wheel, sun sensors, yaw attitude sensor, and the EyasSAT ADCS Module. The students then integrate the ADCS module with the current EyasSAT stack and connect all the sensors and actuators. The highlight of the lab is to demonstrate the functionality of the actuators by a free-hanging test. The effects of the reaction wheel can be demonstrated without any help, but the torque rods must be assisted by a bench-mounted torque rod to simulate a strong earth magnetic field, which greatly speeds up the response and settling time. A picture of the free-hanging test is shown in Figure 13. They must demonstrate the ability to dump the momentum of the reaction wheel by holding the spacecraft steady with the torque rod. Full closed-loop control cannot be demonstrated until the next lab when the sensors are mounted in the correct locations on the structure, which will be discussed in the next section.

Students then complete a lab report summarizing their results, conclusions, lessons learned and update their verification matrix. The lab reinforces the concepts learned in chapter 11.1 of SMAD[1]. Students come away with a strong understanding of ADCS systems and can visualize the effects of magnetic torque and rotational momentum on the spacecraft, as well as momentum dumping. They understand the difference between highly accurate ADCS sensors versus ones that give crude information about the satellites' orientation.

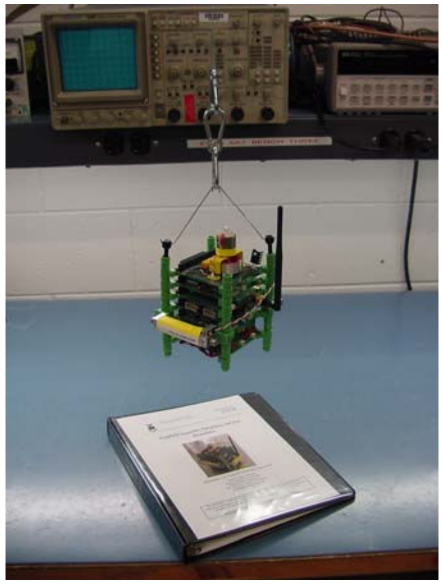

Figure 13. EyasSAT ADCS free-hanging test

Thermal Subsystem and Final System Integration

The grand finale of the lab portion of the course is to complete the integration of EyasSAT and demonstrate full functionality, including the thermal and ADCS subsystems. A picture of the final integrated EyasSAT is shown in Figure 14.

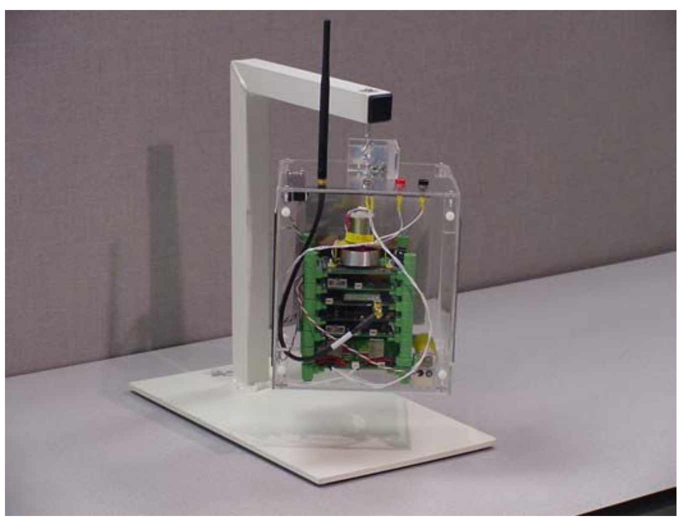

Figure 14. Fully Integrated EyasSAT

Once the students fully integrate their EyasSAT stack into the outer primary structure and connect all the various components, they run a full functional test on the satellite. They are then given a scenario to run through in about 30 minutes, wherein all the telemetry is recorded and later plotted in a final report. Thermal characteristics are explored by illuminating various sides with a halogen lamp and observing the results. A final as-built power budget is determined. Sample results are in Figure 15.

Subsystem	Power (W)	%
Structure	0.00	0%
EPS	0.27	24%
DH	0.25	23%
Comm	0.38	34%
ADCS	0.20	19%
Thermal	0.00	0%
Total	1.10	100%
Duty-cycled ADCS actuators		
Wheel	2.8	-
Torque rod	4.3	-

Figure 15. EyasSAT Power Budget

The most exciting part of the final lab is the closed-loop ADCS functional test. The students spin up the reaction wheel and stabilize the spacecraft using the torque rod. A special mode is initiated where EyasSAT will then follow a light source using the reaction wheel as an actuator and the yaw attitude sensor as the feedback. The students literally make EyasSAT dance!

Applications

EyasSAT can be used for much more than just providing a lab supplement to space systems engineering courses. In addition to supporting our Space Systems Engineering course, the Department of Astronautics is using EyasSAT in our Introduction to Astronautics course for subsystem demonstrations. The FalconLAUNCH program is using EyasSAT as their sounding rocket payload program. Our advanced control systems courses will eventually feature EyasSAT as the capstone controls platform at the end of the two-course sequence. Our FalconSAT program will use EyasSAT as a testbed for new payload and subsystem prototype development and proof-of-concept microsatellite demonstrations.

Users outside our department are also growing. The USAFA Physics Department is prototyping EyasSAT as a high-altitude balloon experiment payload platform. Air Force Space Command is using EyasSAT to support their Space 200 course run by the Space Operations School, which will eventually reach out to the entire mid-level space cadre in the Air Force and DoD. The Air Force Research Laboratory has contributed to the project by developing a micro pulsed plasma thruster for use on EyasSAT. There is also significant interest from other universities as well as companies teaching space short courses.

Future Capabilities

EyasSAT was designed from the ground up to be modular and expandable. Student or instructor built payloads/subsystems can easily be added, such as GPS, digital visible and IR imaging, target ranging and tracking, and proximity operations on an air table—space "battle bots." Upgrades are already being prototyped such as high efficiency solar arrays, composite structures, and a cold-gas thruster propulsion module. Space, not the sky, is the limit!

Conclusions

In less than a year, EyasSAT has revolutionized the way we teach Spacecraft Systems Engineering at USAFA. Students work in small teams over the course of a semester to build a microsatellite after receiving "just in time" teaching on each subsystem. It is a straightforward hand-on approach to teaching a topic that many times becomes an intangible concept due to the lack of relevant and easy-to-use lab hardware.

EyasSAT™ and EyaBUS™ is a registered trademark of Colorado Satellite Services.

Bibliography

1. Wertz, J.R., Larson, W.J, "Space Mission Analysis and Design," 3rd ed., Microcosm, El Segundo, 1998.
2. Heidt, H., Puig-Suari, J., Moore, A.S., Nakasuka, S., Twiggs, R.J., "CubeSat: A New Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation," Proceedings of the Utah State University Small Satellite Conference, Logan, UT, August 2001.
3. Nason, I., Creedon, M., Puig-Suari, J., "CubeSat Design Specifications Document," Revision V, Nov. 2001. <http://ssdl.stanford.edu/cubesat>.
4. Nason, I., Puig-Suari, J., Twiggs, R.J., "Development of a Family of Picosatellite Deployers Based on the CubeSat Standard," Proceedings of the IEEE Conference, Big Sky Montana, IEEE, 2002.
5. Schaffner, J. "The Electronic System Design, Analysis, Integration, and Construction of the Cal Poly State University CP1 CubeSat," 16th AIAA/USU Conference on Small Satellites, AIAA/USU.
6. http://www.atmel.com
7. http://www.maxstream.net

Biographies

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