

USAFA Department of Astronautics

Integrity - Service - Excellence

EyasSAT™

***Transforming the Way Students
Experience Space Systems Engineering***

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**United States Air Force Academy
Department of Astronautics**



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EyasSAT

Abstract

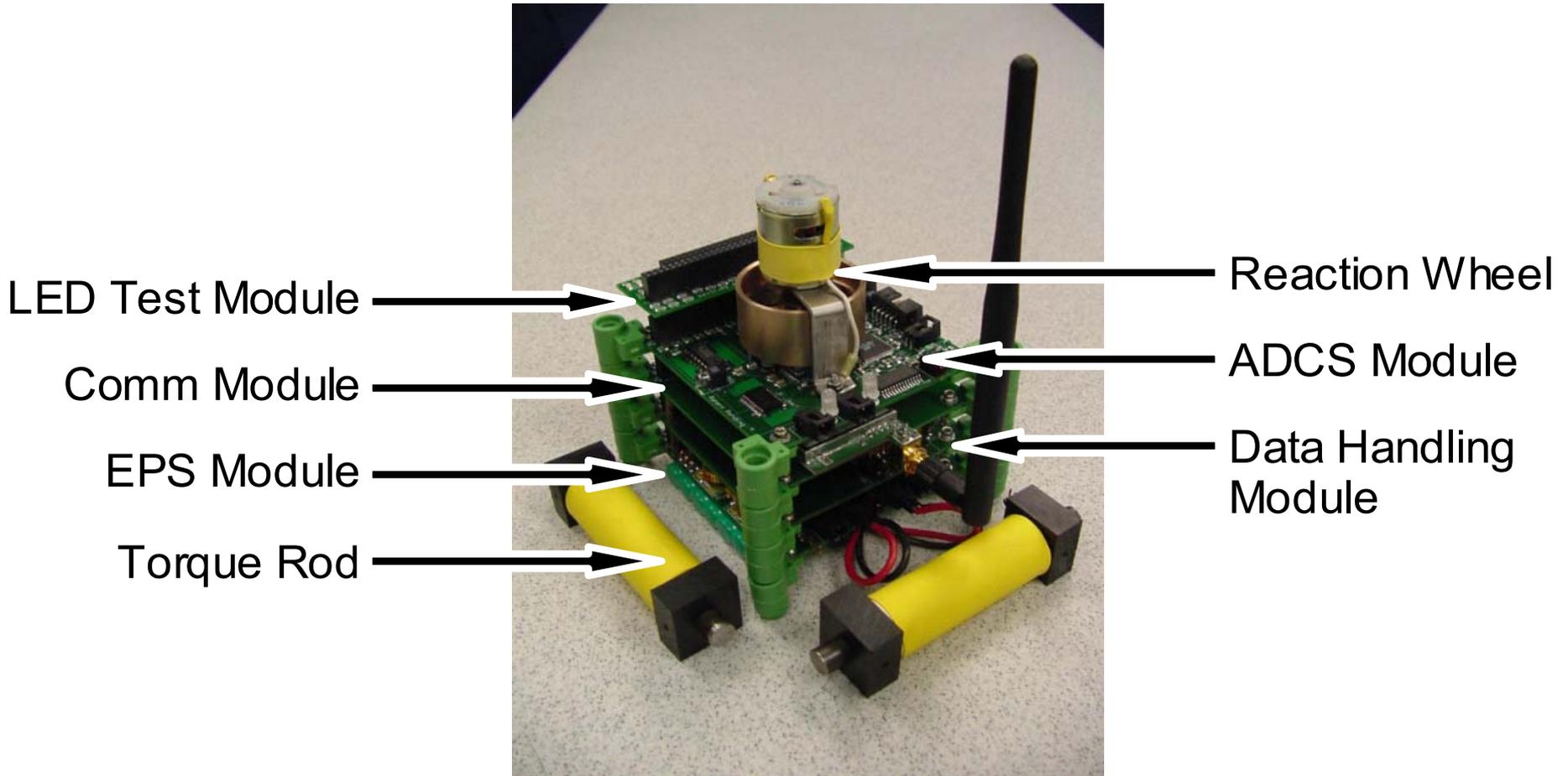
- **EyasSAT has transformed the spacecraft systems engineering classroom and laboratory experience at the USAF Academy.**
- **This new development is called EyasSAT (patent applied for)—a miniaturized, fully functional satellite model that is built up, tested, and “flown” in the laboratory over the course of a semester.**
- **The overall concept, results from two years in the classroom, and a full demonstration will be presented.**



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EyasSAT

Mission Objectives





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EyasSAT ***Research Partners***

- **EyasSAT was co-developed between the U.S. Air Force Academy, Colorado, USA and Colorado Satellite Services of Parker, Colorado, USA**
- **A Cooperative Research and Development Agreement (USAF CRDA NUMBER 04-AFA-239-1, 25 August 2004) was used as the research vehicle**
- **Significant contributions of funding and course development were provided by the National Security Space Institute, Air Force Space Command, Colorado Springs, Colorado, USA**



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EyasSAT

Mission Objectives

- ***“Learning space by doing space”*** experience to support ***“building officers of character who understand space”***
- **Enhances understanding and demonstrates basic functionality of spacecraft subsystems**
 - **Structure**
 - **Electrical Power**
 - **Data Handling**
 - **Communications**
 - **Attitude Determination and Control**
 - **Thermal Control**
- **Provides expandable platform for**
 - **Experimental payloads**
 - **Additional subsystems, such as propulsion**



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Mission Objectives

- EyasSAT originally designed for junior-level Astronautics 331 “Space Systems Engineering” course
- Course text: *Space Mission Analysis and Design, 3rd edition*
- Student teams of 2-3 test and integrate an EyasSAT “kit” over the course of a semester
- Lab sessions immediately follow a block of subsystem-specific lessons
- No module assembly is required, i.e. students do not solder up modules from kits
- Focus is on acceptance testing, characterization, and integration



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Dual-Audience Format

- The executive overview course option gives a thorough overview of space systems in a short period of time (half-day), suitable for inclusion in a short course.
- The engineering course option takes you through all the executive level steps, but adds depth through activities that require previous or current studies in engineering. The engineering level is suitable for integration into a semester-long course, in six increments of 2-hour sessions

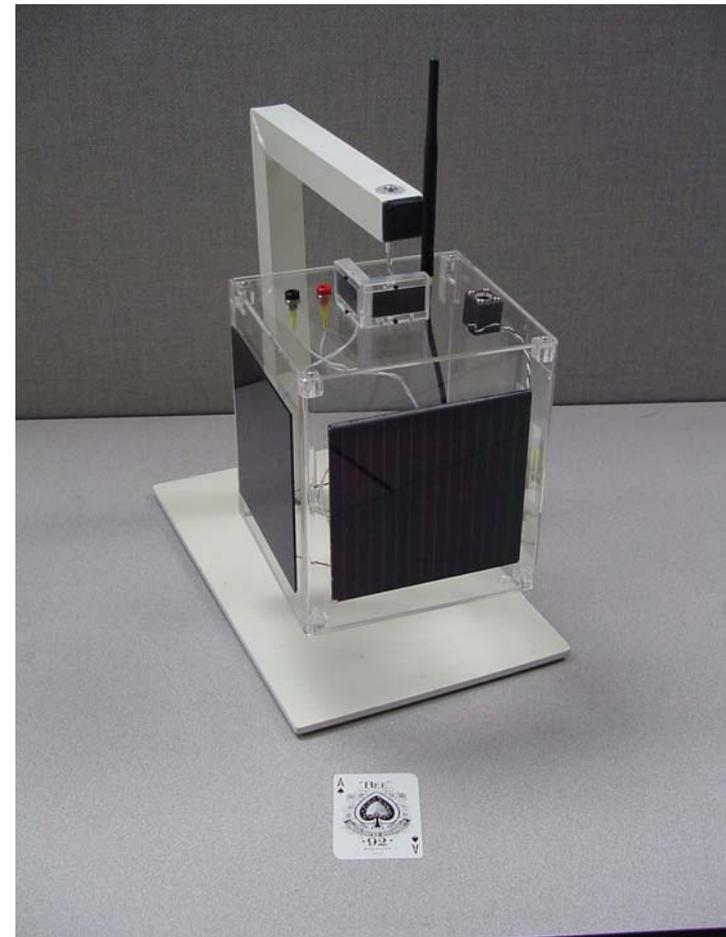


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Structural Subsystem

- Encloses module stack
- Mounting for solar and thermal panels
- Provides lifting point
- Subsystem module corners facilitate stacking of modules
- See-through construction eliminates “black box” thinking
- Dimensions: 7.5” L x 7.5” W x 8.5” H
- Volume: 478 in³





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Structural Subsystem Lab

- **Prelab**
 - Review structural subsystem concepts from lecture
 - Predict natural frequency of sample structure
 - Review EyasSAT structural specifications
- **Lab activities**
 - Random vibe and sine sweep measurements
 - Compare data with predicted results
 - Determine mass budget of EyasSAT
- **Lab report**
 - Summarize structure data and conclusions
 - Build EyasSAT mass budget
 - Compare results with other micro-satellite missions
 - Begin EyasSAT specification verification matrix



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EyasSAT

Mass Budget

Subsystem	Mass (kg)	%	LightSat
Payload (generic)	0.5	17%	24.40%
Structure	0.83	29%	22.70%
EPS	0.67	23%	24.60%
DH	0.13	5%	6.50%
Comm	0.08	3%	6.50%
ADCS	0.59	20%	13.00%
Thermal	0.11	4%	2.00%
Total	2.91	100%	100%



ASTRO-331
"EYAS SAT"

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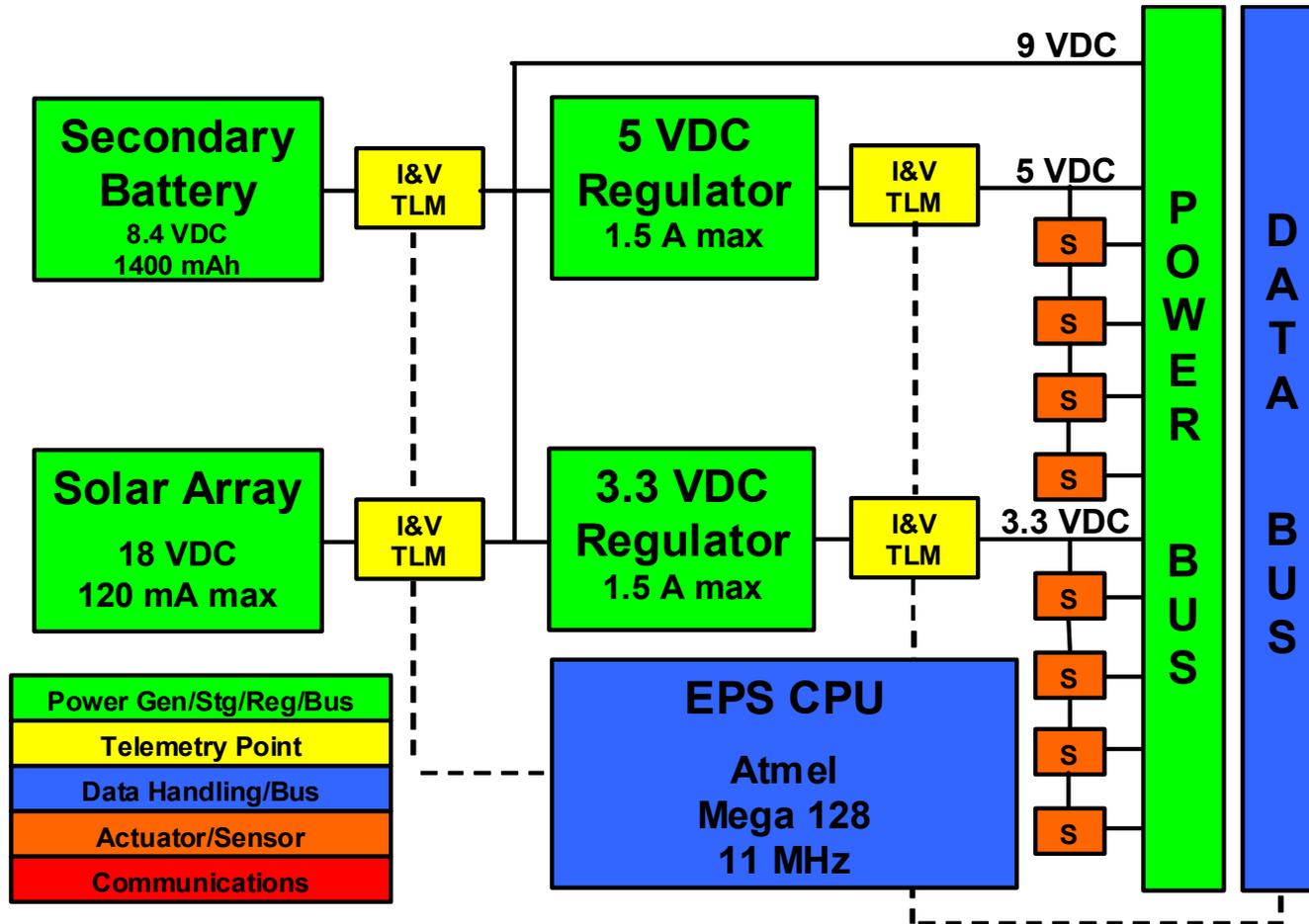
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Electrical Power Subsystem (EPS)

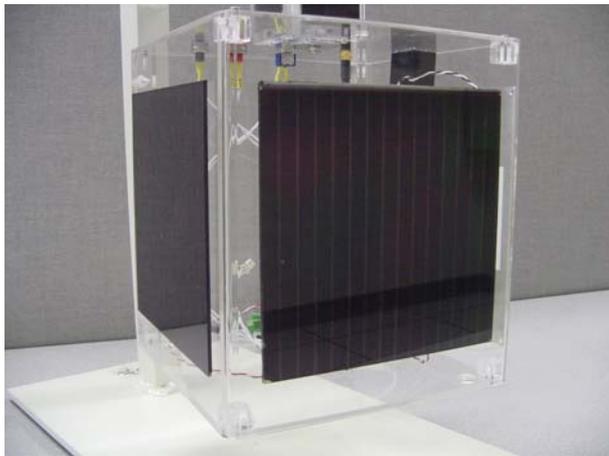
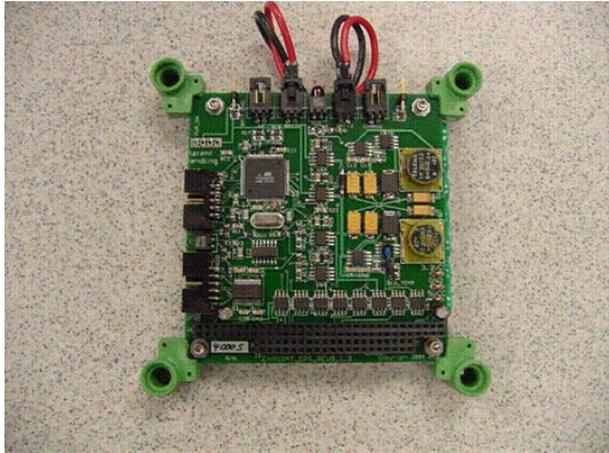




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Electrical Power Subsystem (EPS)



- Power regulation and conditioning module provides regulated 5 and 3.3, unregulated 9 VDC
- Telemetry data through direct connect RS-232 or EyaBUS
- Battery module provides 8.4 VDC, 1.4 mAh through NiMh technology batteries
- Solar array provides $V_{oc}=18$ VDC, $I_{sc}=120$ mA in full sun, demonstrates concept only, peak power of 750 mW at 10 VDC
- Power distributed through EyaBUS



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EPS Lab

- **Prelab**
 - Review EPS concepts covered in lecture
 - Review EyasSAT EPS specifications
- **Lab activities**
 - **Inspect, test, and characterize**
 - Battery module
 - Solar array
 - EPS module
 - **Highlights**
 - Battery charging profile
 - Solar array I-V curve determination
 - Software testing are highlights
- **Lab report**
 - Summarize EPS lab data and conclusions
 - Update EyasSAT specification verification matrix

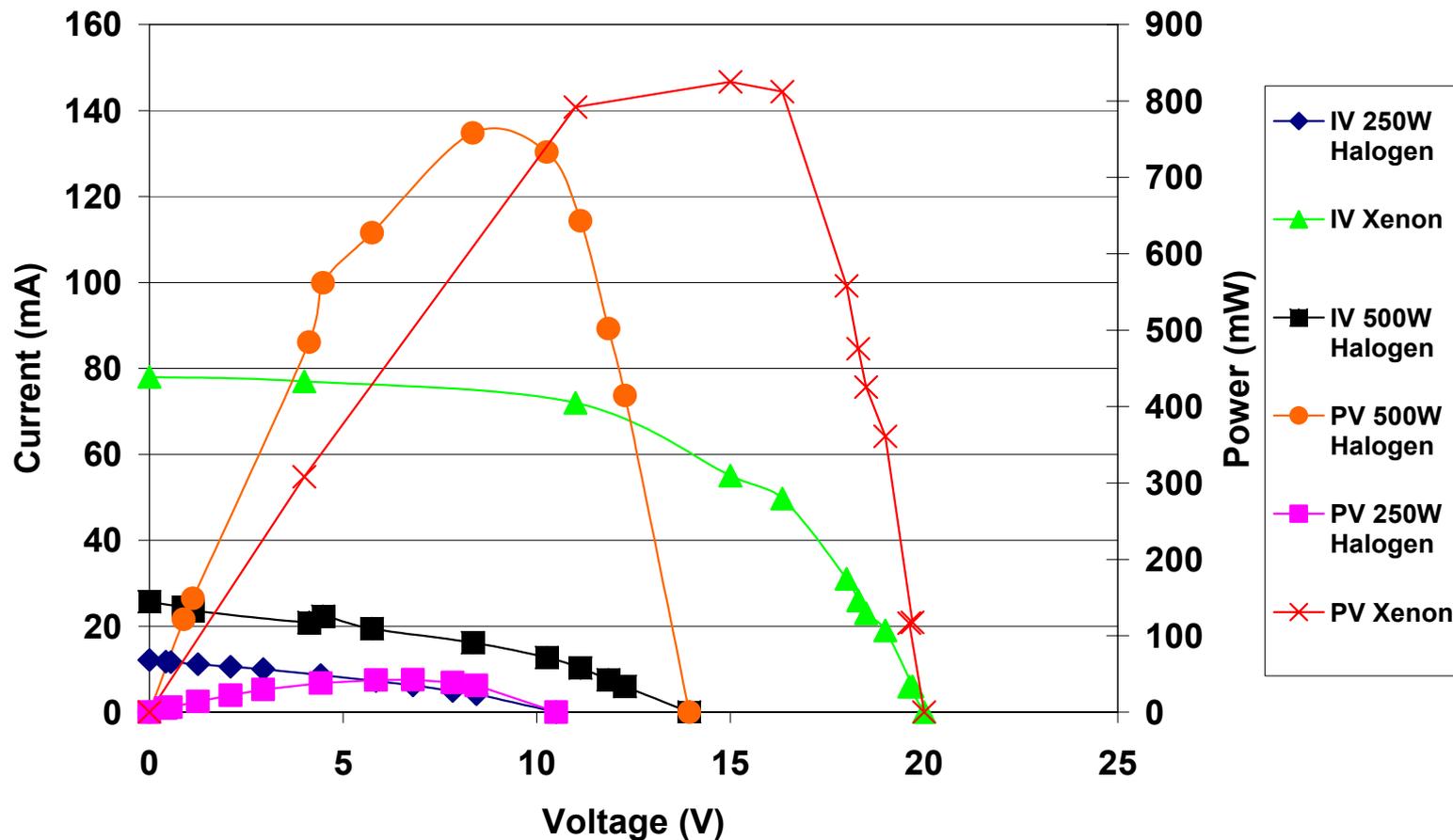


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Solar Array Characterization

EyasSAT Solar Array IV Curve





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LED Quick-test module & Power Budget



Subsystem	Power (W)	%
Structure	0.00	0%
EPS	0.34	21%
DH	0.26	16%
Comm	0.29	18%
ADCS	0.72	45%
Thermal	0.00	0%
Total	1.60	100%
Duty-cycled devices		
Wheel	1.12	-
Torque rod	1.40	-
Comm TX	0.35	-

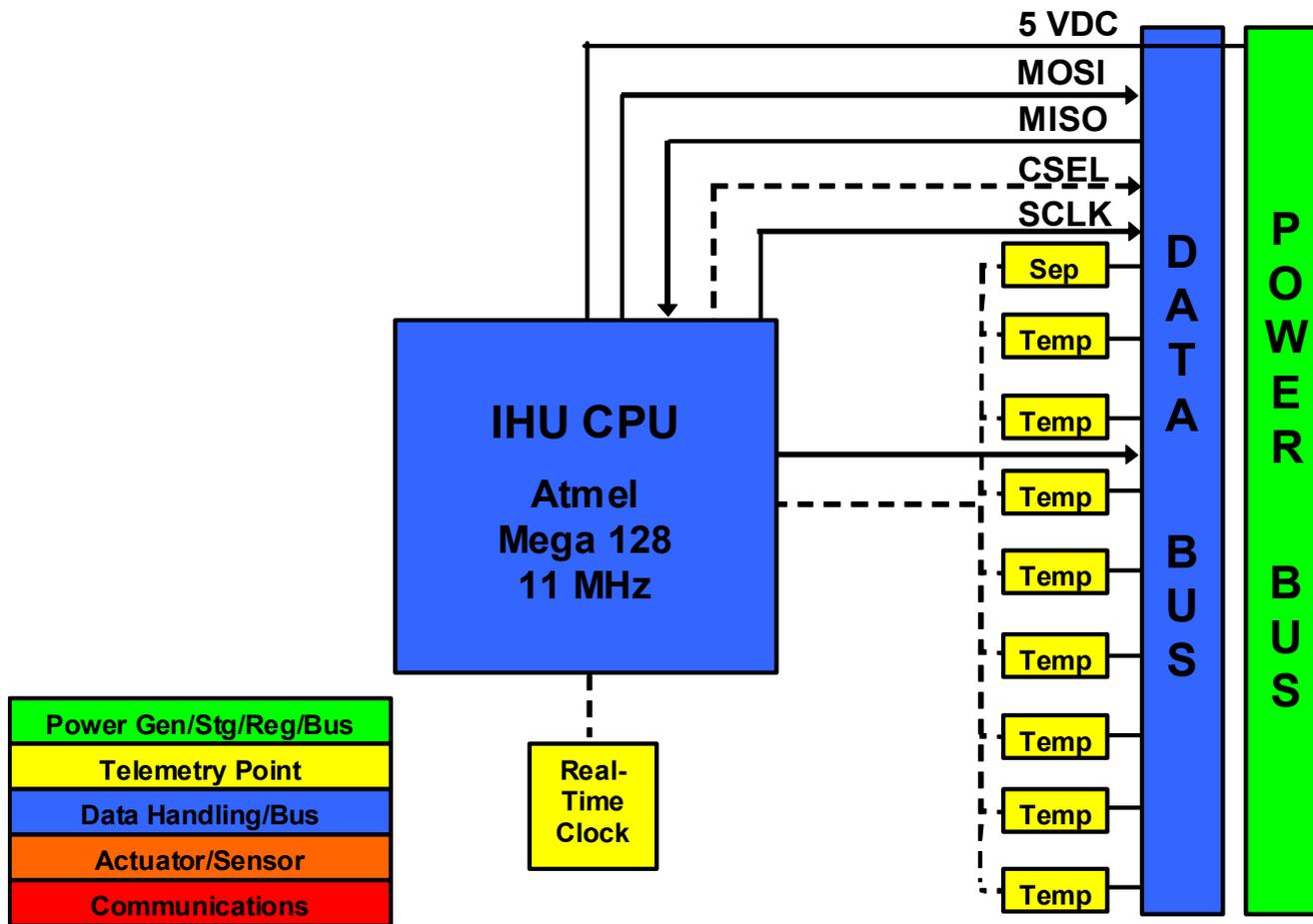




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Data Handling Subsystem (DH)



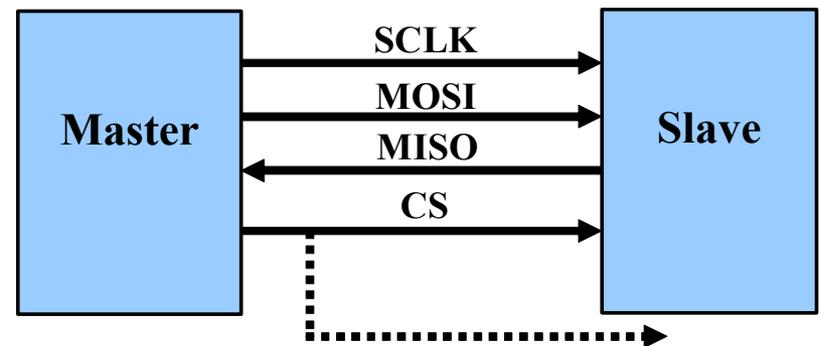
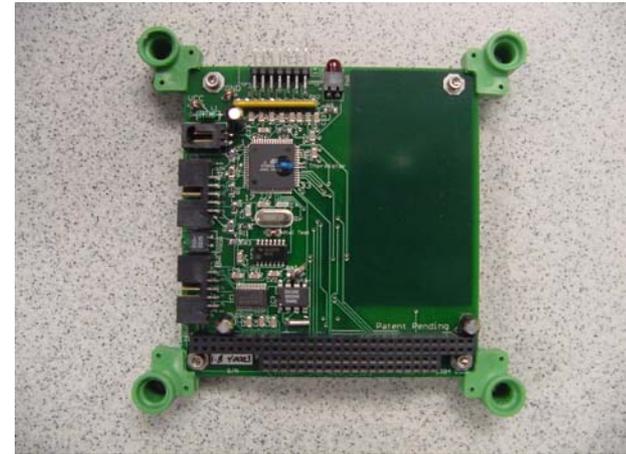


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Data Handling Subsystem (DH)

- Master control module
- Collects/reports telemetry from all connected subsystems through SPI interface on EyaBUS
- Processes commands
- Provides real-time clock for data stamping
- Eight analog thermistor inputs





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DH Lab

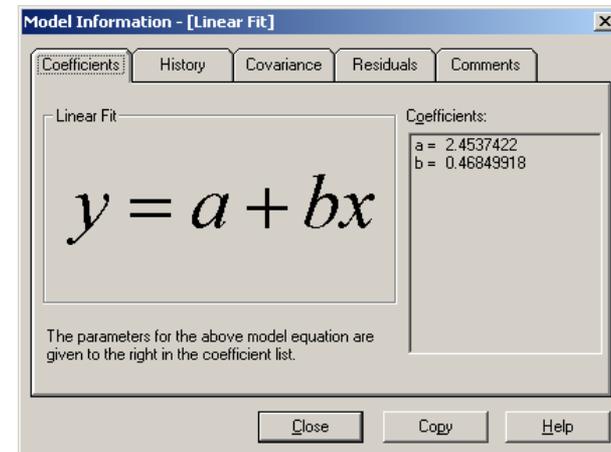
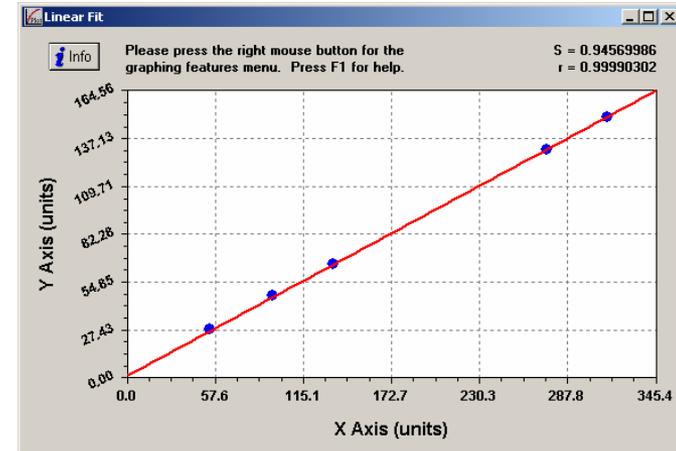
- **Prelab**
 - Review DH concepts covered in lecture
 - Review EyasSAT DH specifications
- **Lab activities**
 - Inspect, test, and characterize DH module
 - Integrated test of EPS and DH modules
 - **Highlights**
 - DH software testing
 - Calibration of EPS
- **Lab report**
 - Summarize DH lab data and conclusions
 - Add to EyasSAT specification verification matrix



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EyasSAT Calibration—revisit EPS

- Quick calibration option
- Full calibration of EPS current and voltage measurements for engineering students
- Reinforces idea that even precision performance components with small deviations can produce large errors when the entire data chain is considered





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EyasSAT Text Terminal Interface

The screenshot shows the 'EyasSAT Control Panel' window. It features a top navigation bar with three tabs: 'Data Handling Subsystem (DH)', 'Attitude Determination and Control (ADCS)', and 'Comm Subsystem (Comm)'. Below this, there are three sub-tabs: 'Text Only Interface' (selected), 'Thermal Subsystem', and 'Electrical Power Subsystem (EPS)'. The main content area displays 'EyasSAT Status' with the following text: 'Power EyasSAT Power Startup Firmware Version:2.1.6 12/15/2004', 'Power P Sep=1 BV=9.2 BI=-22.8 SPV=0.0 SPI=0.0 5V=4.7 5I=6.4 3V=2.8 3I=0.0 S=0', and 'Power Telemetry Command Recieved'. At the bottom of the main area, there is a 'Manual Telemetry Command Window' with a text input field containing 't' and a 'Send Command' button. To the right, there is a 'Data Logging Idle' section with a file path 'C:\EyasSAT\MyEyasSATFile.txt' and an 'Enable File Log' checkbox. Below the main interface, there are labels for 'Errors:', 'EyasSAT Response:', and 'Battery Voltage: .0 V'. At the very bottom, a 'Status:' label is followed by 'EyasSAT Idle'.



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EyasSAT Graphical User Interface (GUI)

EyasSAT Control Panel

Data Handling Subsystem (DH) Attitude Determination and Control (ADCS) Comm Subsystem (Comm)

Text Only Interface Thermal Subsystem **Electrical Power Subsystem (EPS)**

Solar Panel

SPV= .0 V
SPI = .0 mA
SPP= .0 mW

3.3V

V= 2.9 V
I= .0 mA

P@3.3V= .0 mW

3.3V sw1 Experiment #1
3.3V sw2 Experiment #2
3.3V sw3 Experiment #3

Disconnect EPS

Pout Total= 854.0 mW Switch Status= 0000 0000
Efficiency= 71.9 %

Batteries

BV= 8.8 V
BI = -135.0
BP= -1188.0

5.0V

V= 4.7 V
I= 181.7

P@5V= 854.0 mW

5.0V sw4 Experiment #1
5.0V sw5 Experiment #2
5.0V sw6 ADCS
5.0V sw7 Experiment #3
5.0V sw8 Spare

Sep Sw. Lifted

Understanding Space, 2nd Edition

Errors: **Battery Voltage: 8.8 V**

EyasSAT Response:

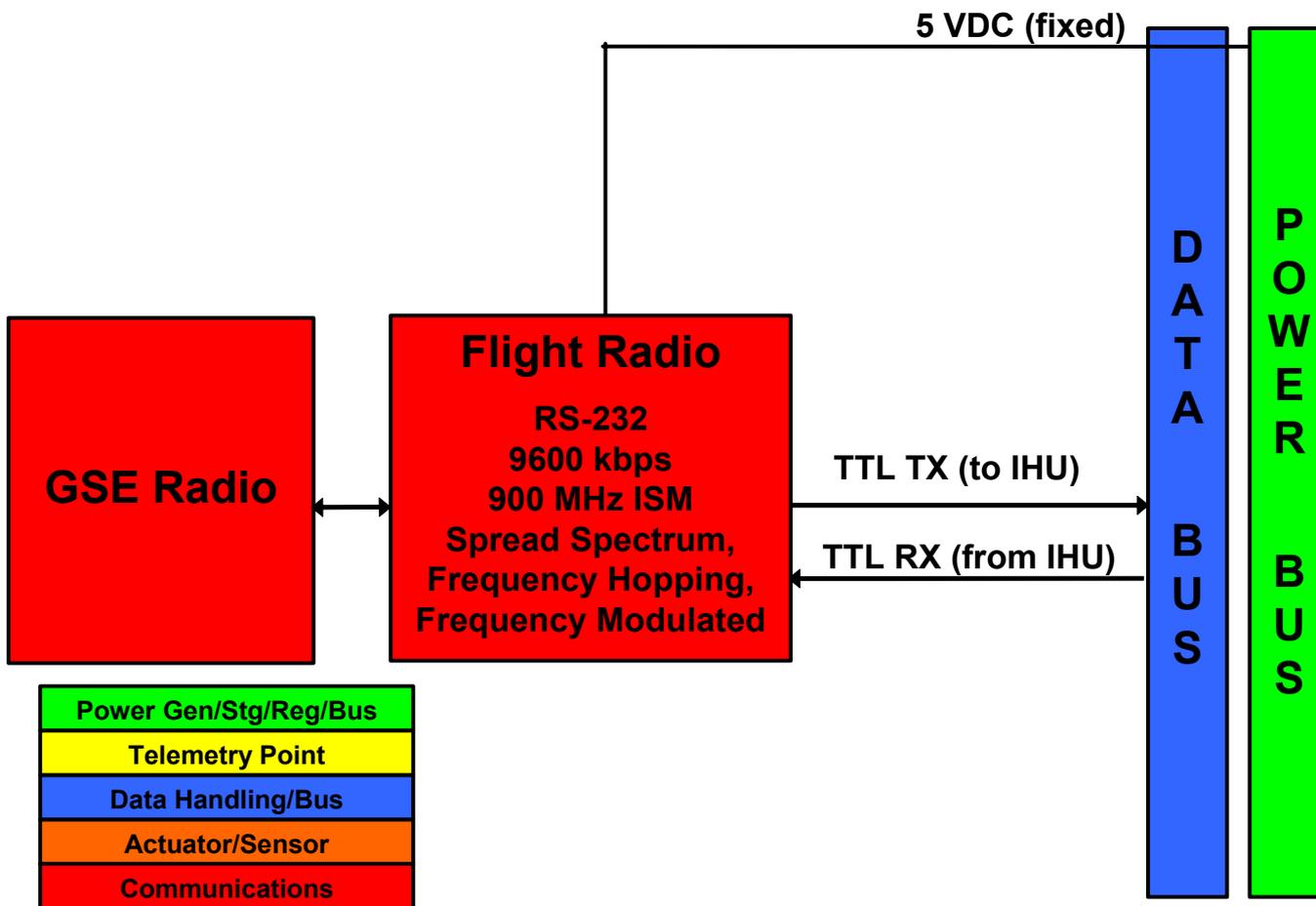
Status: EyasSAT Communicating



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Communications Subsystem (Comm)





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Communications Subsystem (Comm)



- Enables wireless command and telemetry link
- Connects to DH module through EyaBUS
- Ground-end interfaces directly through PC RS-232 serial port
- 9k6 baud, ISM band frequency hopping
- Multi-channel configurable to facilitate multiple lab stations
- Assured data delivery mode



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Communication Lab

- **Prelab**
 - Review Comm concepts covered in lecture
 - Review EyasSAT Comm specifications
- **Lab activities**
 - Inspect, test, and characterize Comm module
 - Software verification of assured delivery mode
 - Integrated testing of EPS, DH, and Comm modules
 - **Highlights**
 - Modulation demos
 - Wireless functionality
- **Lab report**
 - Summarize Comm lab data and conclusions
 - Add to EyasSAT specification verification matrix

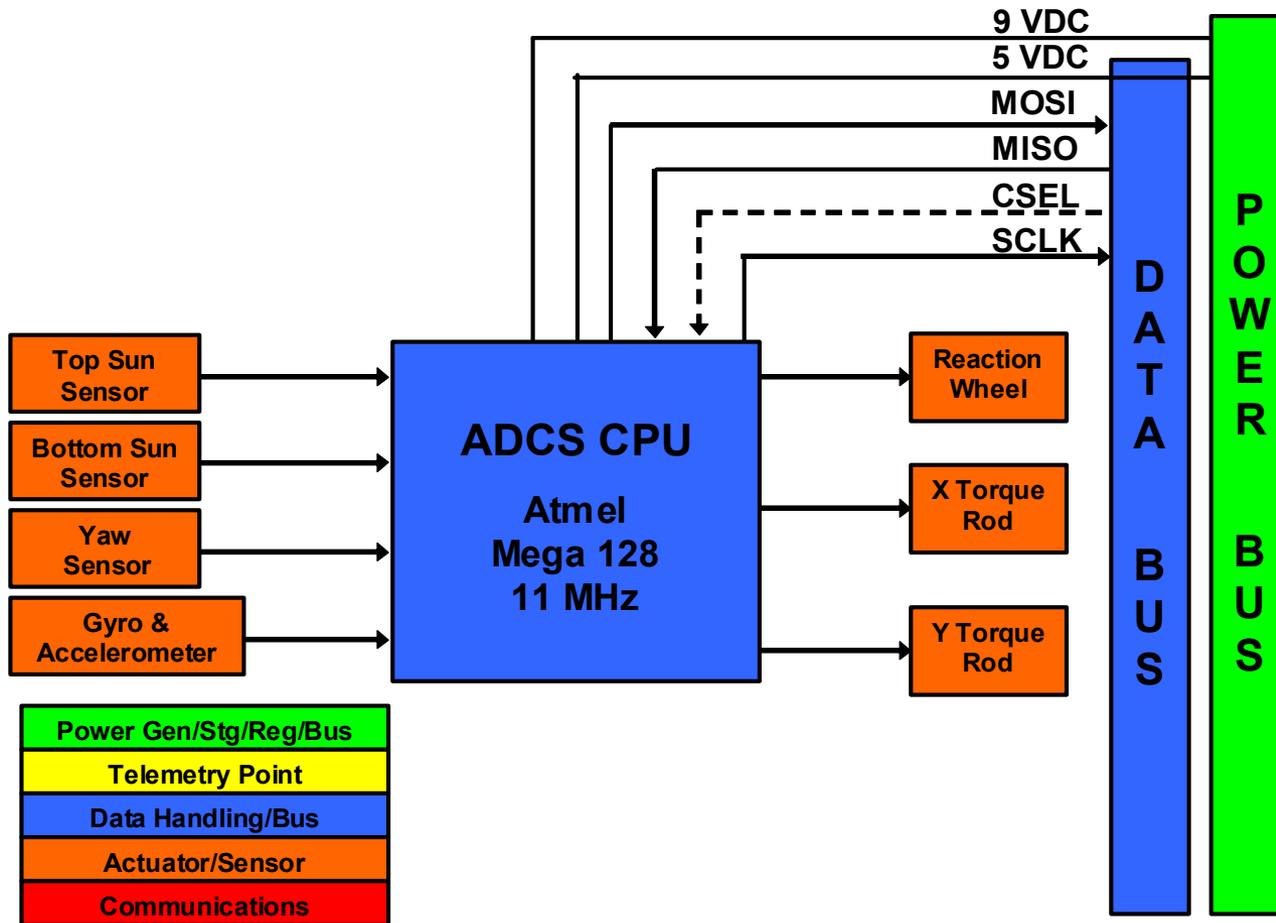




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Attitude Determination and Control (ADCS)



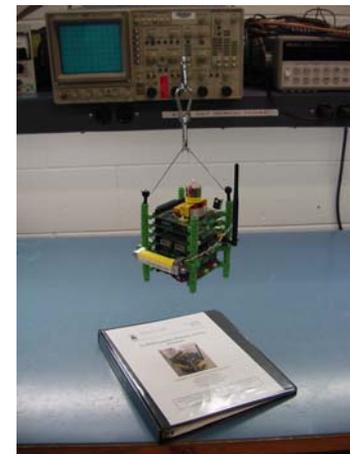


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Attitude Determination and Control (ADCS)

- **Controls actuators**
 - Reaction wheel
 - Torque rods
- **Collects sensor data**
 - Yaw orientation sensors
 - Collects top and bottom sun sensors
- **Reports telemetry through SPI on EyaBUS**
- **Sub control loop regulates speed and controls direction of reaction wheel**





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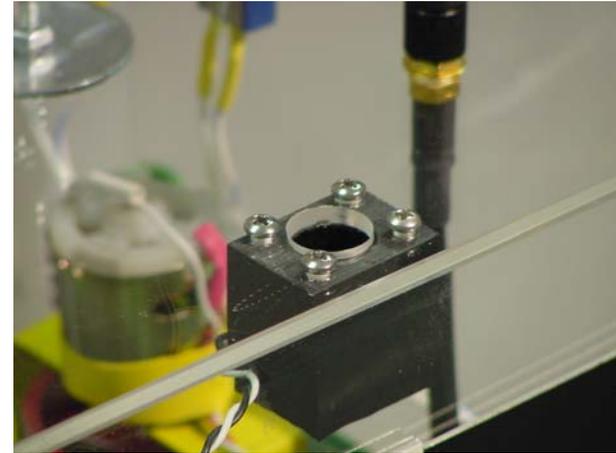
EyasSAT

Attitude Determination and Control (ADCS)

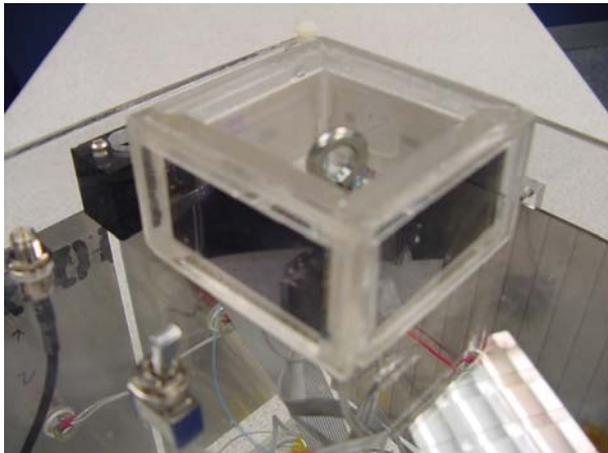
**Torque
Rod**



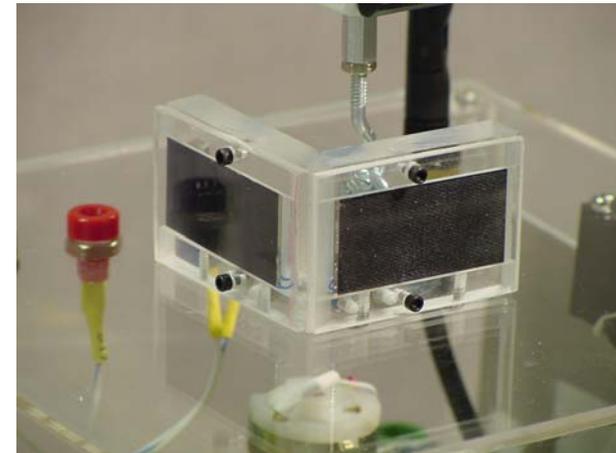
**Sun
Sensor**



**Yaw
Sensor
(4-cell)**



**Yaw
Sensor
(2-cell)**





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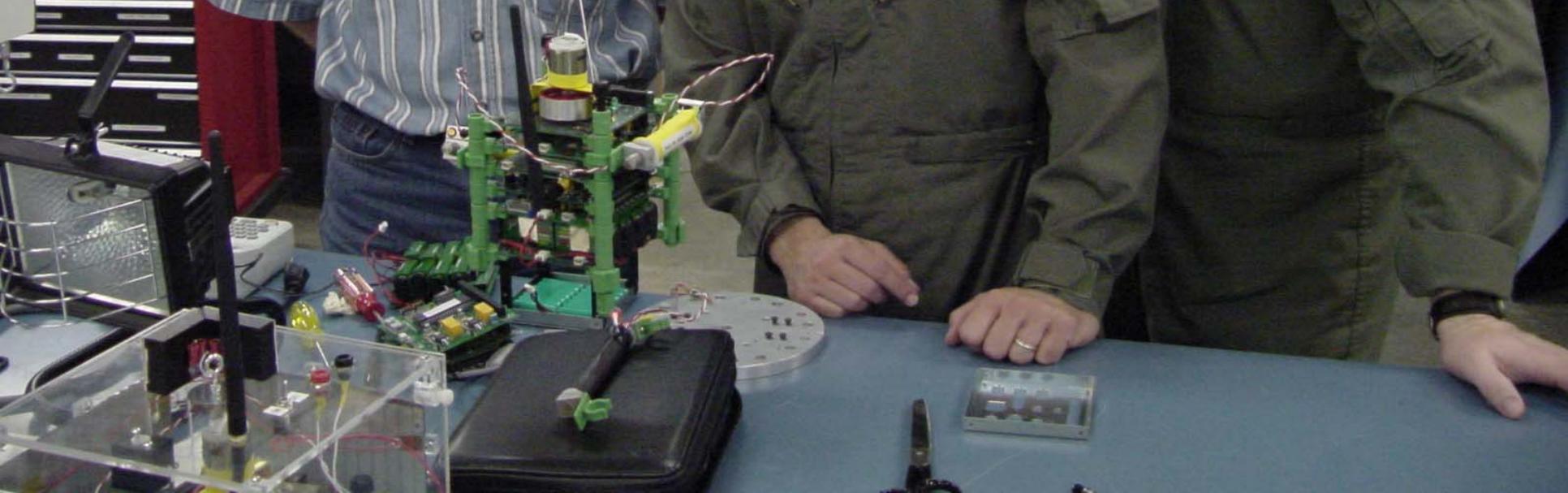
EyasSAT

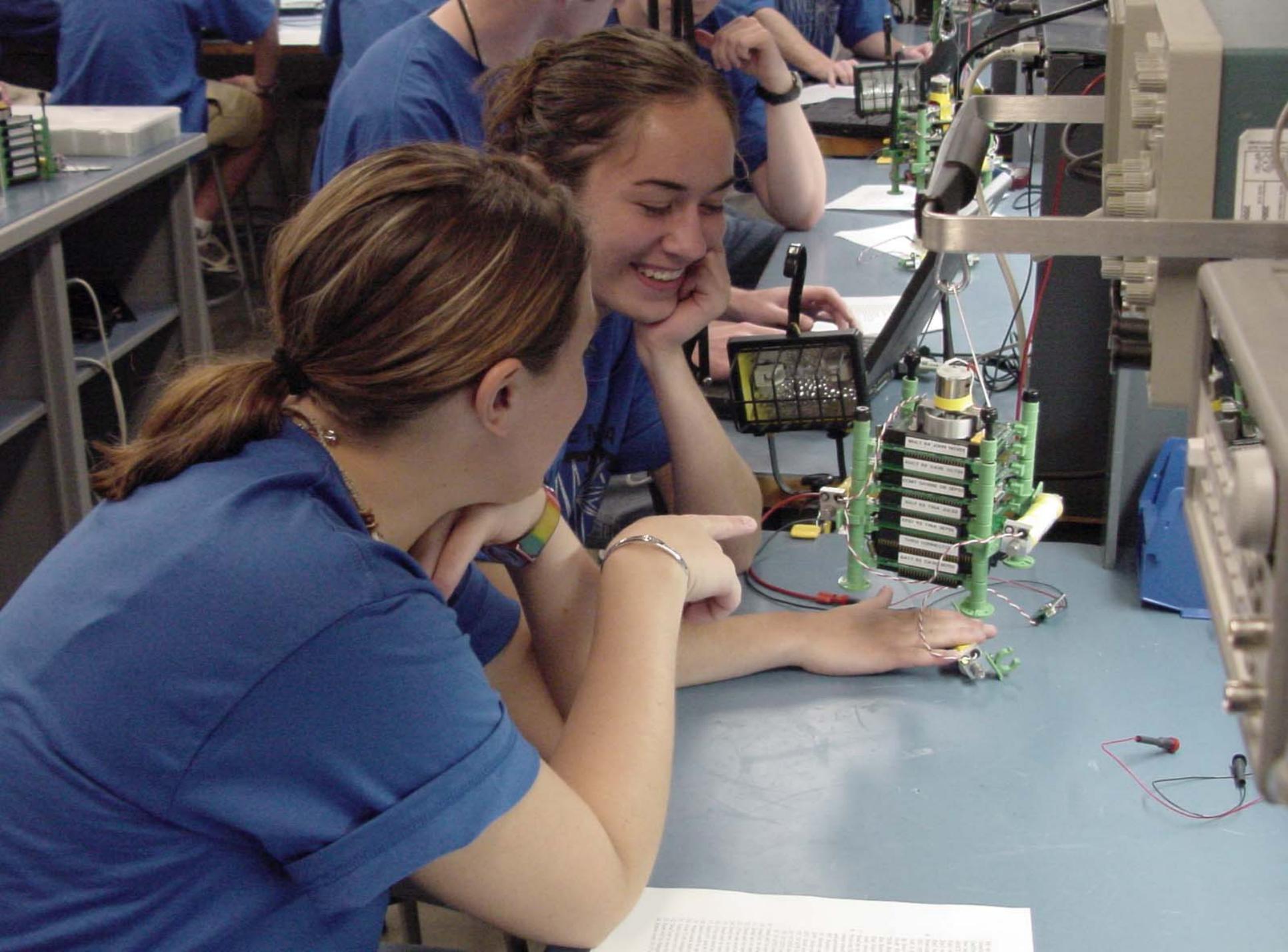
ADCS Lab

- **Prelab**
 - Review ADCS concepts covered in lecture
 - Review EyasSAT ADCS specifications
- **Lab activities**
 - **Inspect, test, and characterize**
 - Actuators: torque rods, reaction wheel
 - Sensors: sun sensors, yaw sensor
 - ADCS module
 - **Integrated test of EPS, DH, Comm, ADCS modules and components**
 - **Free hanging ADCS test/demonstration is highlight**
- **Lab report**
 - Summarize ADCS lab data and conclusions
 - Update EyasSAT specification verification matrix



THIS BENCH IS RESERVED FOR ASTRO 452
DURING T1 AND T2
DO NOT REMOVE TEST EQUIPMENT FROM AIR BENCH
WITHOUT PRIOR APPROVAL FROM LAB TECHNICIAN
WHEN YOU ARE FINISHED WORKING CLEAN BENCH AND
RETURN TOOLS BACK TO TOOLCART. REMEMBER THAT THERE
ARE OTHERS NEEDING TO USE THESE RESOURCES AFTER YOU.



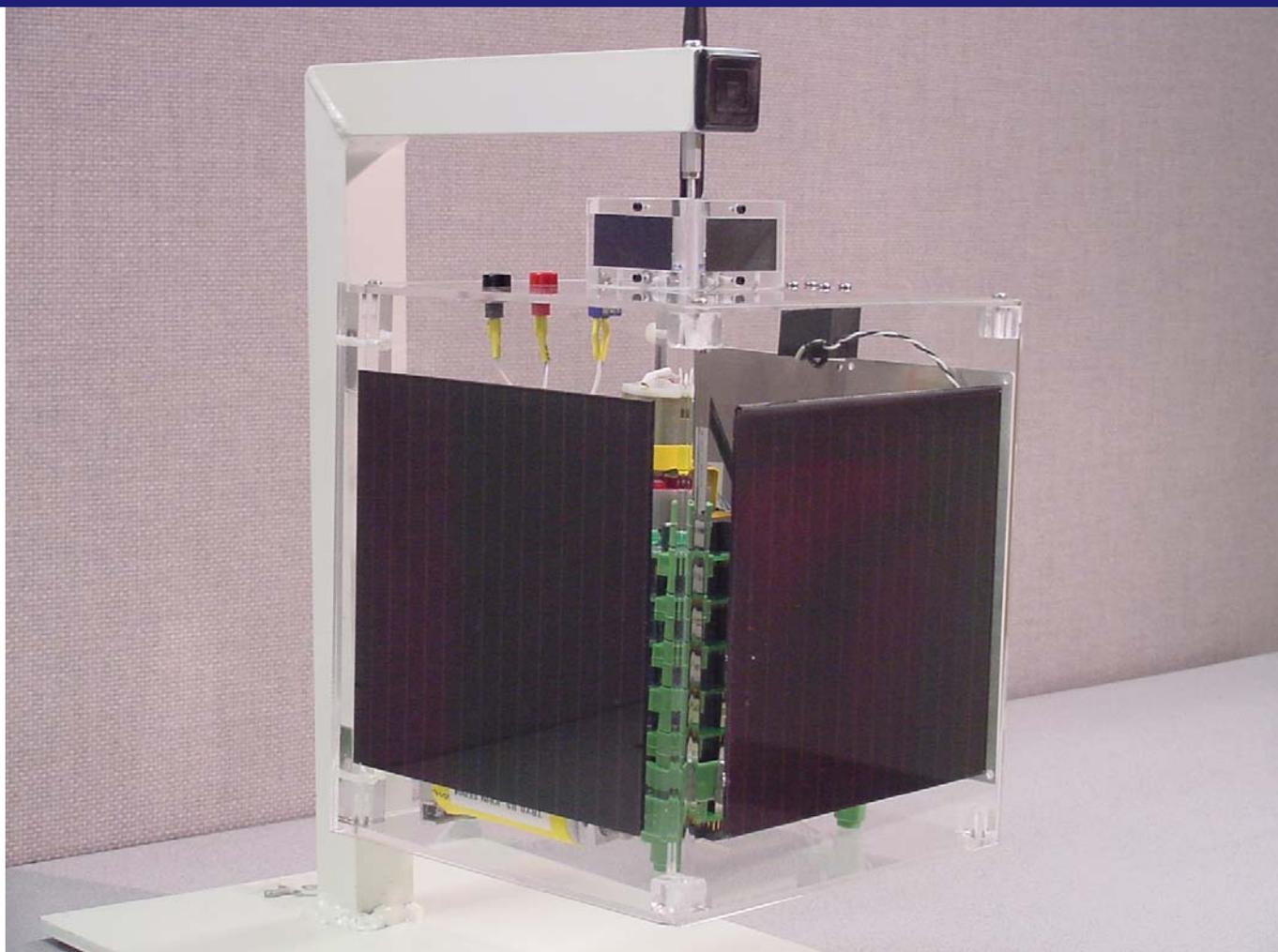




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Integration/Thermal Lab



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Thermal and Integration Lab

- **Prelab**
 - Review thermal concepts covered in lecture
 - Review EyasSAT thermal specifications
- **Lab activities**
 - Integrate EyasSAT stack with outer structure
 - Integrated testing of final spacecraft configuration
 - Inspect and test thermal control surfaces
 - Full functional test and thermal profile
 - Closed-loop control demo is highlight (light following)
- **Lab report**
 - Summarize thermal and integration lab data and conclusions
 - Finish EyasSAT specification verification matrix





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EyasSAT ***Applications***

- **Space systems engineering courses labs**
- **Professional short course concept reinforcement and/or mini-labs**
- **Introduction to astronautics course demonstrations**
- **Advanced controls course labs**
- **Balloon experiment payload platform**
- **Sounding rocket payload platform**
- **Proof of concept microsatellite demonstrations**
- **Testbed for new payload and subsystem prototype development**
- **Student independent study project platform**



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EyasSAT

Future Capabilities

- **EyasSAT was designed to be modular and expandable**
 - **Student or instructor built payloads/subsystems can easily be added, such as:**
 - **GPS**
 - **Digital visible and IR imaging**
 - **Target tracking**
 - **Proximity operations on air table—space “battle bots”**
 - **High efficiency solar arrays**
 - **Composite structure**
 - **Cold-gas thruster propulsion module**
- (all of these are in development at USAFA)**

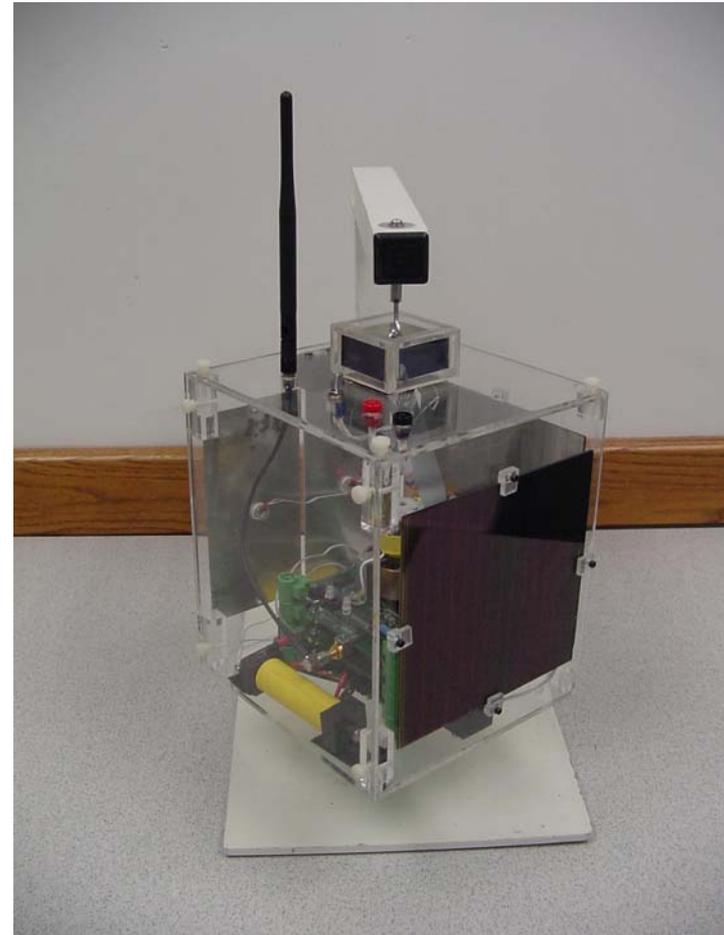


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Summary

- **EyasSAT is a transformational teaching tool for executive, engineering, or even high school courses**
- **Enhances understanding of and demonstrates basic functionality of spacecraft subsystems**
 - **Structure**
 - **Electrical Power**
 - **Data Handling**
 - **Communications**
 - **Attitude Determination and Control**
 - **Thermal Control**
- **Provides platform for payloads and additional experimental subsystems, such as propulsion**





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EyasSAT

Results

- **EyasSAT is now extensively used by the USAF Academy**
 - **Space Systems Engineering course exposes 50+ students annually to the EyasSAT hands-on experience**
 - **Introduction to Astronautics course exposes 900+ students annually to EyasSAT in a classroom setting via instructor demonstrations over six lessons a semester**
 - **Space 200 course exposes 360+ mid-career Air Force Personnel to hands-on half-day executive course**
 - **Summer Seminar program allows 120+ high-school students annually to use an assembled EyasSAT in a hands-on workshop about Space Operations**
 - **Controls Fundamentals courses integrating EyasSAT now**
- **9 Universities have either purchased an EyasSAT or have placed an order—one university has plans to purchase and field several dozen!**



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Results

- **Student comments: “*Building an operational satellite has been one of the most rewarding in-class experiences ever*” and “*The EyasSAT lab was a great learning experience...*”**
- **Enrollment in Space Systems Engineering course up 30% over past two years**
- **Declaration of Astronautical Engineering and Space Operations degrees up 42% over past two years—many attribute motivation given by EyasSAT demos**



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Conclusion

eyassat.com

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