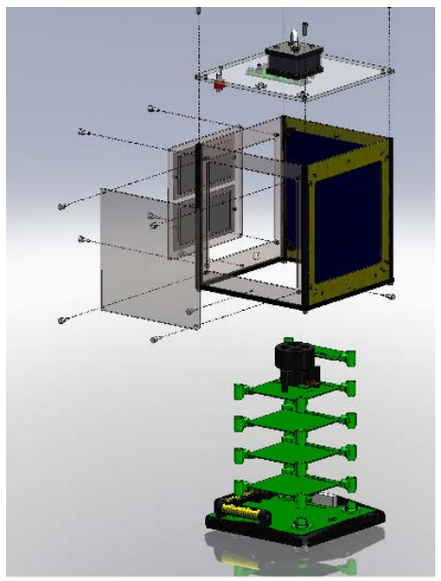
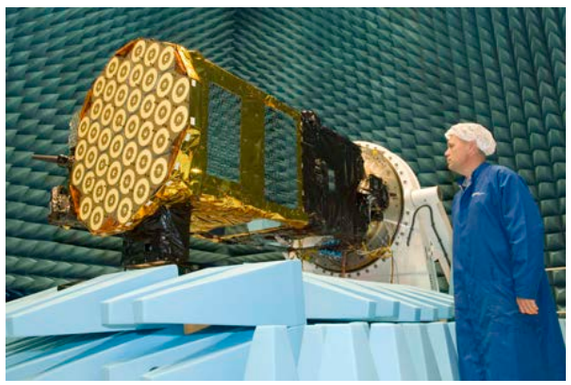
Using a Satellite Simulator to Play Nice with Knowledge



Presented by

Dr Randy Liefer

TEACHING SCIENCE AND TECHNOLOGY, INC.

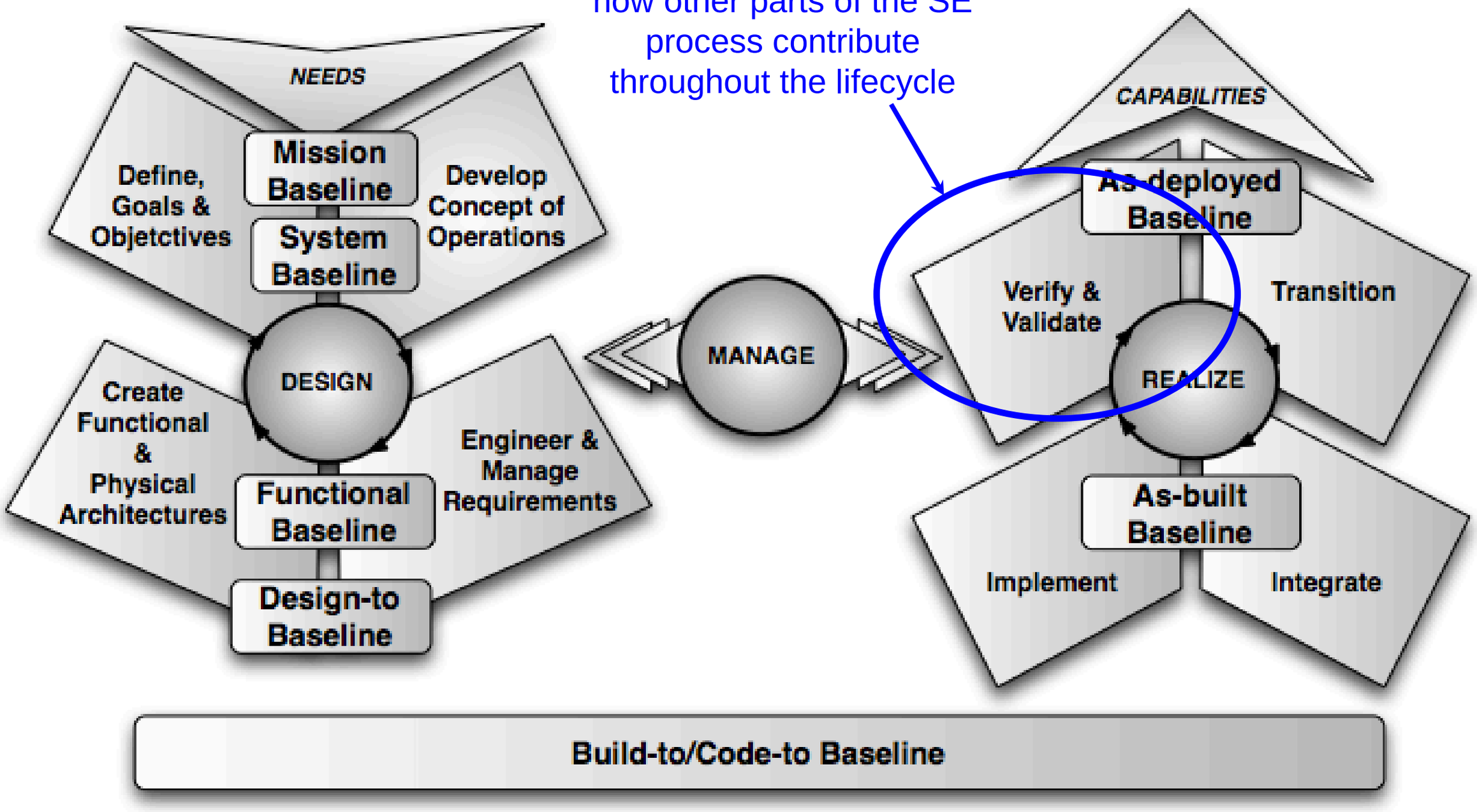


How to Teach Space System Verification & Validation To Young Engineers? (And Why?)

System Engineering Life-cycle Processes

We'll use this model of Systems Engineering Processes to guide our discussion

We'll focus here, but highlight how other parts of the SE process contribute throughout the lifecycle



Note: This is a highly interdependent and iterative set of activities—think ***framework*** not rigid process

"V&V" covers an Umbrella of Activities

- Project verification and project validation encompass a wide variety of highly interrelated activities aimed at answering a several key questions throughout the mission lifecycle in roughly the following order:
  - ***Requirements Validation***: Are these the right requirements?
  - ***Model Validation***: Are the models (that support design and verification activities) correct?
  - ***Product Verification***: Does the system we built or coded meet the requirements we wrote?
  - ***Product Validation***: Did we build and/or code the right system? (sanity check on all of the above)
  - ***Flight Certification***: Is the system ready to fly?

Note: **These topics usually receive little attention in undergraduate programs**

Our Charter

- **Commissioned by NASA to develop V&V course**
- **Need a tool (simulator) to enable “learning by doing”**
- **Must be affordable, portable, robust**
- **Solution: EyasSAT !**

Hands-On V&V Education with EyasSAT

Requirements Validation

REQUIREMENT	VERIFY METHOD (LEVEL)	EVENT(S)	SUCCESS CRITERIA	VALID REQ'T ?	VERIFY STATUS?	COMMENTS
3.1 System Characteristics: **EyasSAT System characteristics shall be as refined by the following:**	Inspection (SYSTEM)	System Acceptance Review	If verification of all characteristic requirements have been successfully completed.			
3.1.1. System Definition: EyasSAT system major components shall include the following: (1) Structure & Integration Subsystem (SIS), (2) Electrical Power Subsystem (EPS) Module, (3) Data Handling Subsystem (DHS) Module, (4) Communication Module (Comm), and (5) Attitude Determination & Control Subsystem (ADCS) Module, LED Test Module assembled as per specifications	Inspection (SYSTEM)	Subsystem Baseline Physical Inspections AND System Baseline Physical Inspection	If all specified major components are included			
3.1.2. System Mass: Total system mass shall not exceed 3.0 kg, Subsystem mass is allocated as follows:	Inspection (SYSTEM)	System Baseline Physical Inspection	If system mass does not exceed 3.0 kg.			
3.1.2.1 SIS Mass: SIS mass shall not exceed 1.5 kg.	Inspection (SUBSYSTEM)	Subsystem Baseline Physical Inspections	If SIS mass does not exceed 1.5 kg			
3.1.2.2 EPS Mass: EPS Module mass, including LED Test Module, shall not exceed 0.5 kg.	Inspection (SUBSYSTEM)	Subsystem Baseline Physical Inspections	If EPS mass does not exceed 0.5 kg			

EyasSAT Exercises

Software Verification & Validation

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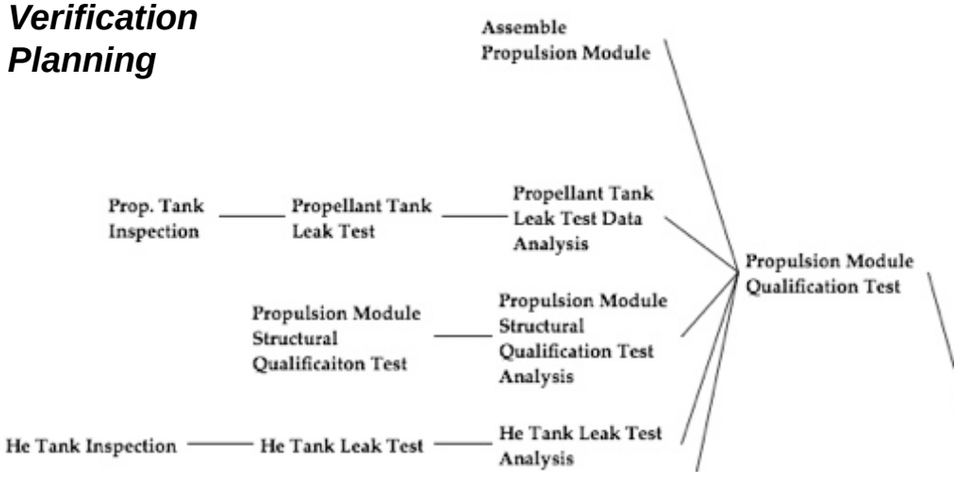
TeTI COURSE MATERIAL

THIS IS A PORTION OF THE CODE THAT RESIDES IN THE EYASSAT DH MODULE.  SOME CODE HAS BEEN
REMOVED FOR SIMPLICITY AND CLARITY.
/*****************************************************************************************
DH module command decode.
In this module we act on the two characters of the command sent from the ground.
'cmdModule' is the first character, 'cmdSetting' is the second.  'cmdModule' tells us which
 module the command is directed to, cmdSetting is the value we are attaching to that command.
Some cmdModule letters are followed by a second 'sub command' letter, then a value.
Some commands are directed to and acted on by the DH module, others are passed to other
 modules in the EyasSAT stack. Within the DH there are virtual modules such as the telemetry
 module and the clock module.
'i' is for commands acted on directly by the DH firmware and is followed by a sub command letter
'c' is for the clock module and is followed by a sub command and a value
't' sets the telemetry delay and is followed by the delay value
*****************************************************************************************/

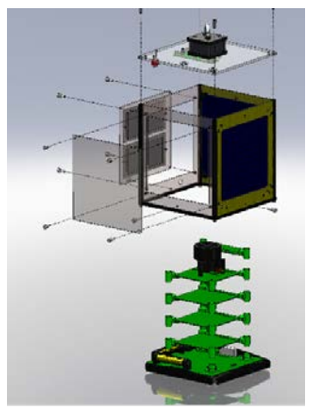
void process_command(void)

{
      switch (cmdModule) {
         //***** Clock Module ********************************************
            case 'c' :   //Clock Module Command Section (Virtual module)
                  switch (cmdSetting) {
                        case 'h' :
                              if (cmdValue>=0 & cmdValue<=24) {
                                    hour=cmdValue;
                                    sprintf(ack0string,"Clock Hour Now:%d",hour);
                                    rtc_set_time(hour,minute,second);
                              } else {
                                    sprintf(ack0string,"Clock Hour Must Be Between 0 and 24, not
%f",cmdValue);
                              }
                              break;
                        case 'm' :
                              if (cmdValue>=0 & cmdValue<=60) {
                                    minute=cmdValue;
                                    rtc_set_time(hour,minute,second);
                                    sprintf(ack0string,"Clock Minute Now:%d",minute);
                              } else {
                                    sprintf(ack0string,"Clock Minute Must Be Between 0 and 60,
not %f",cmdValue);
                              }
                              break;
                        case 's' :
                              if (cmdValue>=0 & cmdValue<=60) {
                                    second=cmdValue;
                                    rtc_set_time(hour,minute,second);
                                    sprintf(ack0string,"Clock Seconds Now:%d",second);
                              } else {
                                    sprintf(ack0string,"Clock Seconds Must Be Between 0 and 60,
```

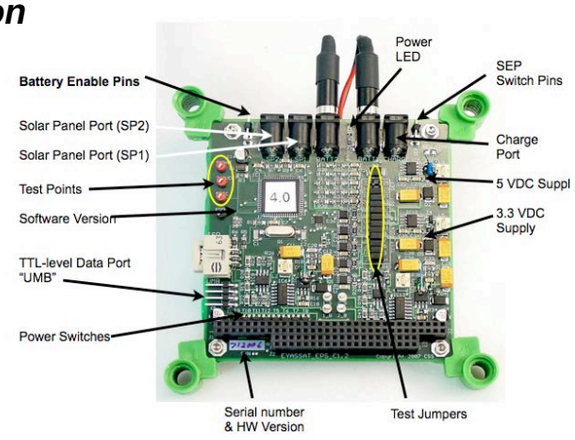
Verification Planning



System Integration



Subsystem Verification

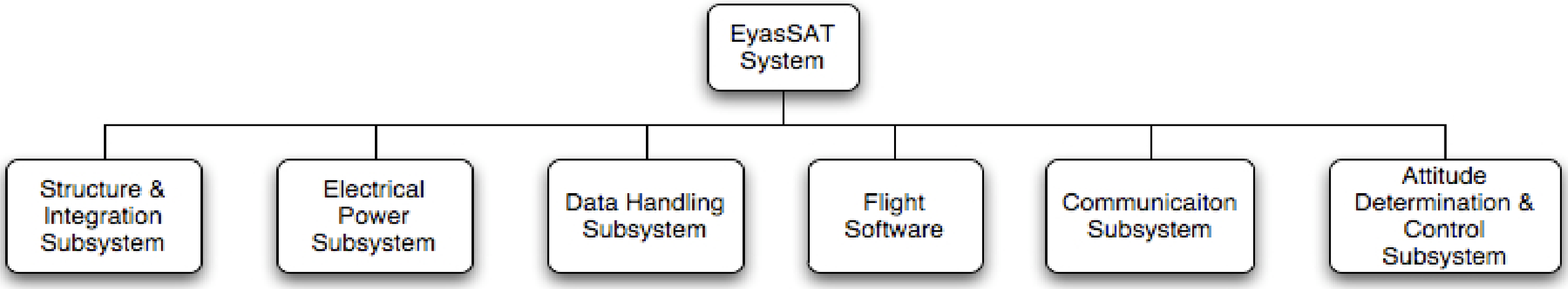


EyasSAT Background

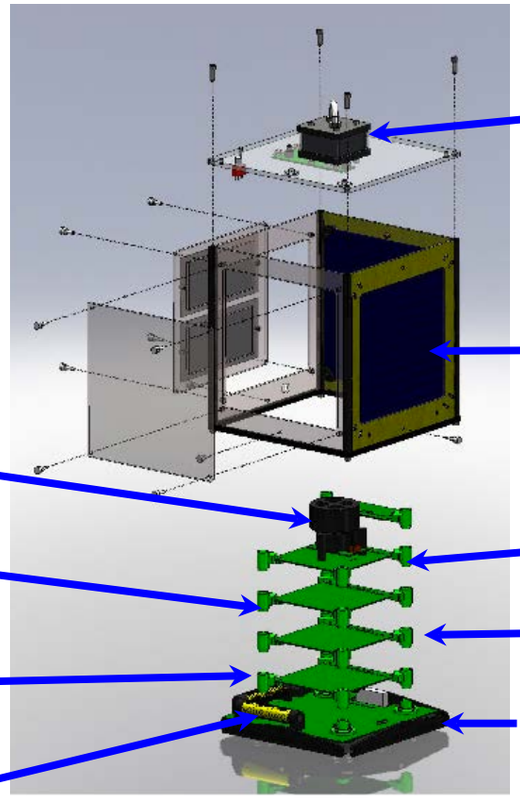
- EyasSAT is a fully functional nano-satellite simulator designed for teaching spacecraft systems engineering in the classroom and laboratory.
  - The name “EyasSAT” has its roots in falconry, an “eyas” is a “baby falcon” or “fledgling bird.”
  - The falcon is the mascot of the US Air Force Academy, where the concept for EyasSAT was hatched.

- EyasSAT was co-developed under a Cooperative Research and Development Agreement (USAF CRDA NUMBER 04-AFA-239-1, 25 August 2004) by the U.S. Air Force Academy, Colorado, USA and Colorado Satellite Services, Parker, Colorado, USA.

EyasSAT Physical Architecture

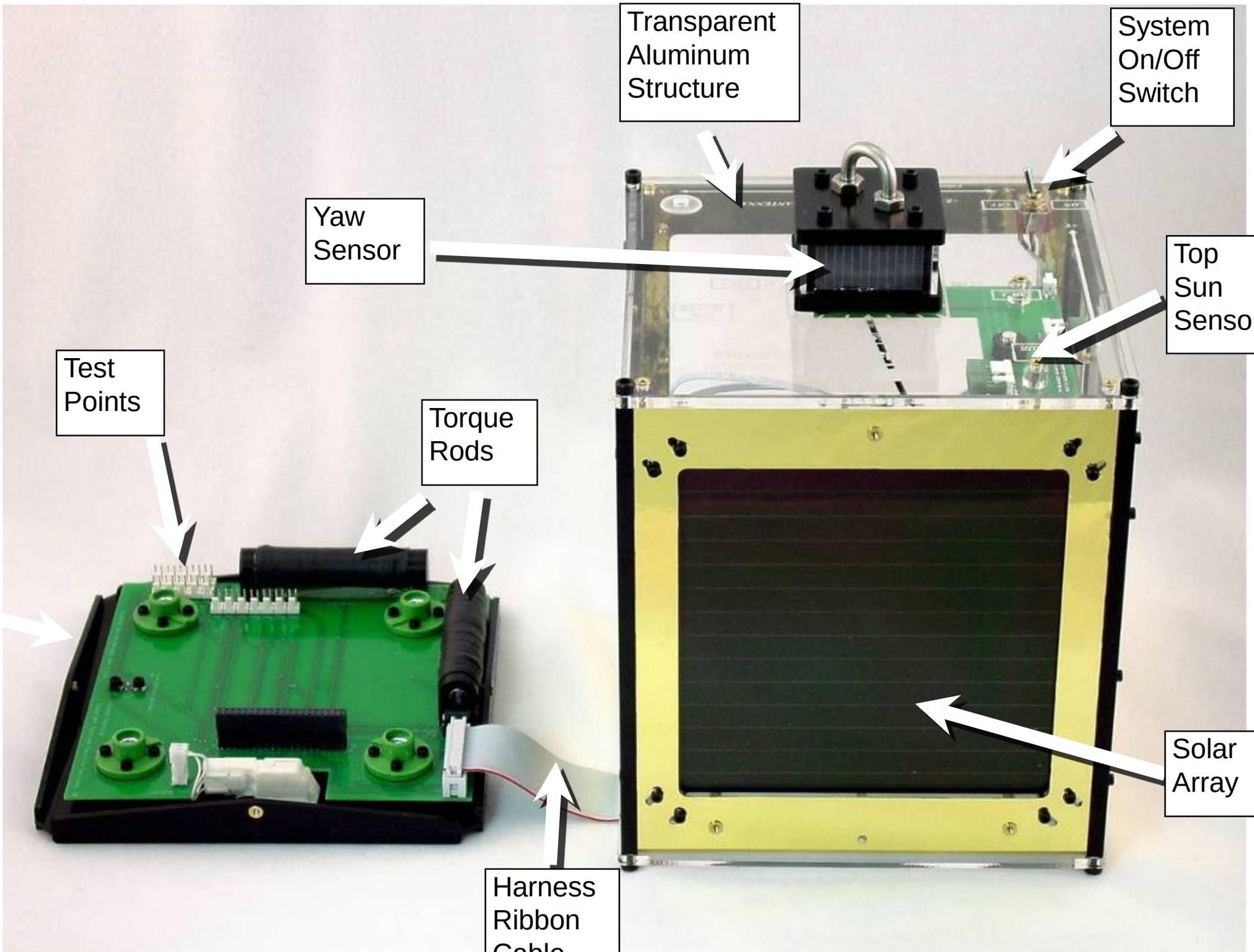


EyasSAT Integration



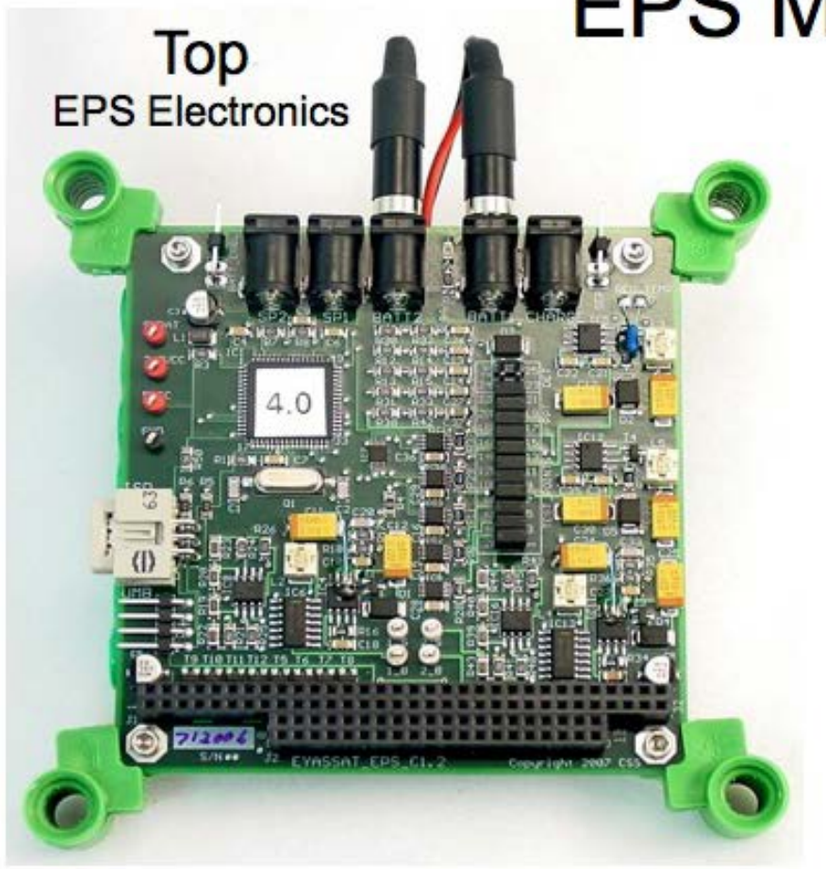
EyasSAT Fully Assembled

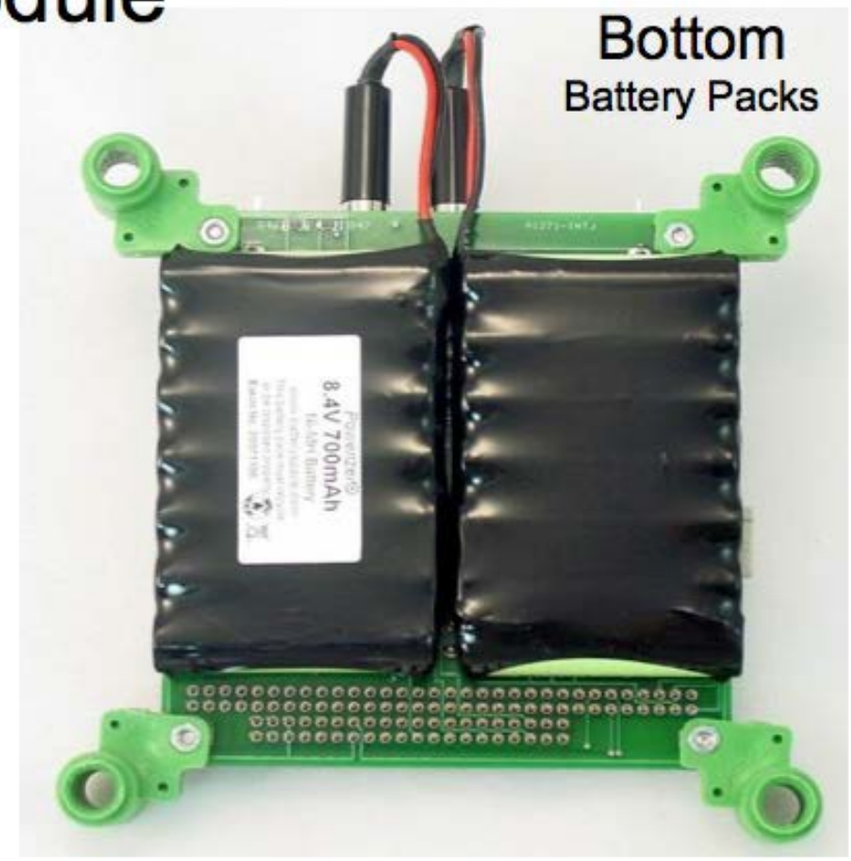
Structures & Integration Subsystem



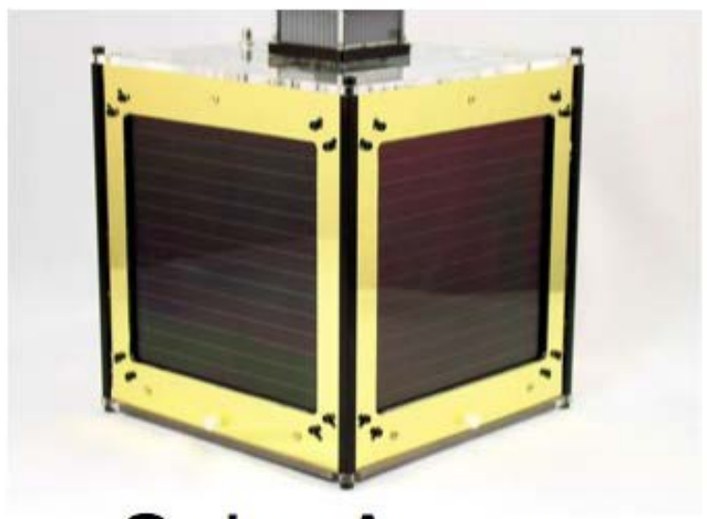
EyasSAT EPS Hardware

EPS Module



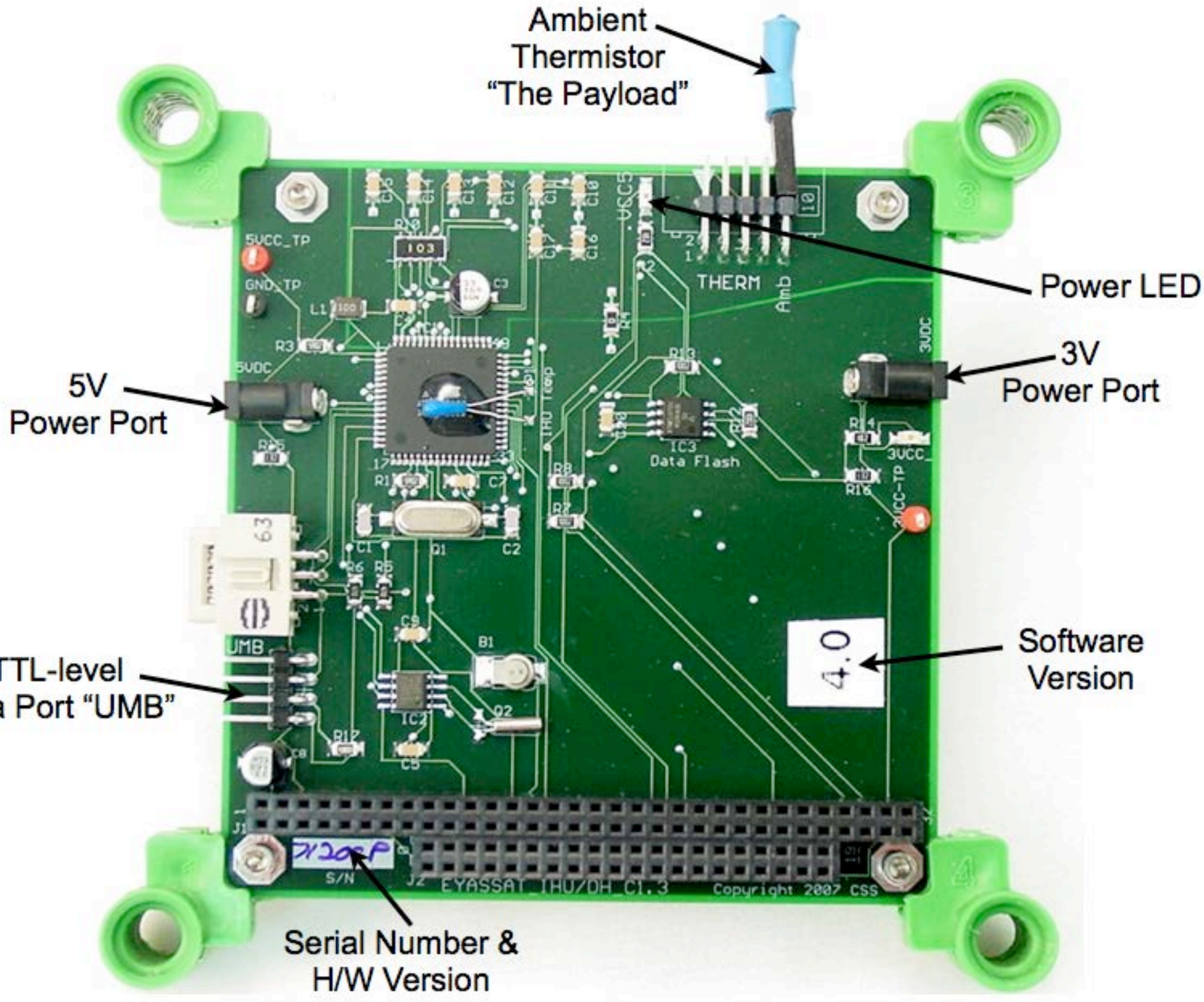


LED Test Module

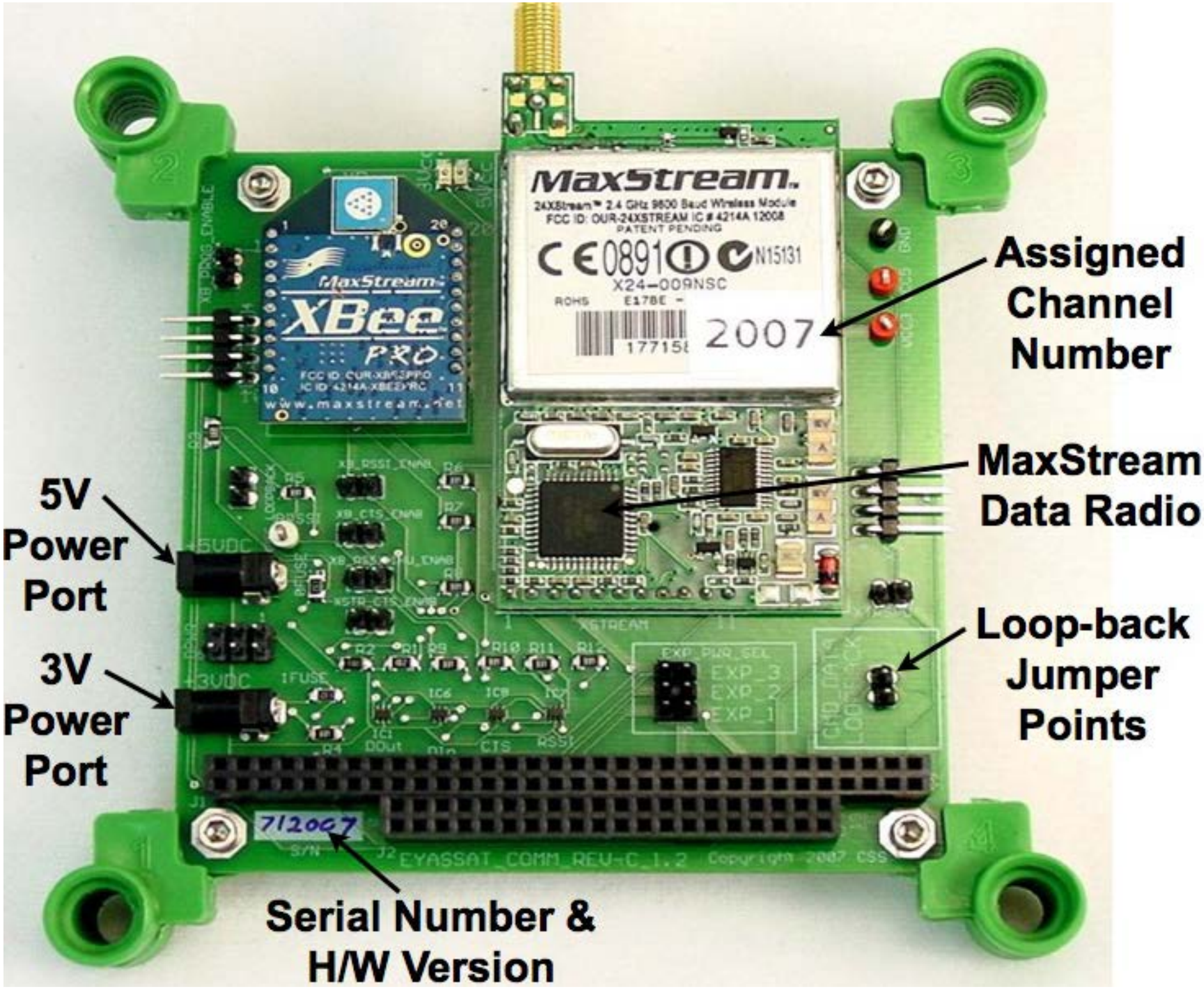


Solar Arrays

Data Handling Subsystem

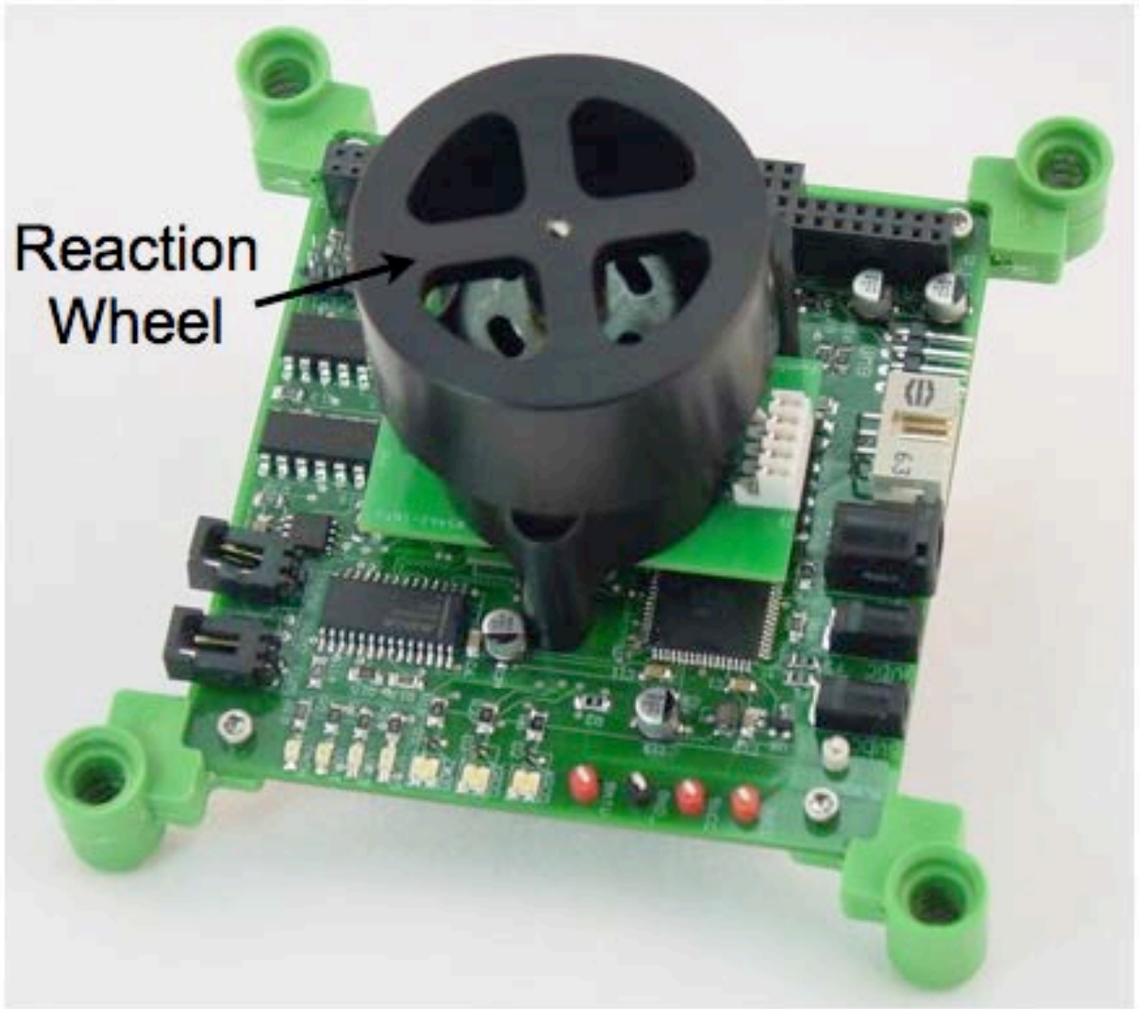


EyasSAT Comm Subsystem Hardware

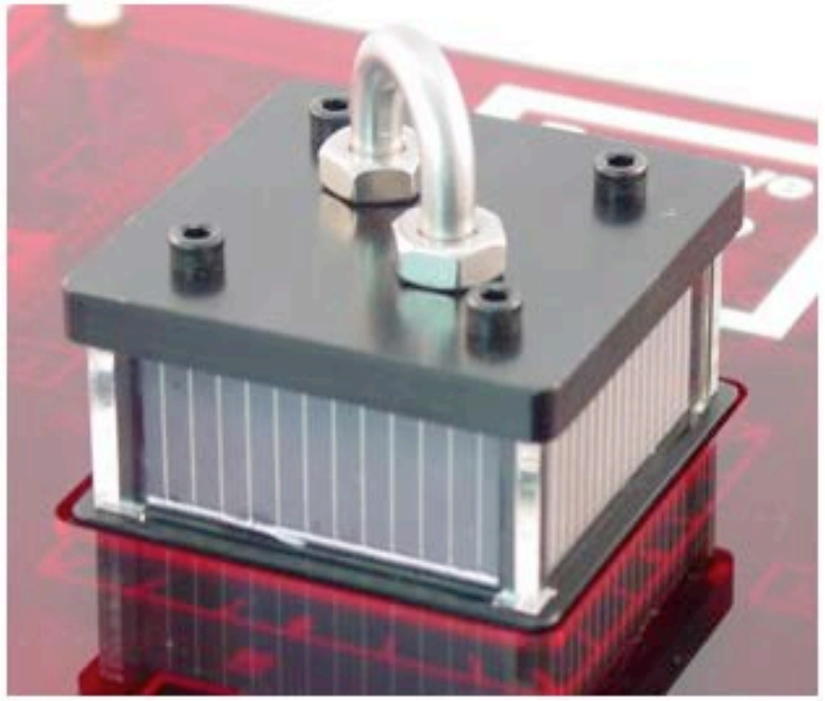


EyasSAT ADCS Hardware

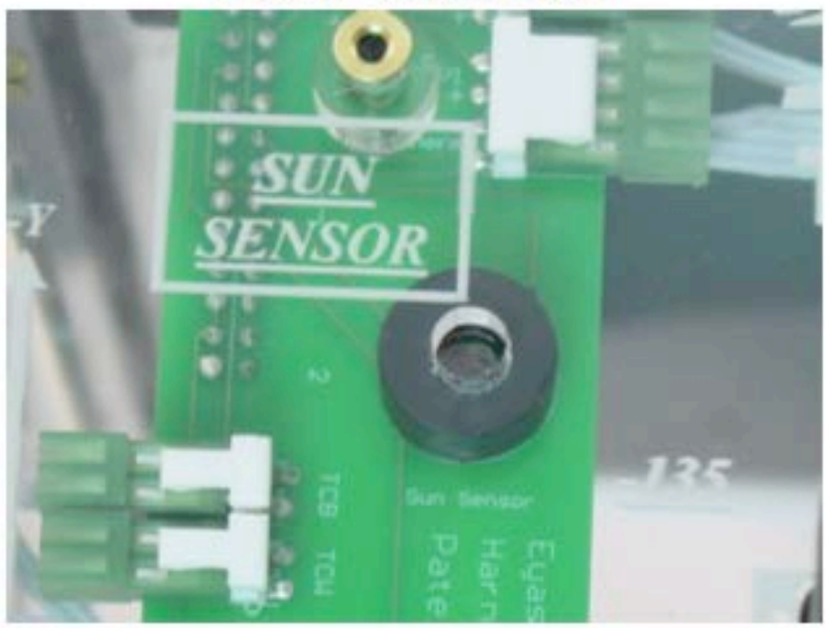
ADCS Module



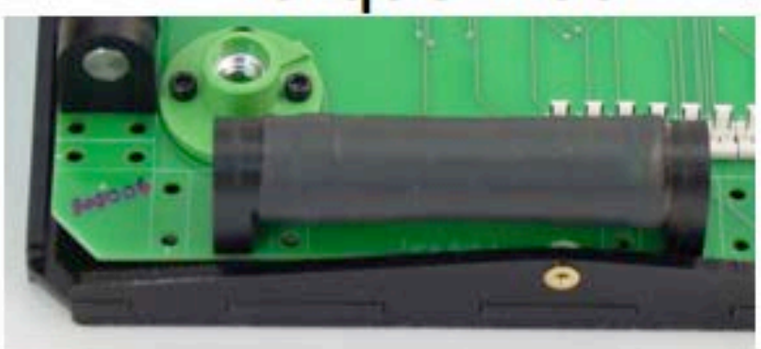
Yaw Sensor



Sun Sensor



Torque Rod

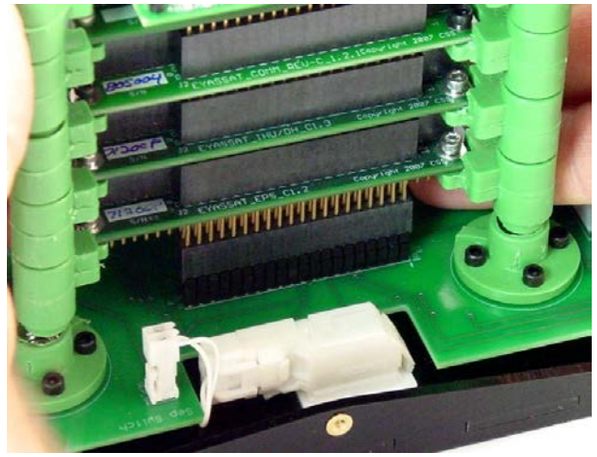


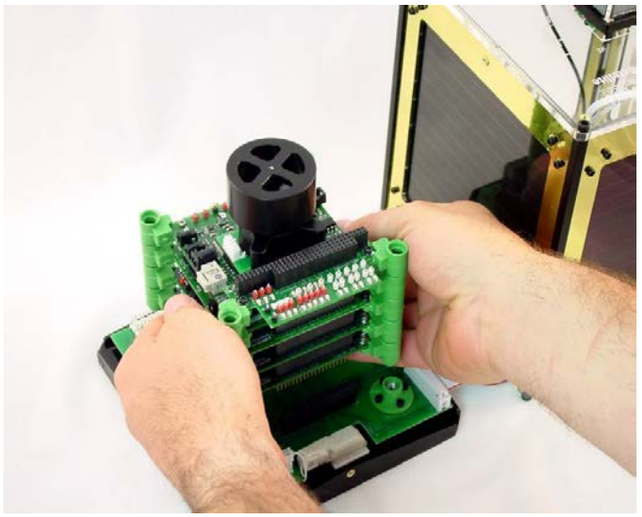
EyasSAT Requirements Verification Matrix

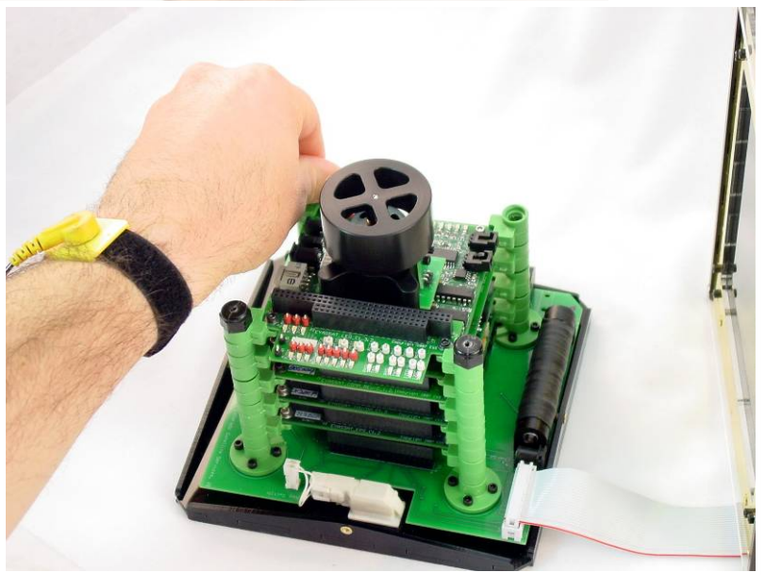
Excerpt...

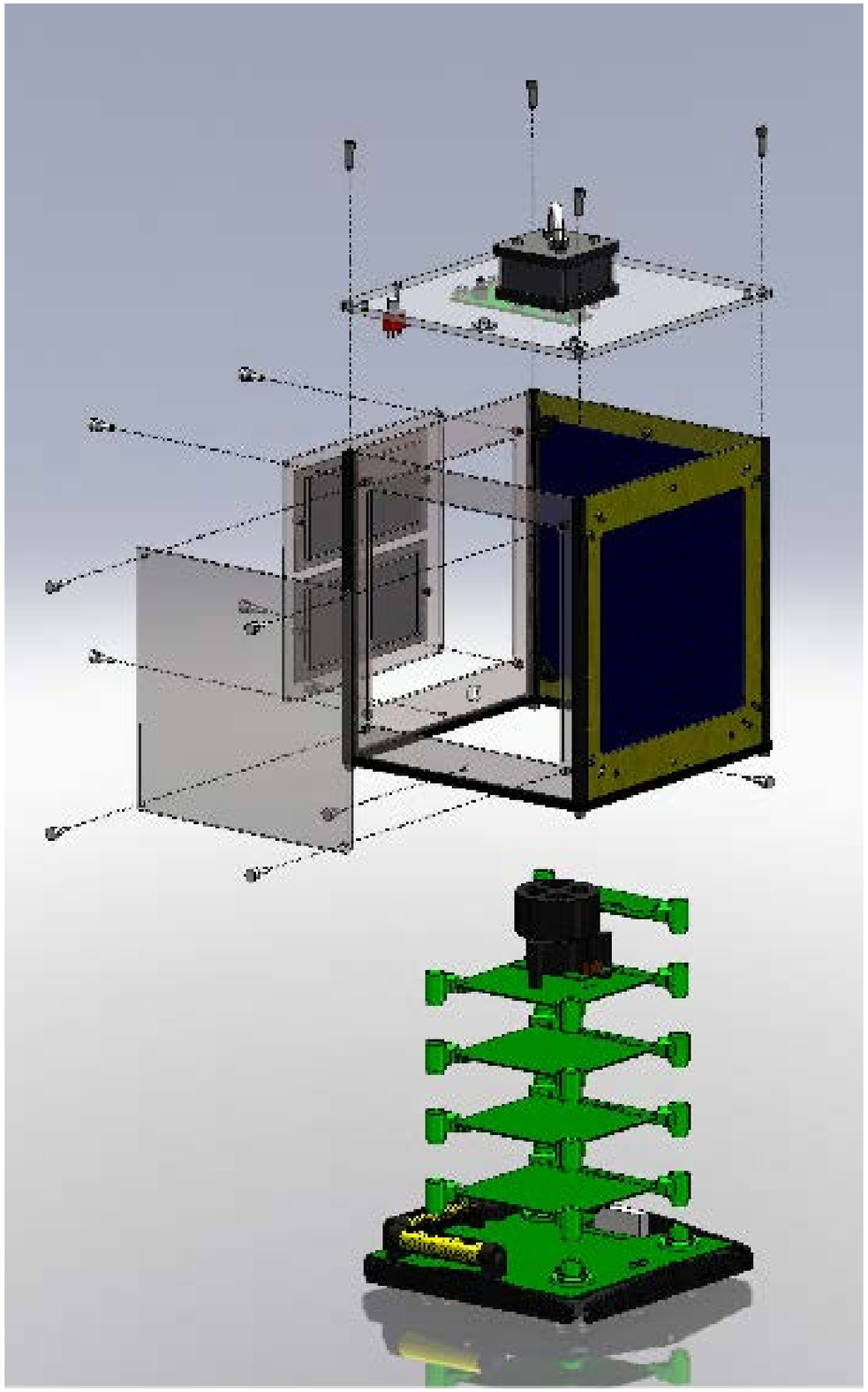
No.	Name	Description	Verification Method(s)	Acceptance Criteria	EWO	Event Task	Status
3.01	System Characteristics	EyasSAT System characteristics shall be as refined by the following subordinate requirements:	Inspection	If verification of all characteristic requirements have been successfully completed.	310	SAR-01	
3.01.01	System Configuration	System Configuration: EyasSAT system shall be assembled from the following configuration end items: (1) Structure & Integration Subsystem (SIS), (2) Electrical Power Subsystem (EPS) Module, (3) Data Handling Subsystem (DHS) Module, (4) Communication Module (Comm), and (5) Attitude Determination & Control Subsystem (ADCS) Module, LED Test Module assembled as per specifications	Inspection	If all specified major components are included	110	EyasA&I-03 EyasSAT Assembly and Integration	
3.01.01.01	SIS Configuration	Structure & Integration Subsystem (SIS) shall be configured as described in the subsystem specification	Inspection	If SIS is configured as described in the subsystem specification	010	SIS-03 Inspection	
3.01.01.02	EPS Module Configuration	Electrical Power Subsystem (EPS) Module and LED Test Module shall be configured as described in the subsystem specification	Inspection	If SIS is configured as described in the subsystem specification	020	EPS-03 Inspection	
3.01.01.03	DHS Configuration	Data Handling Subsystem (DHS) Module shall be configured as described in the subsystem specification	Inspection	If DHS is configured as described in the subsystem specification	030	DHS-03 Inspection	
3.01.01.04	Comm Configuration	Communication subsystem module shall be delivered as configured as described in the subsystem specification	Inspection	If Comm Module is configured as described in the subsystem specification	050	Comm-03 Inspection	

EyasSAT Assembly





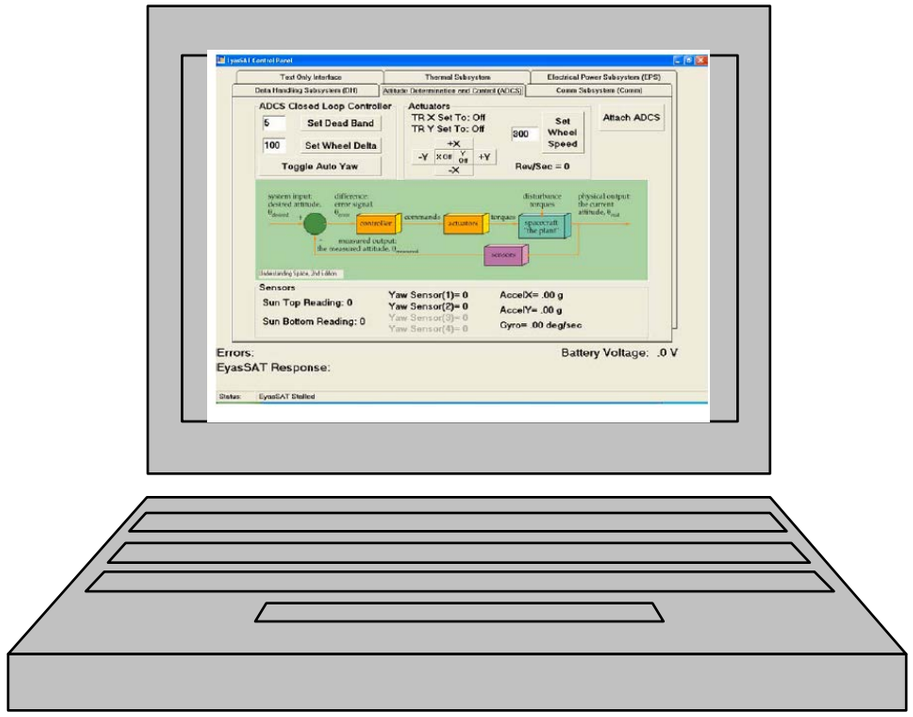




EyasSAT Operations System Configuration

Port for RS-232 cable to computer

EyasSAT Ground Station Transmitter/Receiver



EyasSAT C2 Laptop

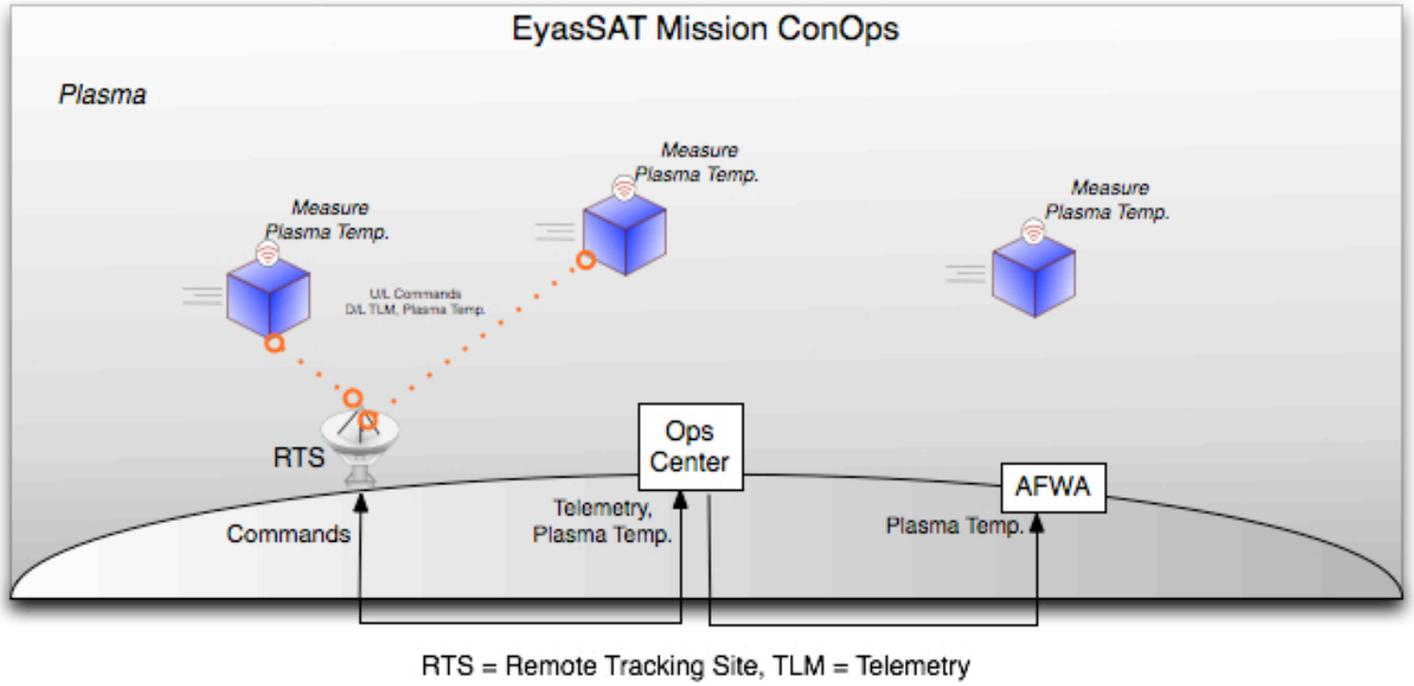
EyasSAT C2 Software

System Validation

Stakeholder Expectations

- KPP 1: Modular, nano-satellite less than 3 kg in mass
- KPP 2: Interface to existing small ground stations
- KPP 3: Provide multi-point (>5) space plasma temperature measurements to within +/- 3 deg of true ambient
- KPP 4: During a typical operational pass, no more than 3 operators shall be able to commission the system and record payload data

ConOps



RTS = Remote Tracking Site, TLM = Telemetry

Software Validation

Validation Events

“Test Like You Fly” Scrimmage

Course Agenda

LECTURES

- Intro to Space Systems Engineering
- The EyasSAT System of Interest
- Validating Requirements & Models
- Verifying Products
- Verification of COTS/NDI
- Software Verification & Validation
- Validating Products and Flight Certification

EXERCISES

- SRPL
- EyasSAT Requirements Validation
- EyasSAT Verification Planning
- EyasSAT Software V&V Event
- EyasSAT Subsystem Verification Events
- EyasSAT System Verification Events
- EyasSAT System Validation Events
- EyasSAT System Acceptance Review

Goal: Achieve an ability to analyze, synthesize and critically evaluate V&V plans and real-world implementations through interactive lectures and hands-on exercises

Customers and Availability

- **Course originally developed for NASA**
- **Regularly taught at all NASA Centers, ESTEC (here in two weeks), industry and the US Air Force**
- **Available in short course format (3 or 4 days)**
- **Offered for graduate university credit through the Stevens Institute of Technology**
- **For more information see www.TSTI.net**
- **Or, contact me: Randy Liefer, rliefer@tsti.net**

Remember: Play Nice with Knowledge!

Commander; First Crewed Mission to Mars

Old Guy