AUSSP
Auburn University Student Space Program

AubieSat-I
Auburn University's First Student Built Satellite

Thor Wilson, Project Manager

AubieSat-I Mission

- AS-I Goals
  - To develop a student satellite building capability at Auburn University
  - To space test a Ga-N based UV sensor developed in the Auburn University Physics Department
- Planned on launching on a Dnepr rocket

Management

- Procedure
  - Define goals and objectives for the semester
  - Define milestones (including reviews)
  - Make a schedule
  - Make a work breakdown structure (specific tasks)
  - Monitor and control activities at bi-weekly meetings
  - DOCUMENTATION

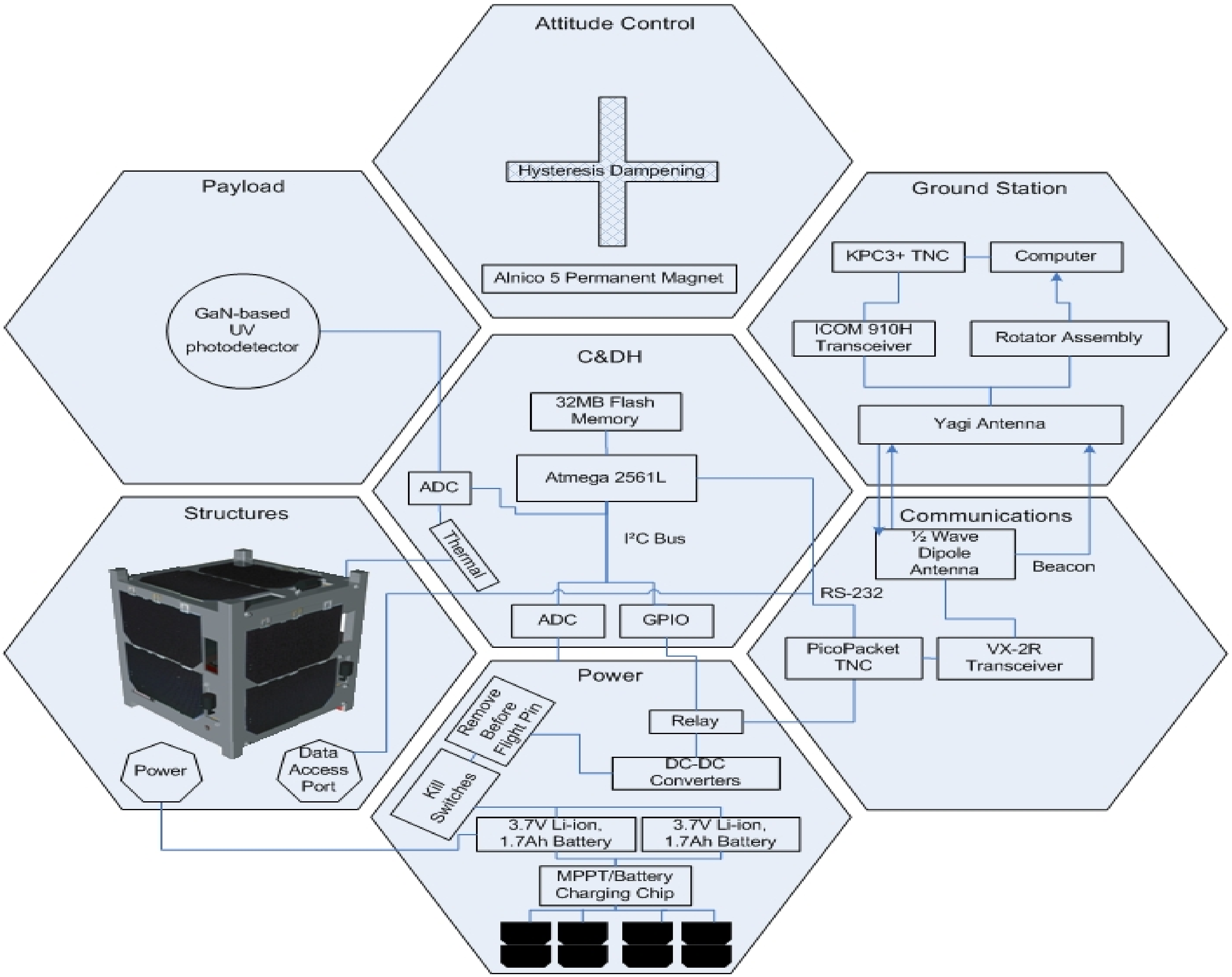
Systems Engineering

Eric Grimes/Thor Wilson, Systems Engineering

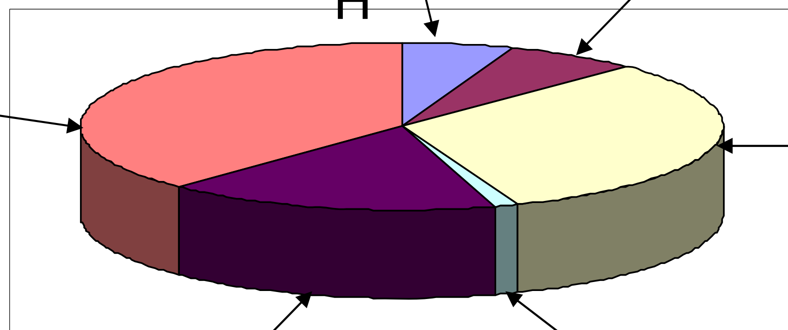
Design Philosophy

- Conform to all Cal Poly specifications
- Simplicity/COTS parts
- Redundancy
- All components selected through trade studies

Functional Block Diagram



Mass Budget



Subsystem		CBE	CBE + 10%	Initial estimate
ADC		48	53	110
C&DH		60	66	60
COMM		281	309	150
PAYLOAD		10	11	70
EPS		150	165	160
STRUCTURE		333	366	400
	Total	882	970	950

Failure Modes Analysis

Code	Name	Description
4	Mission Failure	If this error cannot be mitigated, the mission will be a failure – no communications to the ground station.
3	Reduced Lifetime	If this error cannot be mitigated, the mission is still a success, but further research is needed to extend mission lifetime in future missions.
2	Reduced Capability	If this error cannot be mitigated, the mission is still a success, but further research is needed to provide increased capability.
1	Non-Critical	If this error occurs, the primary mission could still be accomplished without additional need for redundancy.

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Payload

Justin Van Cleave, Payload

Purpose

- Effectiveness
  - Space environment
  - Performance over lifespan
- Key characteristics
  - Responsively (325nm): ~ 0.1 A/W
  - UV/V selectivity: ~ 10^6
  - Dark current density @10V: ~ 0.8 nA/cm^2

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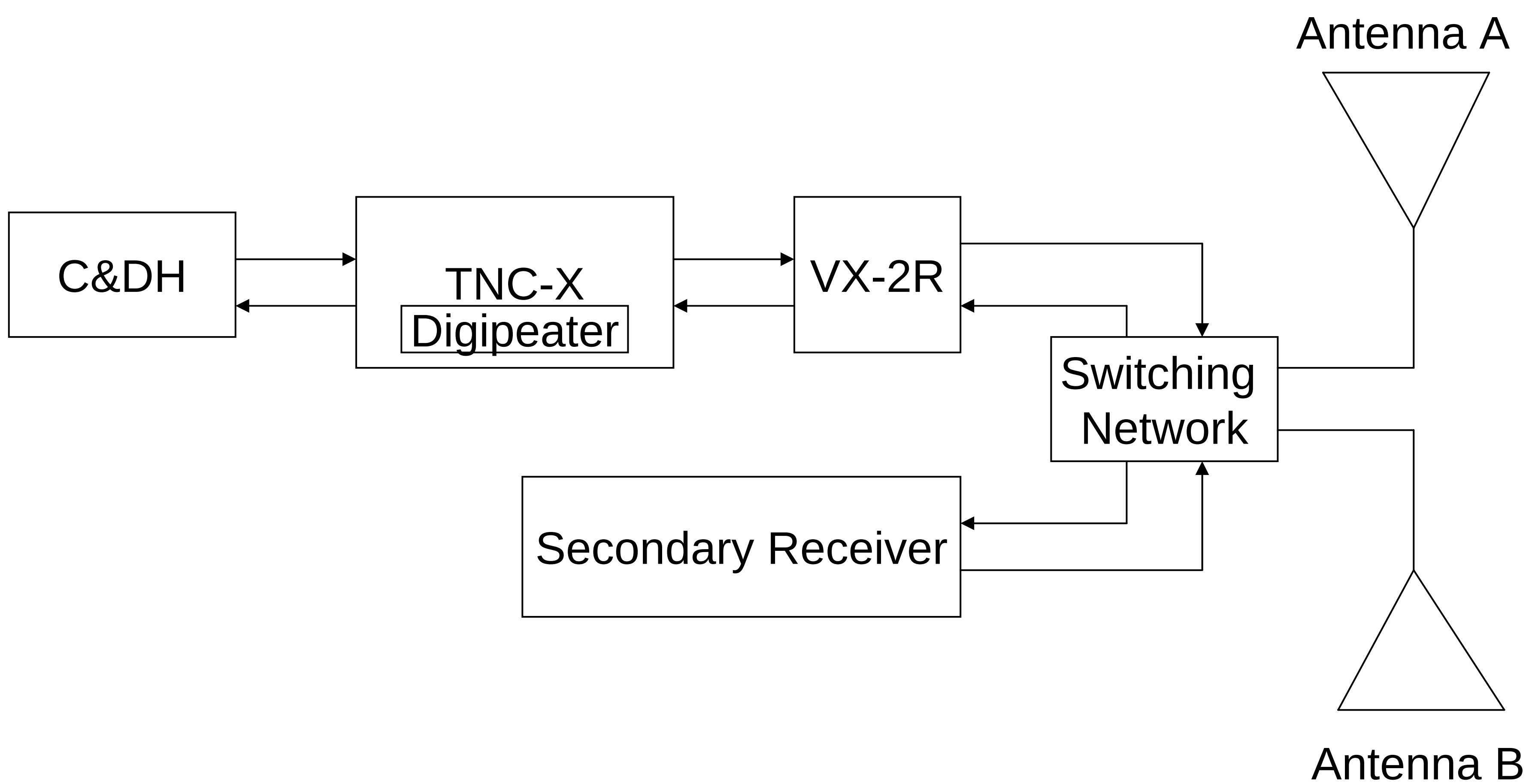
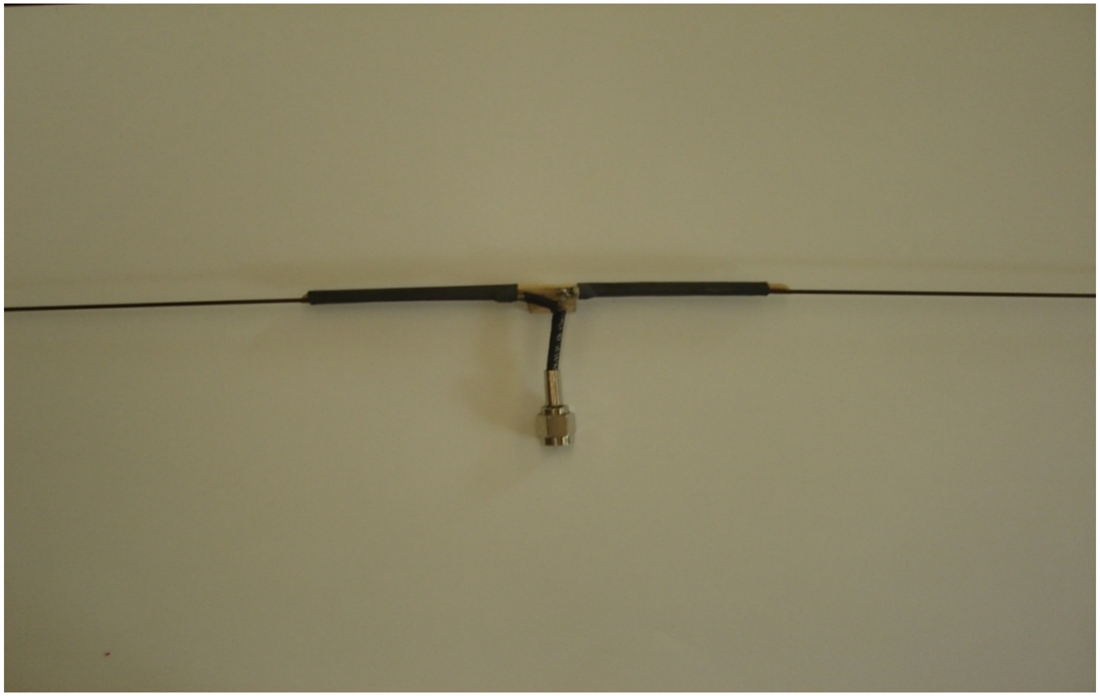
Communications

Robert Thompson/Thor Wilson, Communications

Functional Block Diagram



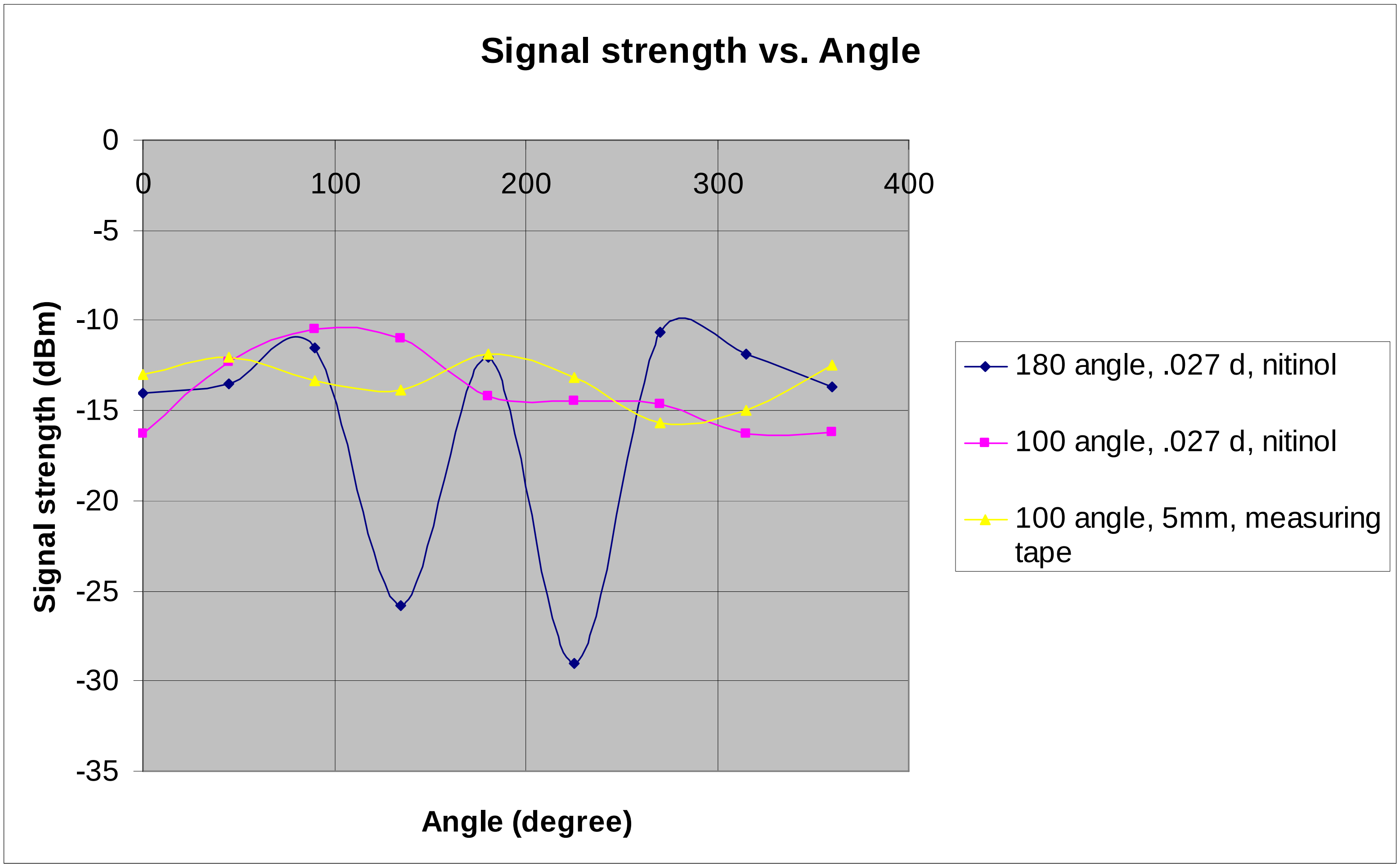
Antenna



- Center feed half-wave dipole
- Amateur Band frequency 435-438 MHz
- Approximately 34 cm
- Made of Nitonol or Measuring tape

Antenna Testing

- Configuration of half wave dipole with best test results was angle of 100 degrees between antenna arms.



Beacon

- Done through primary communications system

- Function
  - Help tracking
  - Provides secondary communications

- Two Modes
  - Data beacon – Short burst of data from TNC-X
  - Morse code beacon – C&DH keys VX-2R to create Morse code

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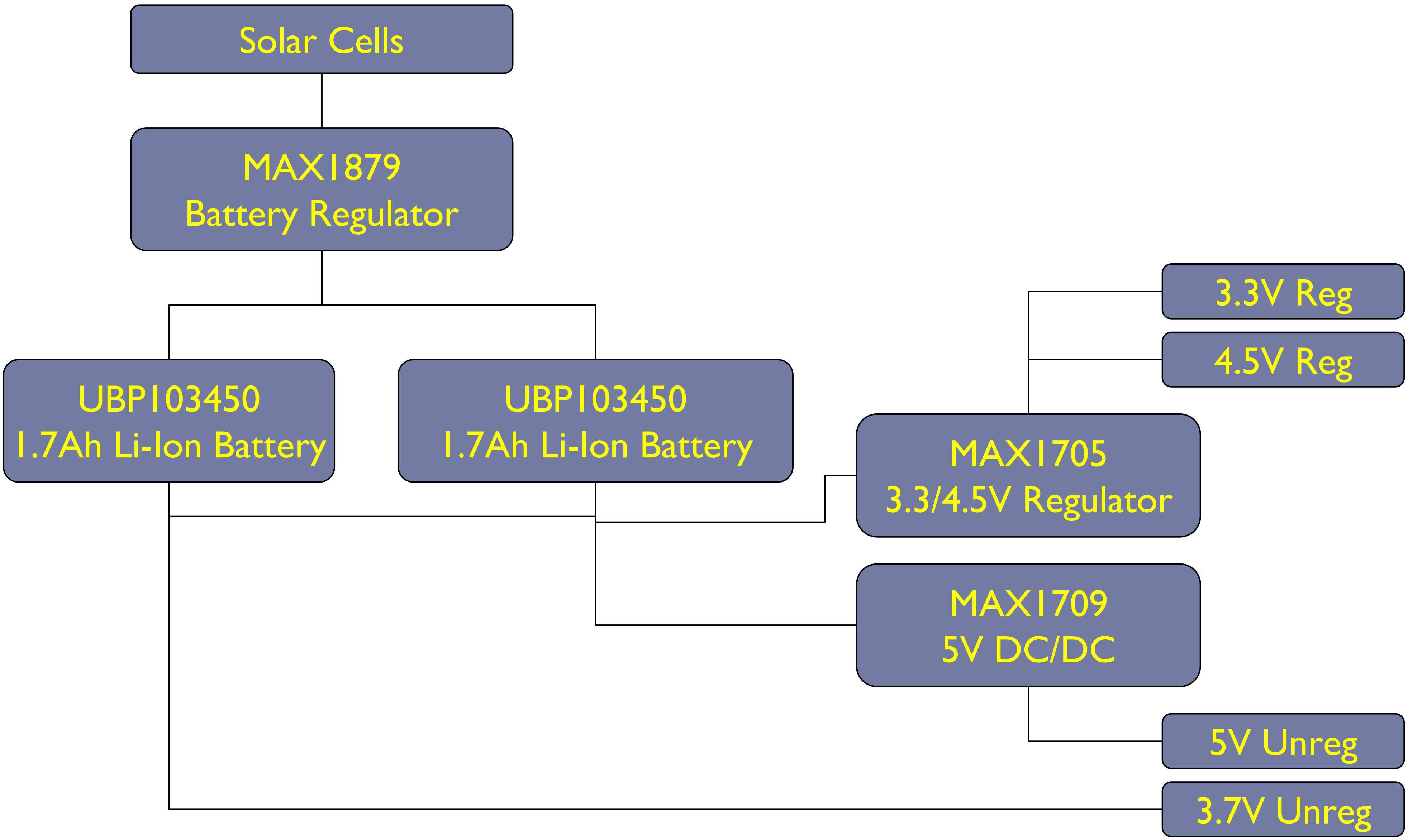
Electrical Power System

Michael Carroll, EPS

Block Diagram



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Attitude Determination and Control

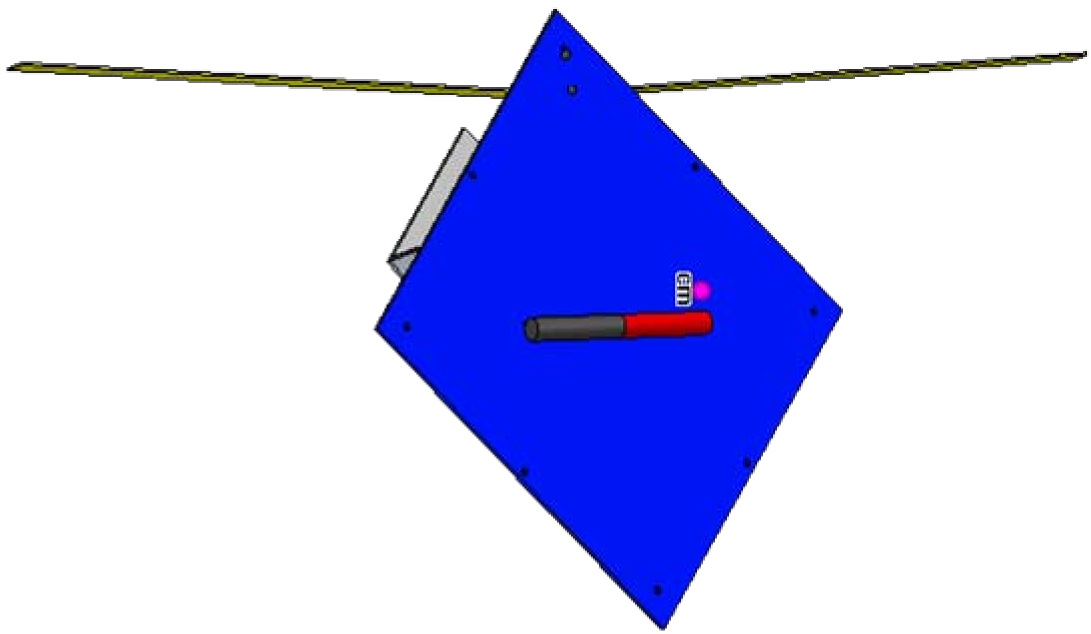
Justin Van Cleave, ADC

Purpose of Control

- Provide proper orientation primarily for communication
- Passive magnetic control
- Hysteresis Dampening to help control

Orientation of Magnet

- After antenna testing was complete the ideal orientation of the magnet was determined



Attitude Determination

- Passive system requires no determination
- Use of "coarse sun-sensor"
  - Based on data transmission constraints
  - Get experience with determination

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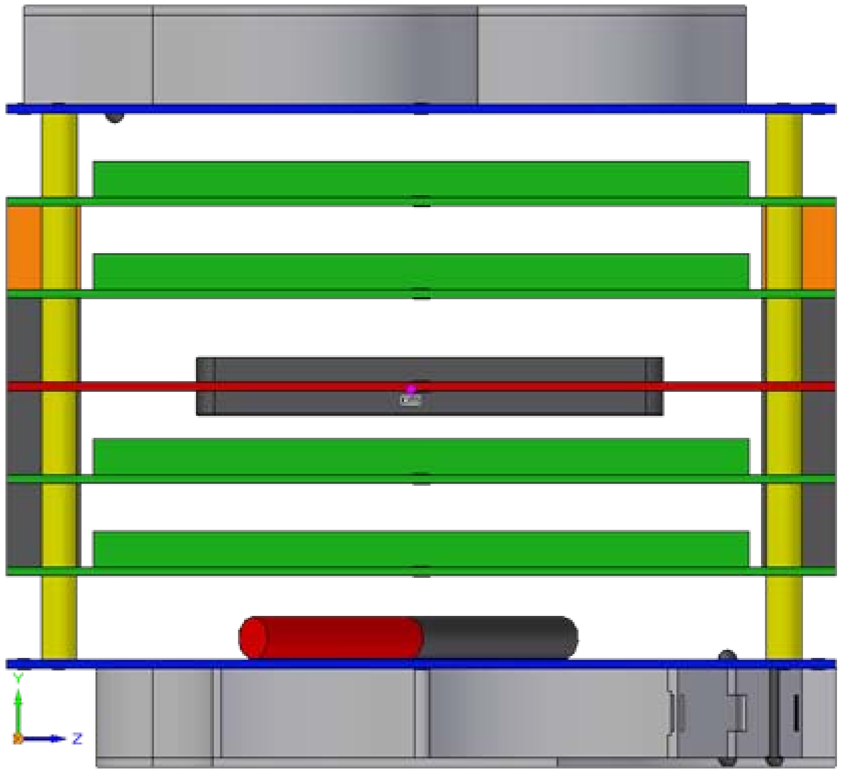
Structures & Mechanisms

Zach Johnston/Neil Dougherty, Structures

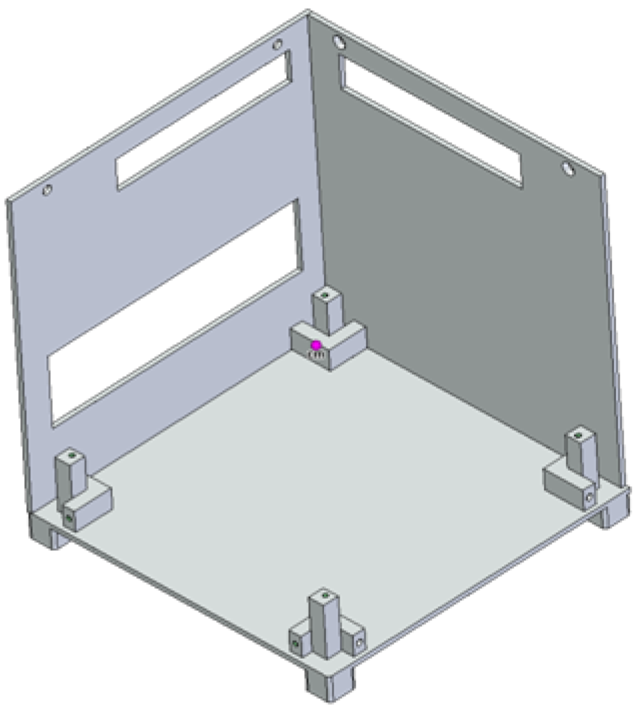
Interior Structure

- Stackable

- Antenna deployment 1
- EPS
- C&DH
- Batteries
- TNC-X and VX-2R
- Secondary receiver
- Antenna deployment 2



External Structure



Side Plate to Bottom Plate Assembly

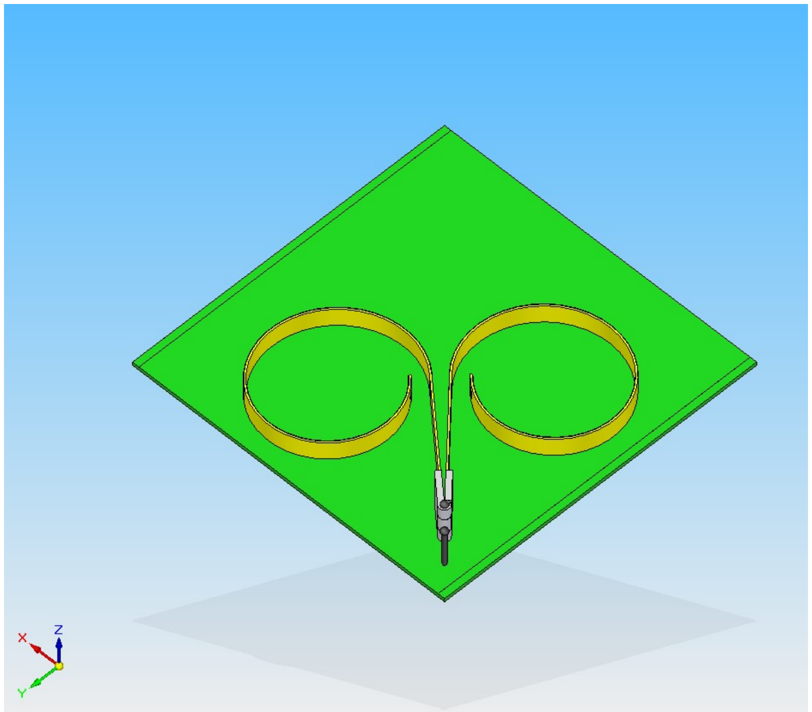
BOTTOM PLATE

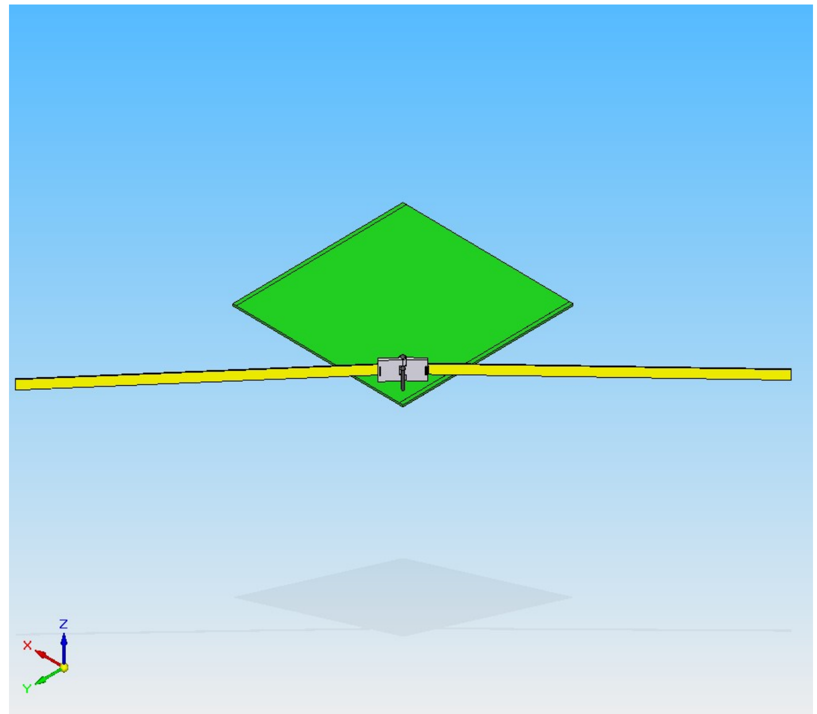
- Support boards with 9.4 mm standoffs with hole to run 10 cm bolt through
- Run bolts through the top plate and boards and fasten bolt to the bottom plate. Boards are secure to these plates

SIDE PLATES

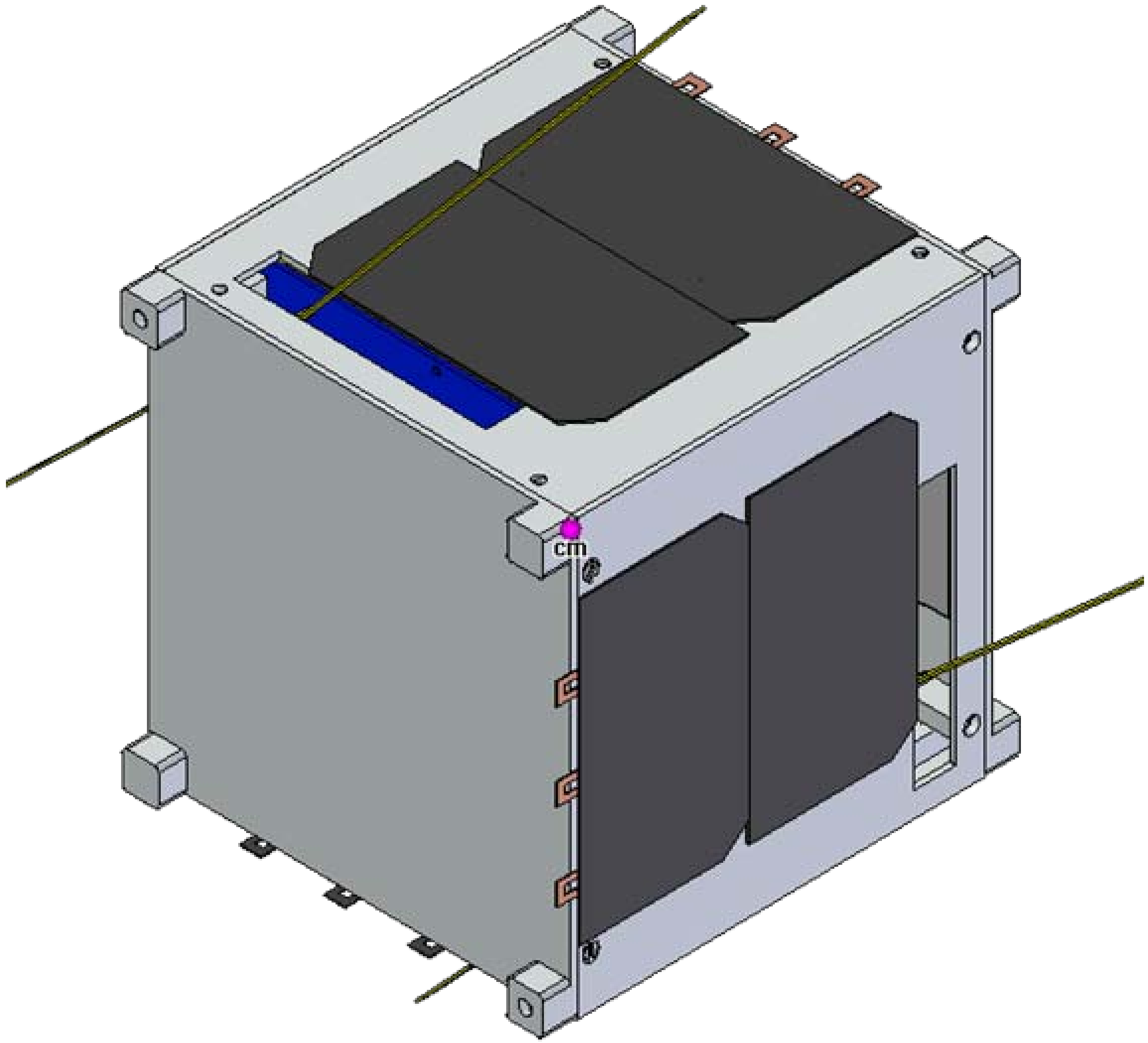
- Four side plates with solar cells screw in to top and bottom plate
- Cutouts for antennas and data port

Antenna Deployment Mechanism





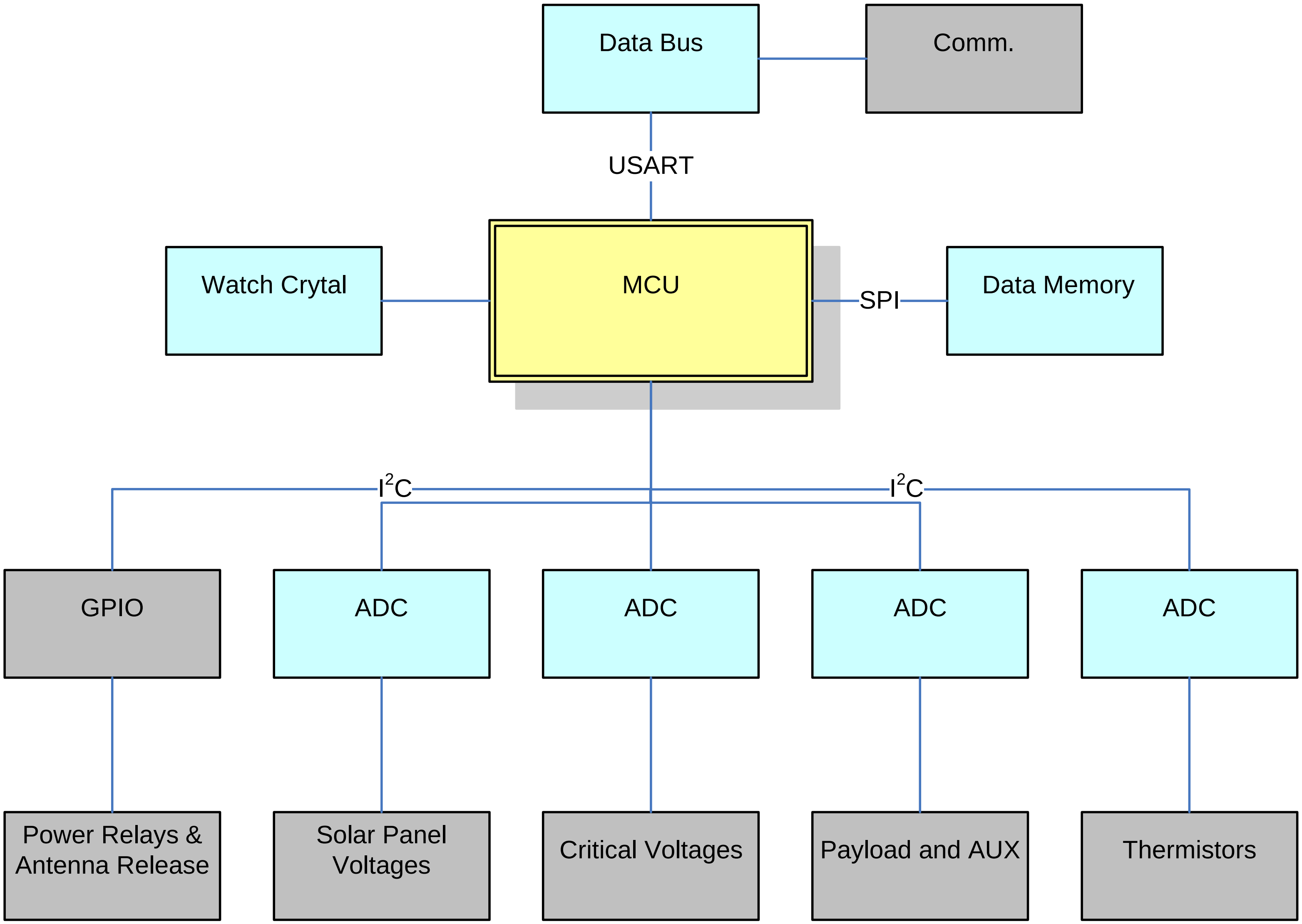
CAD Model



Command & Data Handling

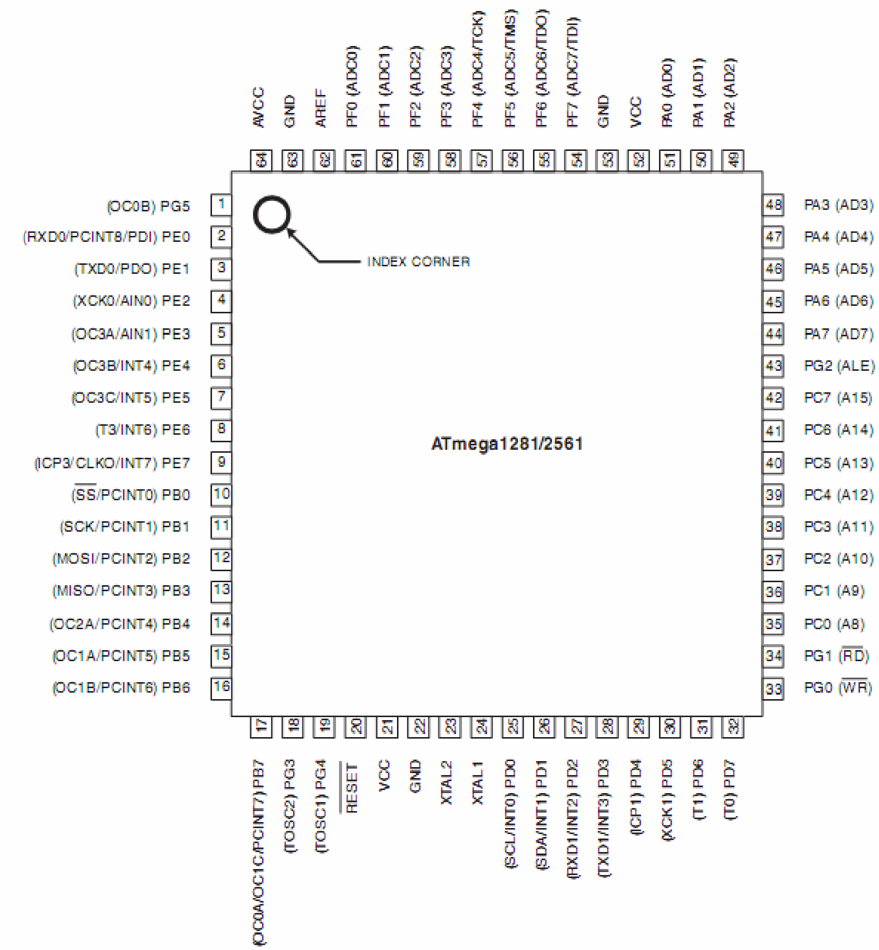
Brad Dutton & William Woodall

Block Diagram



ATmega2561L

- 256kB program storage
- 8kB internal SRAM
- Two Wire SPI
- 2.7V, 15mW
- 16 channel 10 bit ADC
- Open source WinAVR C compiler



Satellite Modes

- One time launch sequence
- Four modes
  - Safe mode – C&DH is on and performs basic tasks, such as battery charging, checking vital housekeeping.
  - Idle mode – Only housekeeping electronics are on. C&DH is storing housekeeping information. Transmitting beacon.
  - Normal mode – Science experiment running, C&DH will be storing data from experiment. C&DH is collecting housekeeping data. Transmitting beacon.
  - Transmit mode – Retrieve and transmit stored data, beacon is off.

Software Design

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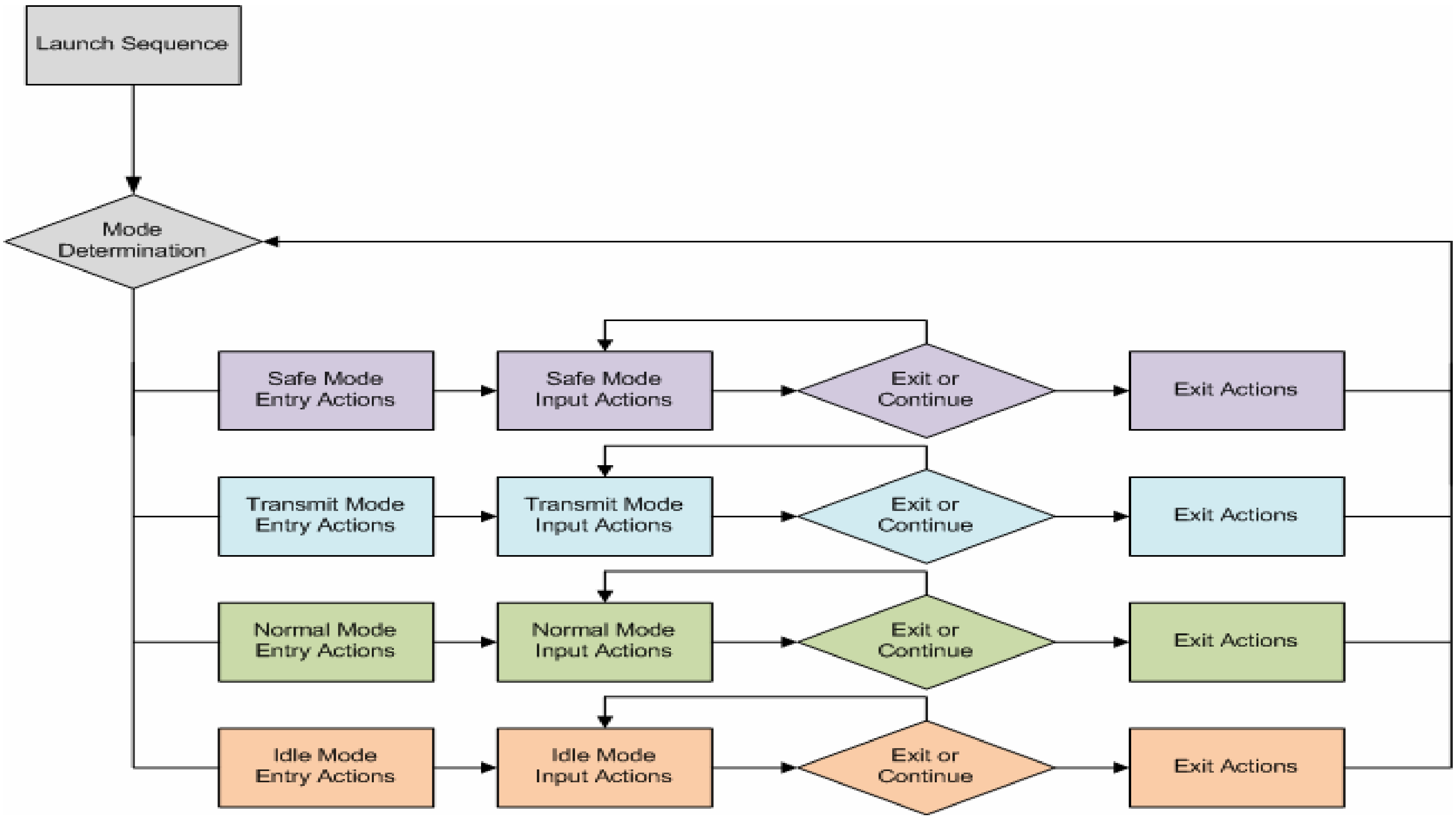
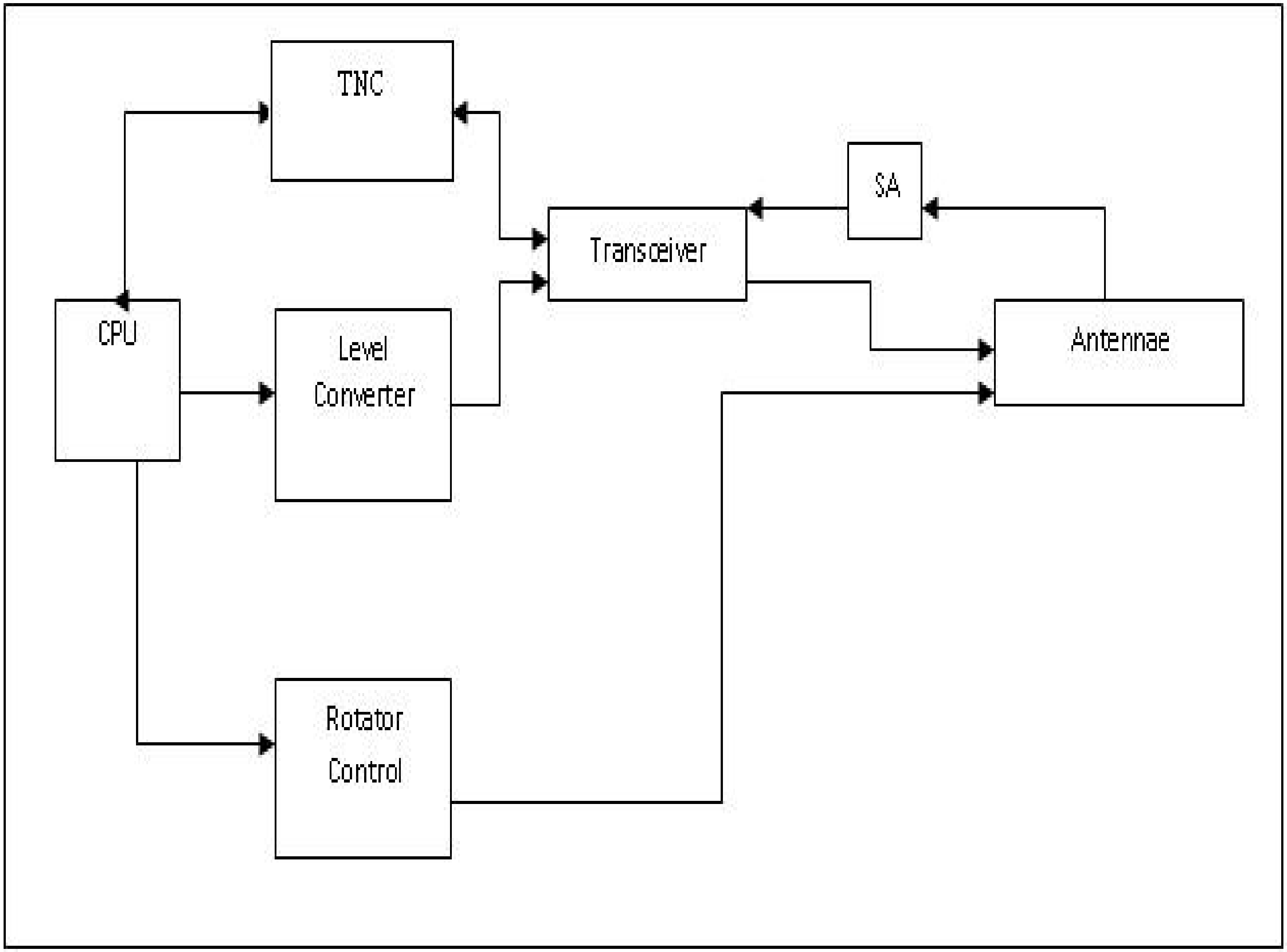
- The finite state machine



Ground Station Software

Block Diagram



Hardware

- Transceiver
  - ICOM 910H
- TNC
  - KCP3+
- Antenna
  - 436CP30 circular polarized Yagia
- Rotator and control
  - Yaesu G5500 rotator
  - Yaesu GS-232A rotator control
- Extra hardware
  - LCU-3 Level Converter

Ground Station Software

Software

- Tracking software
  - NOVA for windows
- Doppler shift software
  - Ham radio deluxe
- Communications software
  - UI-View

Questions

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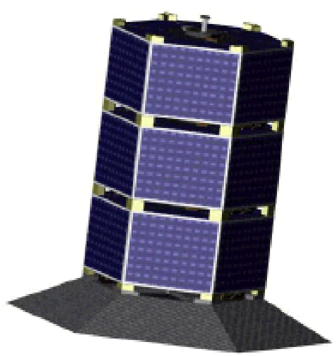
Design Review, Spring 2007

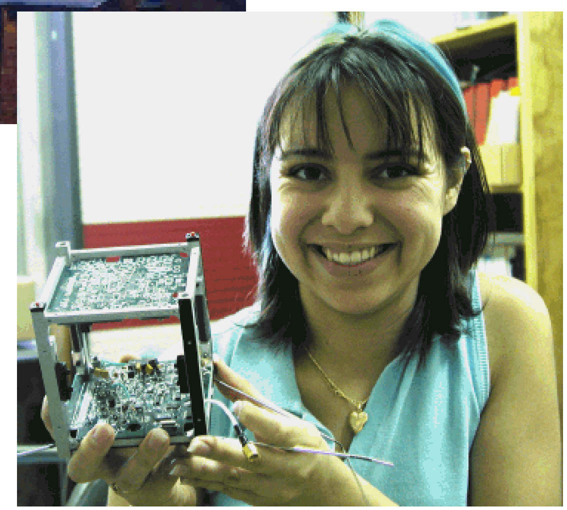
AUSSP: A NASA Space Grant Workforce Development Program

- NASA's Education mission: inspire, engage, educate and employ our youth
- Develop the workforce of tomorrow
- Attract and retain students in the STEM disciplines
- AUSSP: the Auburn University Student Space Program is funded by the Alabama Space Grant Consortium

The National Space Grant Student Satellite Program

From Model Rockets to Mars





Essential Features

- *Hands-on learning*
- *Teamwork*
- *Process*
- *Complements class work*
- *NASA and Aerospace link*

The AUSSP

- Three Teams:
  - Ballooning
  - Small Sats
  - Management
- Learning
  - Management and Systems Engineering
  - Engineering skills
  - Teamwork

The CubeSat Program

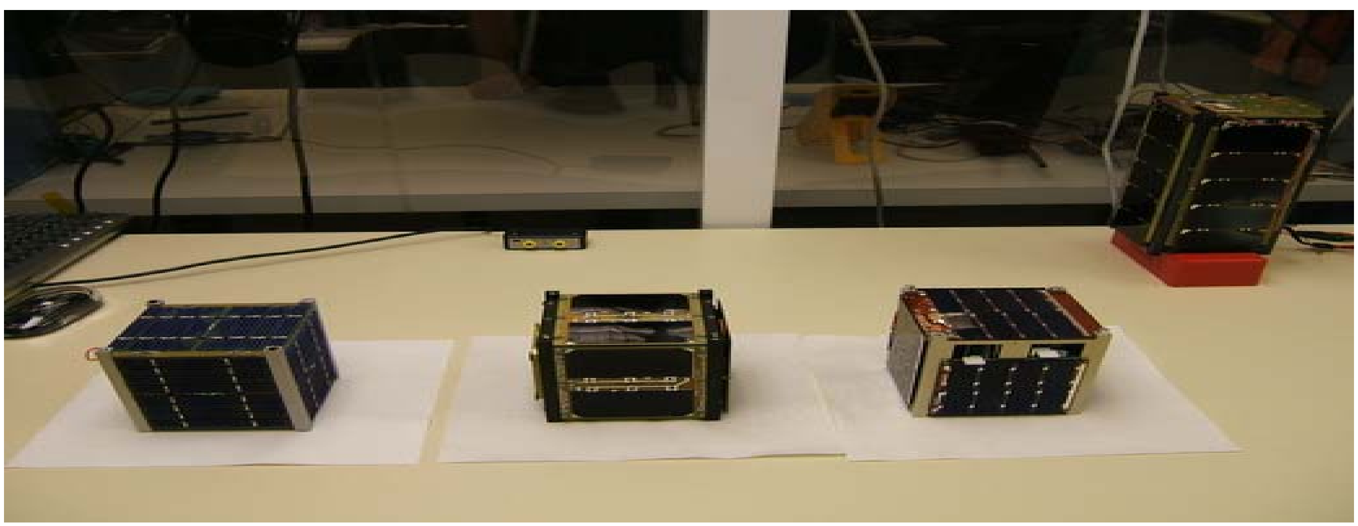
Jamie Droddy, Project Manager

The CubeSat Program

- Developed by Cal Poly & Stanford
- Creates launch opportunities for those previously unable to access space
  - Low –cost launch
  - Standard Deployment System (P-POD)
  - Coordination of required documents & licenses
  - Delivery to launch facility and integration with launch vehicle
- Access to CubeSat Community

CubeSat Specifications

- 10 cm cube (100mm x 100mm x 113.5 mm)
- ≤ 1 kg
- Center of mass w/in 2cm of geometric center
- Thermal expansion of material similar to that of P-POD
- Electrically dead during launch
- No operation until 15 minutes after launch
- Qualified & Accepted per Cal Poly Specifications



Amateur Radio Use

- FCC Licensing
- FCC & IARU regulations governing amateur satellite operation
  - Capable of killing all transmission whenever requested to do so
- Orbital Debris Mitigation Report

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AubieSat-I

Our Mission

AubieSat-I Mission

- AS-I Goals
  - To develop a student satellite building capability at Auburn University
  - To space test a Ga-N based UV sensor developed in the Auburn University Physics Department

Spring 2007 Goal…

- A functional table-top prototype of AS-1
  - All subsystems powered by EPS
  - All subsystems nominally operational
  - All subsystems properly interfaced
  - Fully operational Ground Station

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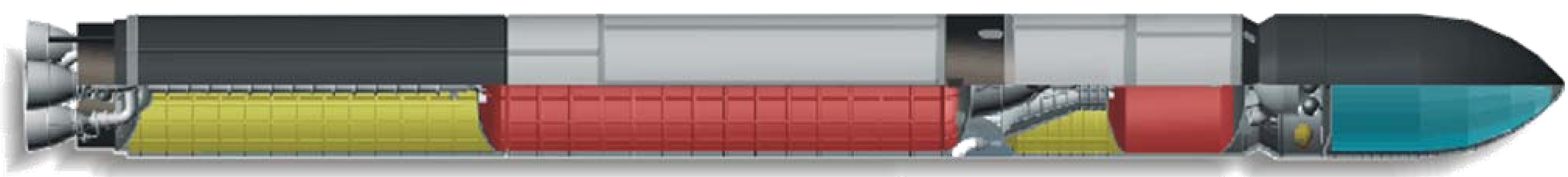
Mission Analysis

Eric Grimes, Systems

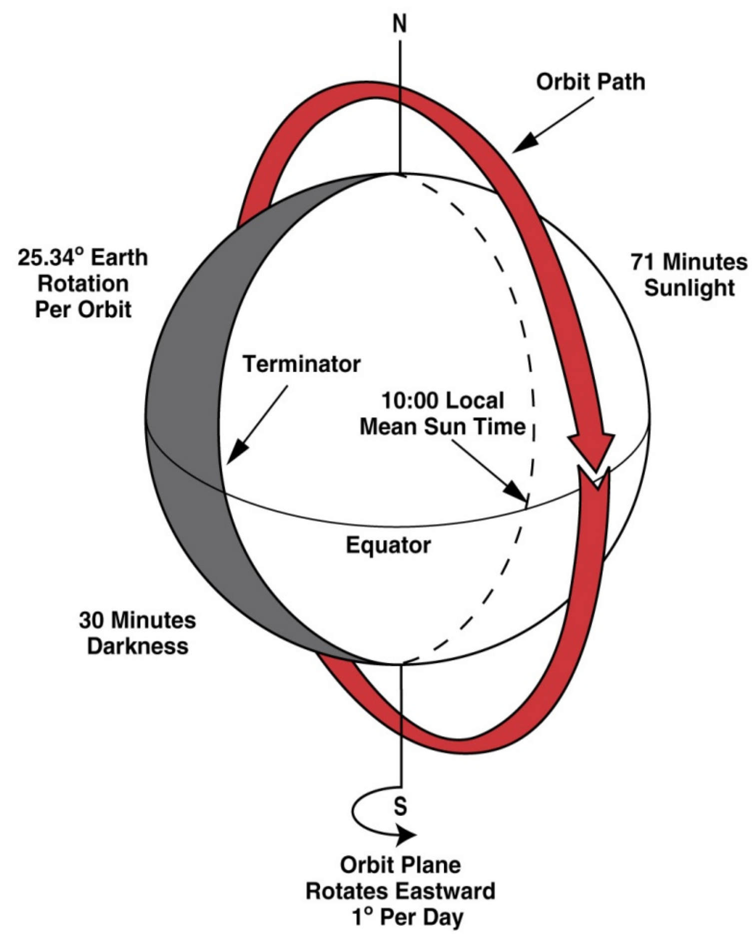
Launch, Dnepr III

- Kosmotras, Baikonour Cosmodrome (Kazakhstan – 63°E and 46°N)
- Converted RS-20 (SS-18) ICBM
- Delivery for final integration: April, 2008
- Launch date: Summer 2008!!



Orbital Parameters

- Sun-synchronous, near polar
- Inclination: ~98° (slightly retrograde)
- Period: ~99 min
- Altitude: ~650 km (LEO)
- Eccentricity: ~0.008
- 30-35 minute eclipse time



Systems Engineering

Eric Grimes/Thor Wilson, Systems Engineering

Design Philosophy

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- Simplicity/COTS parts
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Functional Block Diagram

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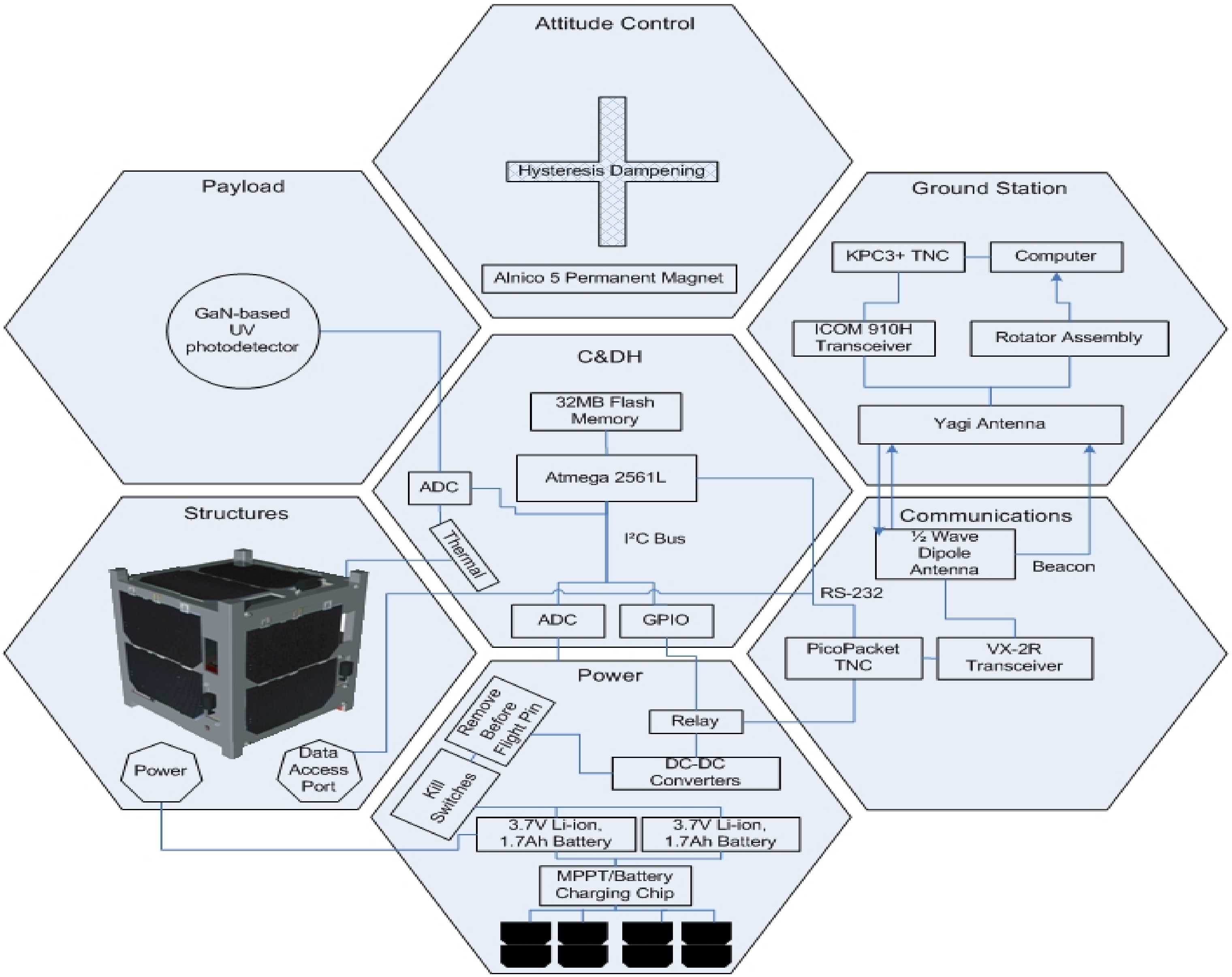
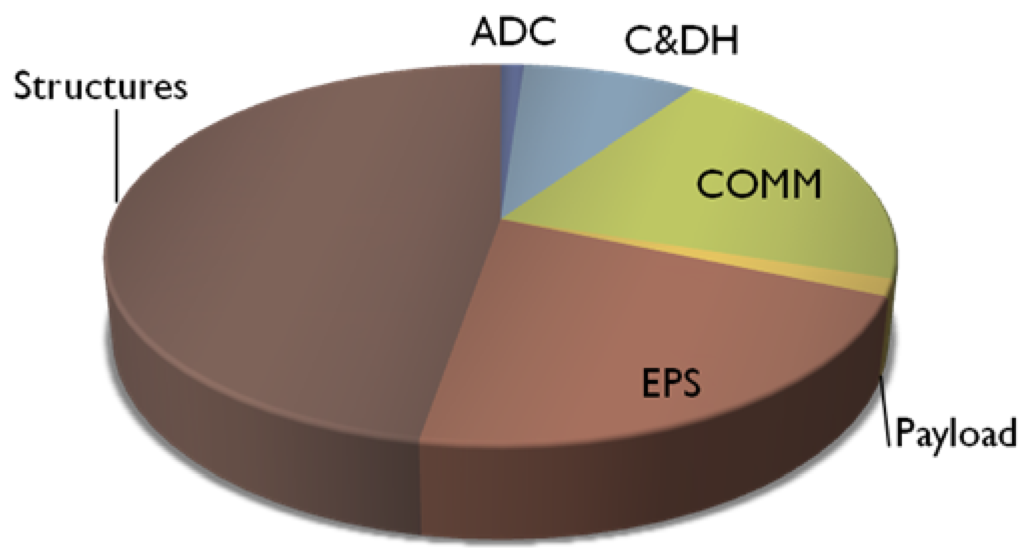


Mass Budget

Subsystem	CBE	CBE + 10%	Initial estimate
ADC	8	8.8	110
C&DH	60	66	60
COMM	143	157.3	150
PAYLOAD	10	11	70
EPS	150	165	160
STRUCTURE	332.44	365.684	400
Total	703.44	773.784	950

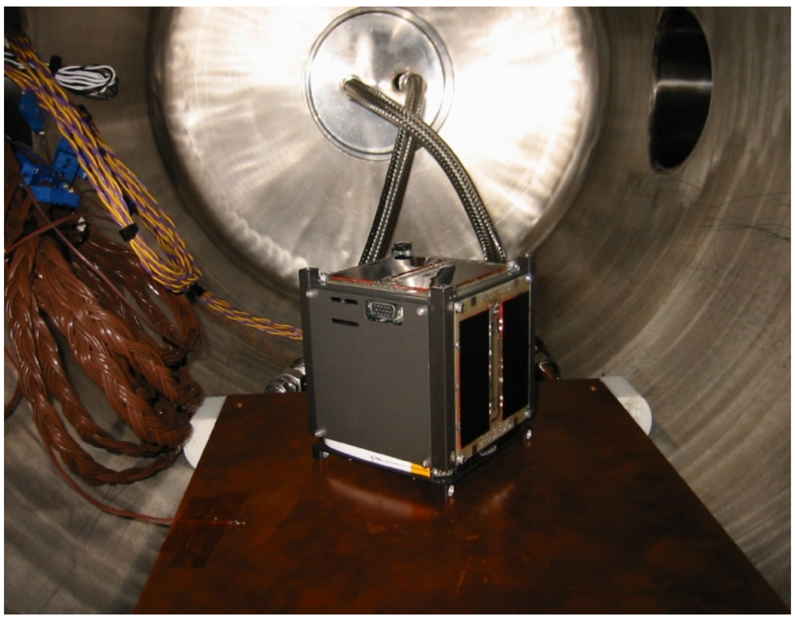


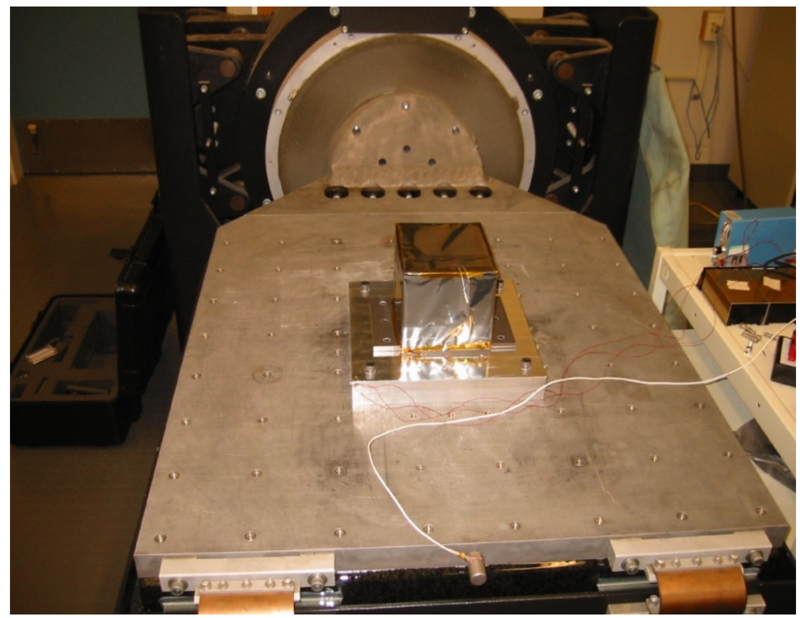
Failure Modes Analysis

Code	Name	Description
4	Mission Failure	If this error cannot be mitigated, the mission will be a failure – no communications to the ground station.
3	Reduced Lifetime	If this error cannot be mitigated, the mission is still a success, but further research is needed to extend mission lifetime in future missions.
2	Reduced Capability	If this error cannot be mitigated, the mission is still a success, but further research is needed to provide increased capability.
1	Non-Critical	If this error occurs, the primary mission could still be accomplished without additional need for redundancy.

Flight Qualification

- Acceptance Testing:
  - Ensure safety of launch vehicle
- Qualification Testing (Functional)
  - Maximum probability of mission success



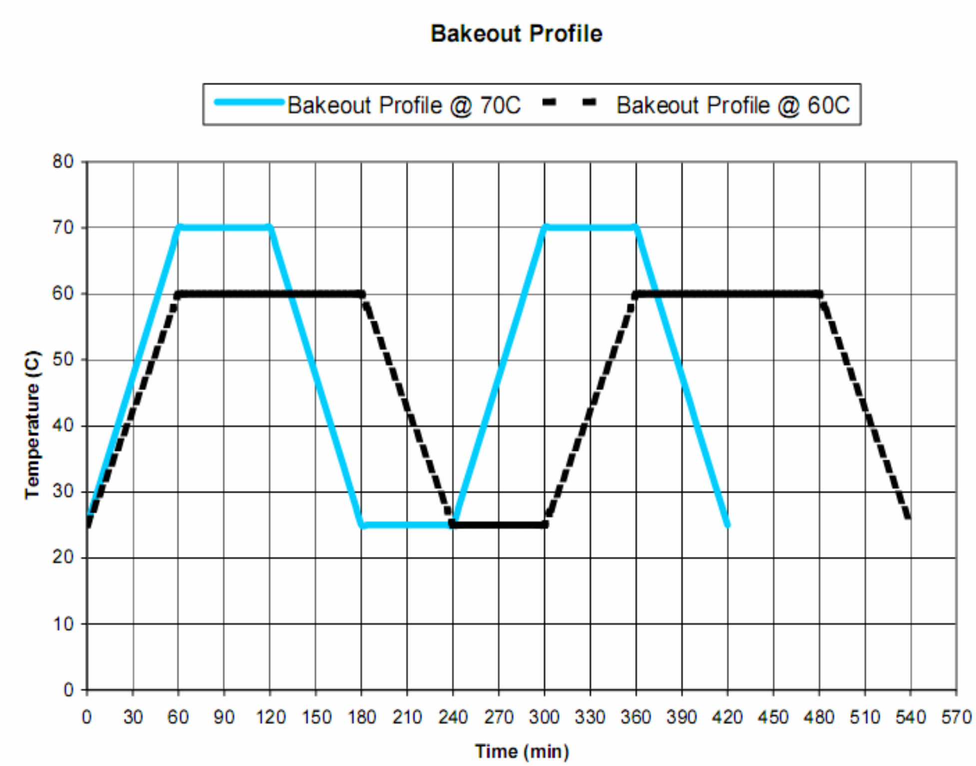


"Test as you fly, fly as you test."

Acceptance Testing

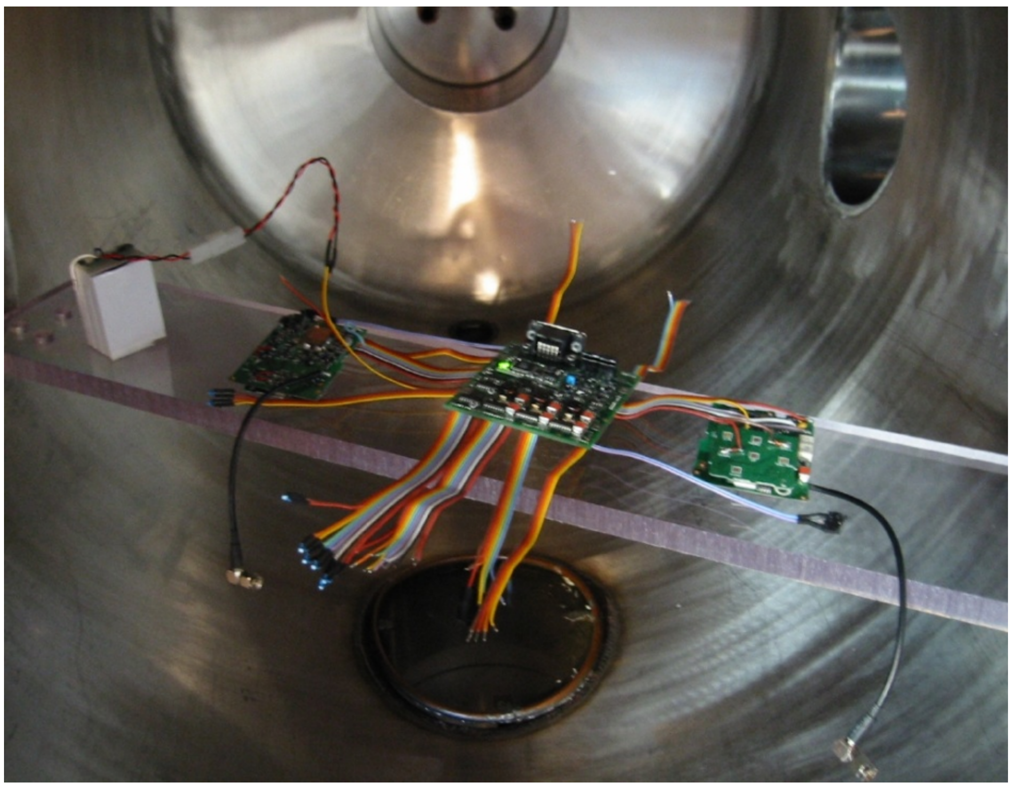
- Safety of launch vehicle
  - Vibration
  - Thermal vacuum (5 x 10^{-4} Torr)

Dnepr Vibration Profile		
Frequency (Hz)	Liftoff G^2/Hz	1st Stage Burn G^2/Hz
20	0.0105	0.0105
40	0.0105	0.0105
80	0.0105	0.0105
160	0.033	0.0105
320	0.0525	0.0135
640	0.0525	0.0135
1280	0.0255	0.00675
2000	0.0075	0.00675
Duration	35 seconds	831 seconds



Qualification Testing

- Maximize probability of mission success
- Components tested individually first



Future

- Include final redundancy – Summer 2007
- Flight qualification plans – Summer 2007
- Individual component qualification – Summer 2007
- Qualification review – Fall 2007

Payload

Justin Van Cleave, Payload

Overview

- GaN based "visible blind"
  - Almost no response from visible light
- Key characteristics
  - Responsivity (325nm): ~ 0.1 A/W
  - UV/V selectivity: ~ 10^6
  - Dark current density @10V: ~ 0.8 nA/cm^2

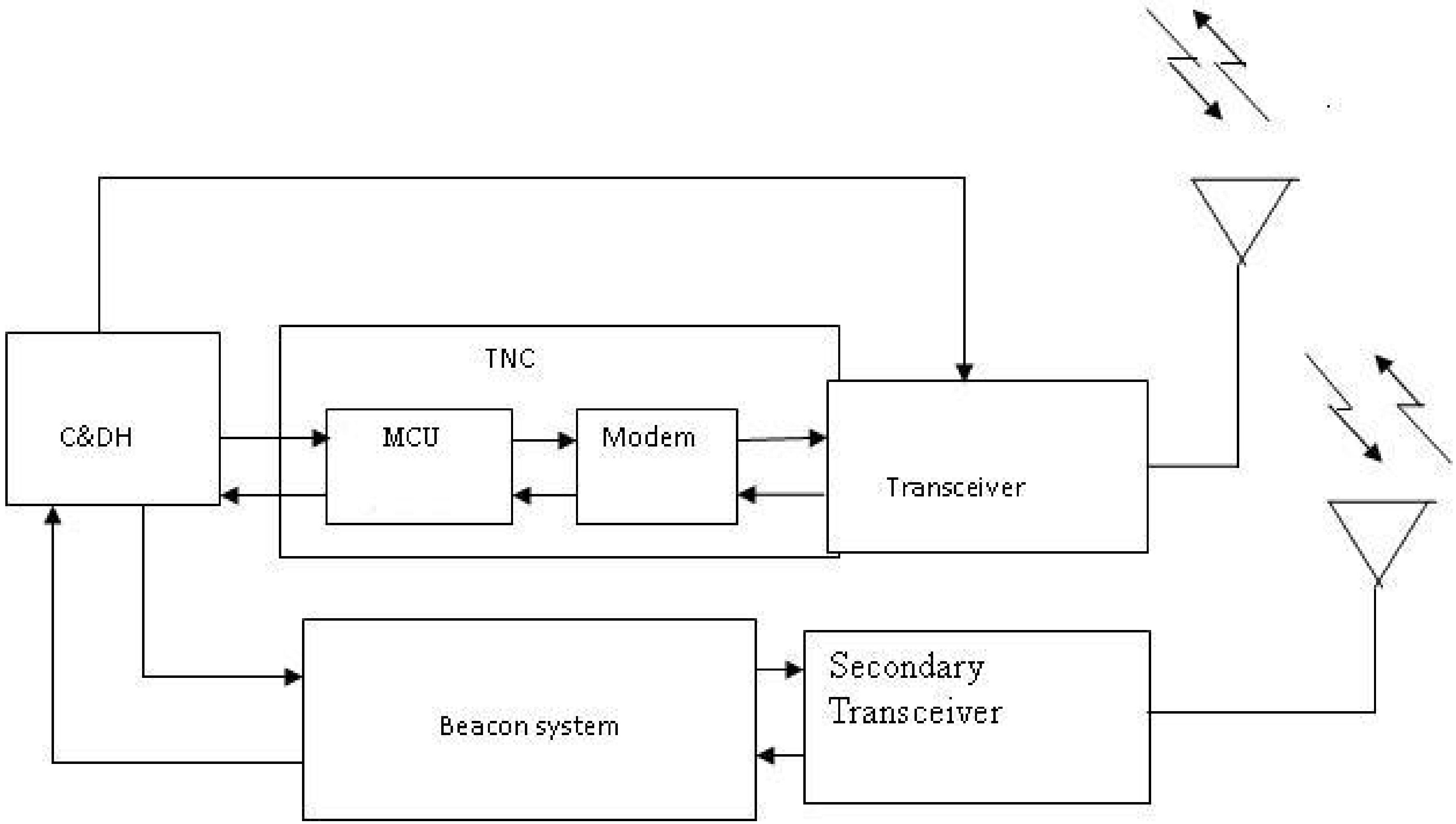
Purpose

- Effectiveness
  - Space environment
  - Mission lifespan
- Future work
  - Build circuit to measure current
  - Design housing and lens for cell

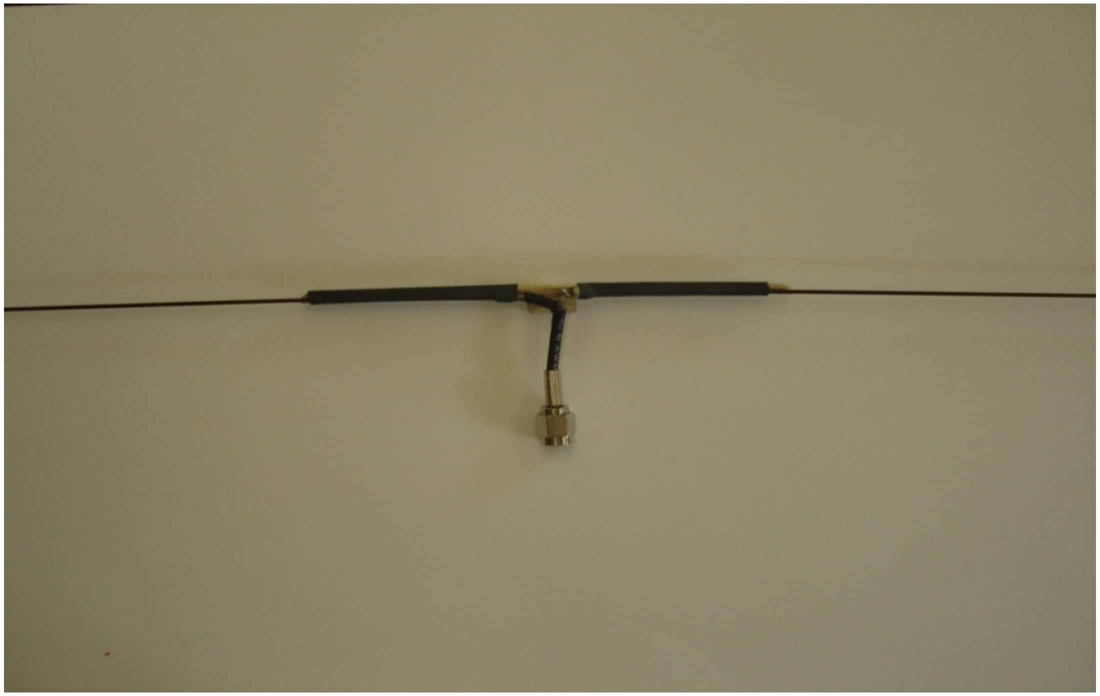
Communications

Robert Thompson/Thor Wilson, Communications

Functional Block Diagram



Antenna



- Center feed half-wave dipole
- Amateur Band frequency 435-438 MHz
- Approximately 34 cm
- Made of Nitonol

Nitonol

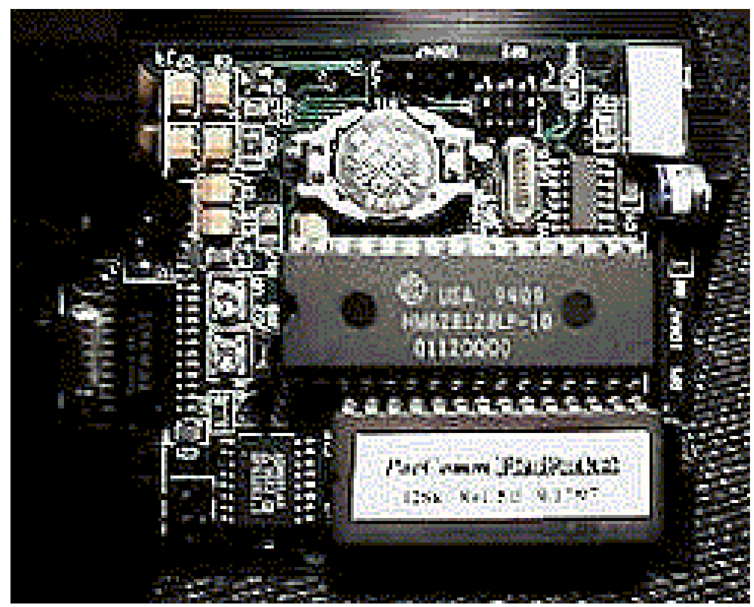
- Super Elastic Wire
  - Shape memory alloy
- Conductivity
  - Nitinol 1.27×10^{4}
  - Copper 5.81×10^{7}
  - Rubber 1×10^{-13}
- Diameter
  - .027 in

VX-2R

- FM Transceiver
- Power Output
  - 2 W
    - 6 V
    - 1.5 A
  - 1 W
    - 3.7 V
    - 1.2 A
- Structure (estimated)
  - Mass 41 g
  - Size 43 x 73 x10 mm

PicoPacket

- PicoPacket
  - Z80181 Microprocessor
  - TCM3105 Modem
  - Mass: 63 g
  - Volume: 8x6x1.2 cm
  - Voltage: 7-14 V
  - Current: 50-70 mA
  - Data Rate: 1200 baud



Beacon

- Function
  - Help tracking
  - Provides secondary communications
- Basic hardware
  - CW transmitter
  - Morse code generator
- Still in design phase

Link Budget

Options:				
NRZ Data Rate =	1200		Baud	
G/S Receiver Noise Figure =	3.7		dB	
G/S Antenna Gain =	14.15	0	dB	Not final
AS-1 Transmitter power (W)	1.064		W	

Assumptions:			
Demodulator Threshold (FM) =	21		dB
Bit Error Rate; 1 in =	1.00E+04		BER
Data rate to BW ratio =	10		Ratio
Path Distance =	2500		km
Operating Frequency =	436		MHz
Craft DC to RF Efficiency =	0.2		Ratio
Demodulator Inefficiency =	3.5		dB

Constants:			
Boltzmanns constant =	1.38E-23		J/K
Effective temperature, K =	290		K

Link Situation:			
Carrier to noise ratio (C/kT)	14.5		dB
IF Bandwidth =	12000.0		Hertz
Noise power =	4.80E-17		Watts
Noise power (dBm) =	-133.18		dBm
Receiver noise level =	-129.48		dBm
Input Carrier to Receiver =	-114.98		dBm
Wavelength =	0.688		Meters
Path loss =	-153.19		dB

Link Budget Calculation:		
Required Rcvr Input Power =	-114.98	dBm
G/S Cable and connector loss =	-0.1	dB
G/S rcvr antenna gain =	14.15	dB
Free space path loss =	-153.19	dB
Polarization mismatch loss =	-3	dB
AS-1 transmitter antenna gain =	0	dB
AS-1 Cable and connector loss =	-0.1	dB
AS-1 Transmitter power (dBm) =	30.26941628	

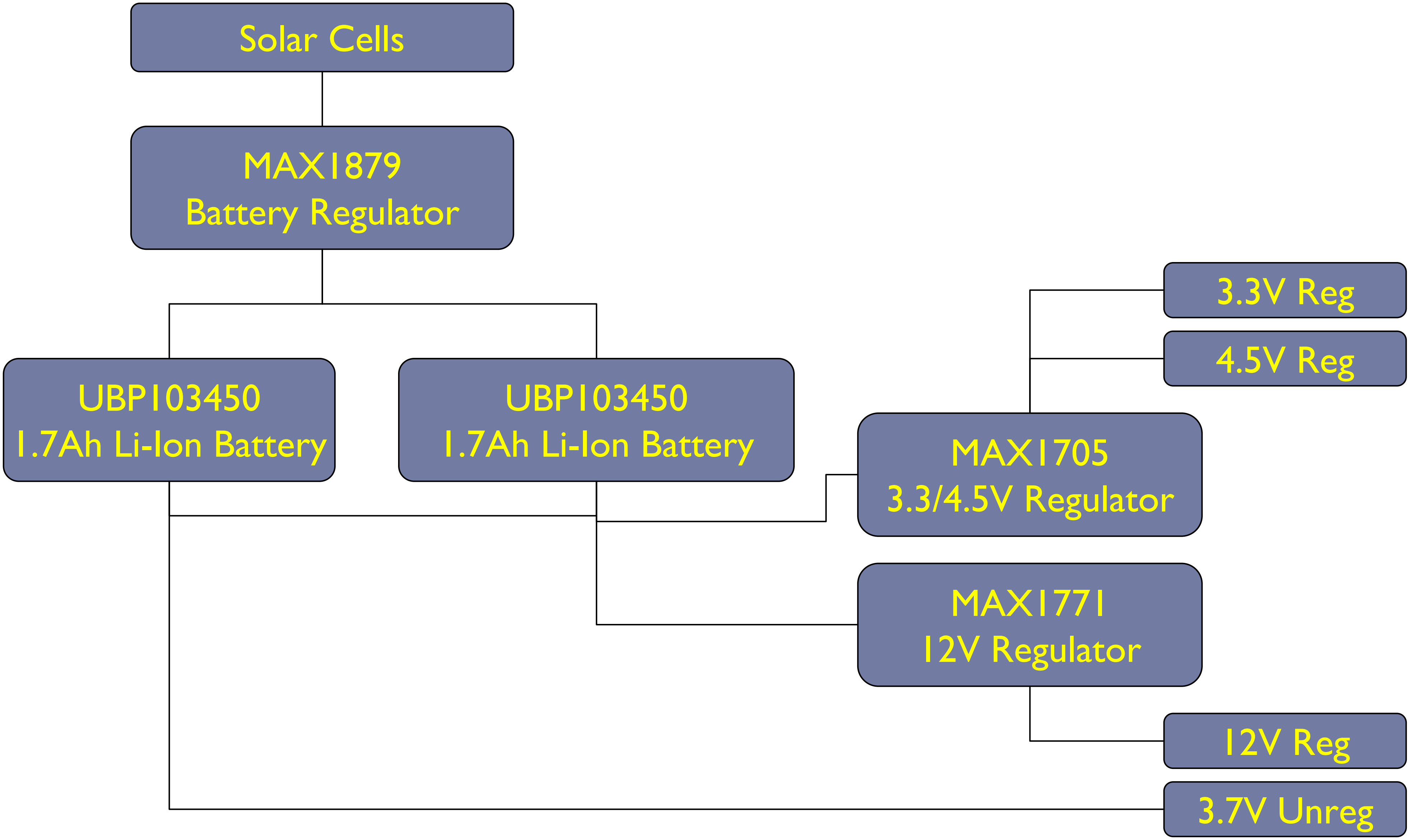
AS-1 Transmitter power (dBW) =	**0.27**	**dBW**
AS-1 Transmitter power (W) =	**1.064**	**Watts**
AS-1 Transmitter prime power =	**5.320**	**Watts**

Link Margin	**3.01**	**dB**
Required transmitter power (dBm)	**27.26**	**dBm**
Required transmitter power (W)	**0.531731418**	**Watts**
Required transmitter prime power =	**2.658657091**	**Watts**

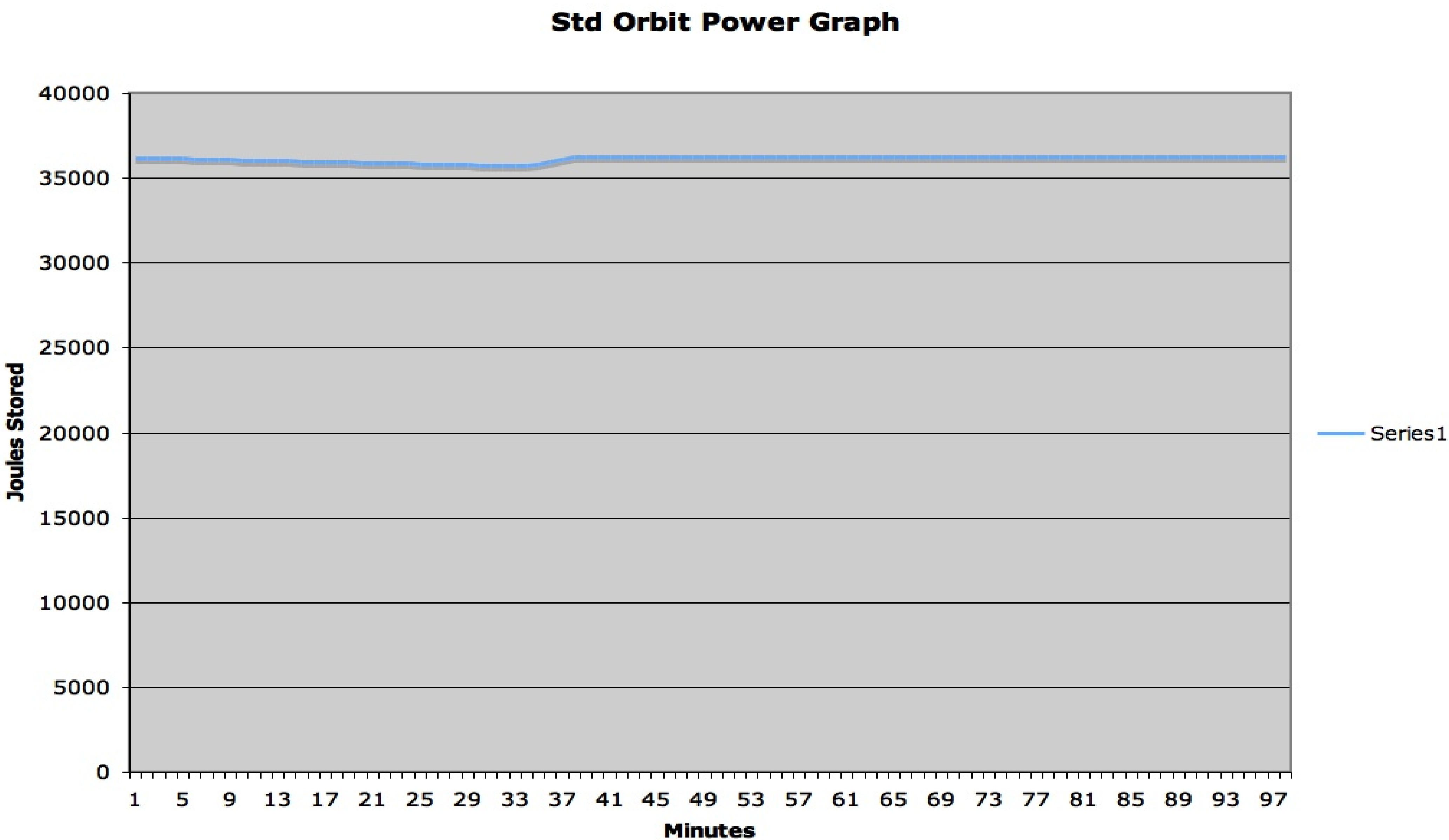
Electrical Power System

Michael Carroll, EPS

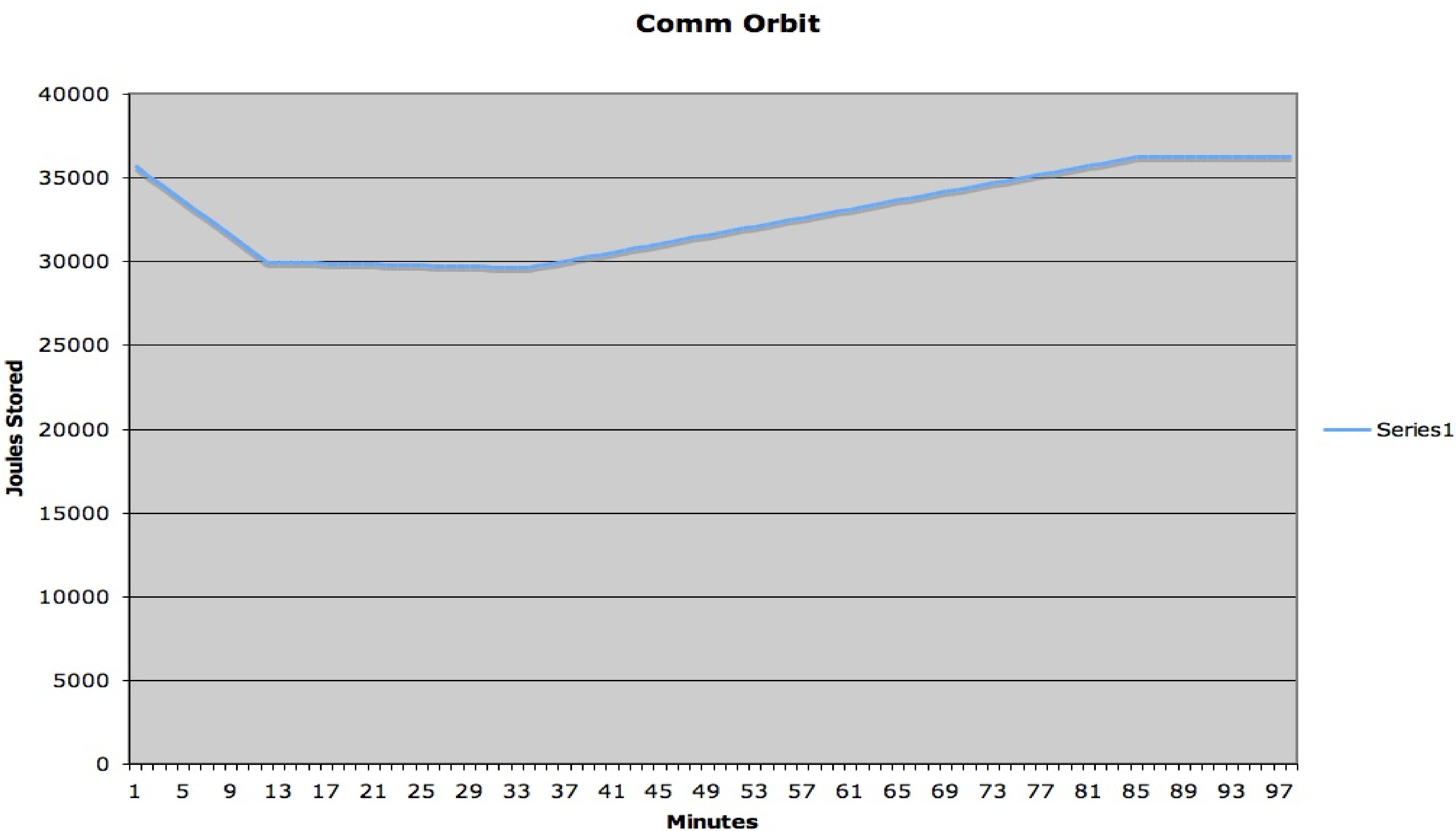
Block Diagram



Standard Orbit



COMM Orbit



Comm Orbit
40000
35000
30000
25000
20000
15000
10000
5000
0
Joules Stored
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97
Minutes
Series1

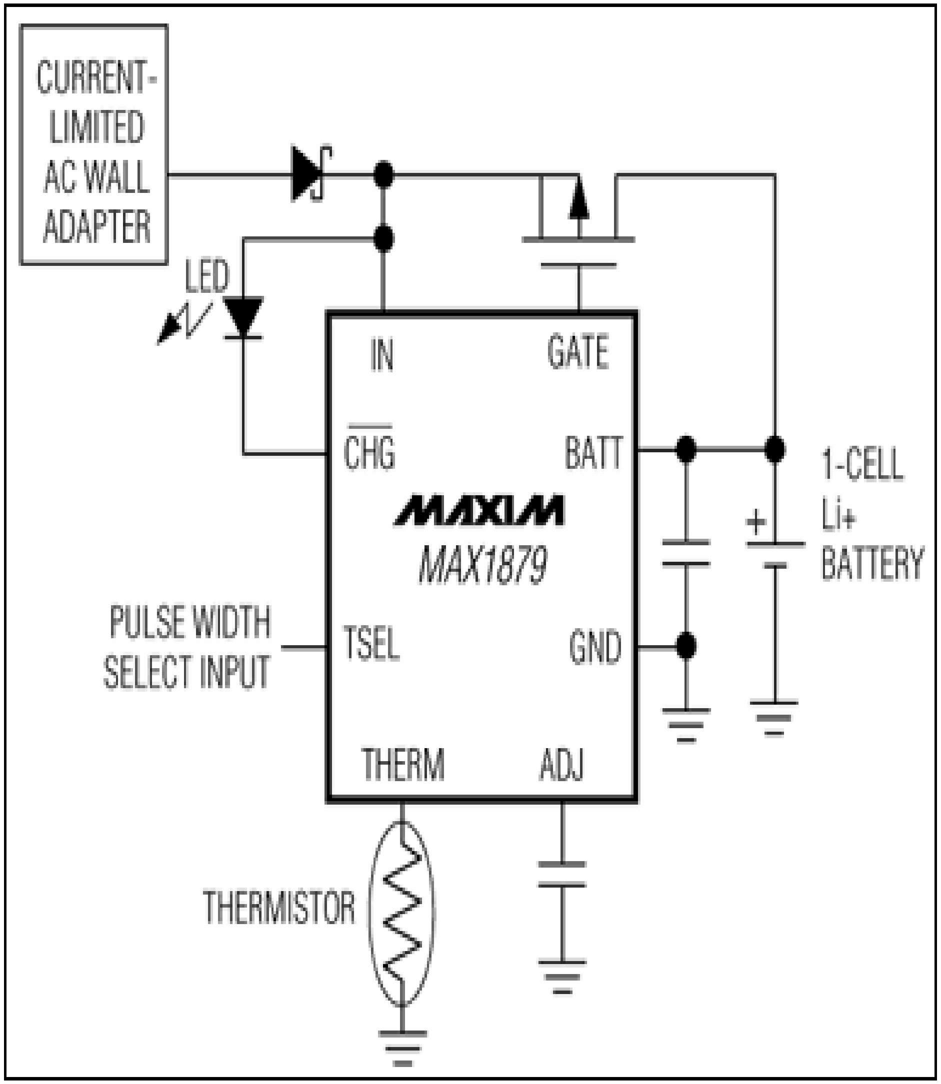
Power Supply

- Power is supplied by solar cells on 5 faces of the satellite.
- Each face has two 26.8% efficiency solar cells.
- Each face has an open circuit voltage of 4.4V.

Energy Storage

- Two Lithium-Ion batteries will be used to store energy.
- Each battery is rated for 1.7Ah, which is roughly 18,115 Joules, under specific conditions.
- The open circuit voltage on the batteries is 3.7V
- The batteries are connected in parallel to provide peak current.

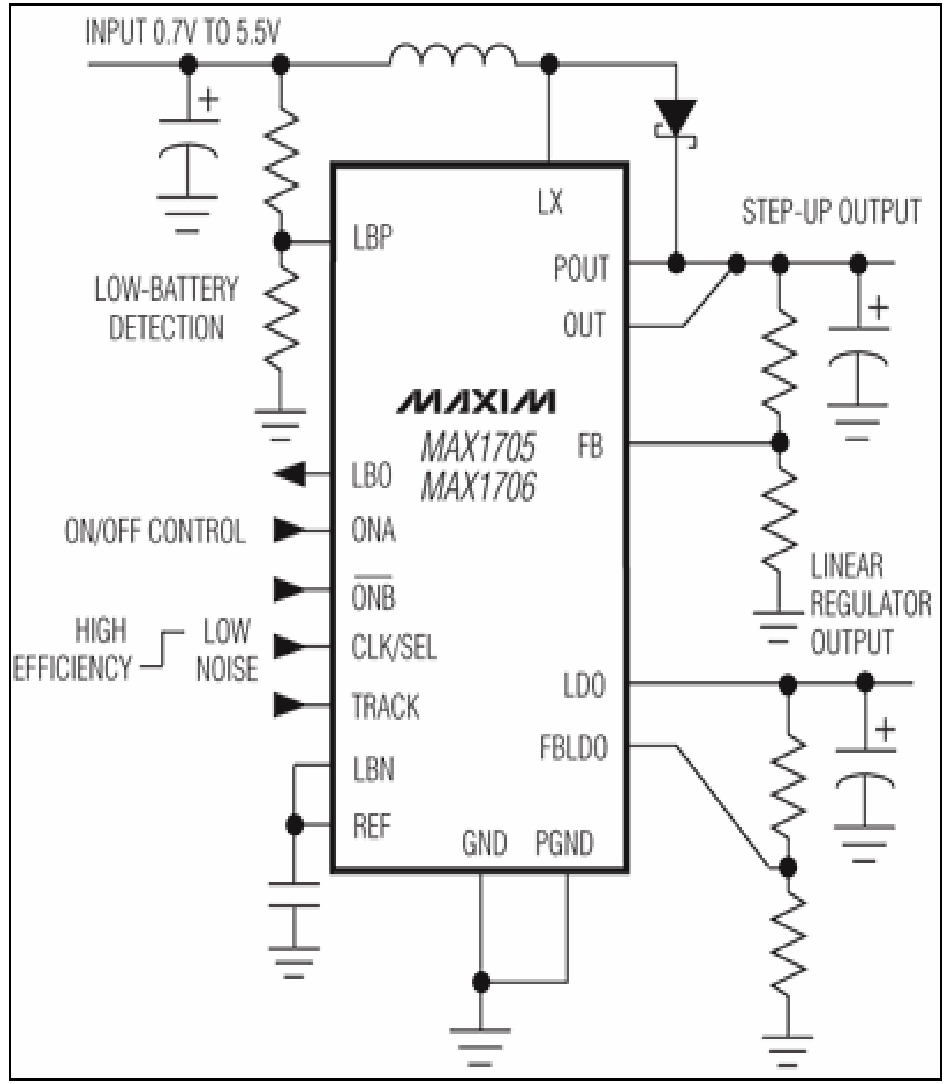
Battery Regulators



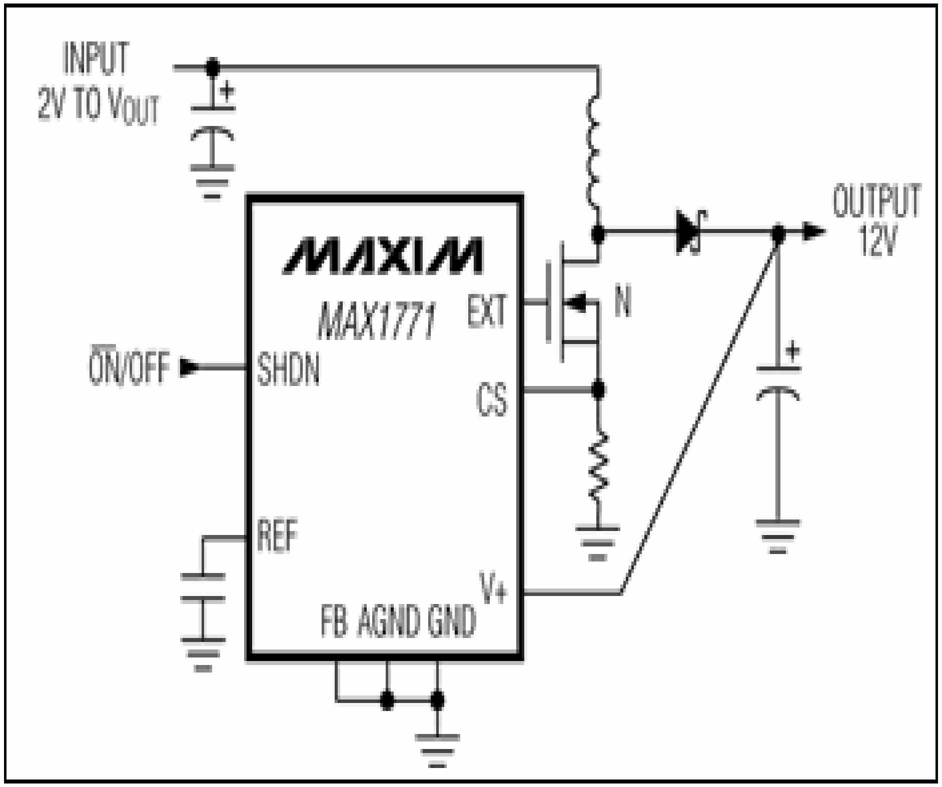
- Each battery will be regulated by the Maxim 1879 Li-Ion regulator.
- The MAX1879 was selected for it's over-voltage, under-voltage and temperature protection.
- Also an easy to assemble, proven circuit.

3.3V/4.5V Regulator

- The 3.3V and 4.5V regulated busses are provided by the MAX1705.
- Multiple regulators are used to provide peak current and redundancy.
- 3.3V is provided on LDO and 4.5V is on POUT as a by-product.



12V Regulation



- The 12V bus is provided by the MAX1771
- The MAX1771 was selected for it's high efficiency.

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Attitude Determination and Control

Justin Van Cleave, ADC

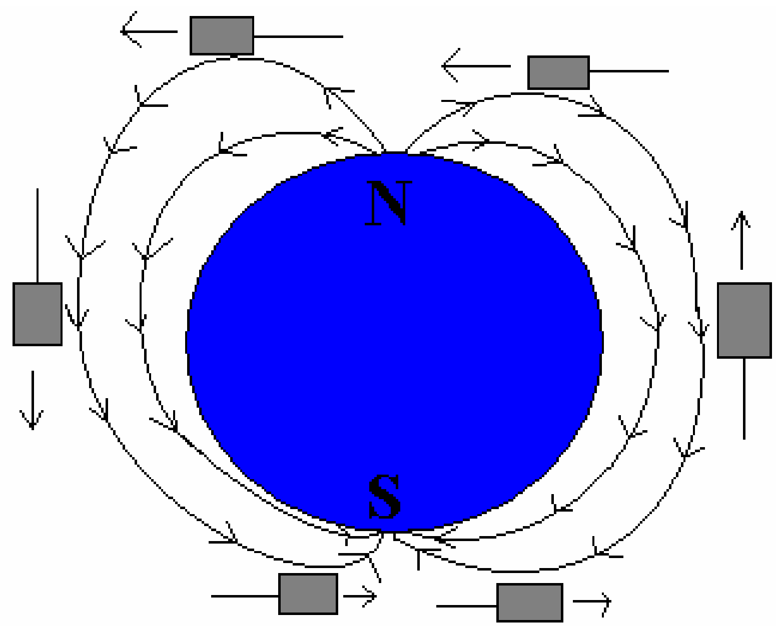
Mission

- Provide proper orientation for:
  - Battery Charging
  - Communication
  - Payload

Magnetic Control

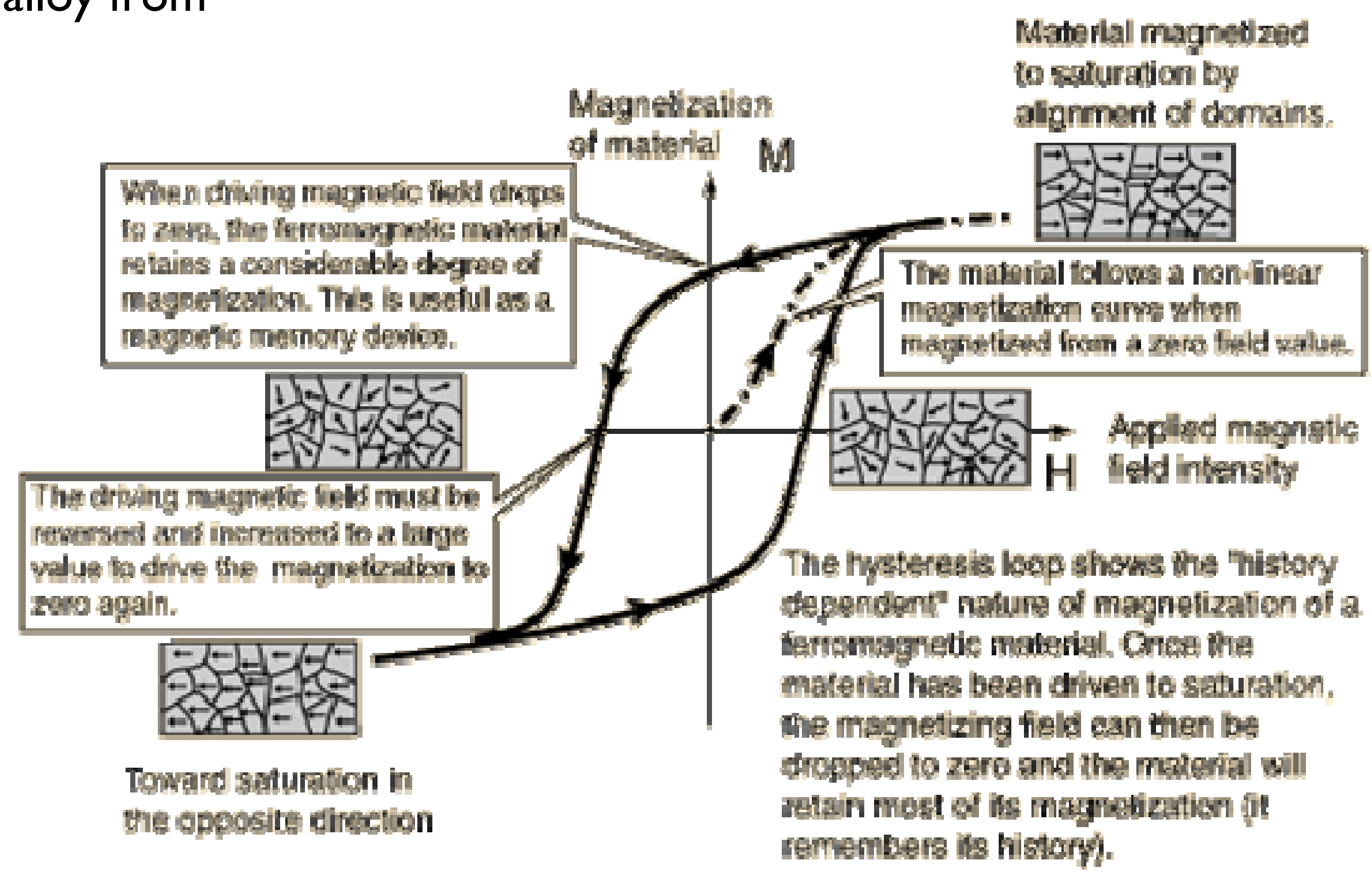
- Passive
- Alnico 5 magnets
- Resistant Forces
  - Gravity Gradient ~ 10^{-9} Nm
  - Air Drag ~ 10^{-10} Nm
  - Solar Pressure ~10^{-10} Nm

- Required Torque
  ~ 10^{-6} Nm
- Required dipole moment
  ~ .048 Am^2
- Dipole moment of magnet
  = .055 Am2



Hysteresis Dampening

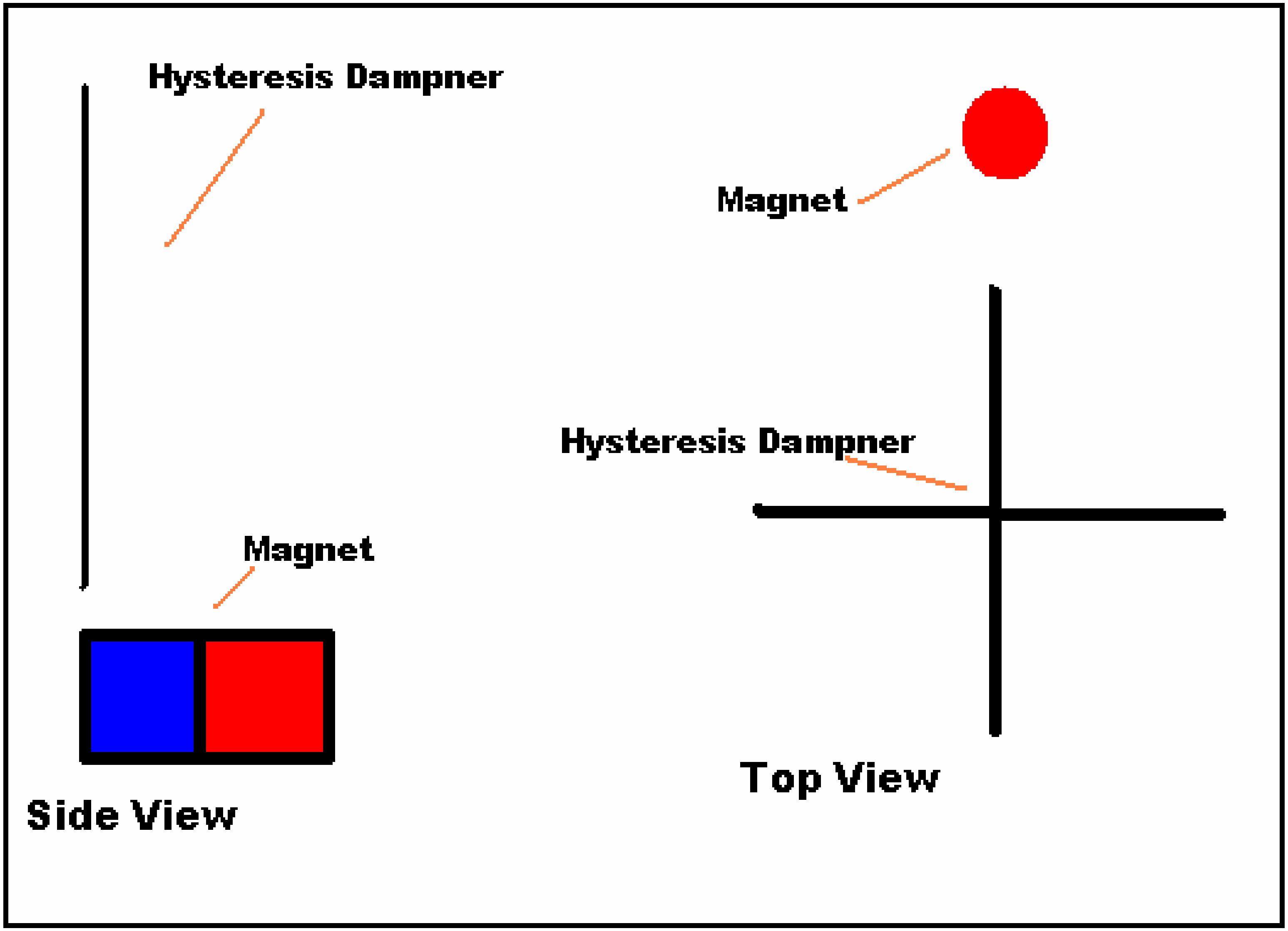
- Loop work provides dampening force.
- Ni/Fe/Mo Permalloy from Goodfellow



Determination

- Passive system requires no determination
- Use of "course sun-sensor"
  - Based on data transmission constraints.

System Orientation



Future Work

- Fabrication of dampener
- Orbital Calculations
- Risk analysis

Structures & Mechanisms

Zach Johnston/Neil Dougherty, Structures

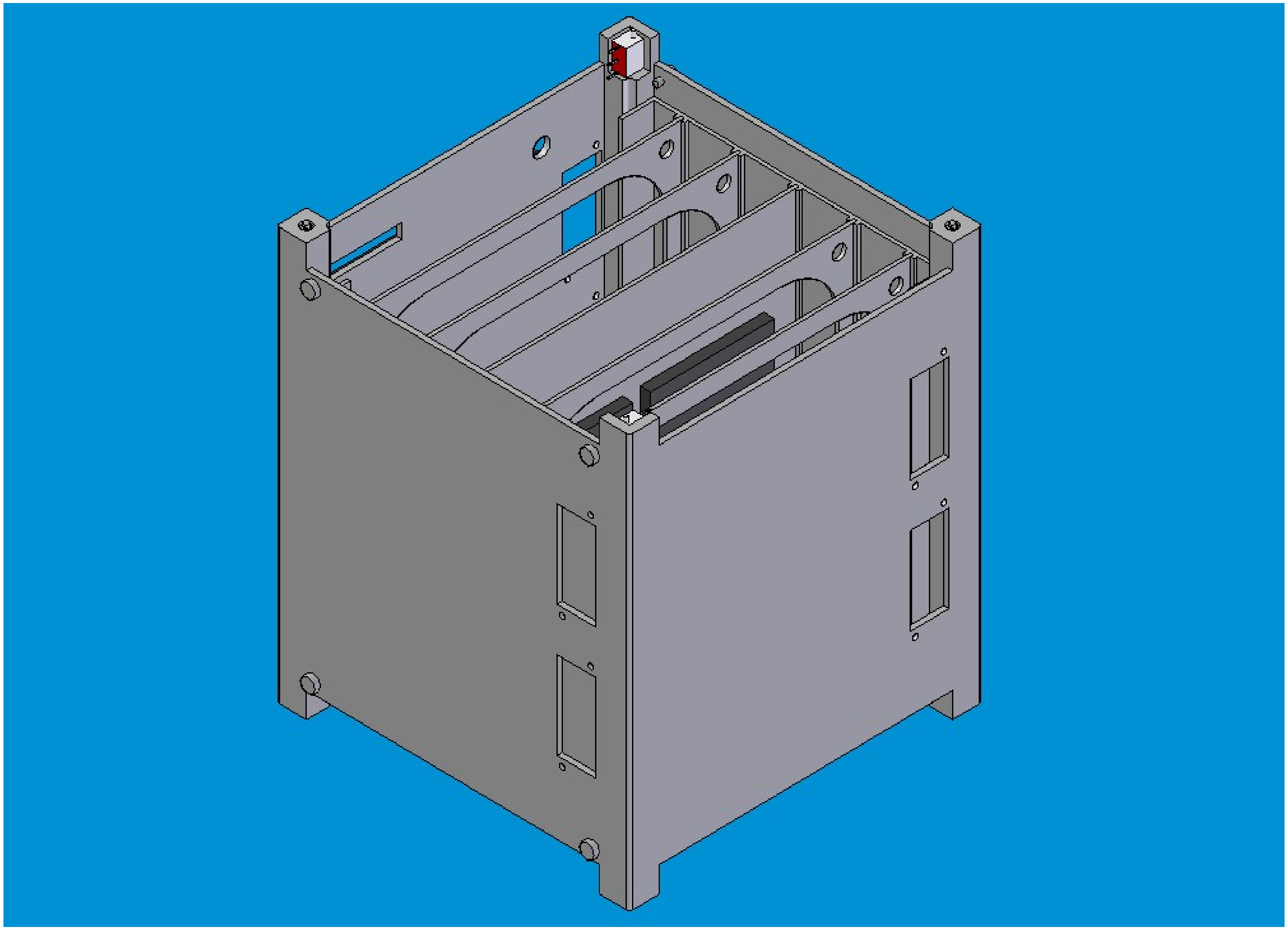
Data Summary

- Mass of Structure: 332.44 grams
- Allotted Mass Budget: 400 grams
- Center of Mass: x-direction .65mm
  y-direction 3.51mm
  z-direction .41mm

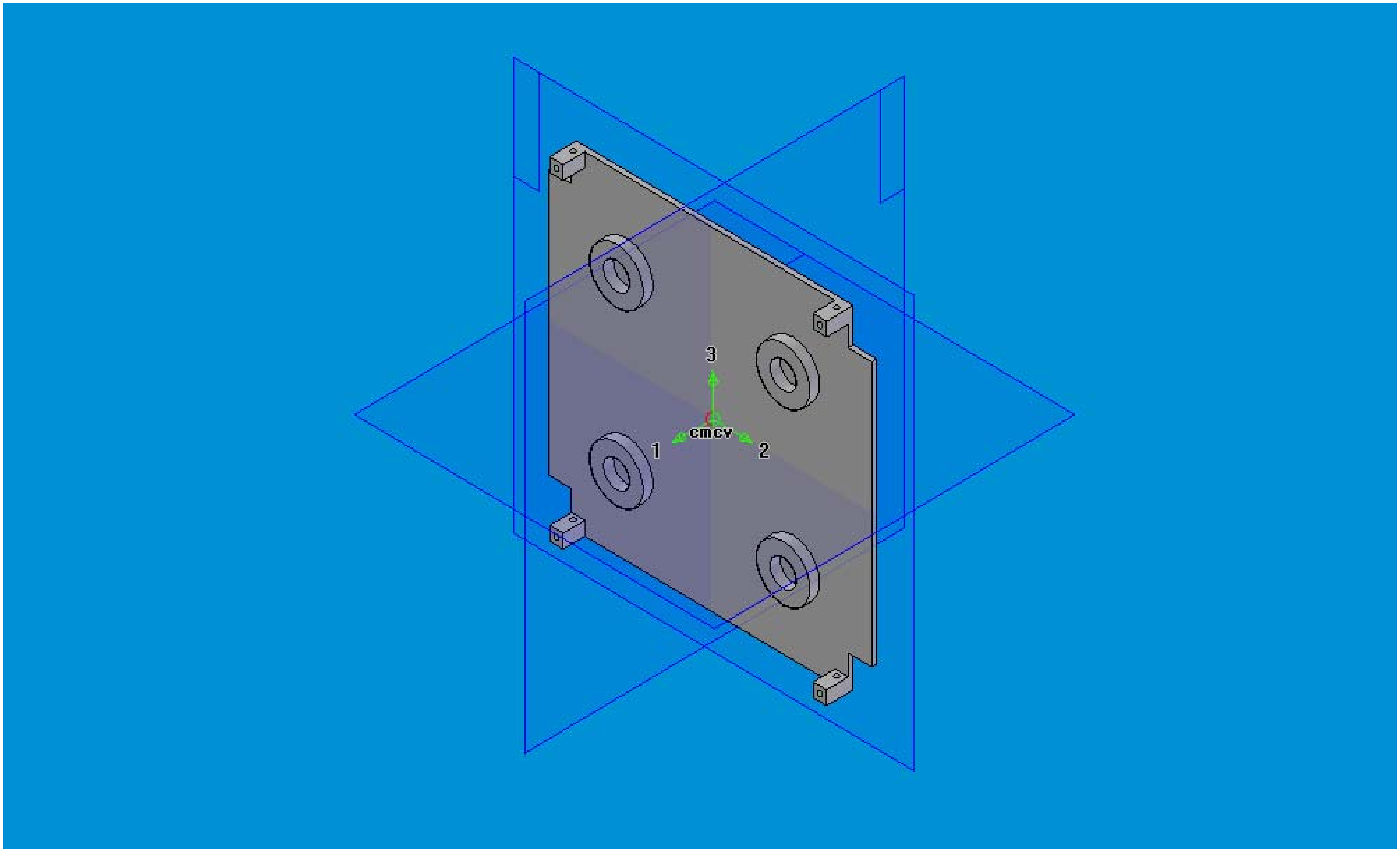
- Allowed Center of Mass Margin: 2 cm

Interior Structure

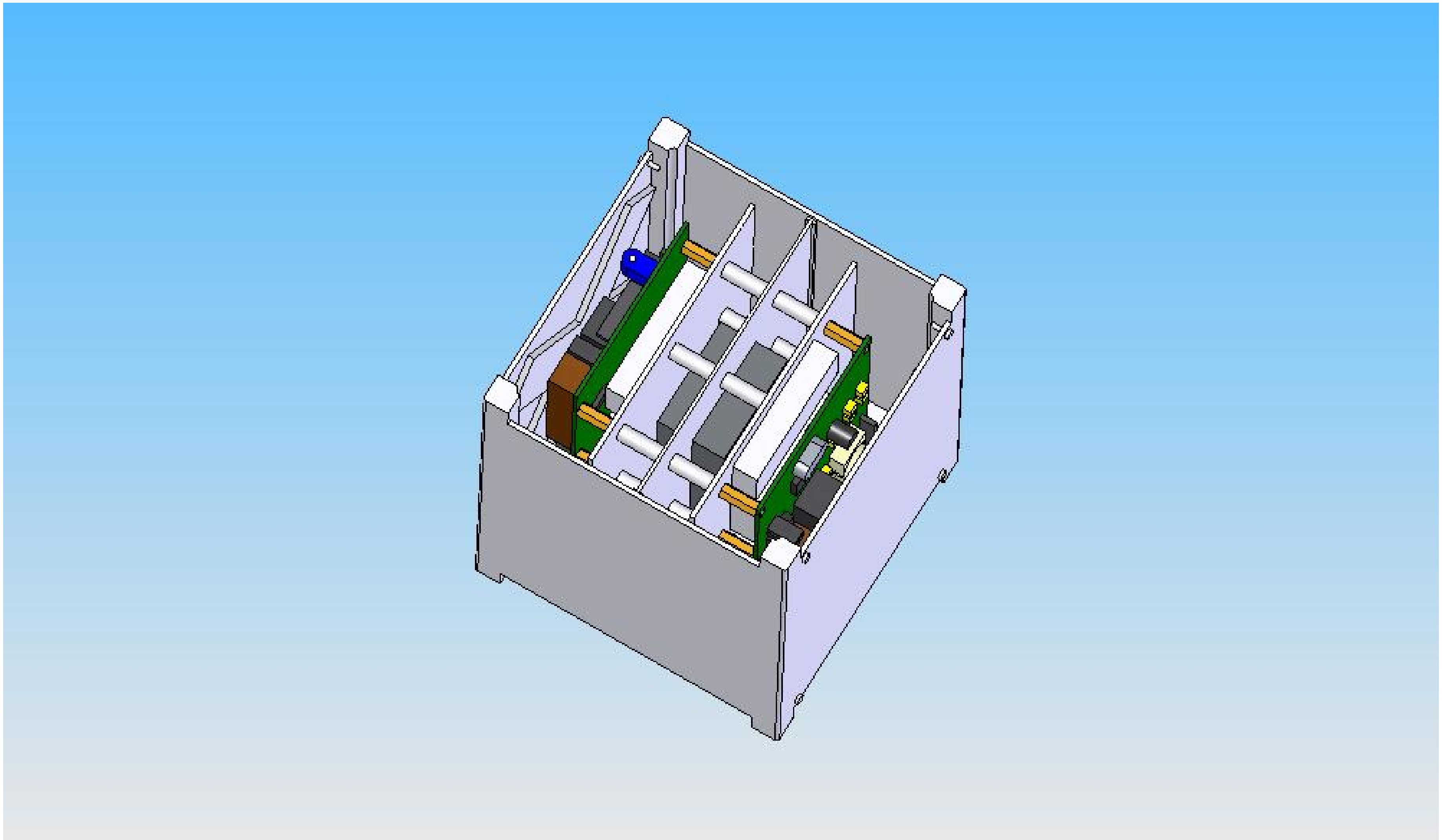
Design 1



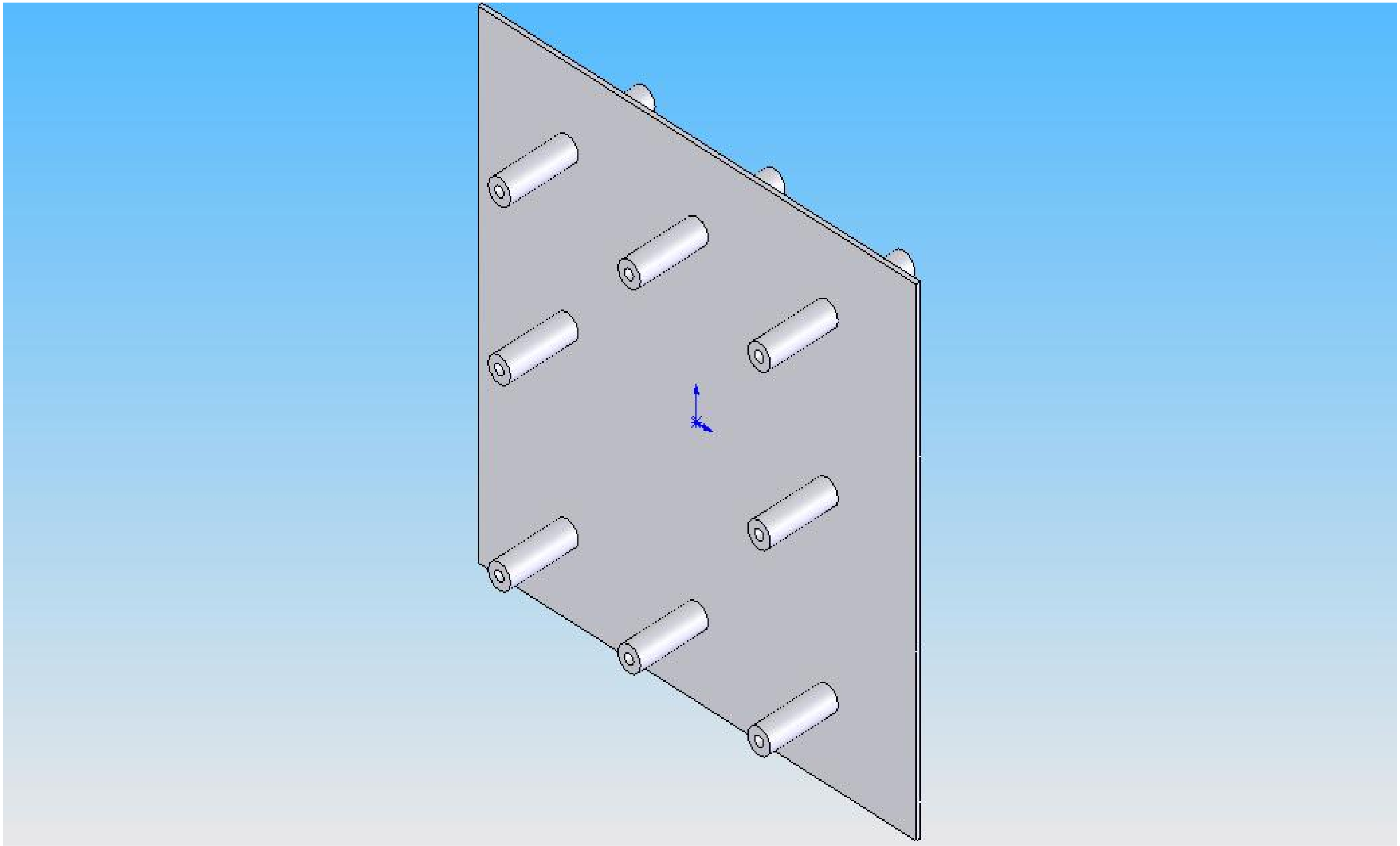
Design 2



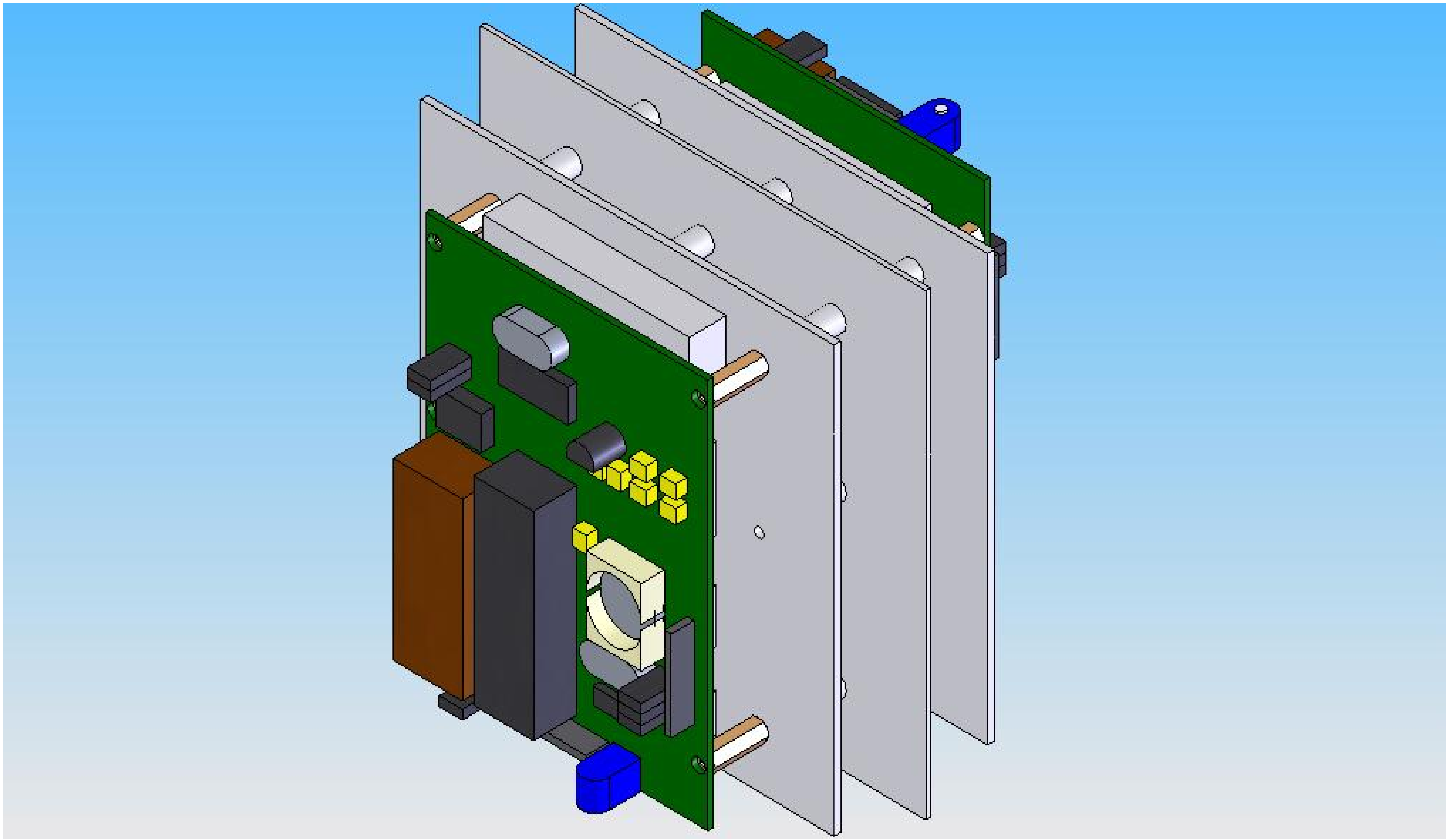
Design 3



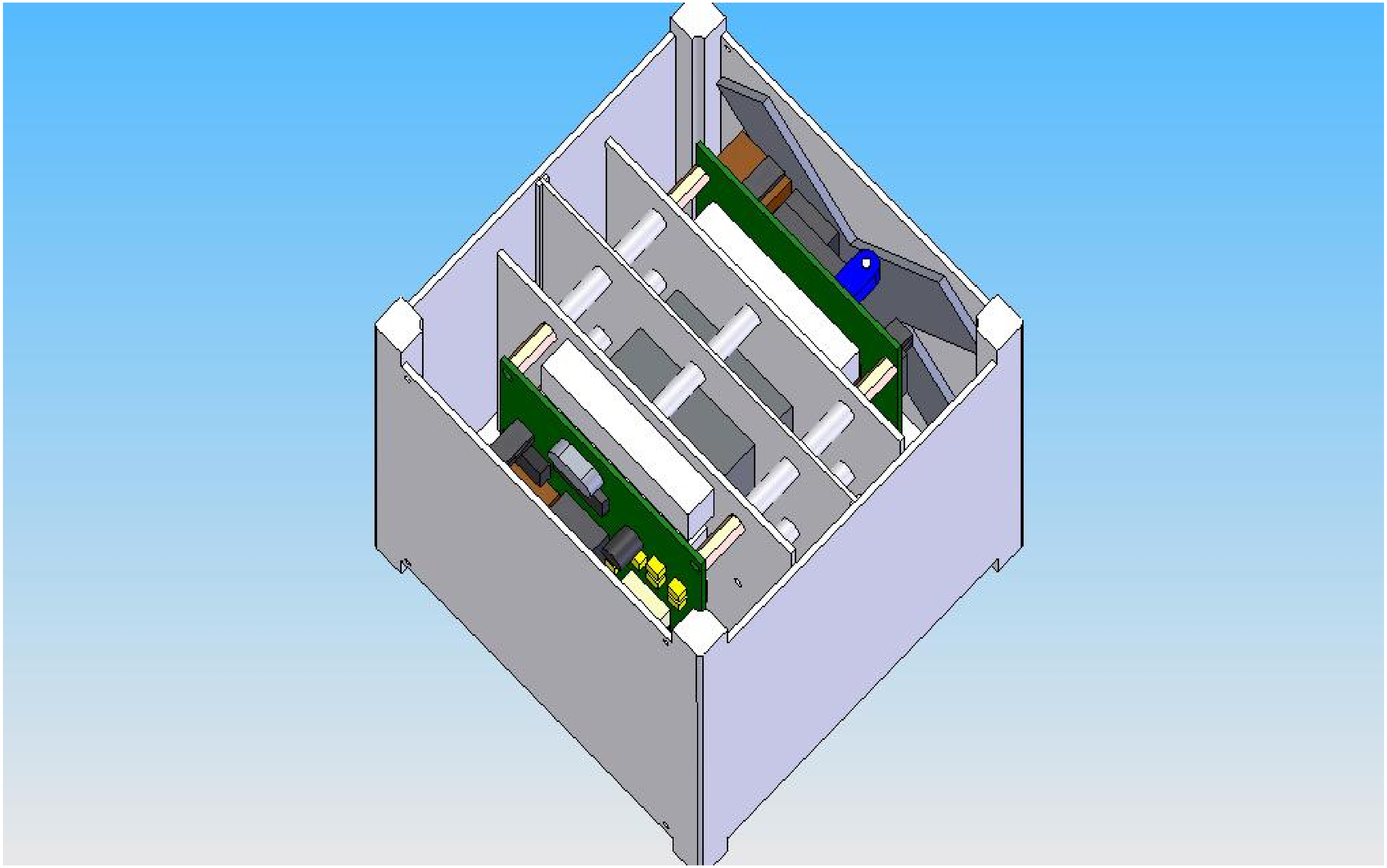
Internal Chassis Plate



Internal Chassis



Integrated Internal Chassis



Exterior Structure

Tube Frame

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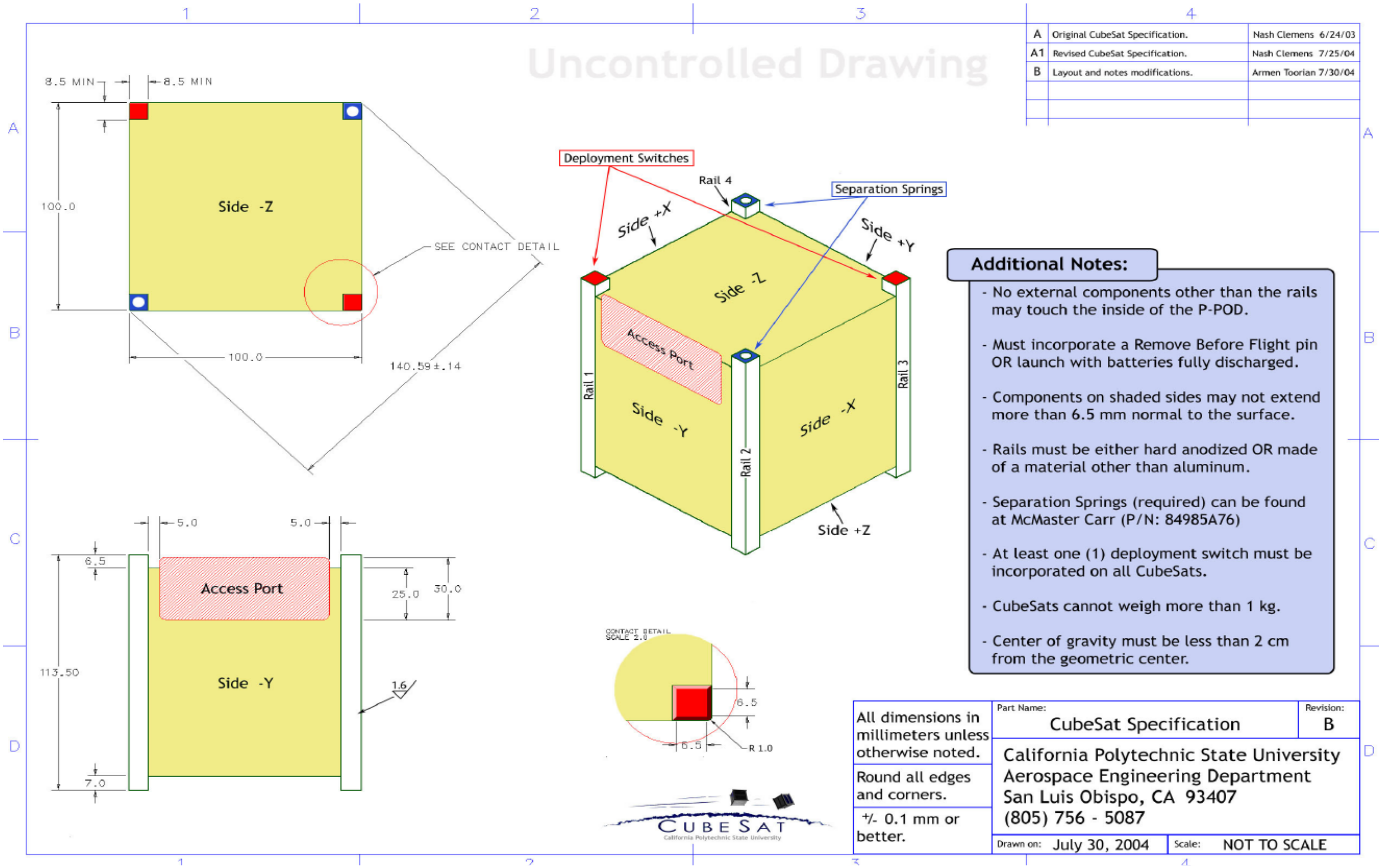
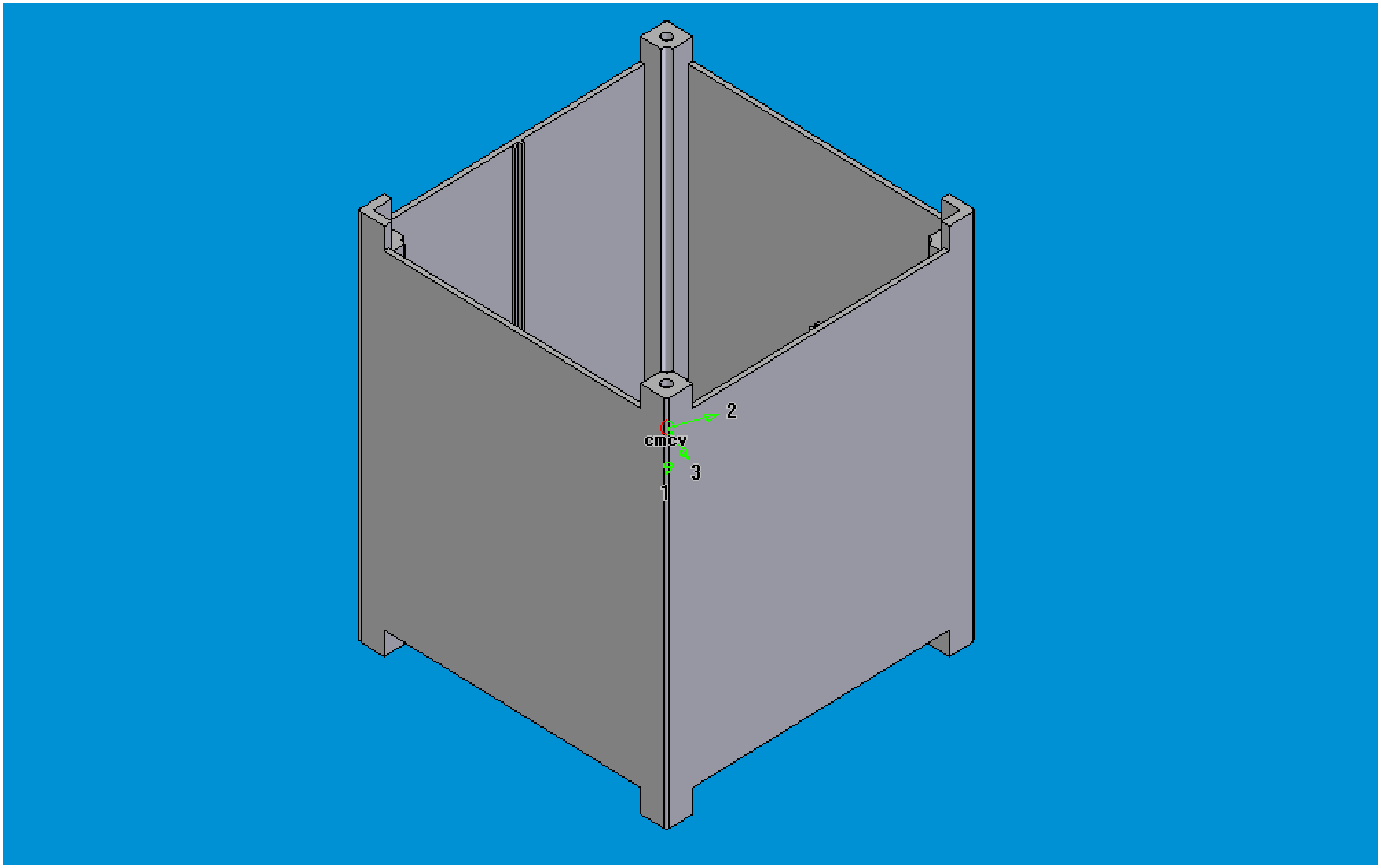
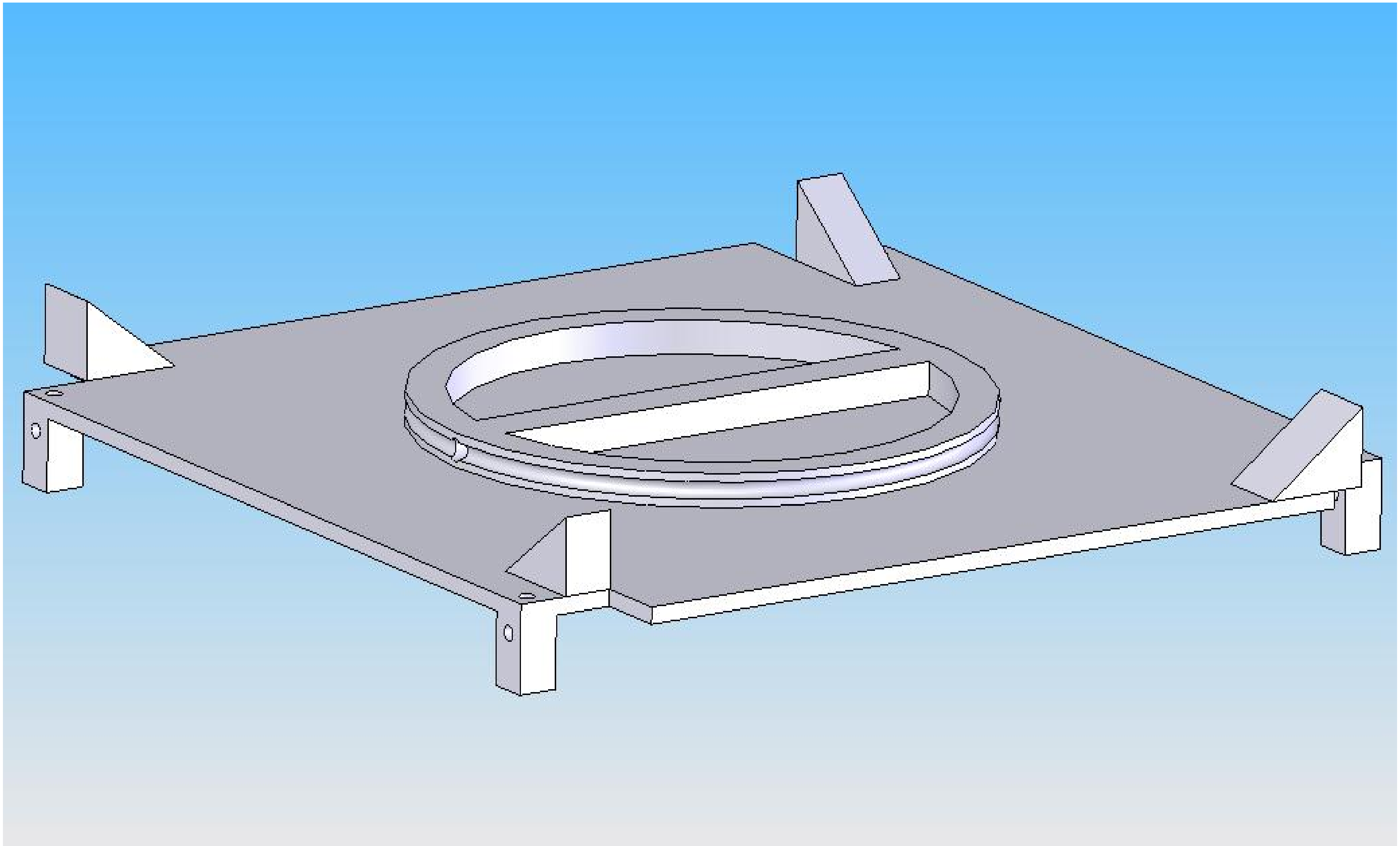


Tube Frame



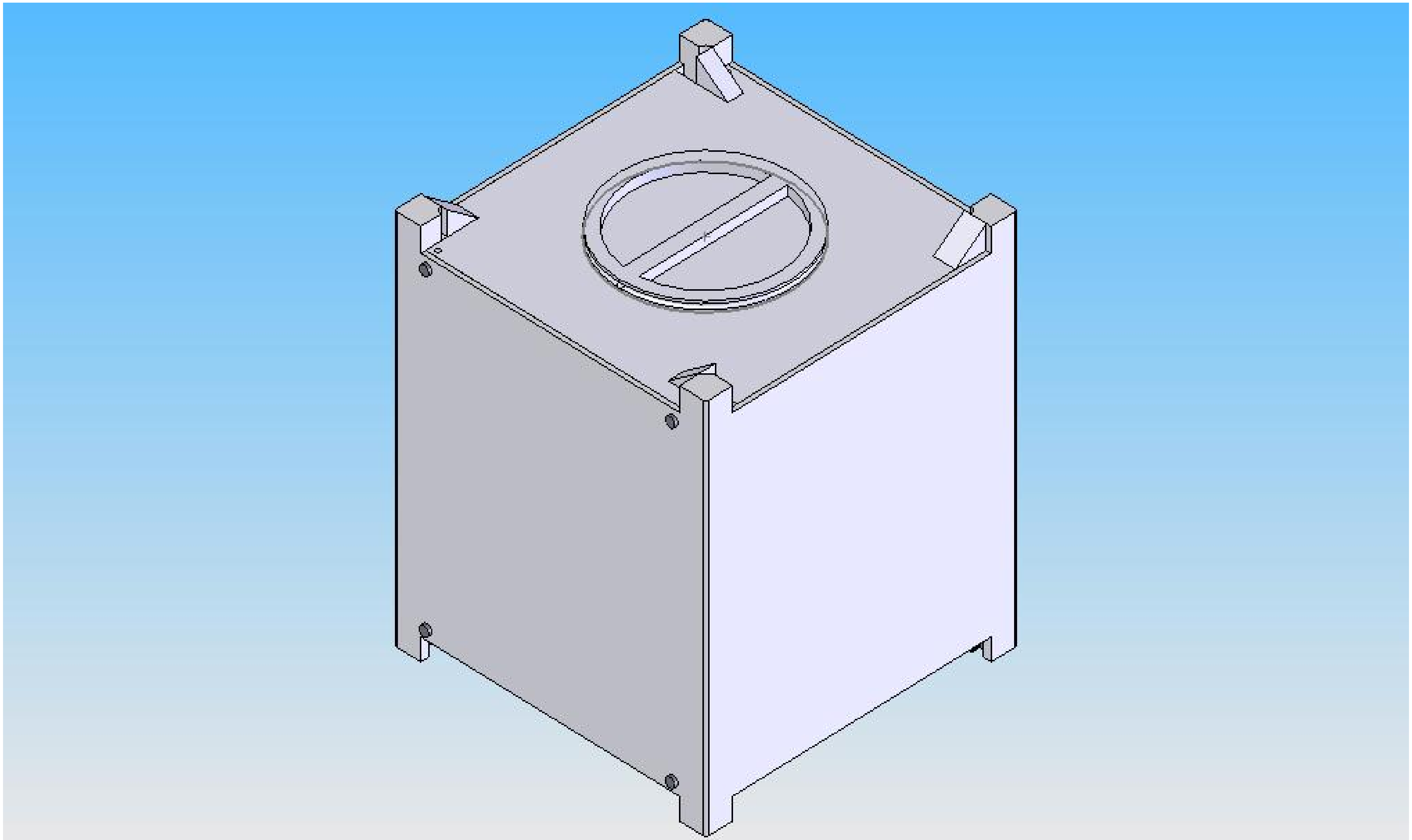
Antenna Deployment Mechanism



Anodizing

- Anodizing is required on the deployment rails of our satellite because of the harsh environment of space.
- Anodizing is an electrochemical process that thickens and toughens the naturally occurring protective oxide on the aluminum

Final CAD Model



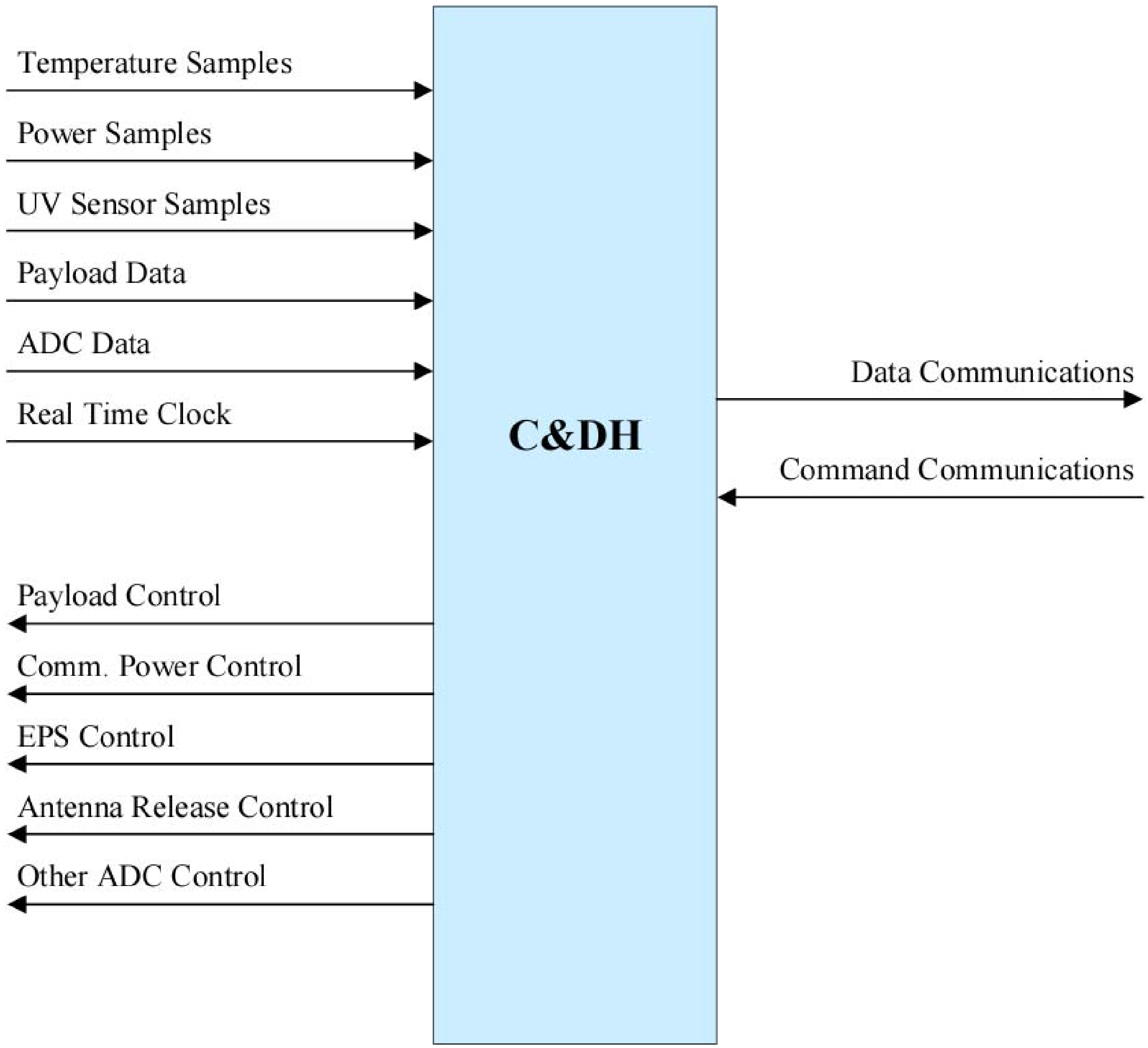
Command & Data Handling

Brad Dutton & William Woodall

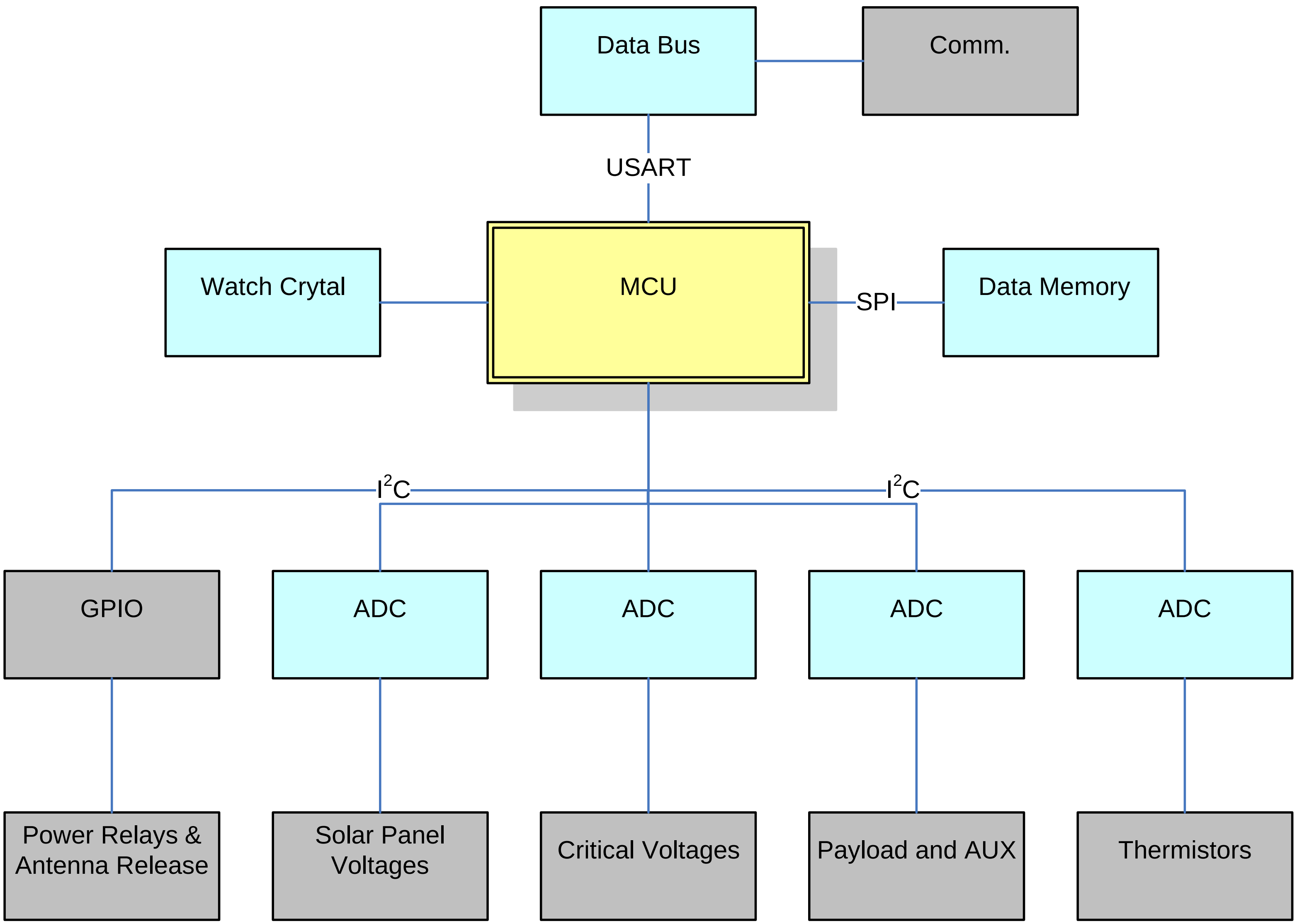
Command and Data Handling

- Processing, formatting, and storing science and housekeeping data
- Executing ground commands
- Control all of the functions of the satellite

Input / Output Diagram

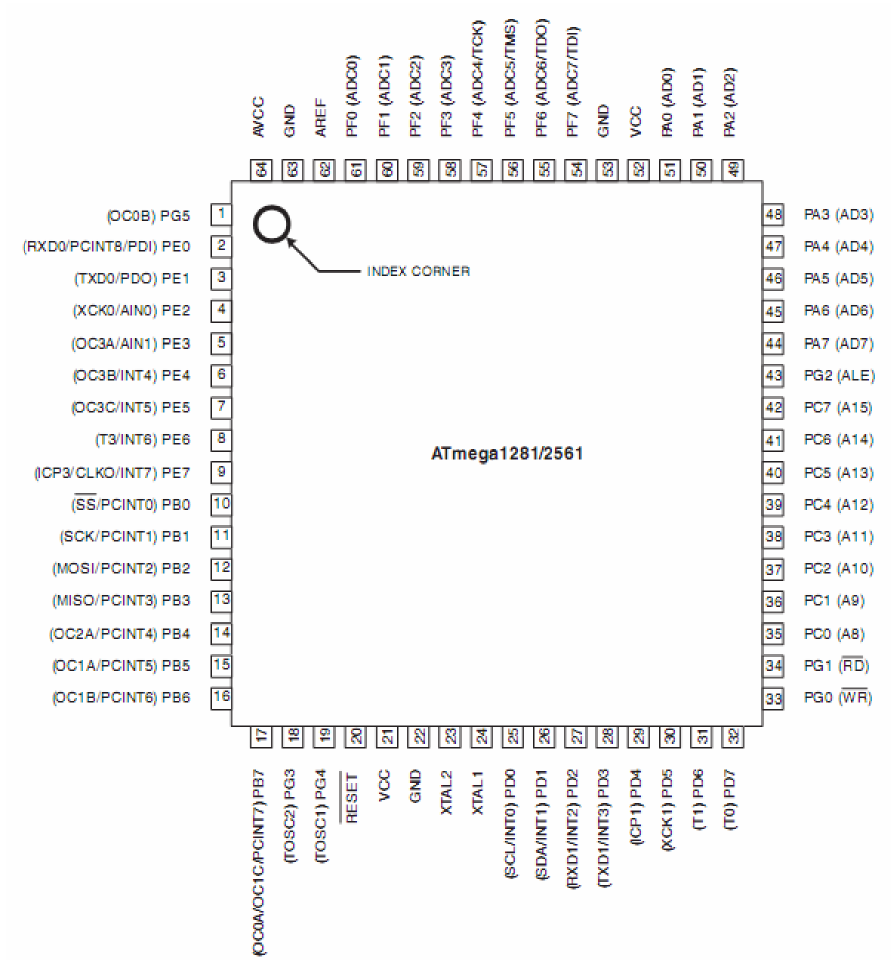


Block Diagram



ATmega2561L

- 256kB program storage
- 8kB internal SRAM
- Two Wire SPI
- 2.7V, 15mW
- 16 channel 10 bit ADC
- Open source WinAVR C compiler



Burr-Brown ADS7828 ADC

- 12 bit, 8 channel multiplexer
- 0.75 mW power dissipation

*Thermistor Data Resolution		
Full Scale (Volts)	ADC Resolution (bits)	Resolution (mV)
5	12	1.220703125
**Voltage Data Resolution		
Full Scale (Volts)	ADC Resolution (bits)	Resolution (mV)
12	12	2.9296875

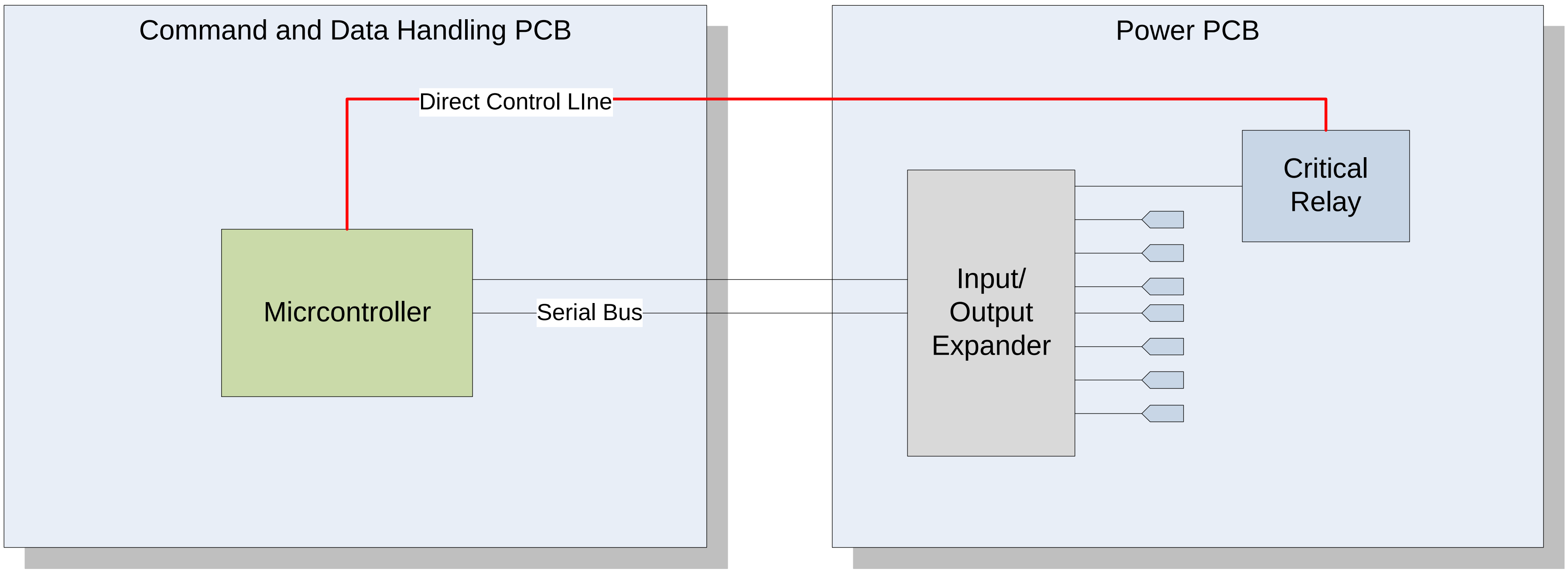
Omron G6HK-2 power relays

- Dual coil latching
- Surface mount, low magnetic interference
- 1A carry current
- 3ms set time, 40mA @ 5V

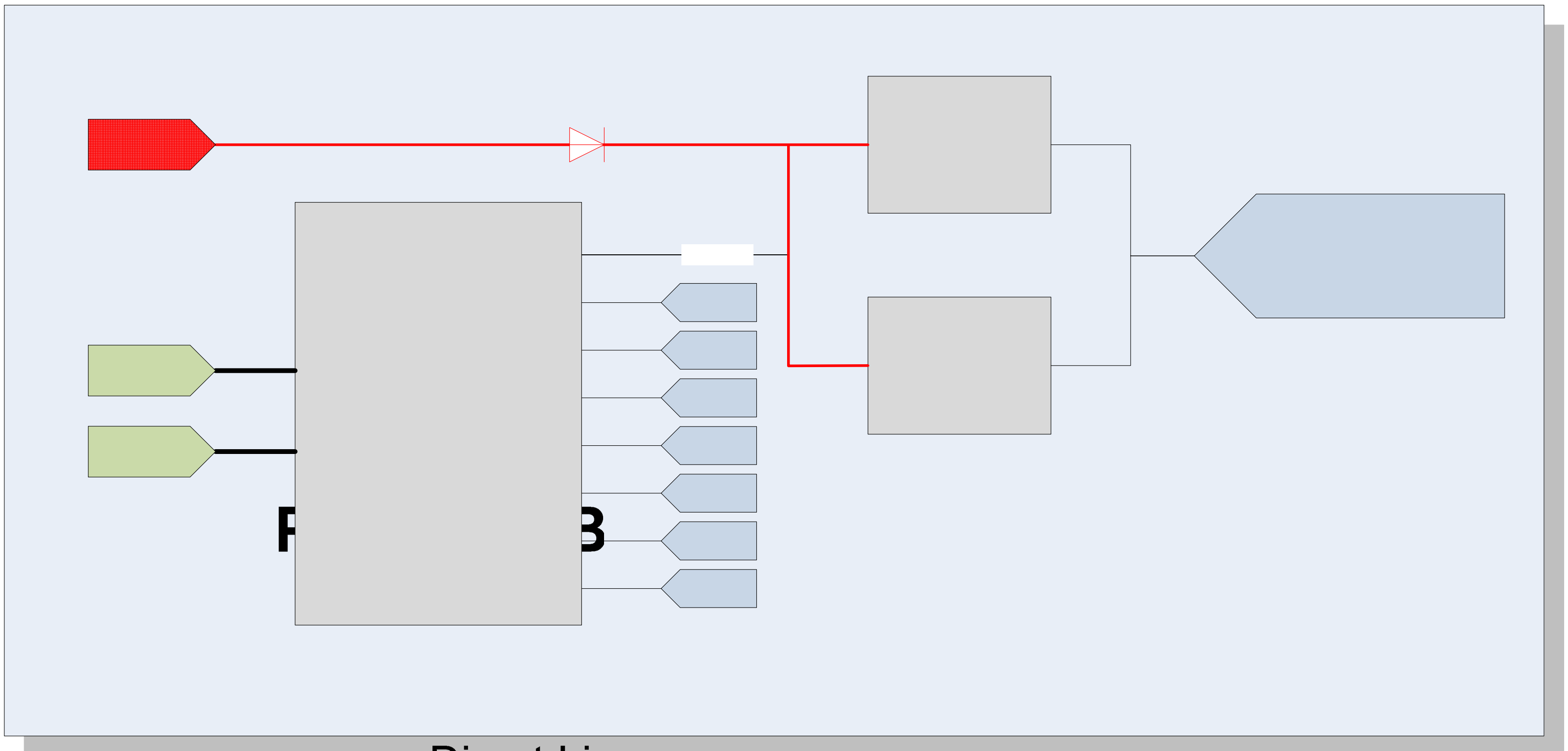
C&DH properties

C&DH Properties Summary V1.0			
Mass	60.7	grams	
Power Consumption	68.6	mW	maximum
Tallest Component	5	mm	3V power relay

Direct Control of Critical Relays



Redundant Critical Relays



Direct Line

Control 0

Control 1

Radiation Trade Study

Radiation Trade Study

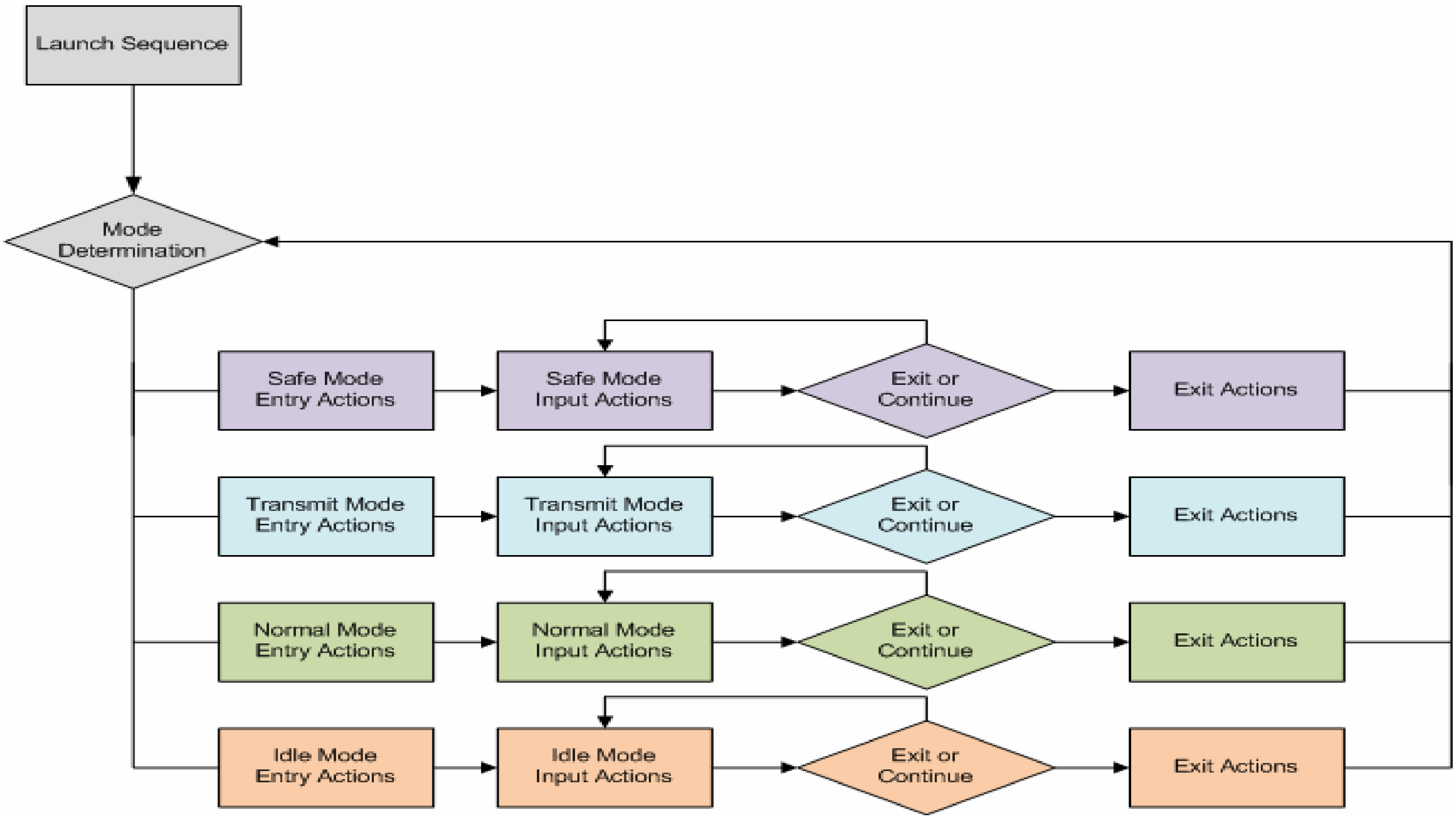
Option	Pros	Cons	Decision	Conclusion
Radiation Hardened Chips	High resistance to radiation	Expensive	No	Too expensive for project scope
Physical shielding	Possibly prevent some radiation exposure	Expensive, heavy, and hard to test.	No	Too expensive and cumbersum in design
Hardware redundancy	Best chance to avoid system failure against radiation	Requires more hardware	Yes	This will be our best chance to safe guard against radiation
Redundant Software Design	Could allow for self checking and error prevention	Complicated and resource intensive	Yes	This has potential to help prevent system failure without much cost
Self healing/correcting software	Could allow self mitigation and healing	Very complicated, possibly too intensive for our microtroller	No	Too complicated and not commonly used on microcontrollers

Operating System

Feature	RTOS	Procedural OS
Resource usage	High	Low
Scheduling	Yes	No
Multi-Tasking	Yes	No
Threading	Yes	No
Design	Complex	Simple
Light weight design	No	Yes
Design knowledge	Documentation	Our design

Software Design

- The finite state machine



Mode Flow Diagram

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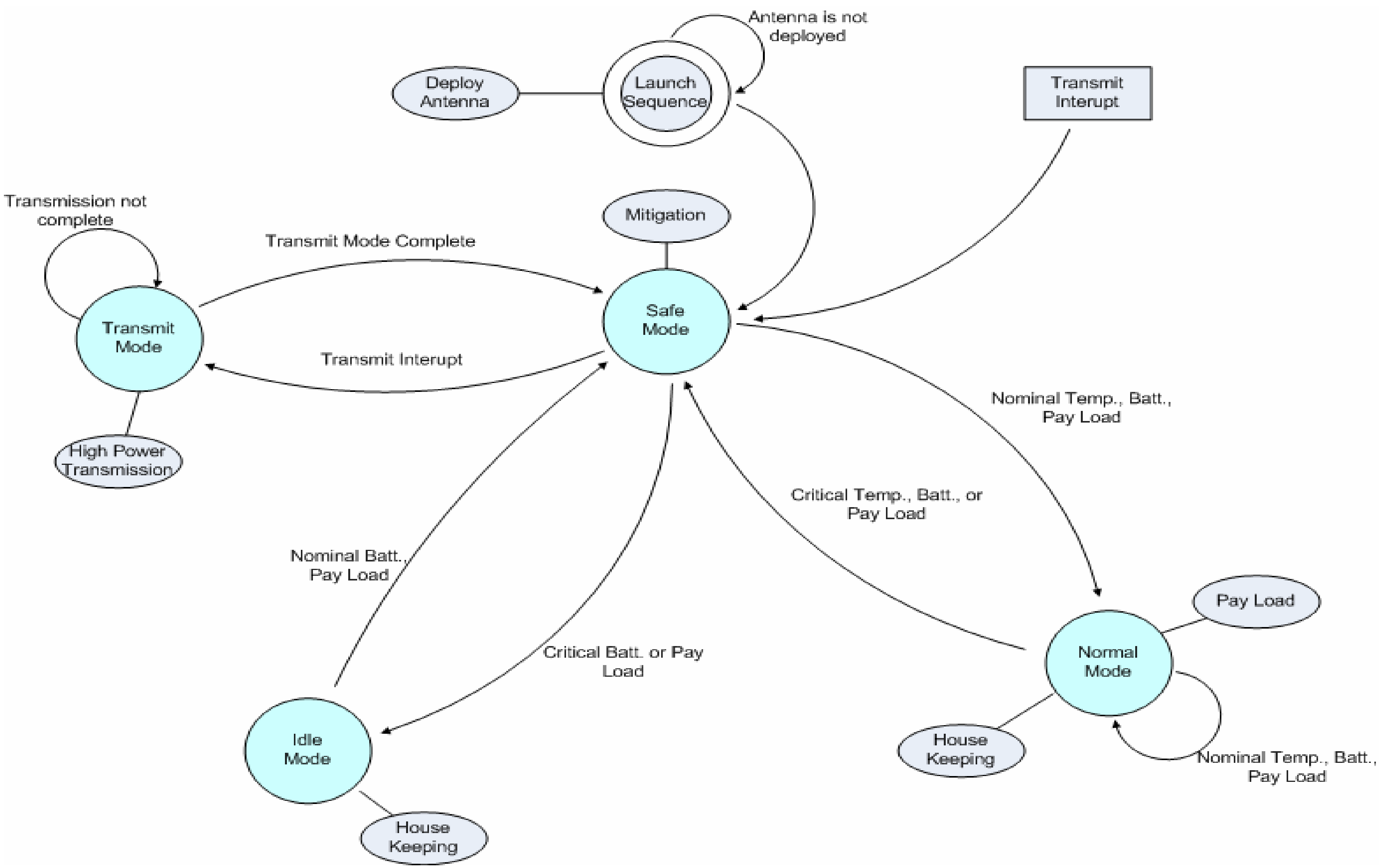
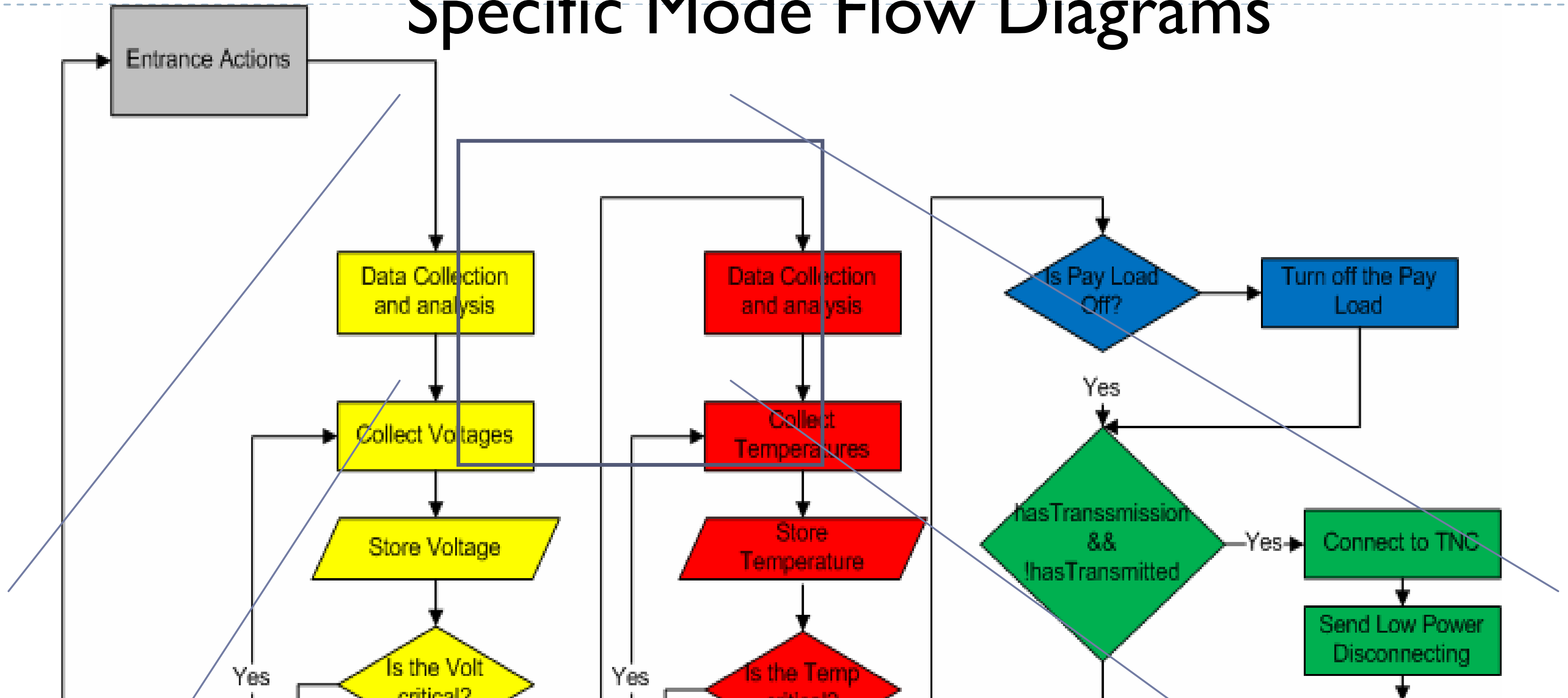


Specific Mode Flow Diagrams



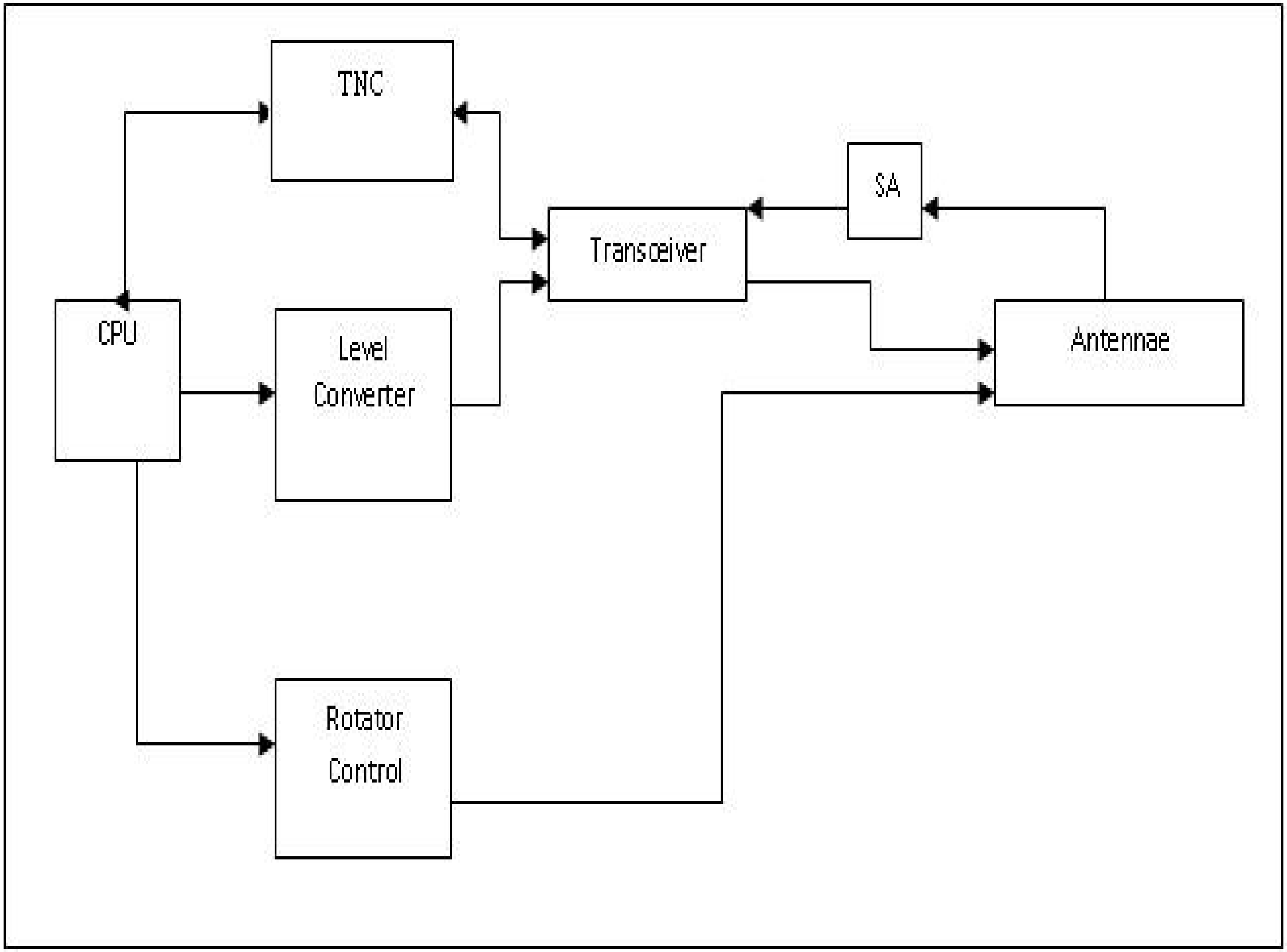

```
//Check to see if there is a transmission and if we haven't responded recently.
if(hasTransmission() && !hasTransmitted())
{
    turnTNCOn();
    connectToTNC();
    printf("<CALLSIGN> AUBIESAT LOWPWR TERN TX");
    disconnectFromTNC();
    turnTNCOff();
}//if(hasTransmission() && !hasTransmitted())

return;
```

Ground Station

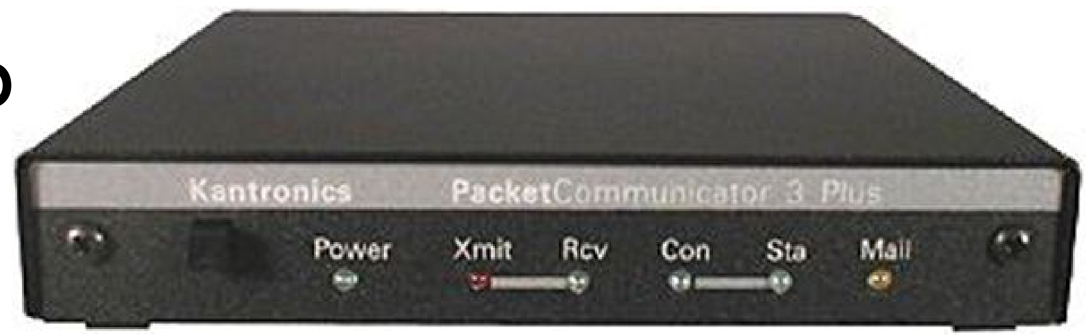
Brian Stump & David Sconzo

Block Diagram



KCP-3 Plus

- Easy setup
- Operating modes- Packet and KISS
- Data rate- 1200 bps
- Extra features: mailb



TNC Basics

- Components
  - microprocessor
  - modem
  - software (in EPROM)
- Two main capabilities
  - AX.25 protocol
  - command line interface

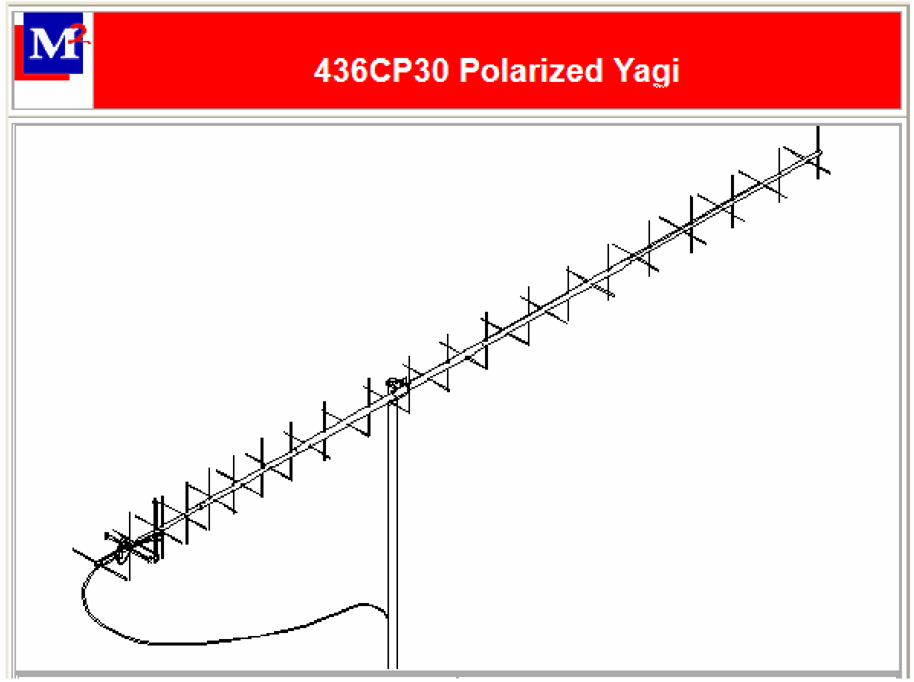
ICOM-910H

- Satellite mode
- Modes
  - FM, SSB, CW
- Frequency bands
  - 2m, 70cm

Antenna Requirements

- Yagi
- beamwidth 20-30 degrees.
- high gain
- circular polarization
- meet size limitations

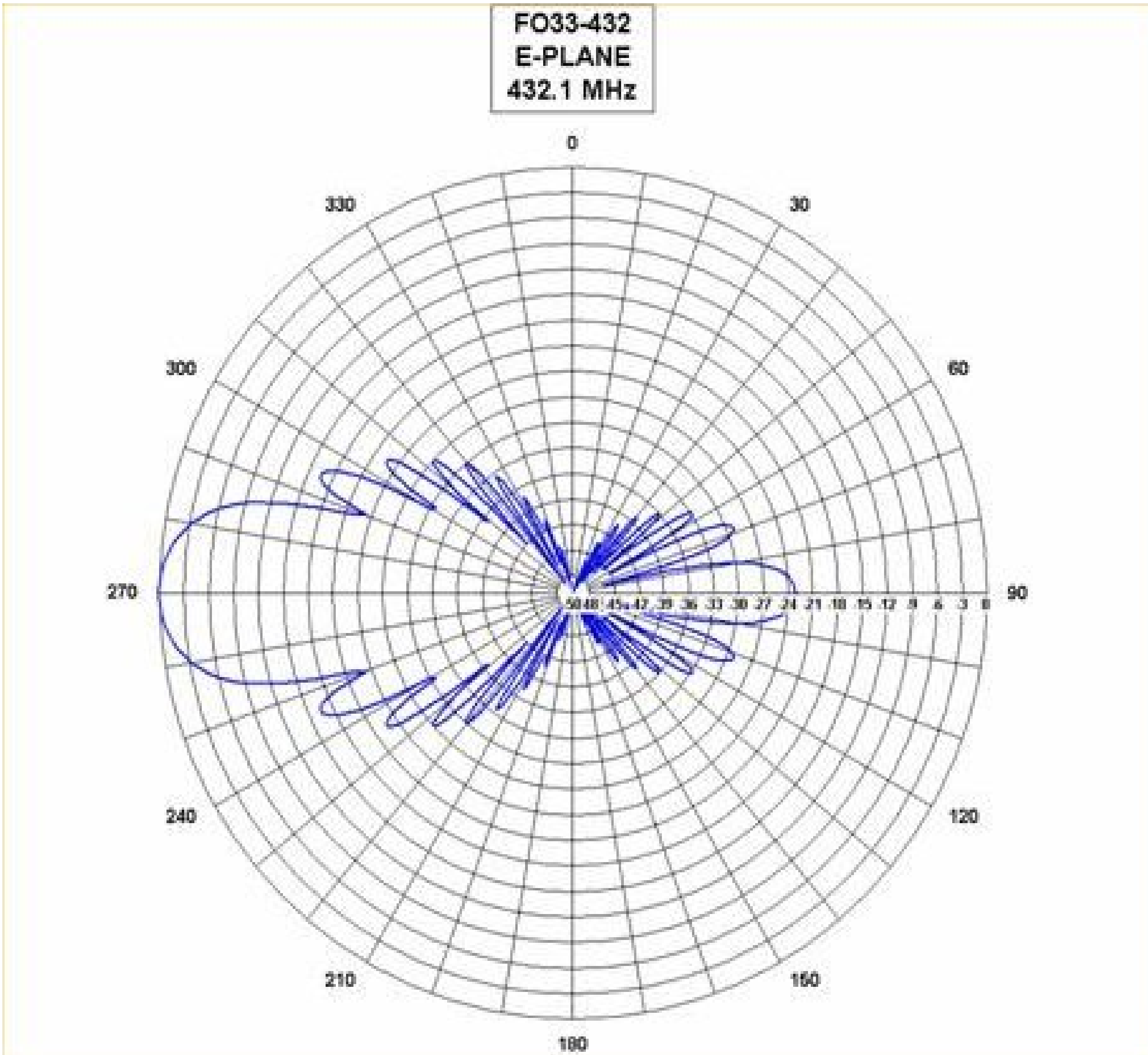
Antenna



Frequency range	432-440 MHz
Gain	14.15 dbdc
Beamwidth	30 degrees
Polarity	Circular
Boom Length	117”

VSWR	1.6:1 Max
Feed Impedance	50 ohms
Power Handling	600 Watts

Radiation Pattern



Extra Radio Hardware

- LCU-3 Level Converter
  - Converts nonstandard positive or negative logic input voltages to standard DTL logic.

- Integrated PCI Card
  - Provides an extra two DB-9 serial ports to the computer.

Rotator Hardware

- Yaesu GS-232A Computer Interface
  - Provides digital control for rotator.
  - Async serial line can be 1200 to 9600 baud.

- Yaesu Rotator G5500
  - points antenna
  - power requirements

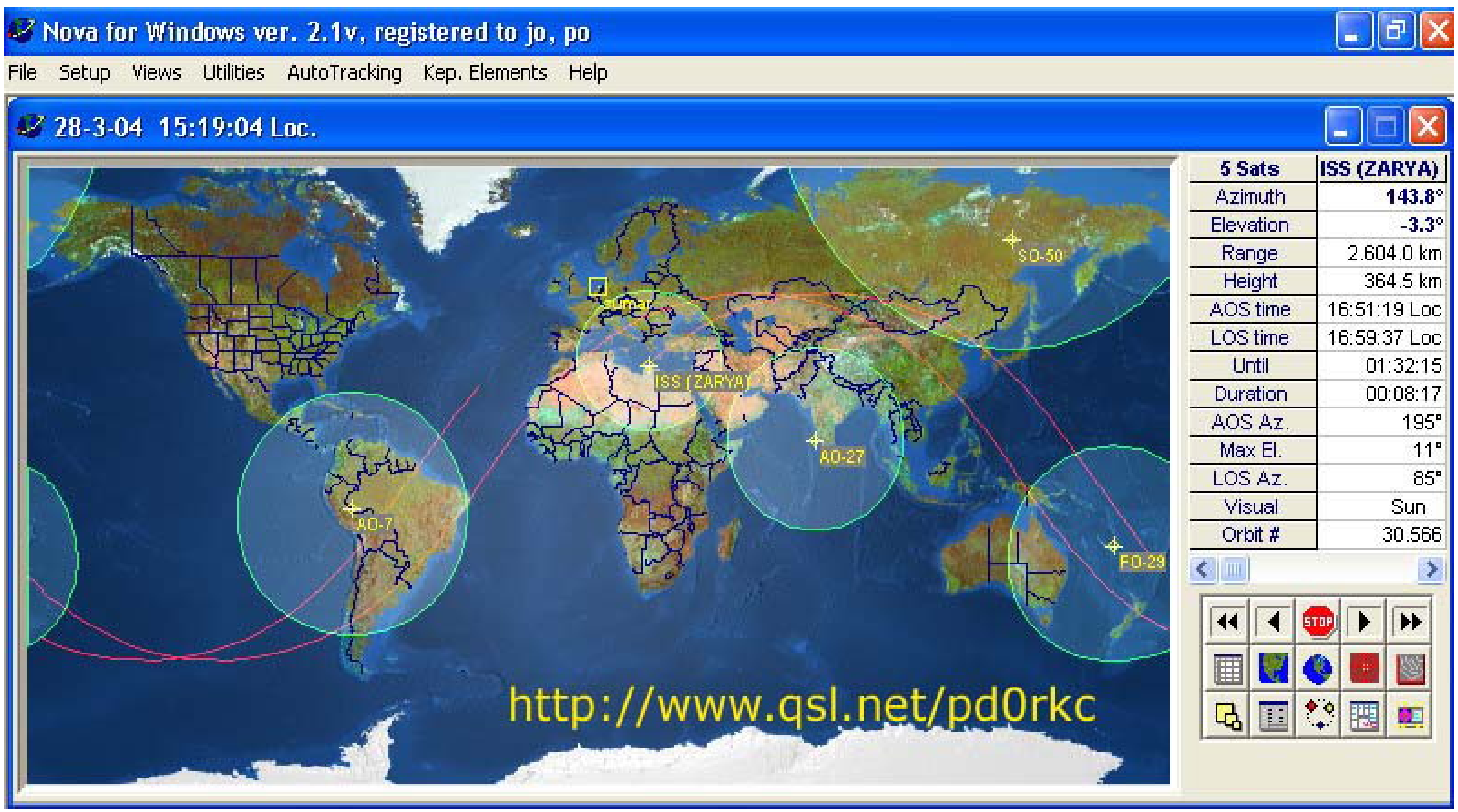
Structure

- Specially design steel and fiberglass structure to mount to the Allison Lab chimney
- Fiberglass boom for rotator
- Option for second 2-meter antenna.
- Built to survive strong winds

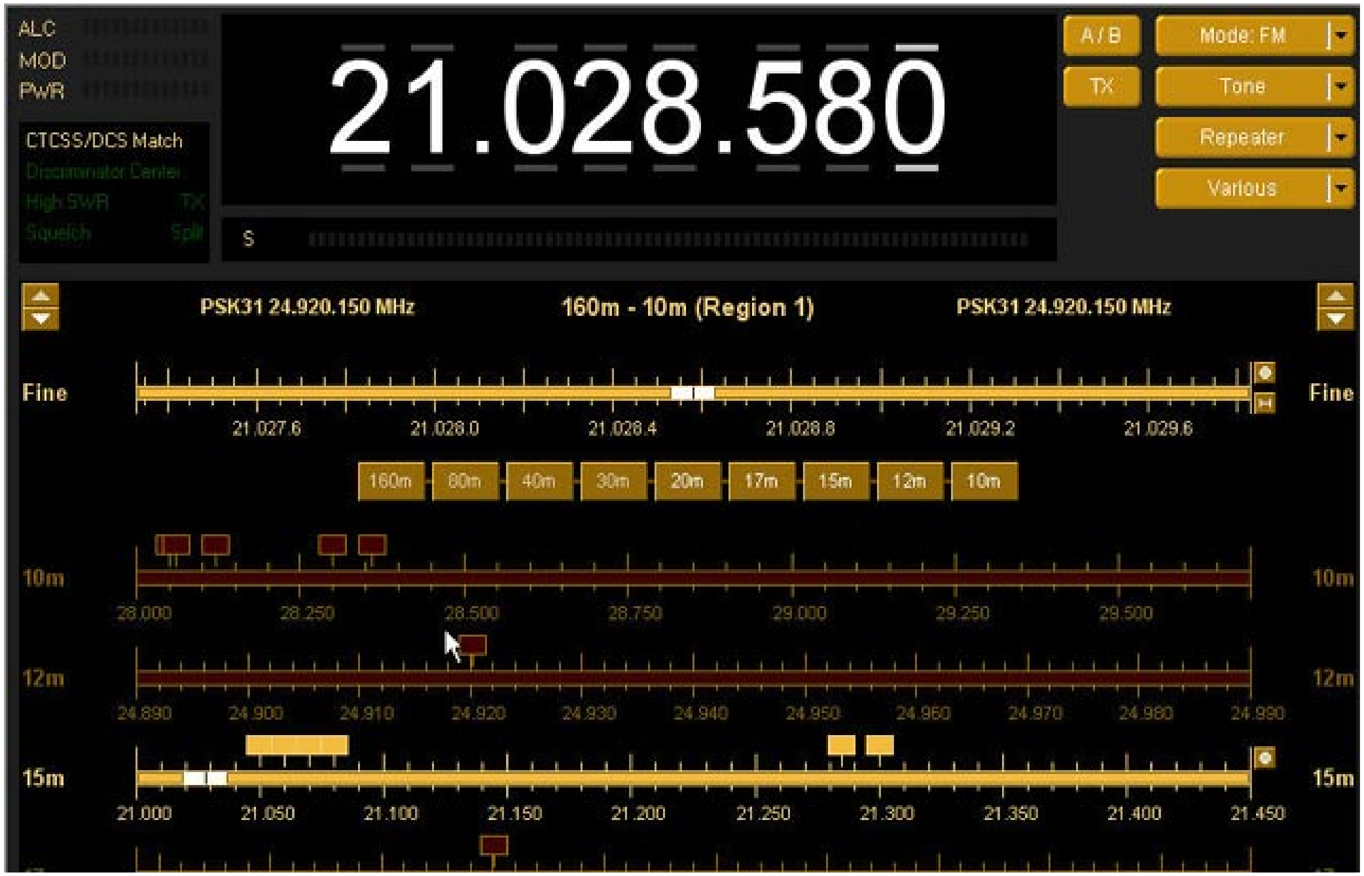
Ground Station Software

NOVA for Windows

- Provides software control for rotator
- Main purpose: az/el antenna autotracking
  - Uses Keplerian elements to predict satellite path
- Daily update of elements from Celestrack
  - NORAD publishes LEO satellites in two-line element format.

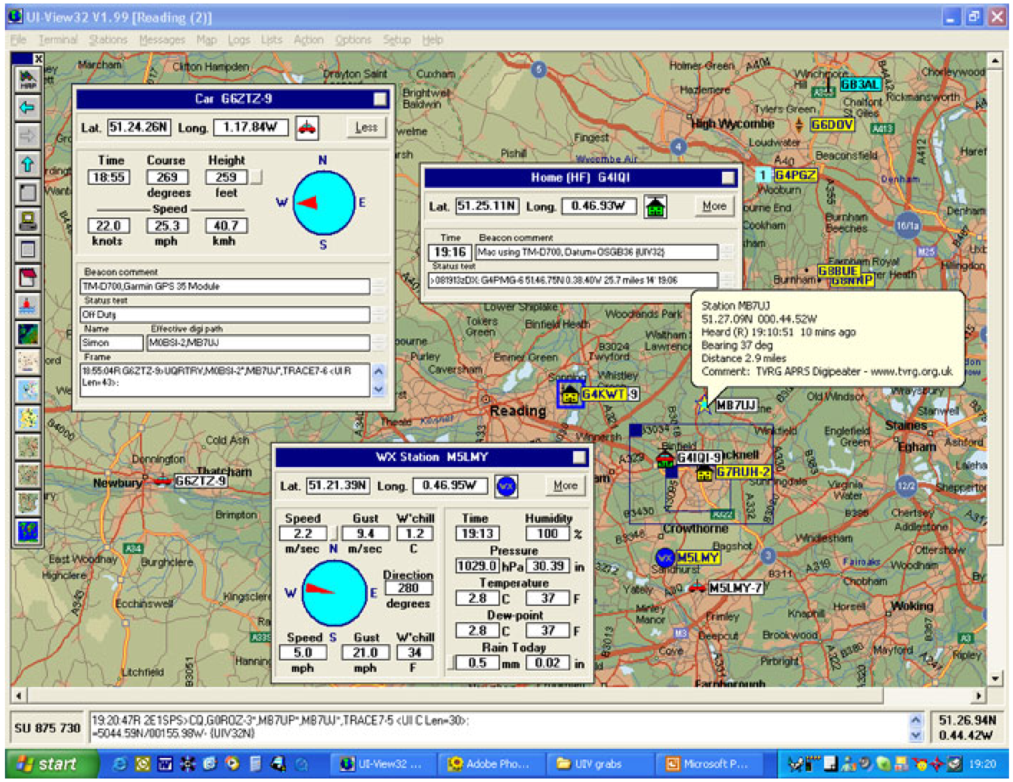


Ham Radio Deluxe



- Provides software control for transceiver
- Main purpose: Doppler shift correction
  - Uses Keplerian elements to predict frequency change.

UI-View



- Not satellite-based.
- Send and receive messages on the local APRS network.
- Track other ground stations.

Future Work

- Develop ground support software to extract satellite information from packets.
- Integrate NOVA, HRD, and new logging program using DDE-capabilities.
- And, of course, track more satellites.