The Colorado Student Space Weather Experiment (CSSWE)

Mission Operations Review

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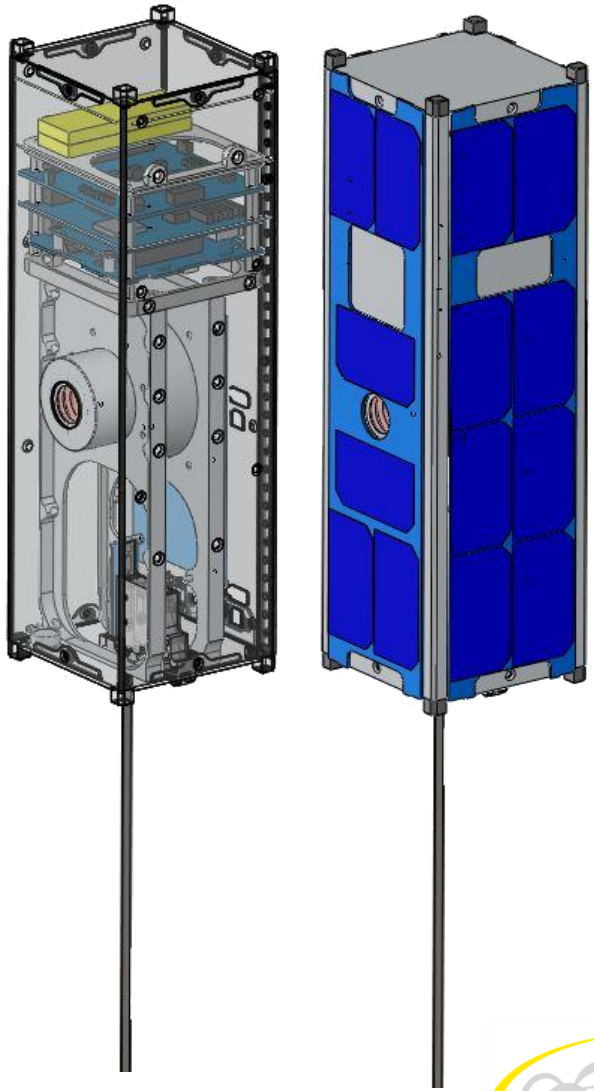
Outline

- Mission Overview
  - ADCS, COMM, GN overviews
  - STK analysis
- Testing to date
  - Day-in-the-life testing
  - TVAC
  - Initial ground station testing, tracking
- Commissioning plan
  - Overview of document, various phases
- Future work before launch

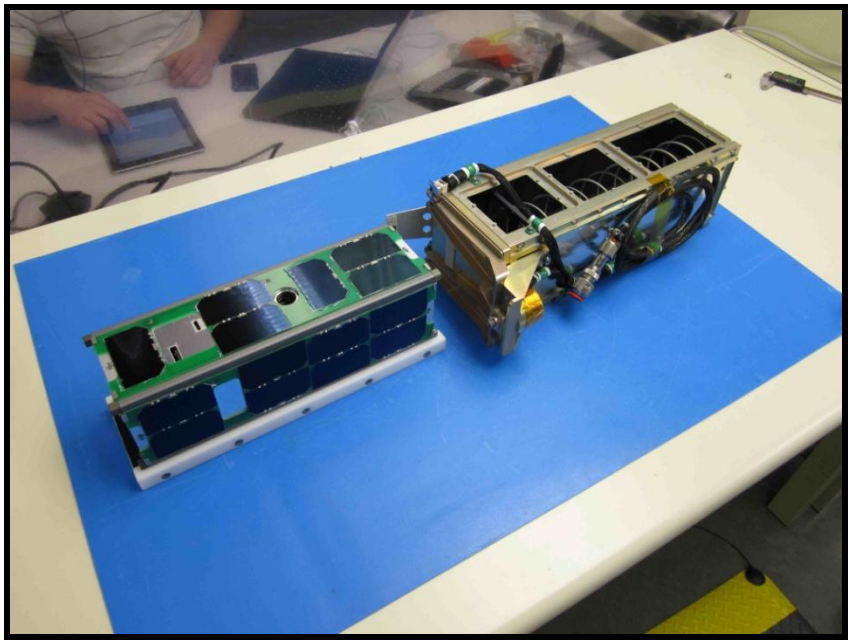
CSSWE

- Mission Statement
  - Develop a student-designed 3U CubeSat for space weather investigation
- Educational Objective
  - A student-led team shall deliver a CubeSat system

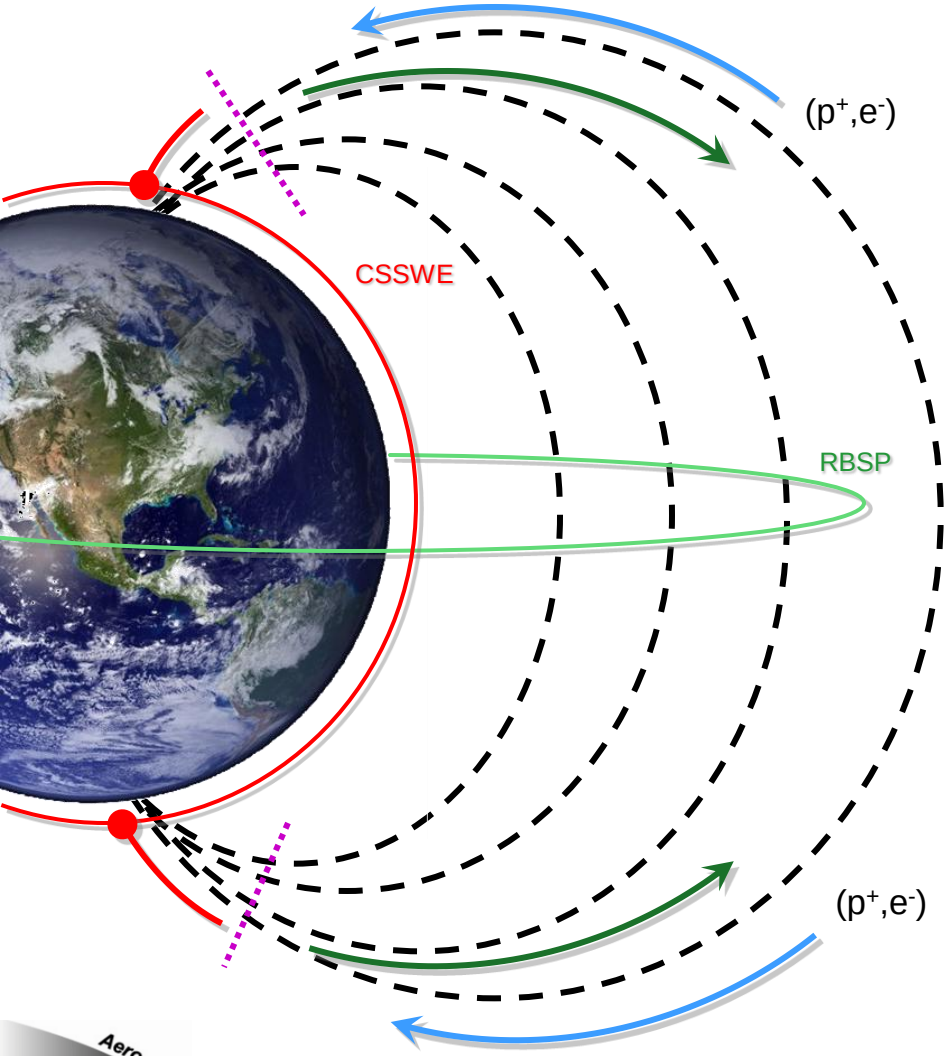


General Requirements

- Science
  - Measure 0.5 – 3 MeV e^-
  - Measure 10 – 40 MeV p^+
  - 6 second time resolution
  - 4 energy bins, 60 degree angular resolution
- CubeSat Interface
  - Fit in a 30 x 10 x 10 cm box
  - < 4 kg mass
  - Completely stand-alone



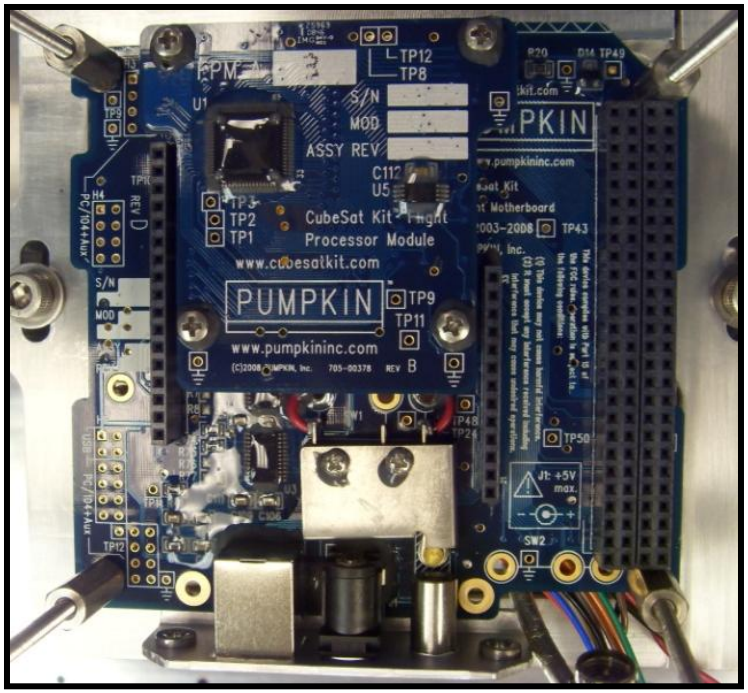
Project Overview, continued



- Selected for NASA ELaNa VI mission
- Secondary payload on NRO L-36 (Atlas V, launching from Aft Bulkhead Carrier)
- Orbit will be 470km x 770 km, 65 deg. incl.
- Delivered Jan 9, 2012
- Launch Aug 2, 2012

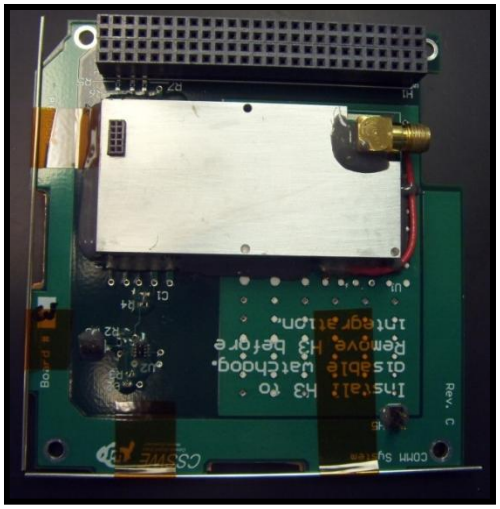
Command &Data Handling

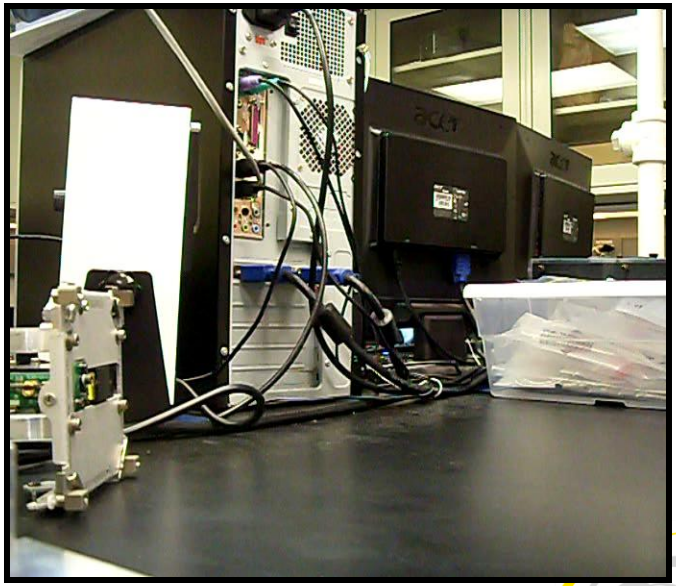
- C&DH is:
  - Pumpkin Motherboard with PPM A3 (MSP430)
  - 2 GB SD card
    - Formatted for 200 days of data
- "Brain" of CSSWE
  - Code developed under supervision of LASP engineers
  - Collects data:
    - Science data (REPTile, magnetometer, photodiodes)
    - Housekeeping data from 40+ onboard sensors
  - 860 kB data generated & stored per day



COMM

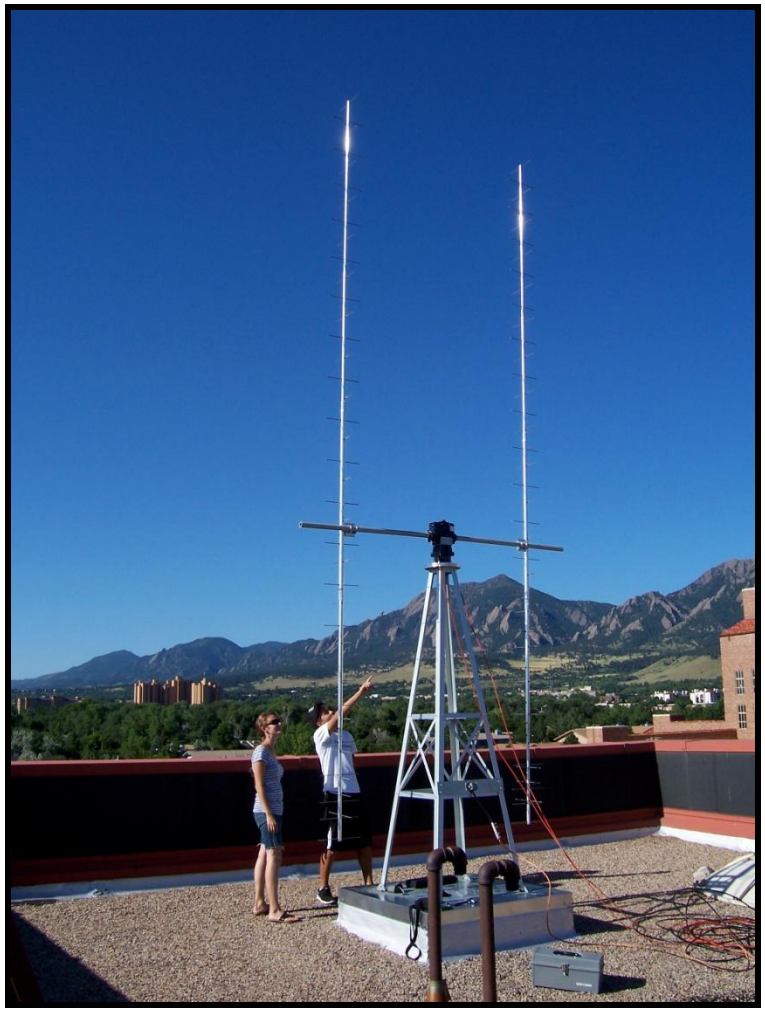
- COTS AstroDev Li-1 radio
- CU-designed PCB
- AstroDev-controlled firmware
- ADM with 48.3 cm deployable tape-measure antenna
- AX.25 packetization
- GMSK modulation
- Half-duplex @ 437.345 MHz



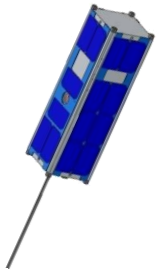


Ground Station

- Ground System is
  - Built for CSSWE and future missions
  - Roof, ops space at LASP
  - UHF Cross-Yagi antenna
  - Kenwood TS-2000 radio
  - Kantronics Kam XL TNC
  - Preamp (Rx)
  - Power amp (Tx)
  - Windows PC running SatPC32
  - ISIS command program



Data Chain



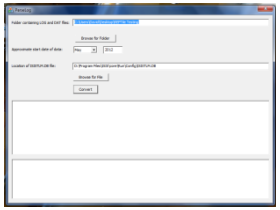
Satellite

GS Antenna

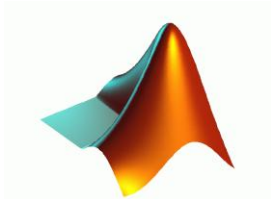
TS-2000 Radio

Kam XL TNC

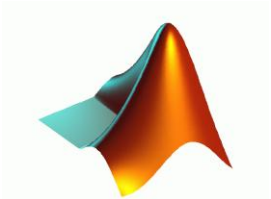
GS computer



ParseLog.exe
Converts binary to ascii & .xls files



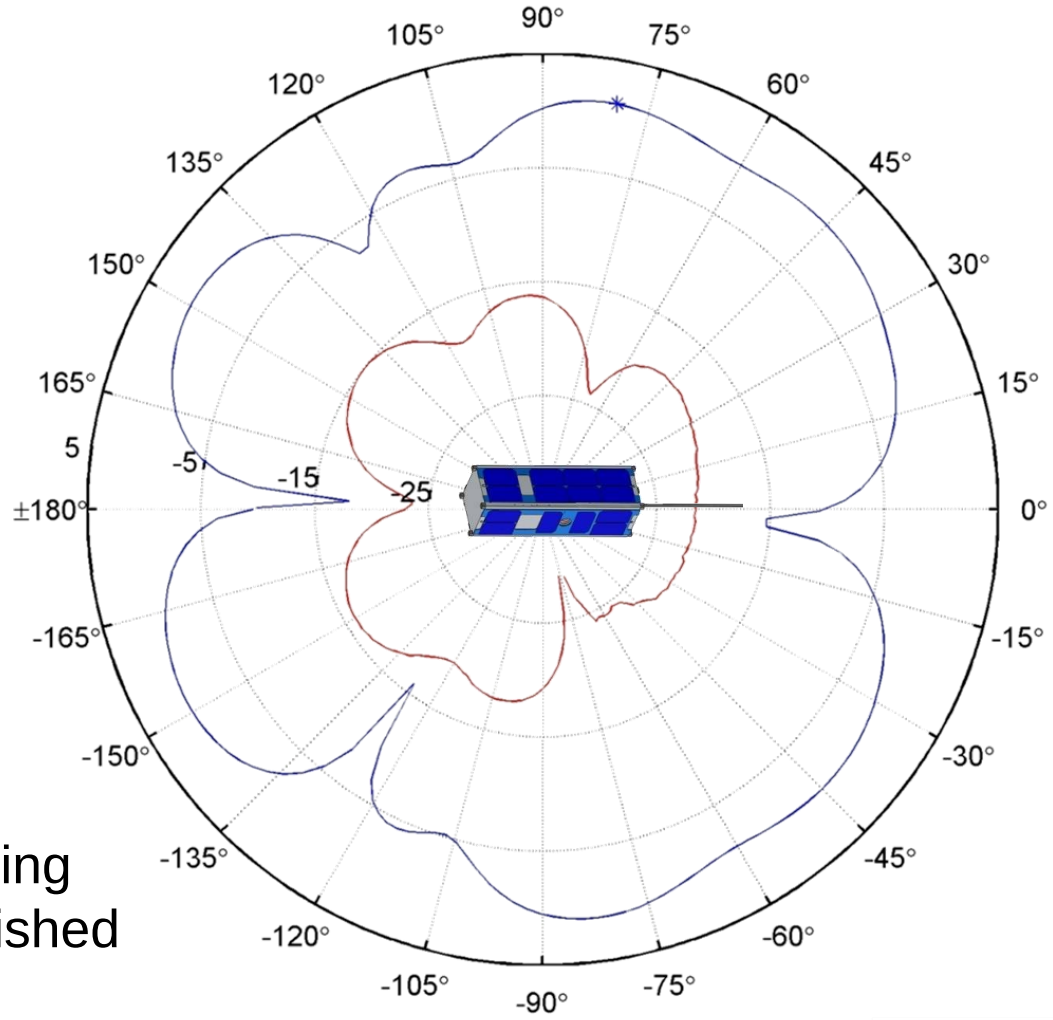
ParseSatData.m
Convert ascii to .mat files



PlotSatData.m
Plot using .mat data

STK Analysis

- Inputs
  - Ground station location
  - Link budget
  - Satellite orbit & attitude
  - Satellite antenna pattern
- Assume
  - 1 min acquisition delay
  - 5 deg. elevation mask
- Outputs
  - Expected pass times
  - Fraction of pass time during which link may be established (“link time”)



STK Analysis Results

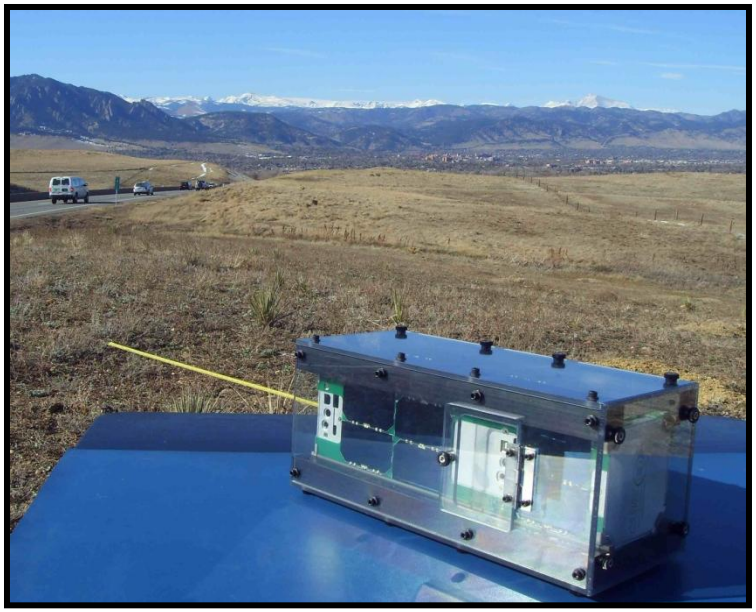
- From Aug 2, 2012 to Aug 15, 2012:

Maximum Range [km]	Average passes per day	Average pass duration [min]	Average link time per pass [min]	Average link time per day [min]	Data budget margin [%]
n/a	5.3	8.9	7.9	41.9	**+75.4**
2000	5.3	8.9	4.9	26.1	**+60.4**
1500*	5.3	8.9	2.3	12.3	**+15.7**

  - Downlink assumes 40% science, 100% error, 100% housekeeping, 20% dropped packet rate
  - Necessary link margin 10 dB higher than calculated

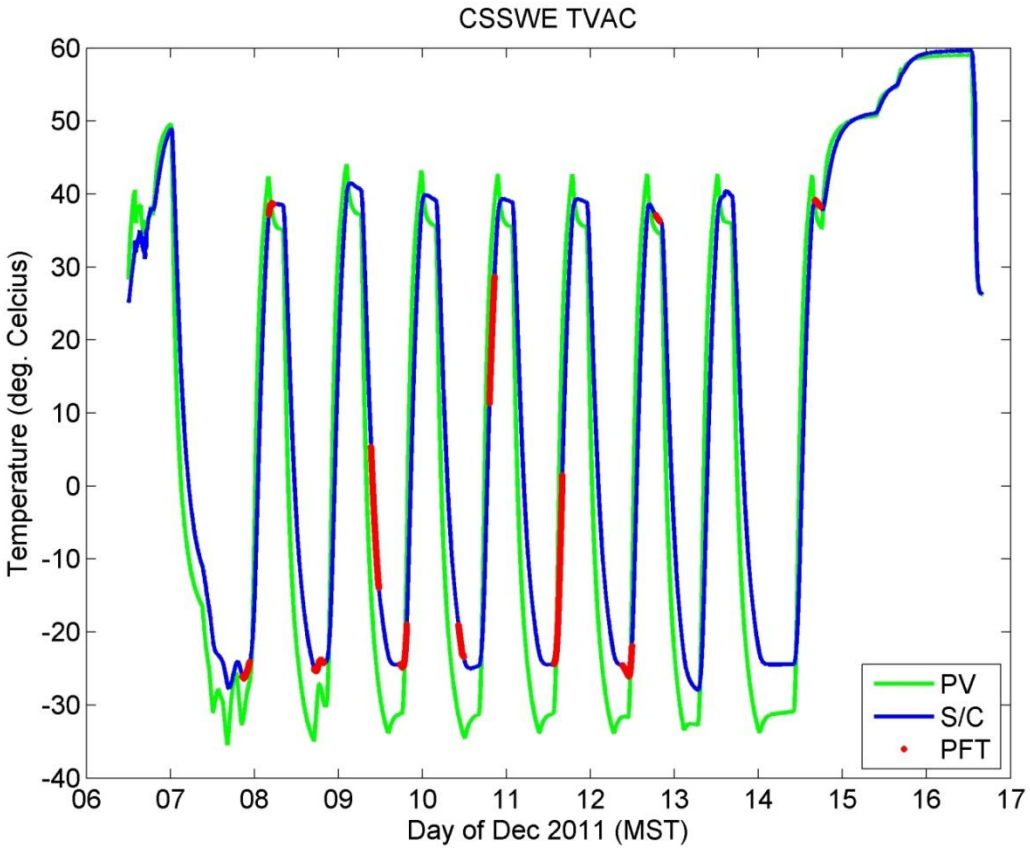
Day-in-the-Life Testing

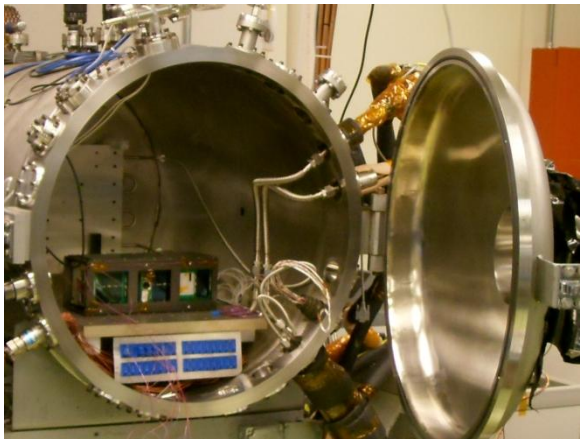
- CubeSat “launched” at Davidson Mesa
  - Antenna deployed autonomously 2 hours later
- Beacon heard and decoded consistently by ground station
- Full CubeSat functionality tested
  - Uplink of commands, downlink of data
  - Preliminary attenuation thresholds also tested

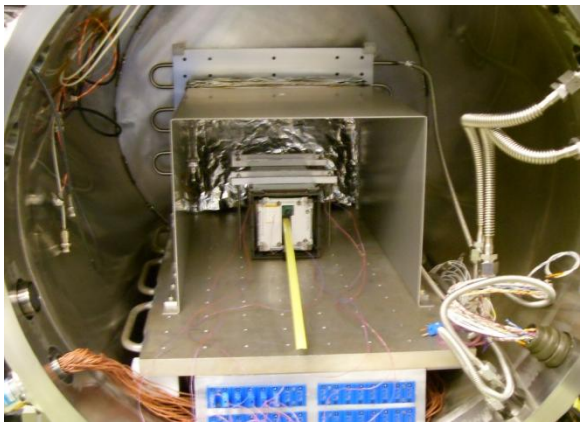


Thermal Vacuum (TVAC) Testing

- System testing in vacuum over expected on-orbit temperature range
- RF communication throughout testing

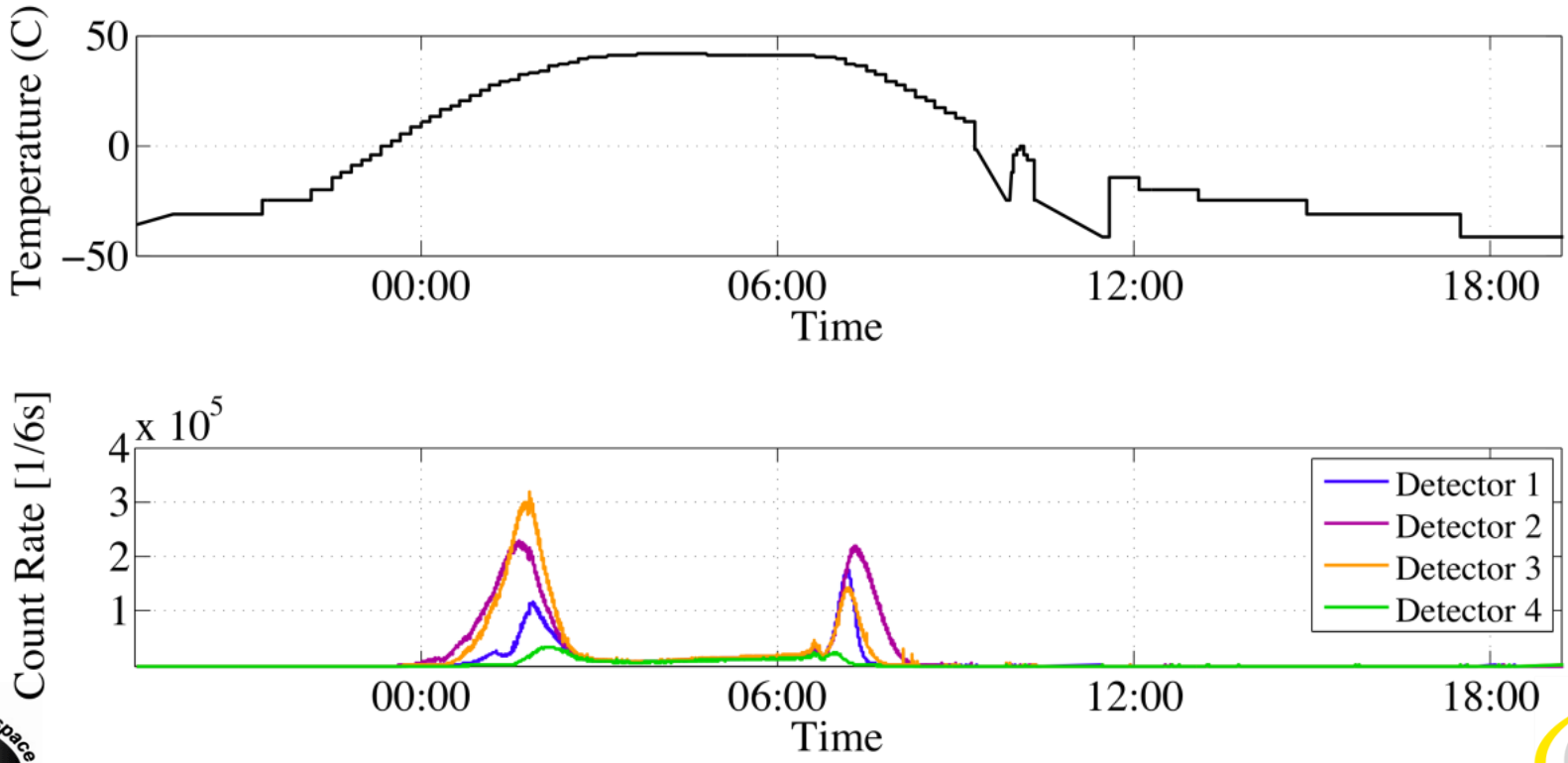






TVAC Testing

- Temperature dependency of system noise monitored
- CubeSat radio frequency drift during temperature swings noted:
  - ~ 437.345 MHz at hot/cold dwells; ~ 437.350 during ramps



Ground Station Testing

- Automated tracking system: SatPC32
  - 7+ satellites have been tracked, heard
- RAX2 beacon successfully decoded!
  - 5 min of beacons
- Ongoing range testing to increase sensitivity

RAX2 Ground Station Client

File View Server

Summary Panel

Attitude

Name	Value	Unit
PNI Mag X	-0.0166	Gauss
PNI Mag Y	0.0435	Gauss
PNI Mag Z	-0.4981	Gauss
Gyro X	0.0125	deg/sec
Gyro Y	-0.225	deg/sec
Gyro Z	1.35	deg/sec
Gyro Mag X	-0.0385	Gauss
Gyro Mag Y	0.1095	Gauss
Gyro Mag Z	0.5105	Gauss

Communications

Name	Value	Unit
UHF NCMD	2057	commands
UHF Radio Temp	-5	deg C
UHF RSSI	-113.3125	dBm
Queue Status	5	packets
UHF # RX	202	bytes
UHF # TX	206842	bytes

External Panels

Name	Value	Unit
+X Current	0	milliamps
+Y Current	0	milliamps
-Y Current	88	milliamps
-X Current	0	milliamps
+X Voltage	1.6489	volts
+Y Voltage	1.3018	volts
-Y Voltage	19.0057	volts
-X Voltage	15.7079	volts

Power System

Name	Value	Unit
3.3V Current (EPS)	71	milliamps
5V Current (EPS)	154	milliamps
Batt Current (EPS)	23	milliamps
5V Voltage (BB)	4.96	volts
3.3V Voltage (BB)	3.296	volts
Batt Voltage	8.1677	volts

Satellite State

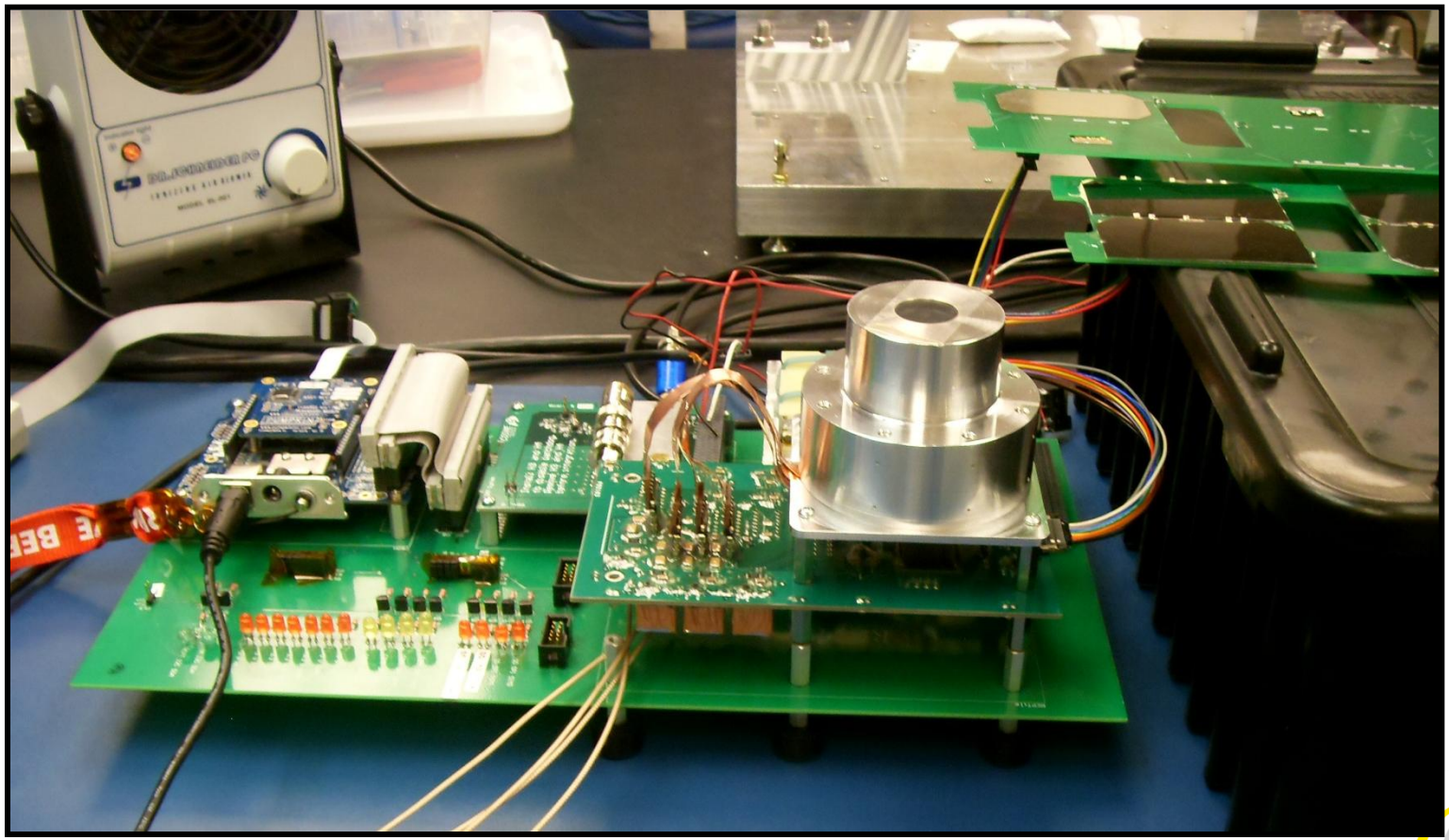
Name	Value	Unit
PR	Disabled	
PIM	Disabled	
IDPU	Disabled	
ADB	Enabled	
PTB	Disabled	
MHX	Disabled	
UHF	Enabled	
Antenna Switch	Lithium	
Polarization Switch	RHCP	
Command Queue	0	commands

Stack Temperature

Name	Value	Unit
FCPU Temp	10.4082	degrees C
EPS Output Reg Temp	7.622	degrees C
Batt Board Temp	10.3878	degrees C
PTB Board Temp	3.4	degrees C
UHF Board Temp	3.4	degrees C
ADB Board Temp	6.2372	degrees C
IDPU Board Temp	1.8	degrees C
PIM Board Temp	-1.4	degrees C

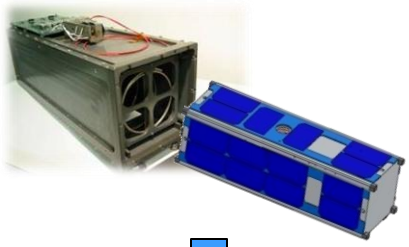
Ground Station Testing

- FlatSat: Duplicate flight model
  - For ground station testing, on-orbit calibrations



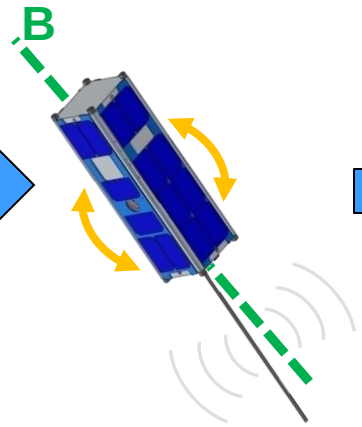
Mission Timeline – Start of Life

(T+0)
Deployment,
Start-up

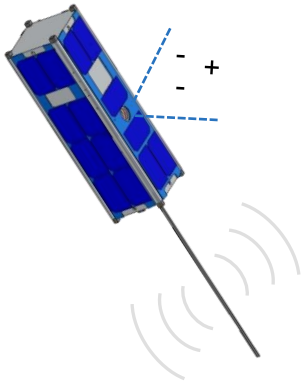


(T+2h)
Antenna
Deployment,
Beacon Begin

(T+1d)
Power Stabilized
(if battery dead)

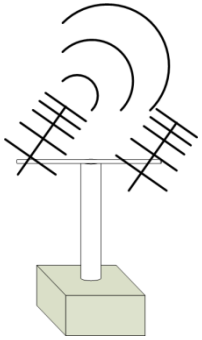


(T+10d)
ADCS
Stabilization



(T+30d)
Begin
Science Ops

(T+2h to T+30d)
Search, Spacecraft
Commissioning



Summary: Phase 1
Tracking

- Initial tracking & identification of spacecraft
- Verify health & safety from beacon
  - Error log
  - Battery
  - Transmitter
  - Solar cells
  - Timestamp
  - REPTile
  - Magnetometer
- Begin to identify CSSWE from other CubeSats

Commissioning: Phase 1
Tracking

- Listen to beacon
  - Man all passes for first 3-4 days
  - Man all daytime passes until tracking is reliable after four days
- Trend HK data
- Check center frequency of transmitter
  - Eye-pattern, may be difficult prior to dumping data
- Build confidence in tracking
  - Reliable listening
  - Decode beacons every pass
  - Run passes at various elevations
- Compare telemetry to TVAC data
  - Match on-orbit to test temperatures

Summary: Phase 2
Commands not requiring SD-card access

- As per Gale's suggestion, avoid doing anything with SD-card until other components are checked out
- Begin all activities on farthest eastward pass
  - Next 1-2 orbits should also be visible
- Initially, only transmit during daytime
  - Always check voltages before requesting data

Commissioning: Phase 2
Commands not requiring SD-card access

- Send noop
  - Commands since boot should increment
- Send echo
  - Try different patterns, verify received echoes
- Request beacon
- Hkdump
  - Dumps instantaneous HK data, doesn't read from SD-card
- Magdump
  - Dumps instantaneous magnetometer data, doesn't read from SD-card
- Readrtc
  - Reads the value of the clock
- Readconfig?
  - May read from SD card if memory is corrupt

Summary: Phase 3
Commands requiring SD-card access

- Begin health and safety check on SD card
  - Checks for write and read ability
  - Start with pokes to SD card
  - Read from SD memory
  - Write to SD memory
- Start playing back stored data
- Make sure transmitter/battery can handle longer transmit times
  - Check voltages and transmitter temperature during passes

Commissioning: Phase 3
Commands requiring SD-card access

- Check beacon errors for “Can’t write to SD card”
- Queryfiles
  - Returns 3 timestamps: Primary science file, HK file, secondary science file (empty)
  - Science timestamps still occur while in safe mode
- Listfiles
  - Sends list of all files on SD-card
  - Includes filename, attribute, creation time, and length
  - Doesn’t actually open the files
- Readconfig
  - Reads config file from SD-card if config file in memory is corrupted

Commissioning: Phase 3
Commands requiring SD-card access

- Request small data dumps
  - HK playback: set timeframe to single packet
  - HK playback: multiple packets
    - Watch radio temperature, battery level
  - Request immediate error packet
    - Returns size of error log
    - Dump the log if it's small, clear if it's too big
- Plot eye-pattern
  - Verify center again, compare to previous results
  - Compare center frequency at different temperatures
- Set antenna deployment status
  - Send no-deploy command until deployment status is written to SD-card
  - Setdeploy writes the deployment status of the antenna to the SD-card

Summary: Phase 4

Begin science operations

- Prepare spacecraft for science operations
- Enter science mode

Commissioning: Phase 4

Begin science operations

- Download all HK data
- Dump & clear error log
- Dump magnetometer data
- Dump something from all 5 file types
- Set RTC to correct time
- Turn off high voltage to REPTile detectors

Commissioning: Phase 4
Begin science operations

- Enter science mode (turns off beacon)
  - Look at change in power draw
  - Look at science data
  - Dump and check HK data
  - Test transition back to safe mode
- Turn on high voltage to detector 1
  - Request beacon, check currents & voltages
  - Collect science data
- Turn on high voltage to detector 2
  - Repeat for detectors 2 – 4

Summary: Phase 5
Nominal operations

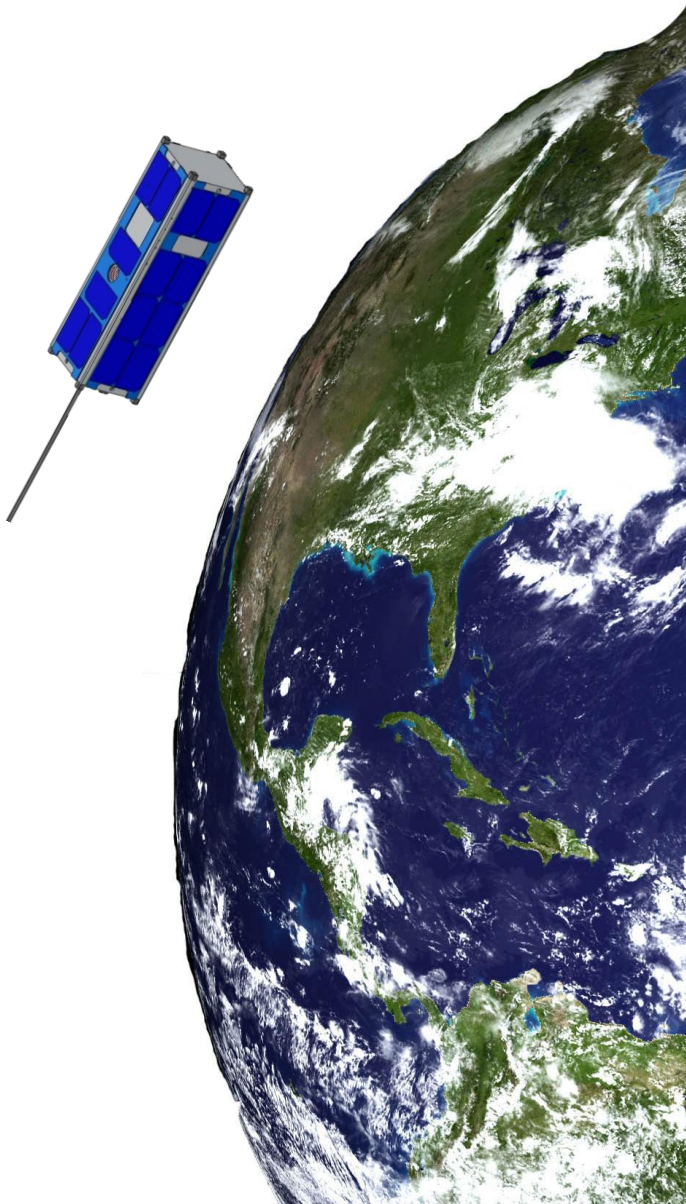
- Nominal operations mode
- Continue with science collection
- Monitor spacecraft health and safety
- 2+ passes per day
  - Required to dump 6 minutes of science data per day
  - Depends on maximum linkable range

Finalizing – To-Do

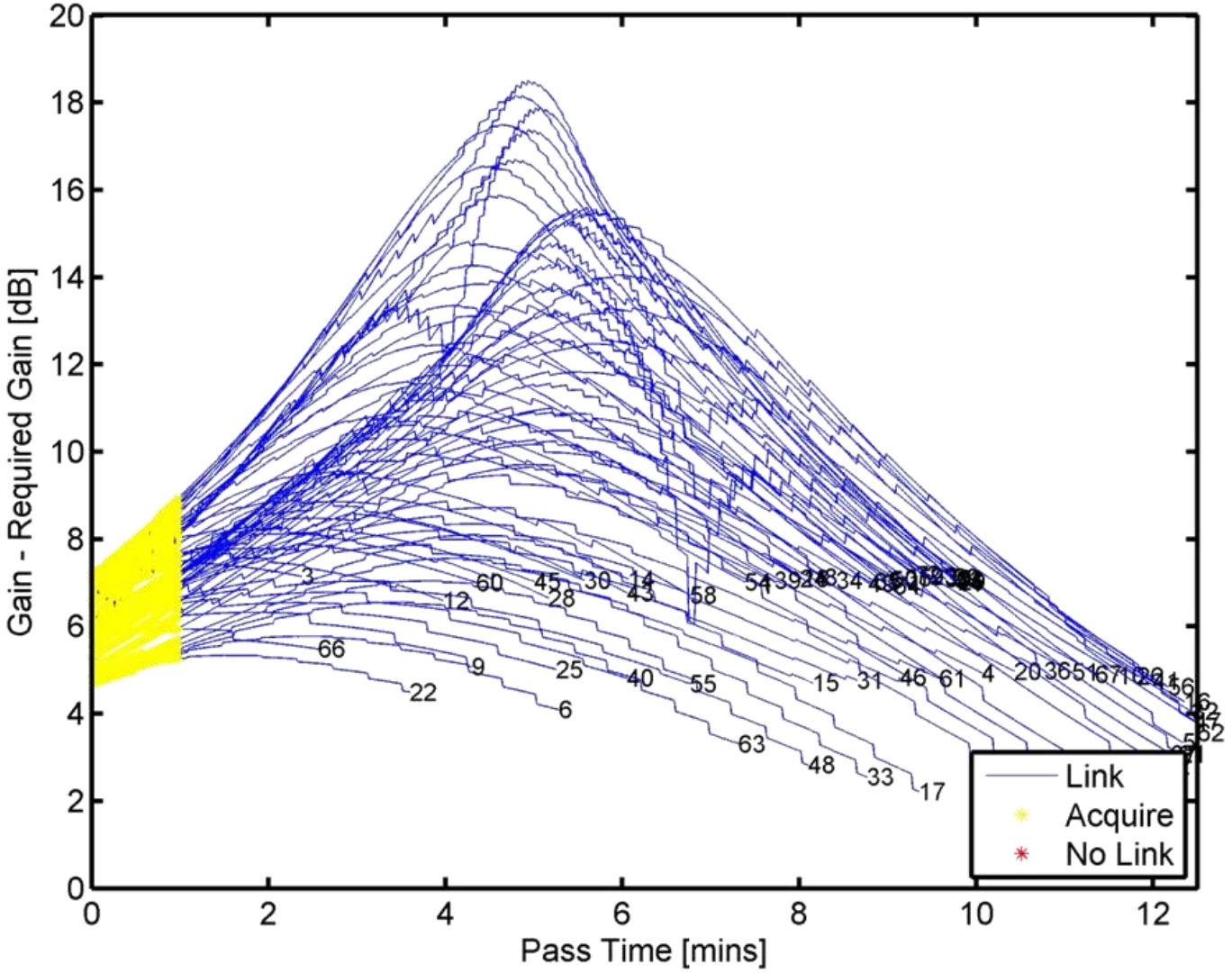
- Beacon decoding software
  - Write program for amateur radio operators
    - Downlink beacon packets and send to LASP via TCP/IP
    - Python and Java scripts
- Extend pass length with RAX-2
  - Adjust antenna calibration/offset
  - Adjust tracking parameters
    - Following vs. leading, delta in azimuth & elevation
- Write commissioning scripts
- Test commissioning scripts using FlatSat

Thank You

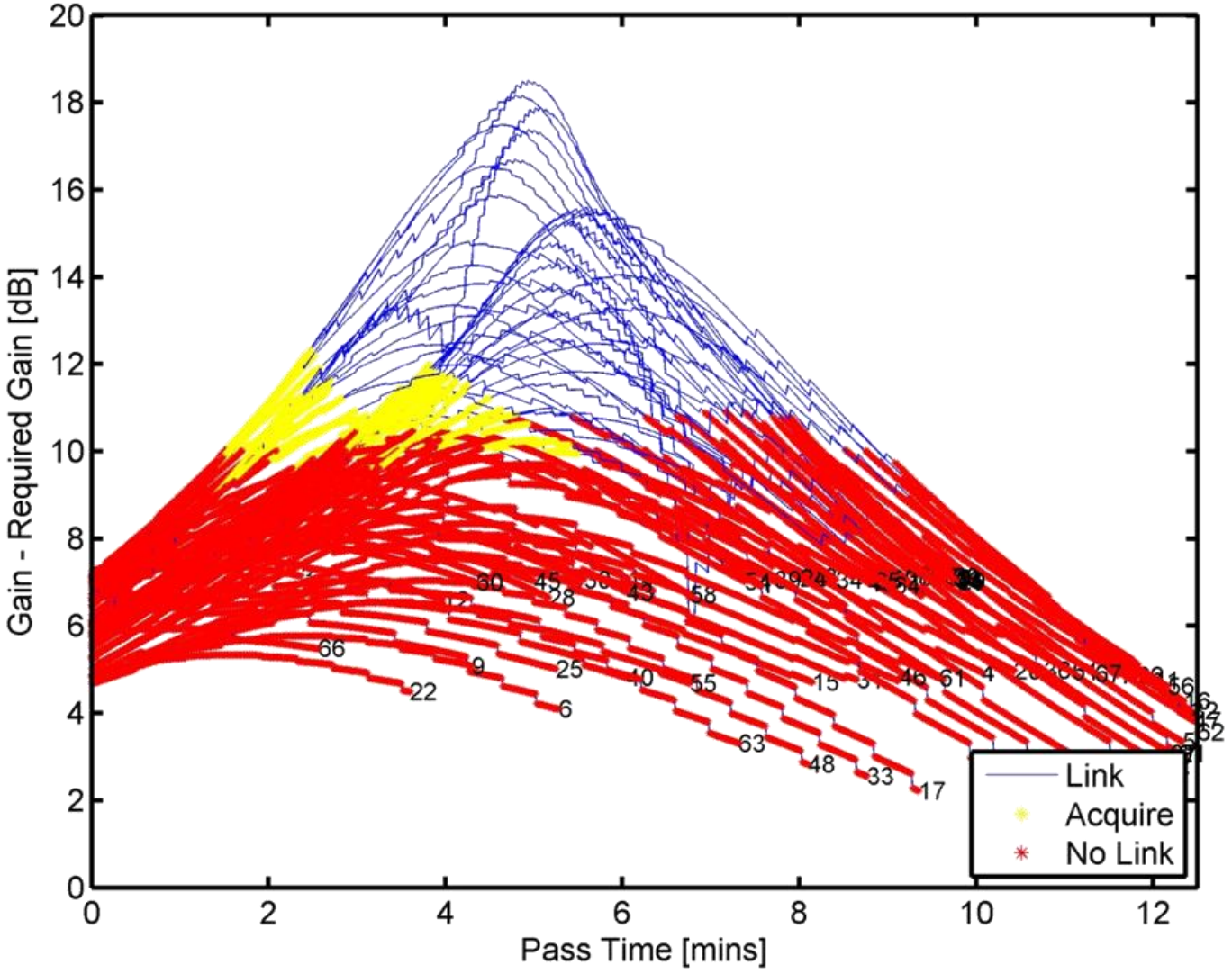
QUESTIONS?



STK Analysis – No Range Limit

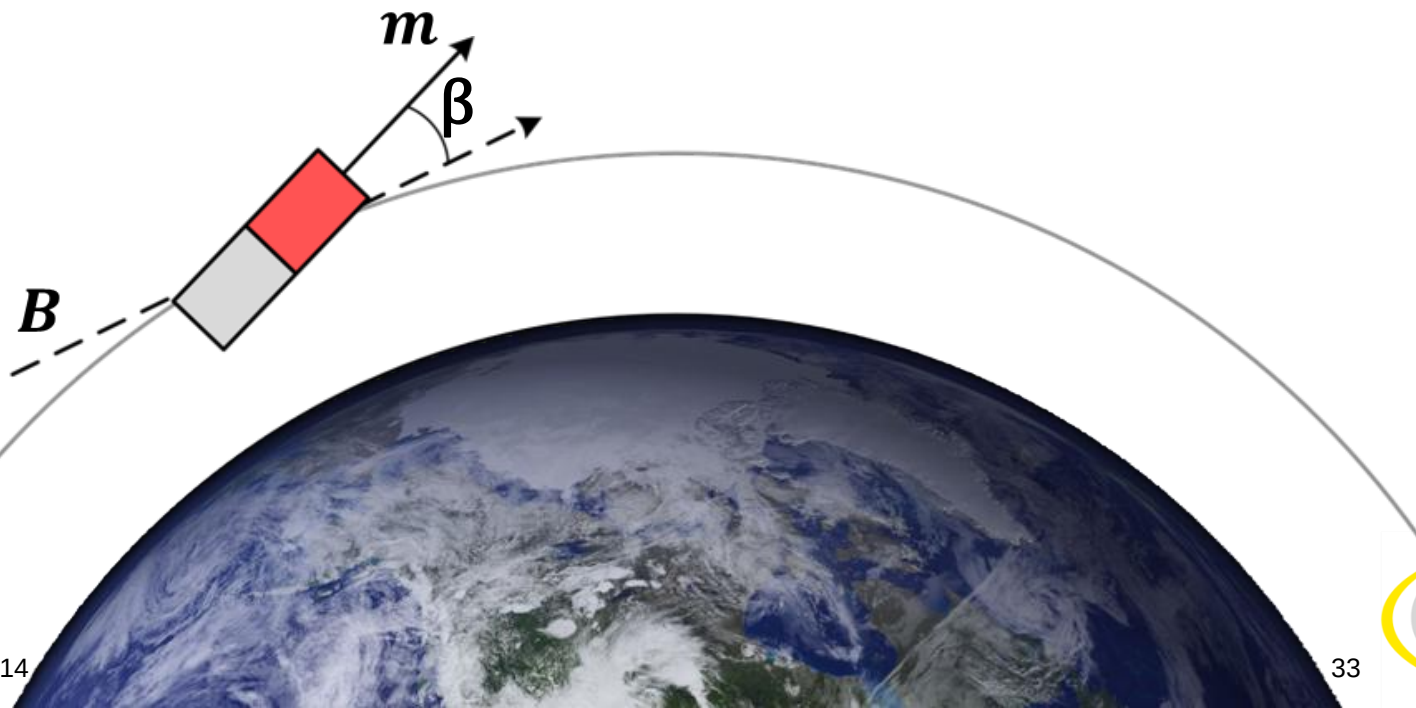


STK Analysis – 1500 km

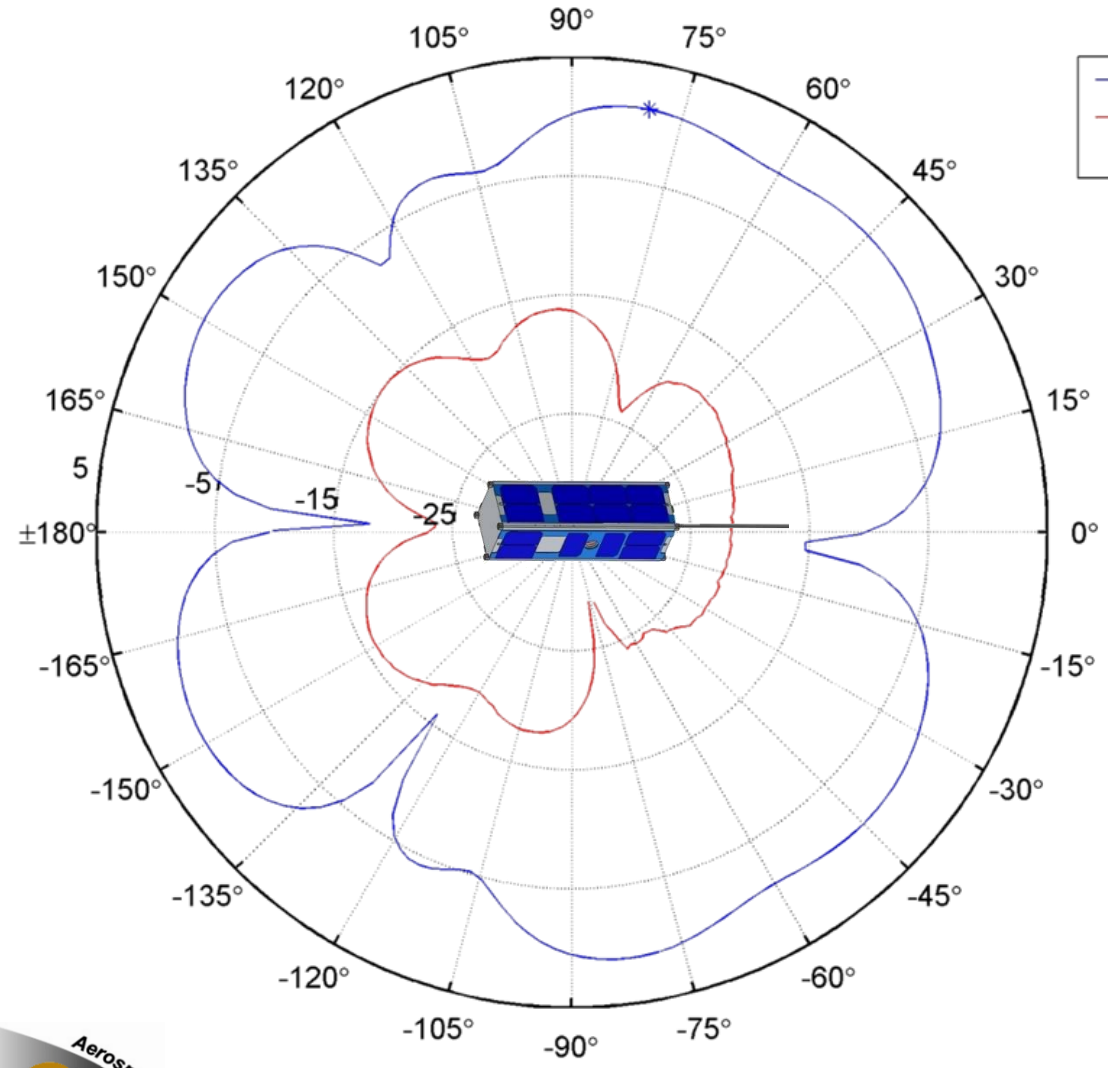


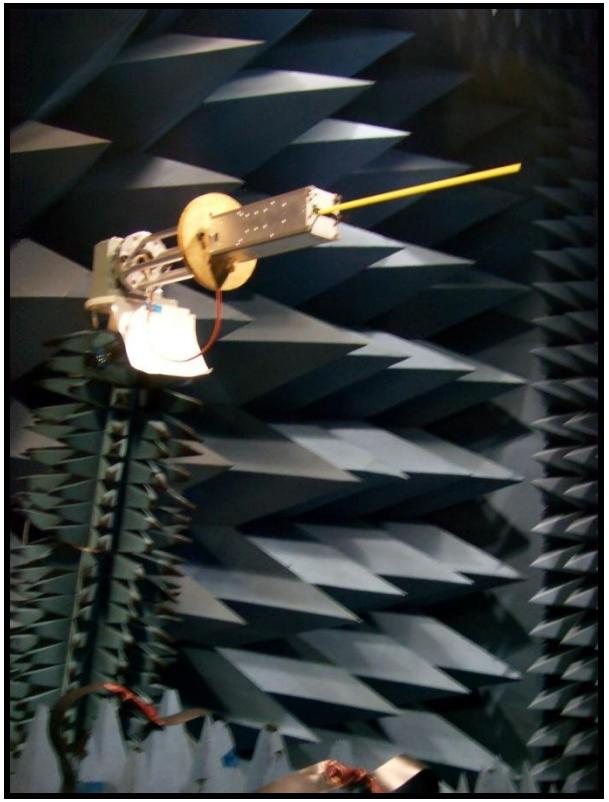
ADCS

- Uses Passive Magnetic Attitude Control
  - Bar magnet
  - Hysteresis rods
- Expected initial spin rate: 18 deg / min
- Expected dampening time: <1 week

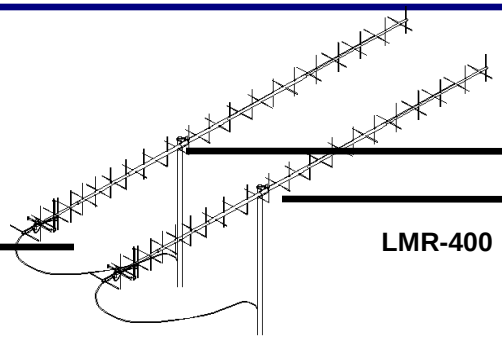


Measured Gain Pattern





Ground System Block Diagram



Yaesu G-5500 Rotator (Az/El)

LMR-400

Splitter

Low Noise Amplifier SSB SP-7000

Static / Lightning Arrestor

Roof

Inside LASP

Manual Rotator Controller

GS-232A to RS-232 Converter

Computer Running SatPC32

(for Doppler control)

Computer Running ISIS

Terminal Node Controller Kantronics Kam XL

Power Supply

LNA Power Supply

Bias T

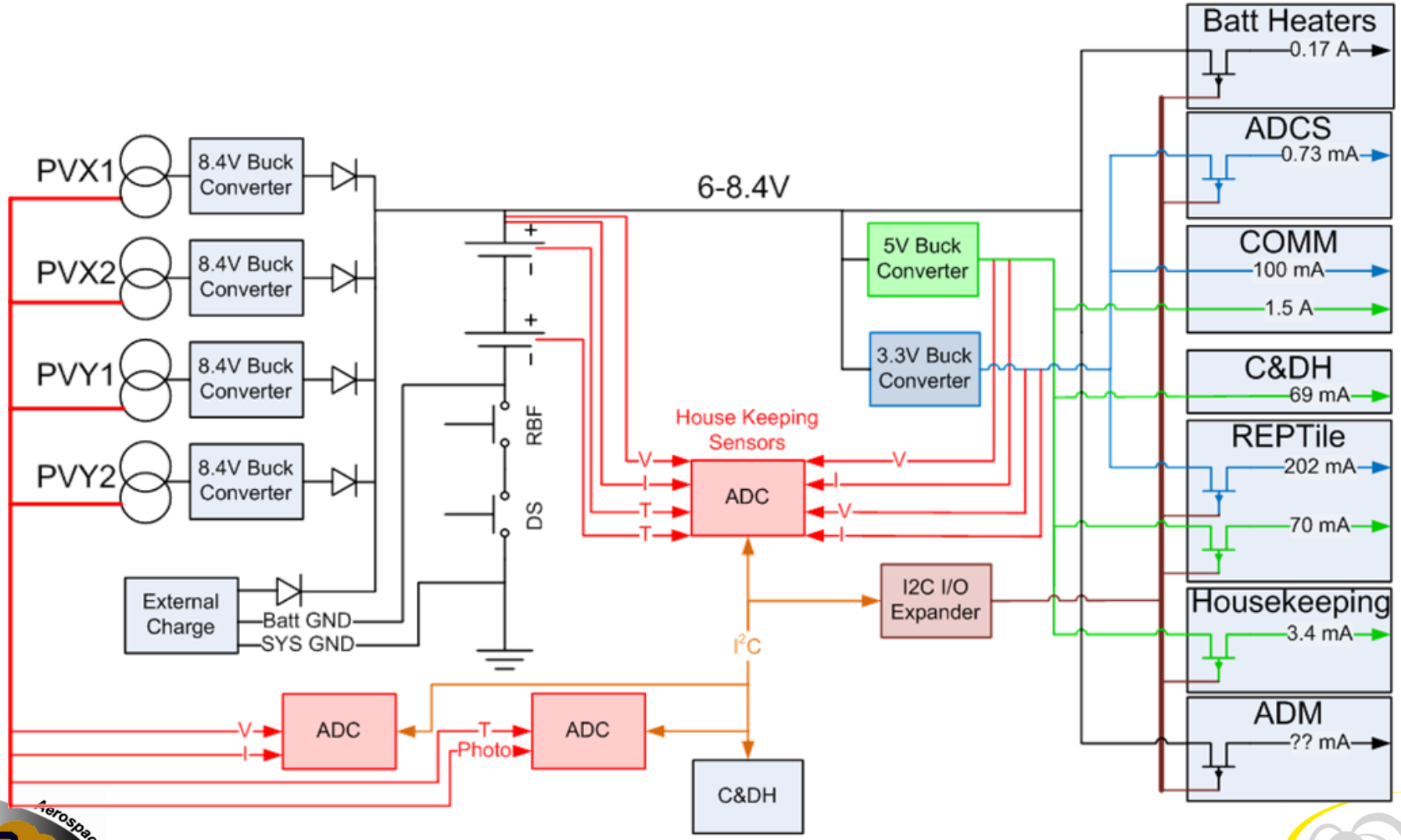
Radio Kenwood TS-2000

Power Amplifier Mirage D-1010-N

Power Supply

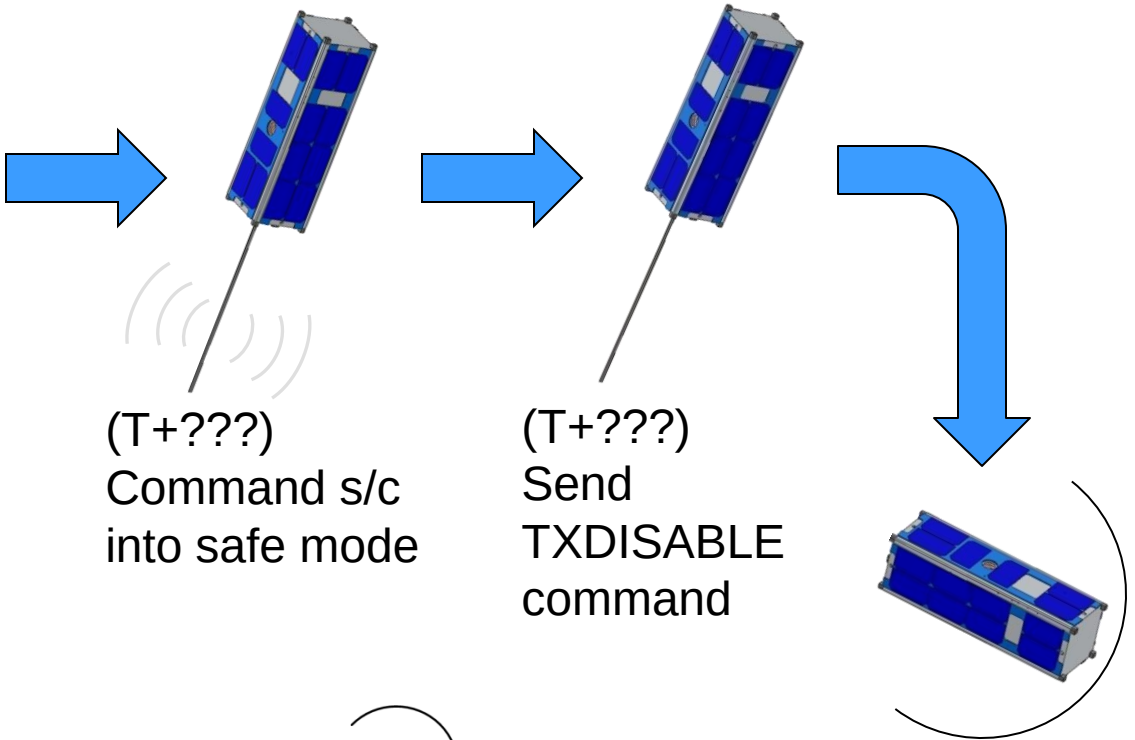
Power Supply

Power System Block Diagram

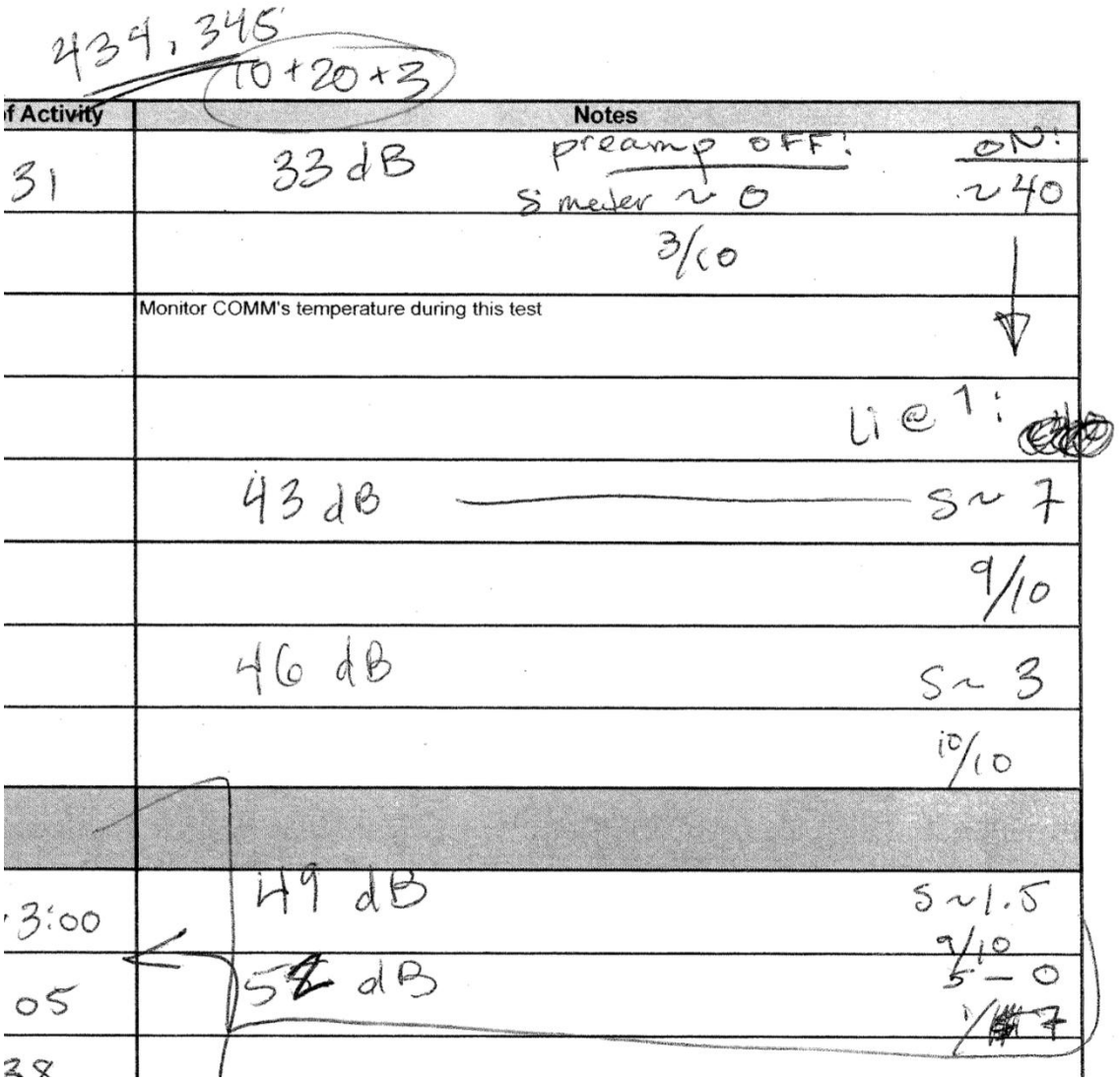


Mission Timeline – End of Life

(T≥120d)
Decision to conclude CSSWE mission



Day-in-the-Life Testing



TVAC Testing

- System operational from -35 to 50 C