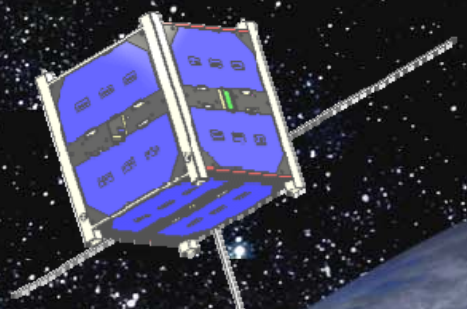
COMPASS-1

Qualification Review
26.06.2006



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Content

- Objectives
- Payloads
- Status of Development & Testing
- Launch Qualification
- Launch Preparations

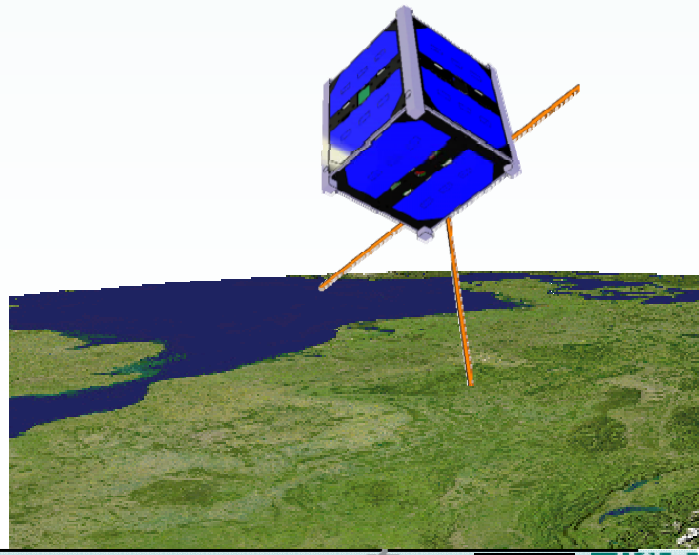
Objectives

Project Objectives

- Insight into the system engineering process and team dynamics
- Better understanding of subjects (technical and management)
- Collaboration and contacts with industry, universities and other Cubesat groups

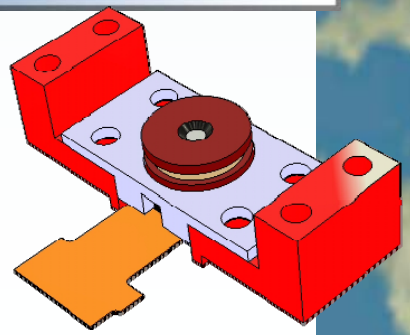
Mission Objectives

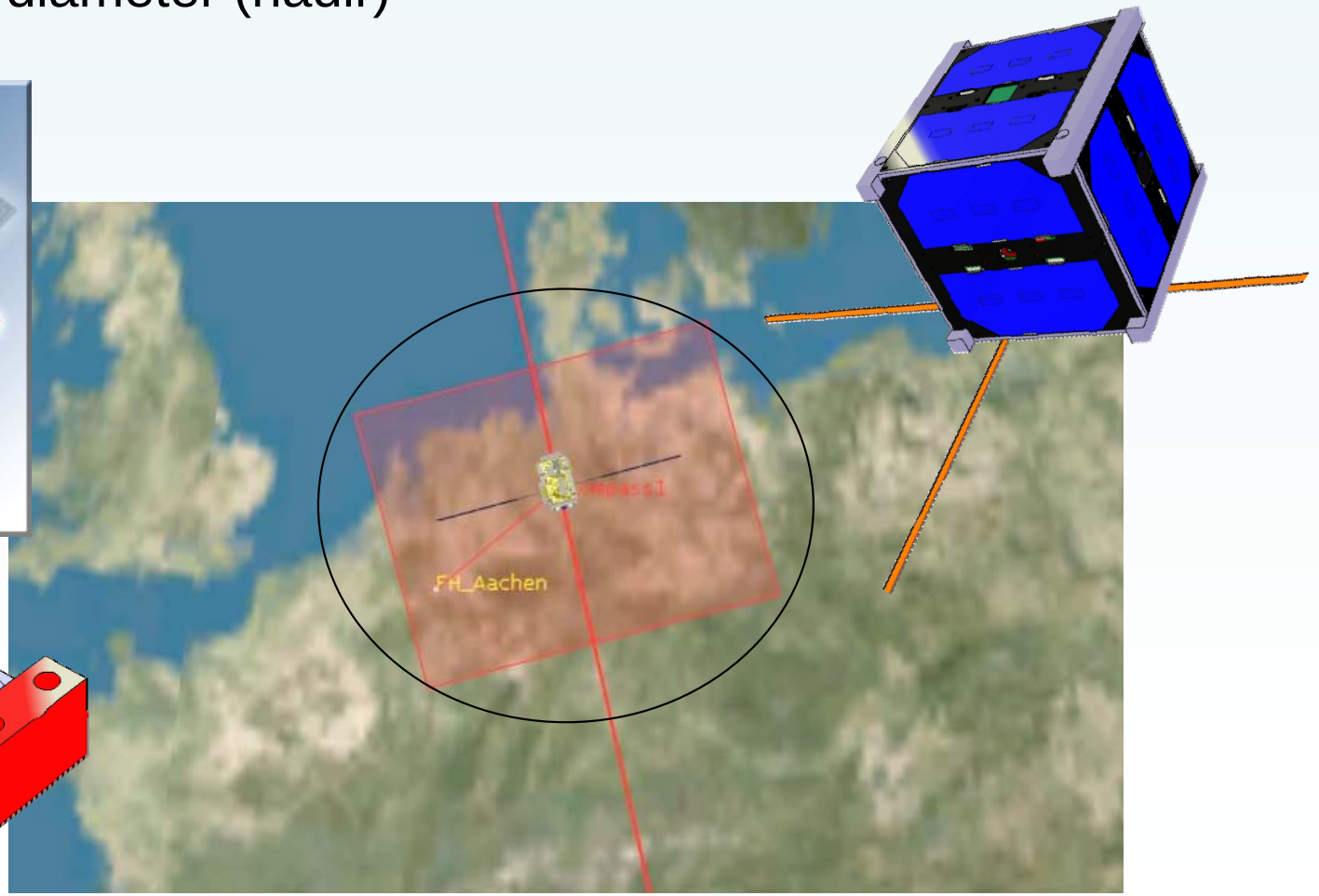
- Remote Sensing with color camera
- GPS validation
- Technology demonstration:
  - Extensive use of COTS components
  - Fast UHF communication downlink
  - Active magnetic attitude control
  - Lithium-Polymer batteries for power storage



Remote Sensing

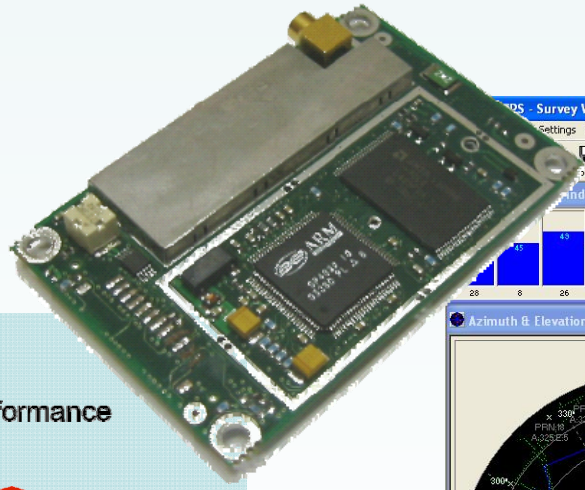
- On request from ground station, the VGA (640x480 pixels) camera (model OV7648FB) will capture color images of the earth below.
- Calculated coverage is a rectangle (ratio 4:3) within a circular view field of 572km diameter (nadir)

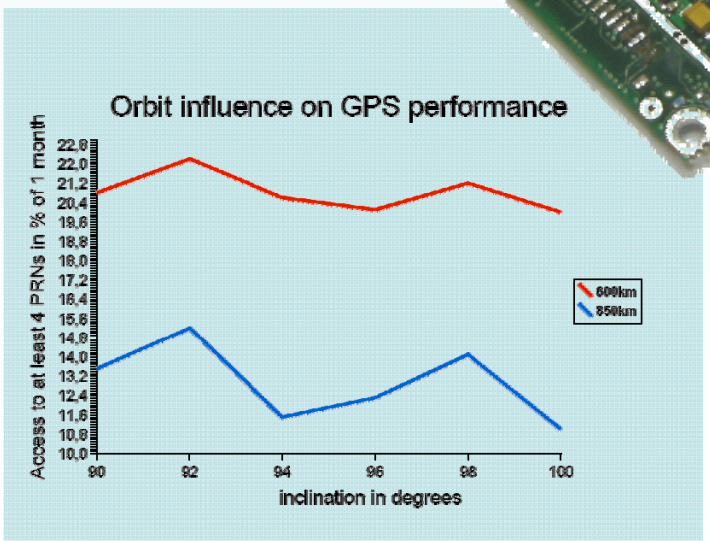


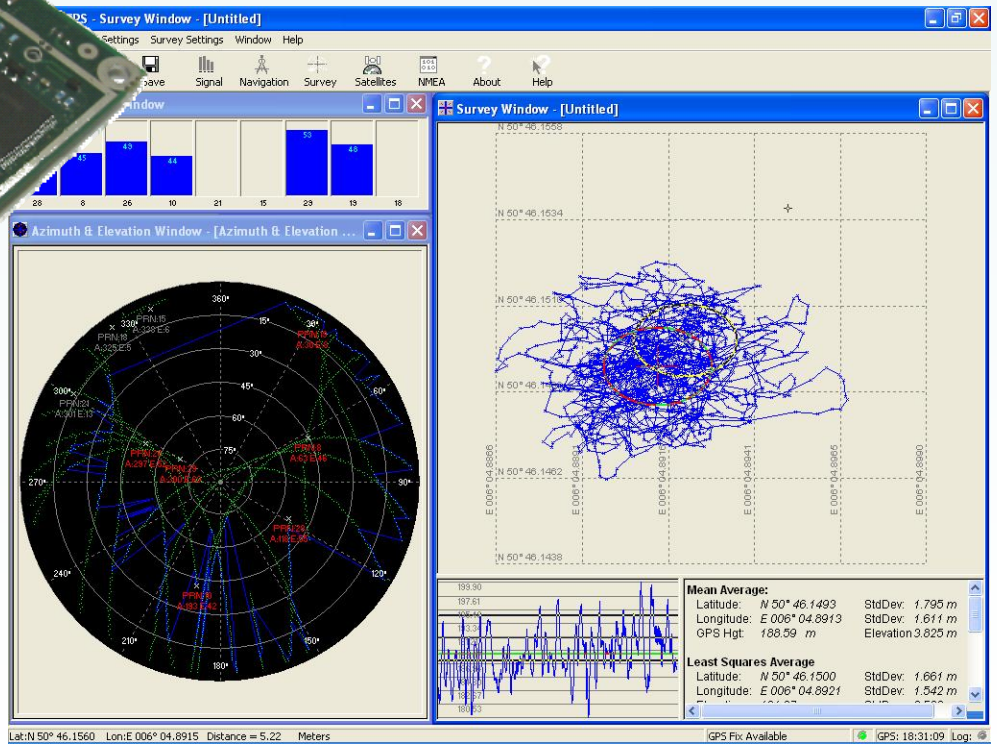


Phoenix GPS Validation

- Implementation of Phoenix GPS into picosatellite
- Measurement of GPS raw data over full orbit







Satellites' Housekeeping Measurements

The satellite periodically transmits a beacon containing critical housekeeping data. Further extensive measurement data can be downloaded on request.

Temperature

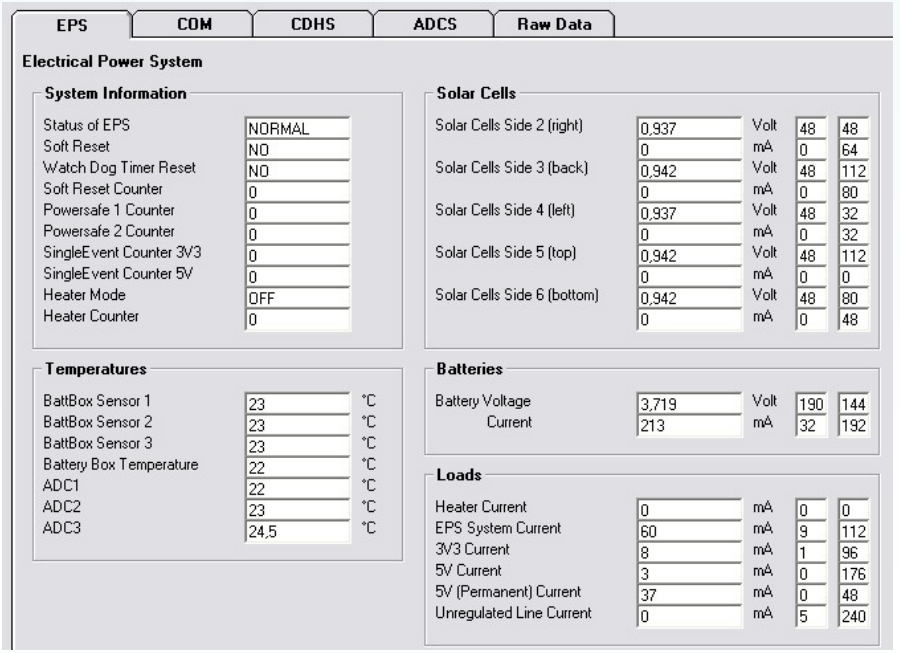
- 1 sensor on each side panel
- Sensors on all subsystem boards, 3 sensors in battery box

Voltage and current

- Monitoring of solar cell output
- Measuring of 3V3 and 5V regulators

Others

- ADCS flight data
- Subsystem information
- etc.

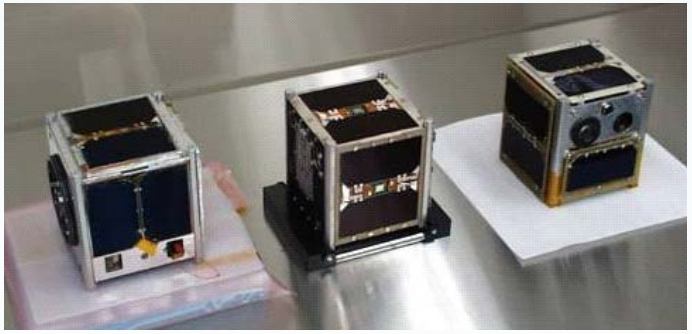


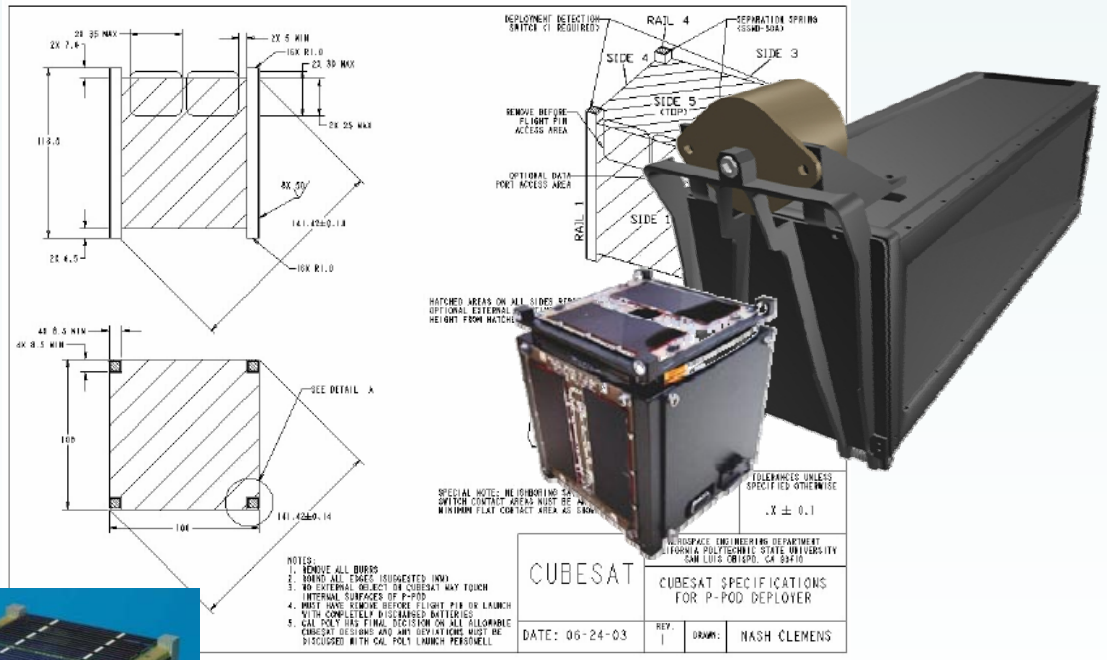
Cubesat Standard

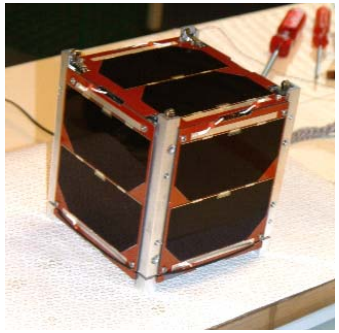
The CubeSat standard has been defined in 1999 by Prof. Twiggs of Stanford University in collaboration with CalPoly University.

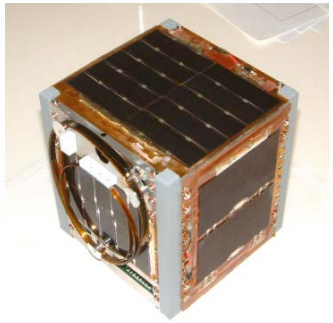
The concept was chosen for COMPASS-1 in order to:

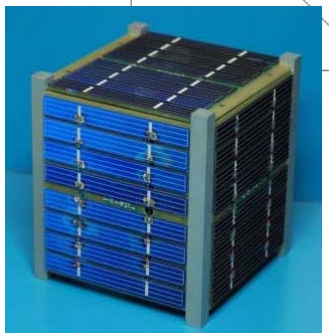
- reduce the launch costs
- simplify the launch interface

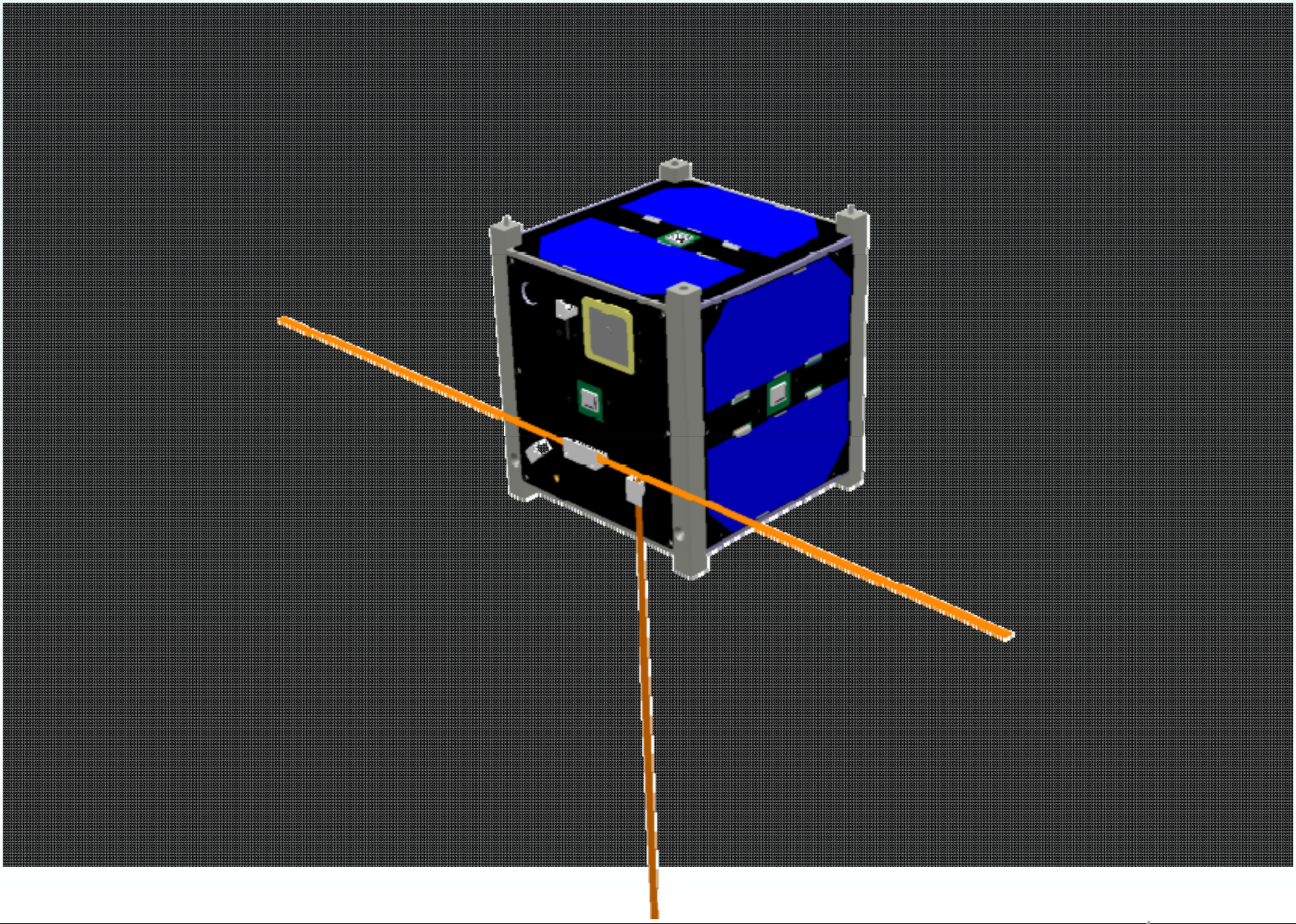


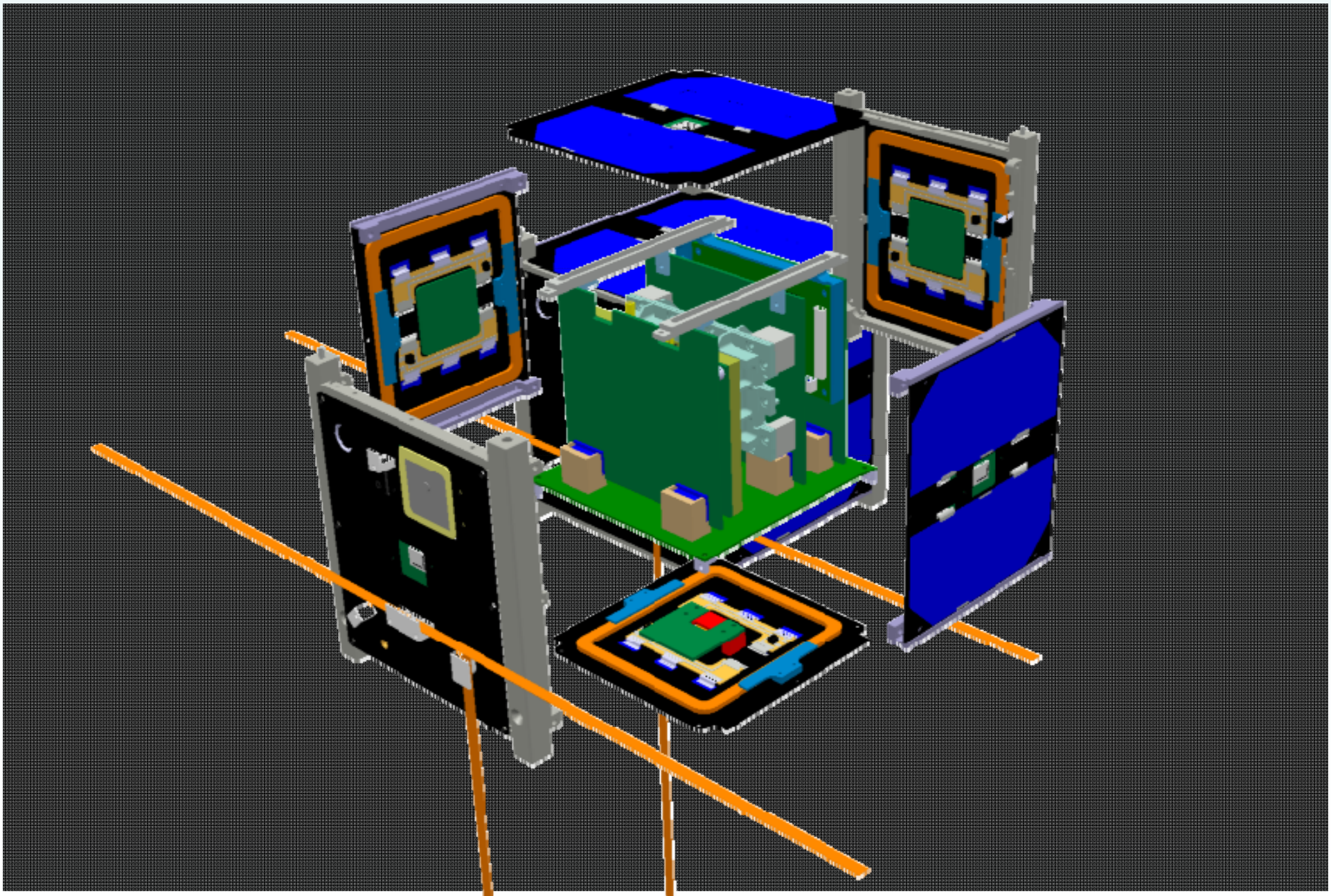


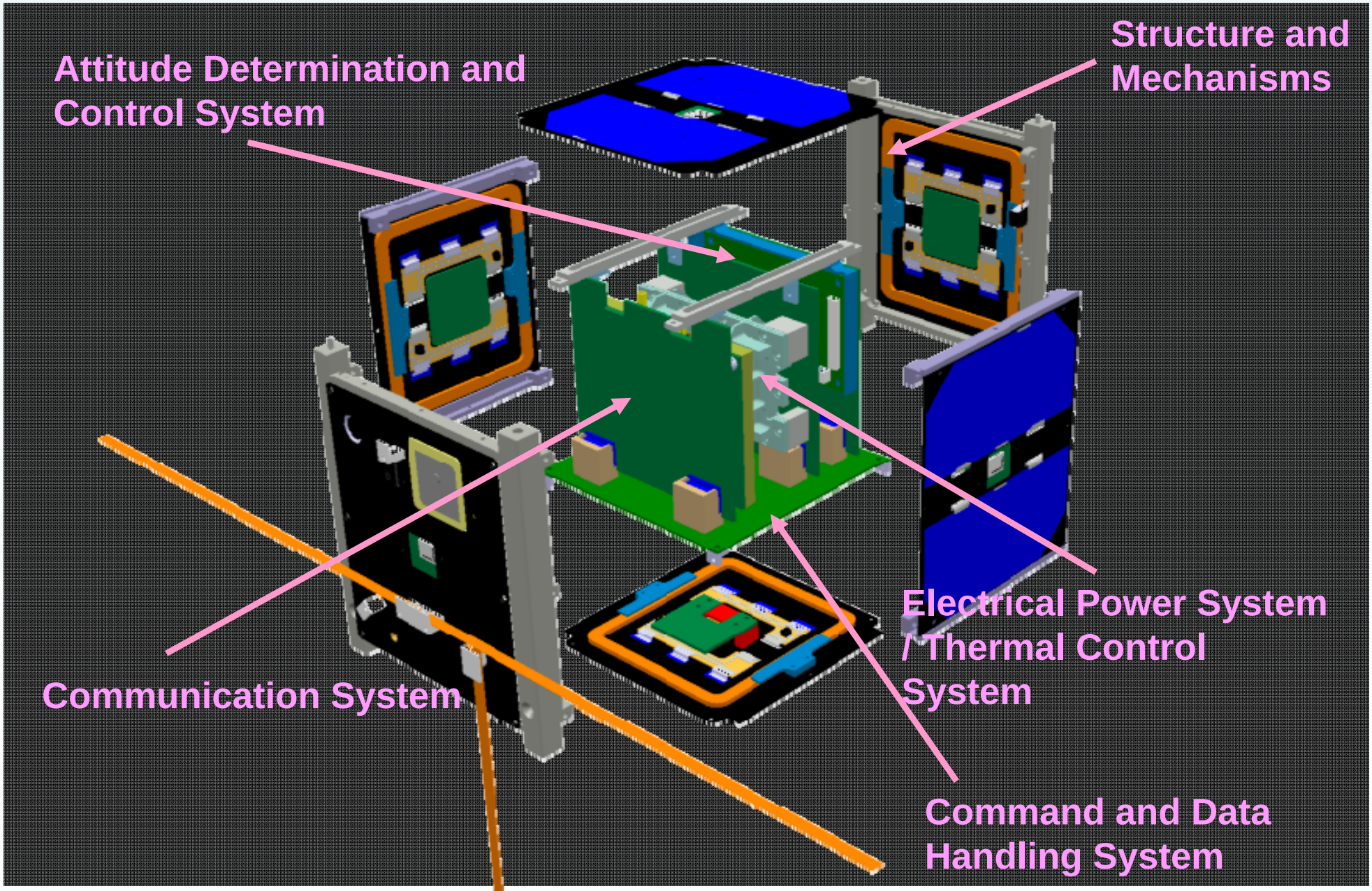




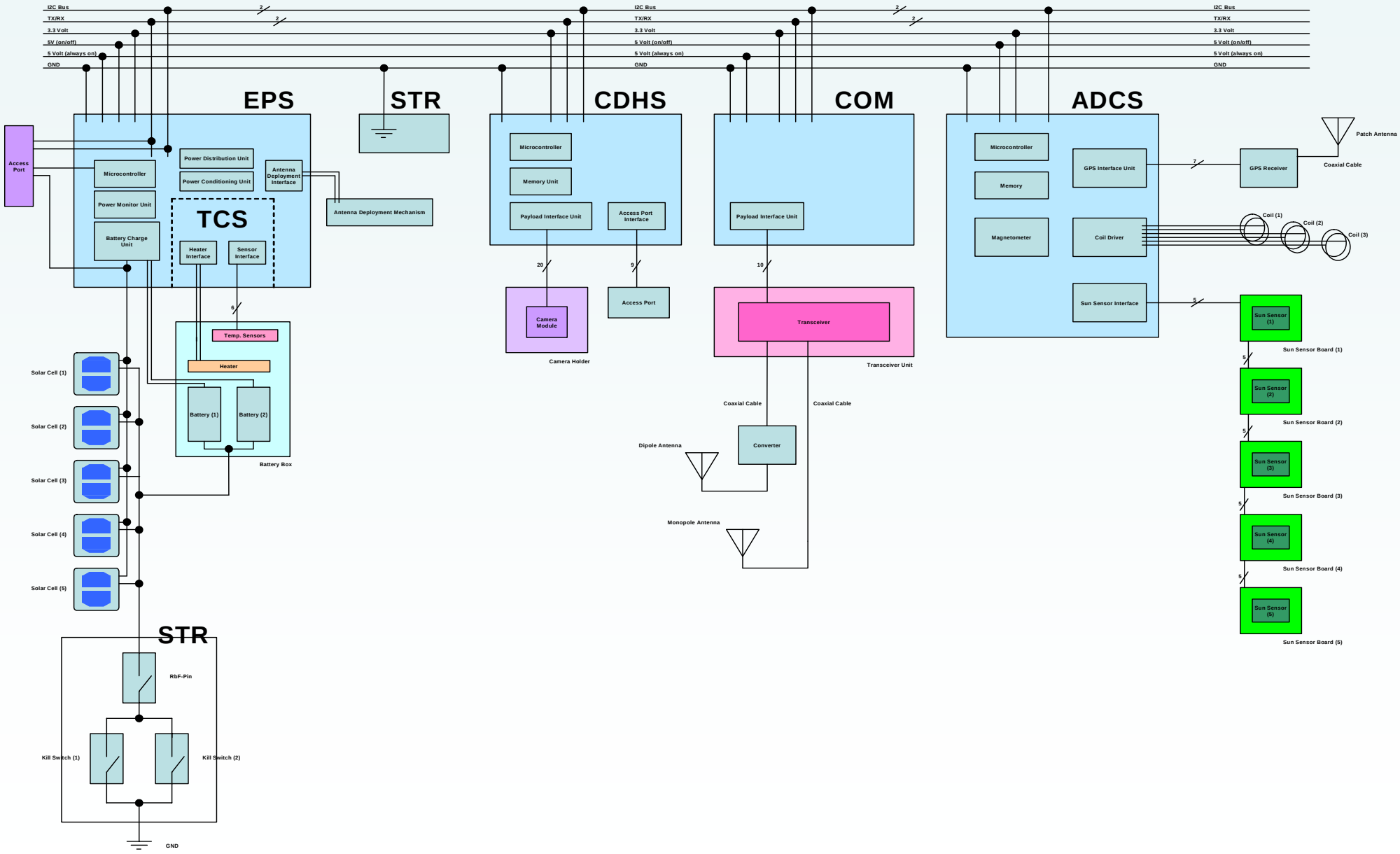







Attitude Determination and Control System
Structure and Mechanisms
Communication System
Electrical Power System / Thermal Control System
Command and Data Handling System

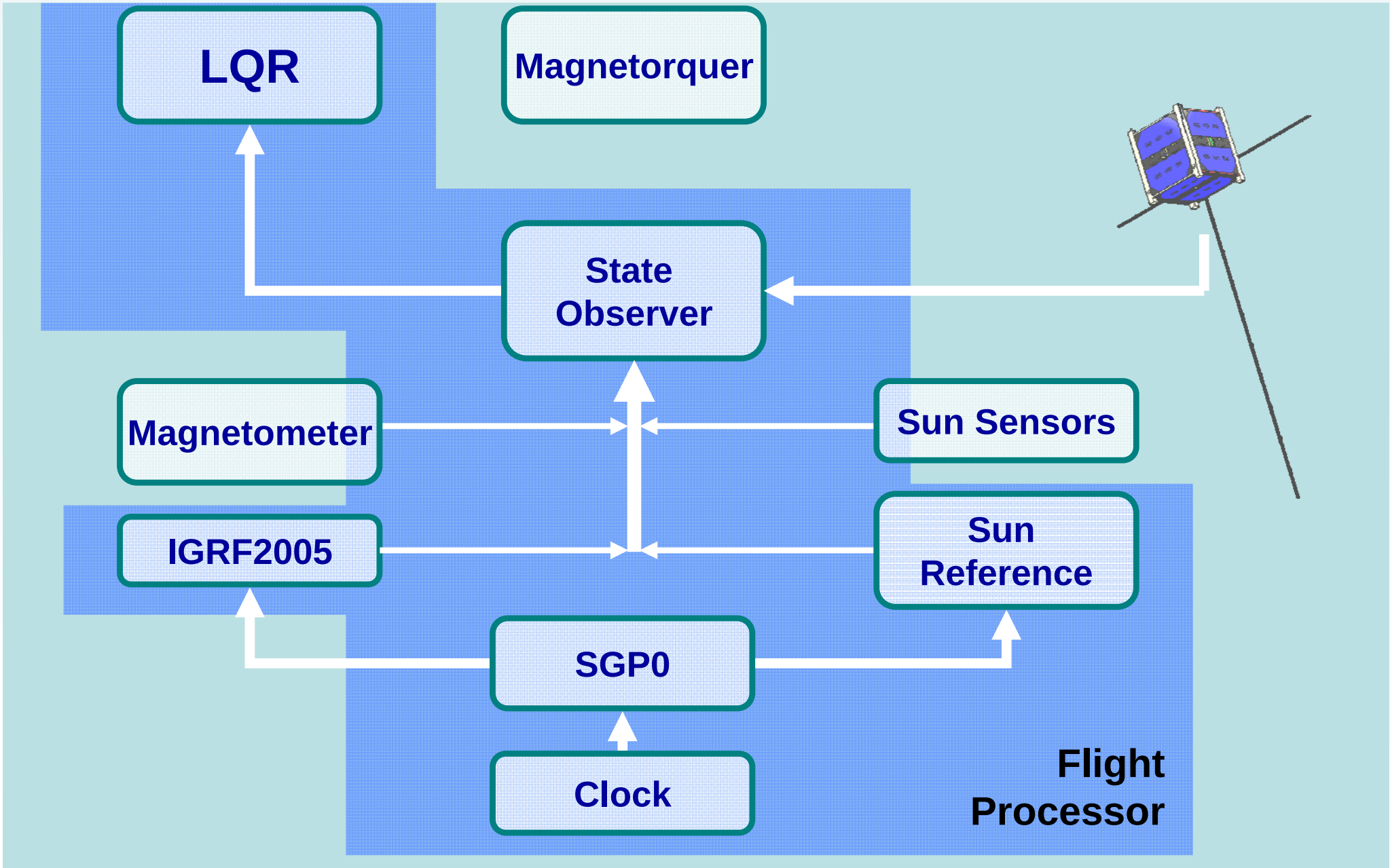
Satellite System Architecture



ADCS Requirements

- Detumble the spacecraft after launch interface separation and antenna deployment
- Determine the dynamic state of the spacecraft using on-board sensor measurements
- Maintain nadir-pointing attitude
- Gather and store housekeeping and engineering data
- Gather GPS telemetry data

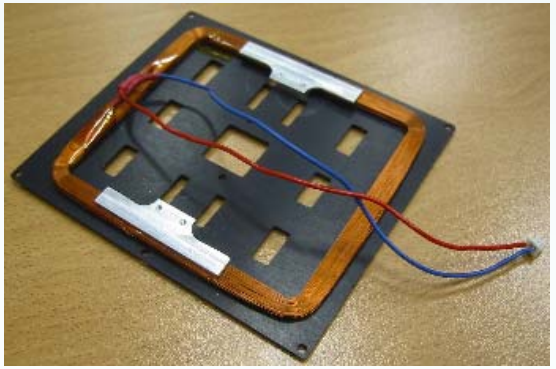
ADCS Concept



ADCS Development Status

Hardware:

- FM & FSM MCU Board & Magnetometer are ready
- FM Magnetorquer ready
- SunSensor hardware in progress



Software:

- Algorithms are encoded
- Low level hardware drivers are encoded

ADCS Outlook

Action Items:

- Calibration of Magnetometer
- Integration (software) of Phoenix GPS
- Update of simulation and parameters
- Programming and Calibration of SunSensors
- Verification of low-level hardware drivers
- Implementation of Watch-Dog Timer

Optional Upgrades:

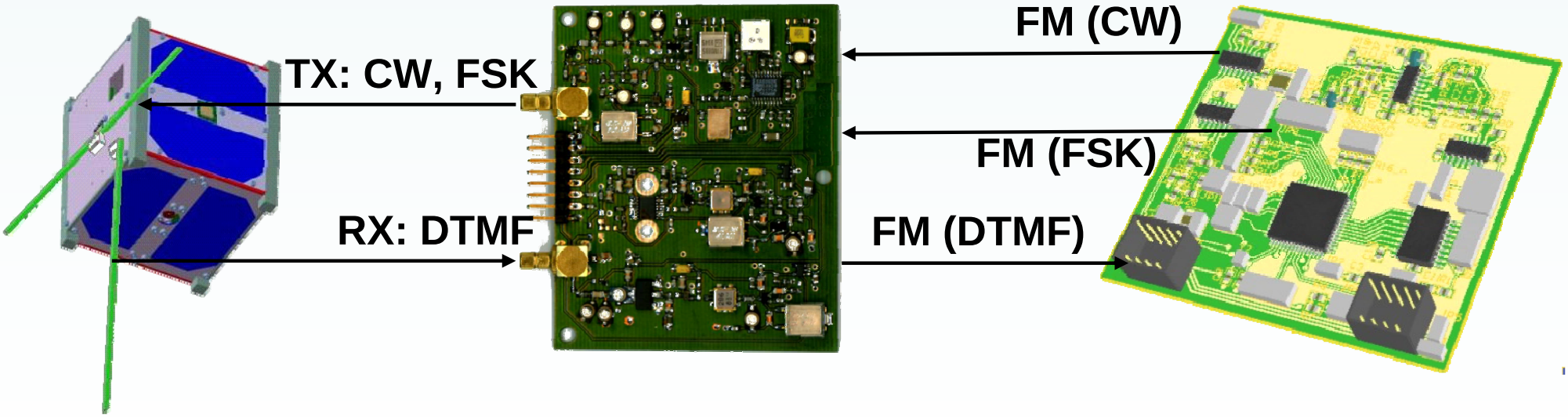
- none

COM Requirements

- 2-way noncoherent communication
- Use amateur frequencies (144MHz, 435MHz)
- Receive commands and data from ground
- Send data packets with 4k8 (9k6) baud rate
- Periodically send beacon

COM Concept

- The backbone of the communication system is the rf transceiver that modulates the low frequency signals (FSK and CW) onto the designated amateur carrier frequency and vice versa.
- The antennas are adjusted to the designated rf wave lengths
- Reception of DTMF and FSK modulation is realized through ICs.



Communication Architecture

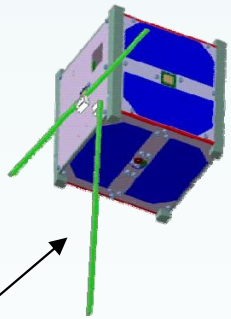
Uplink (DTMF)

- Set time
- Upload OLE
- Update LQR
- Request image [new or stored]
- Request HK, XHK
- Request GPS Data
- Switch ADCS mode [Control, Safe, GPS, Detumbling]

* Switch TX on/off
* Resend packet [start, number]

Downlink (CW beacon)

- beacon data



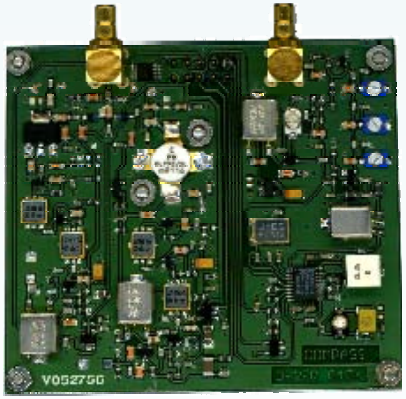
Downlink (FSK)

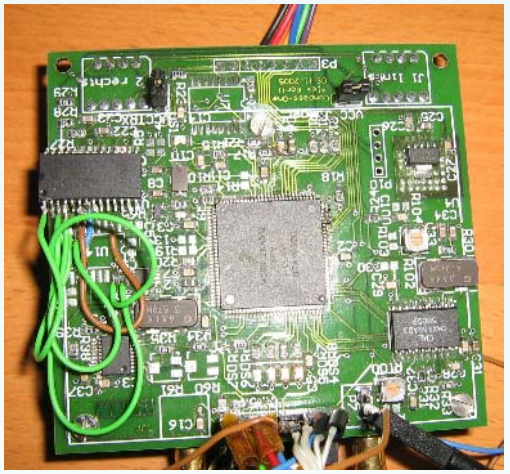
- Housekeeping (256 Bytes)
- extended HK (300 Kbytes)
- GPS data (300 Kbytes)
- Image (300 Kbytes)

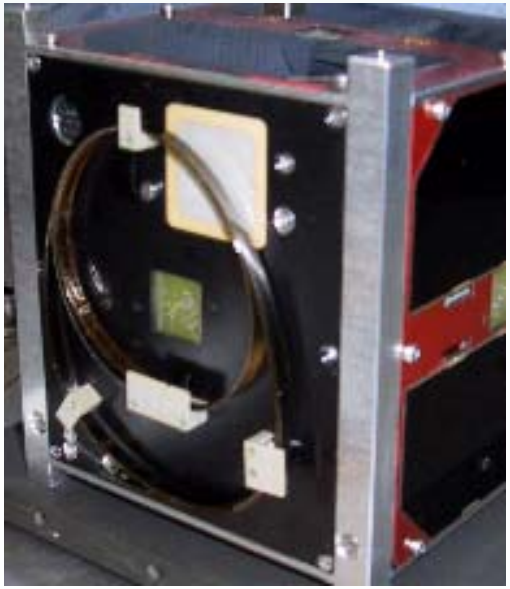
COM Development Status

Hardware:

- EM Board is functionally working (4k8)
- FM/FSM in progress
- EM Transceiver ready
- FM Transceiver in progress
- FM Antennas ready







Software:

- Hardware drivers are coded
- System-level communication is ready

COM Outlook

Action Items:

- Calibration of COM FM to FM Transceiver
- Implementation of software on system level
- Implementation of Watch-Dog Timer

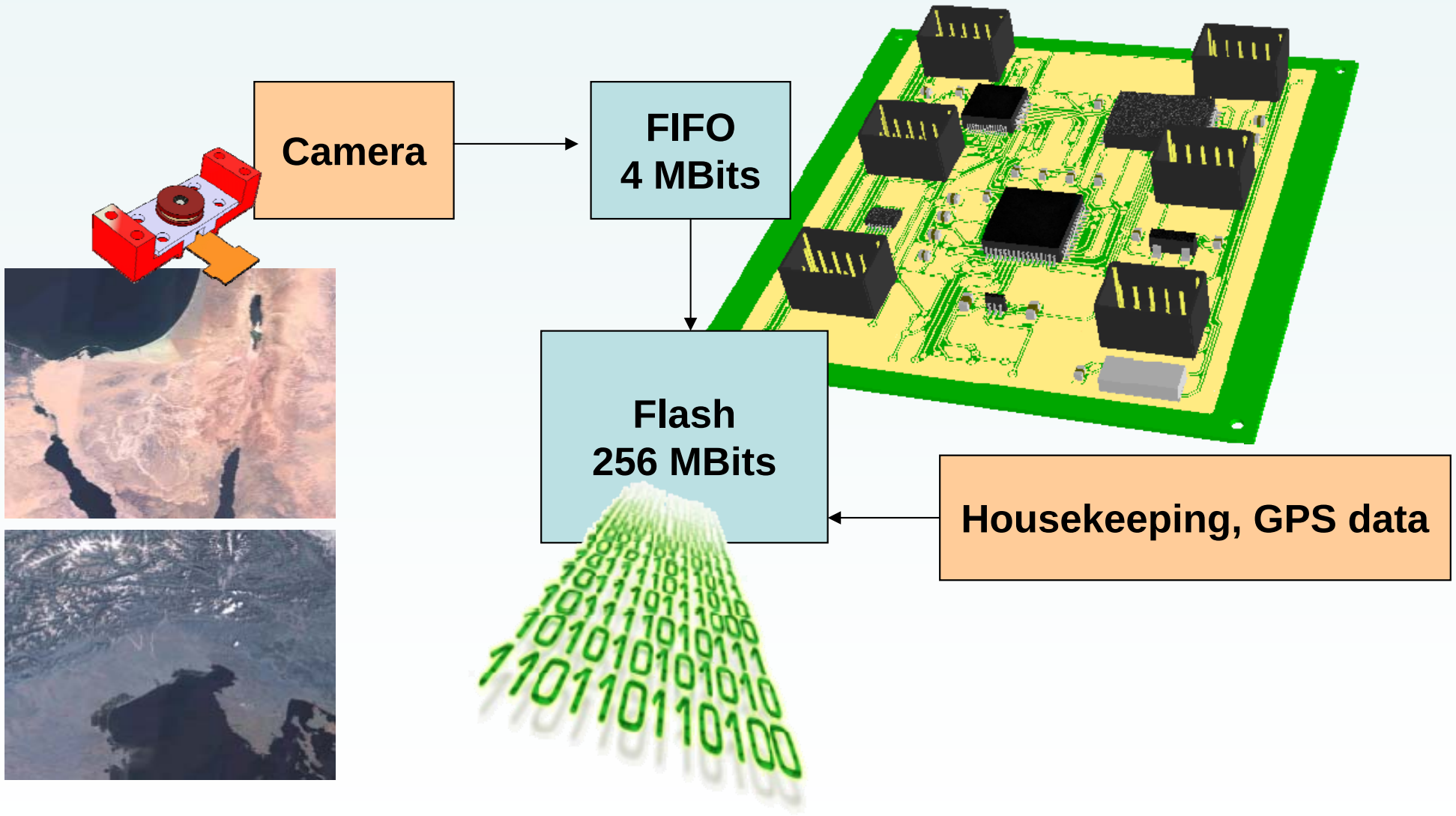
Optional Upgrades:

- Improve modem baud rate from 4k8 to 9k6

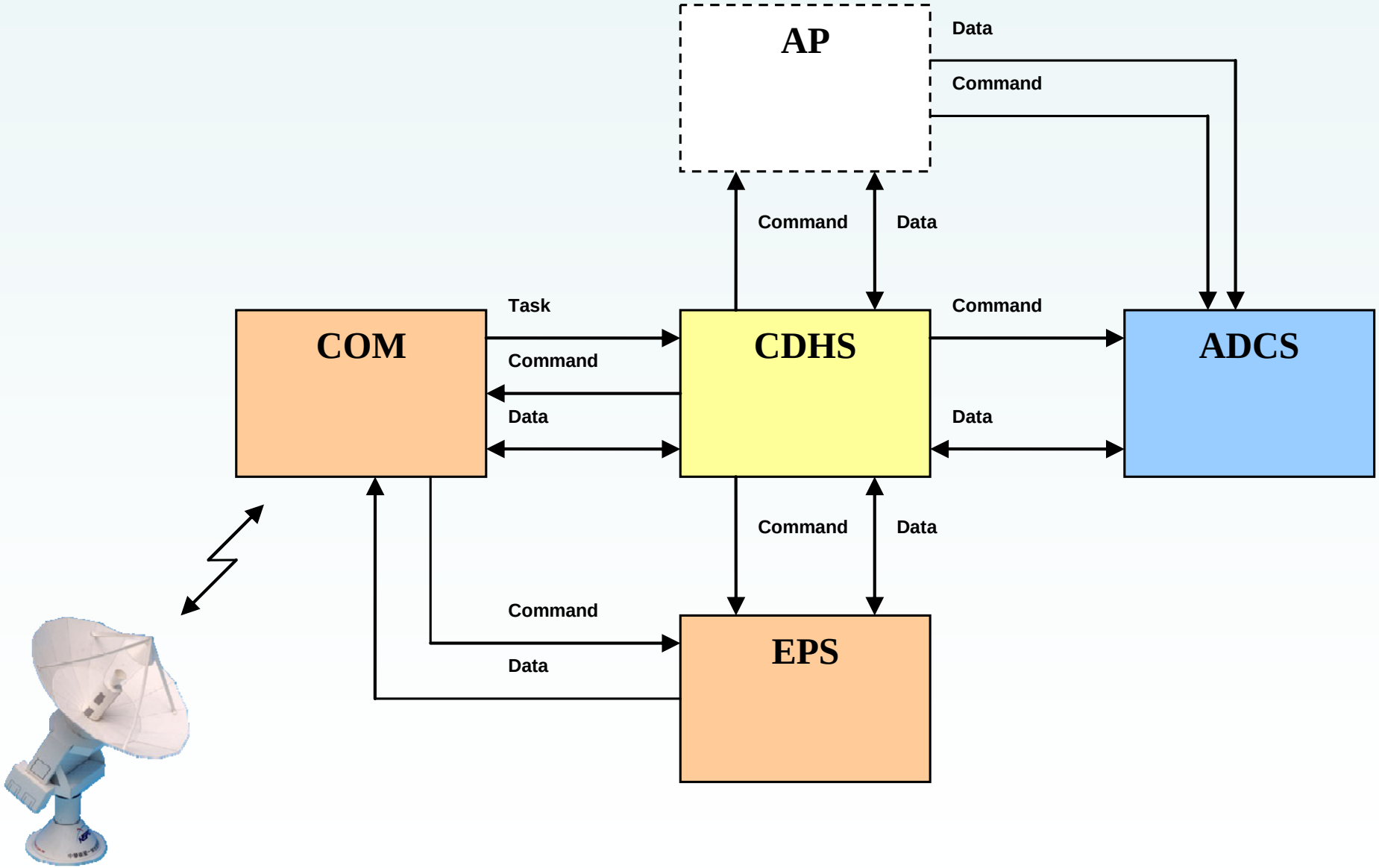
CDHS Requirements

- Receive the tasks from ground station via COM system
- Execute mission tasks and store payload data
- Gather and store housekeeping data

CDHS Concept



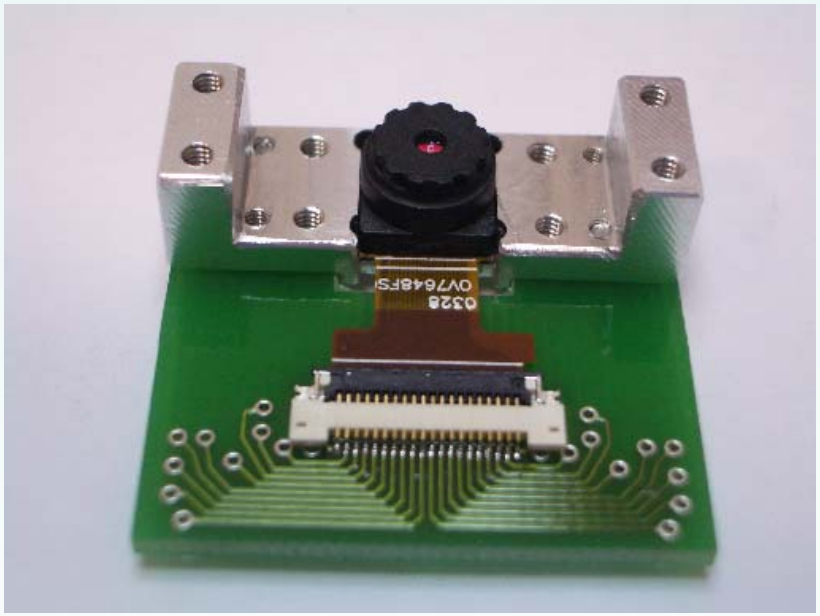
Internal Communication Architecture



CDHS Development Status

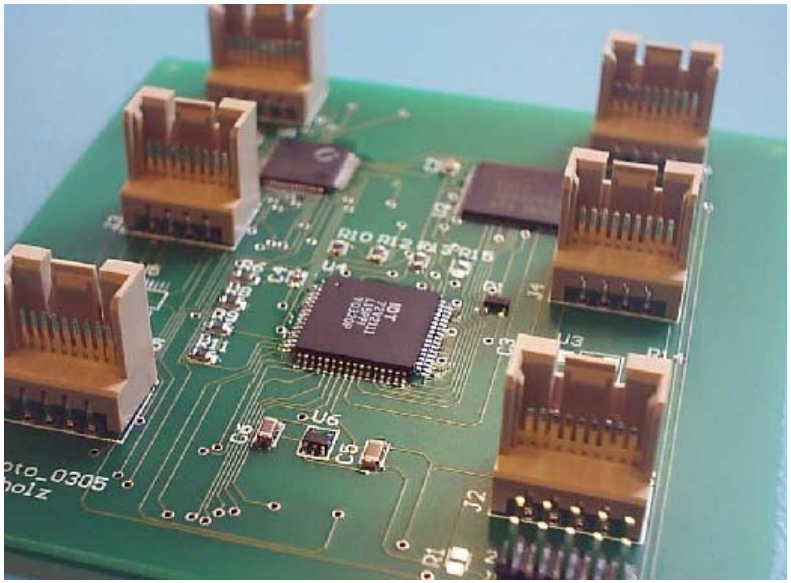
Hardware:

- EM, FM and FSM ready
- Payload (Cam) interface ready



Software:

- Software is encoded and tested



CDHS Outlook

Action Items:

- Implementation of Watch-Dog Timer

Optional Upgrades:

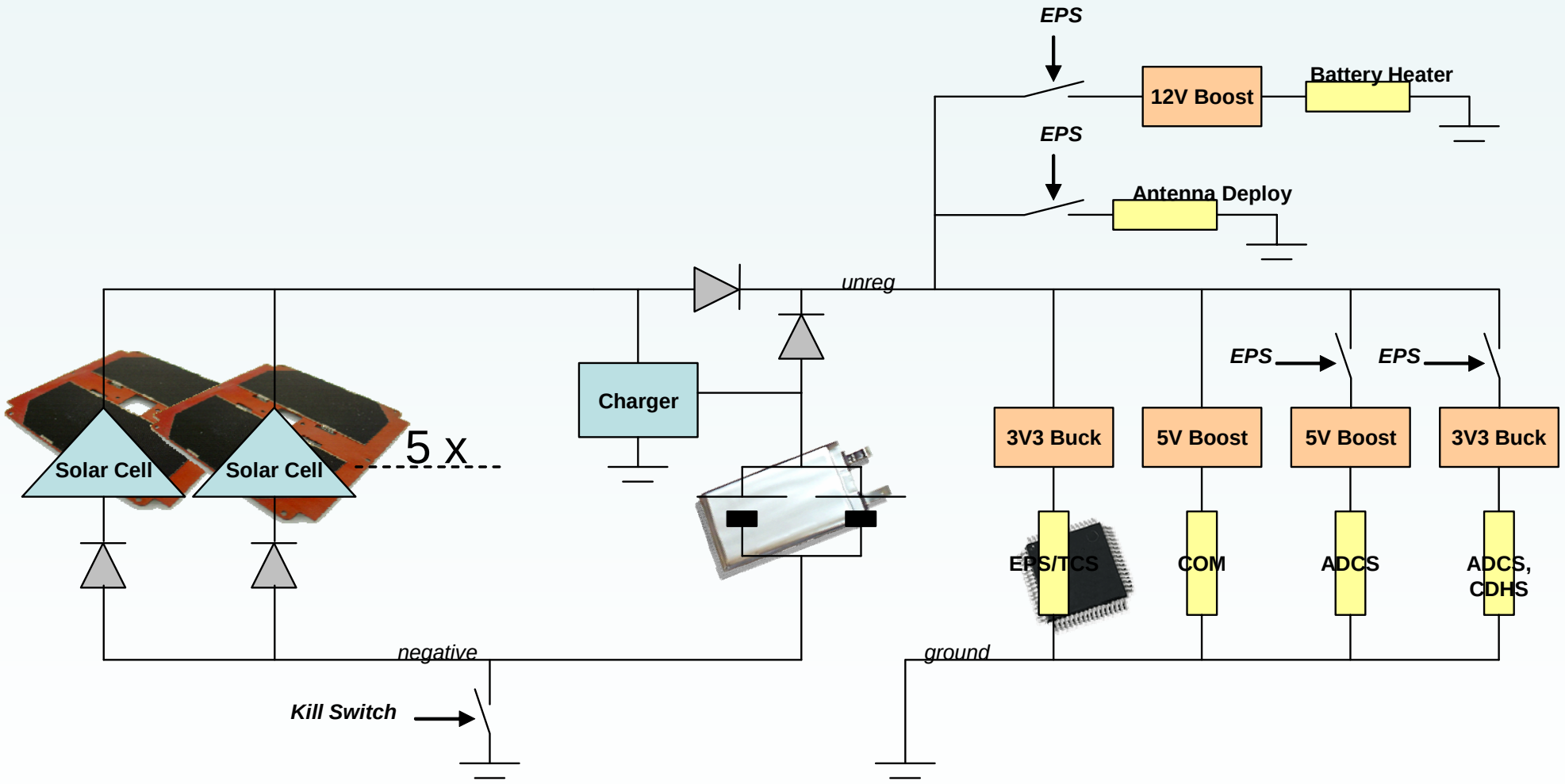
- Implementation of ‘task scheduler’
- Error detection and correction
- Image compression

EPS/TCS Requirements

- Supply bus voltages of 3.3 and 5 Volt
- Allow current flows up to 2 Ampere
- Monitor current, voltage and temperatures
- Cut-off loads when battery is low (Powersafe)

- Maintain components within their temperature limits

EPS/TCS Concept



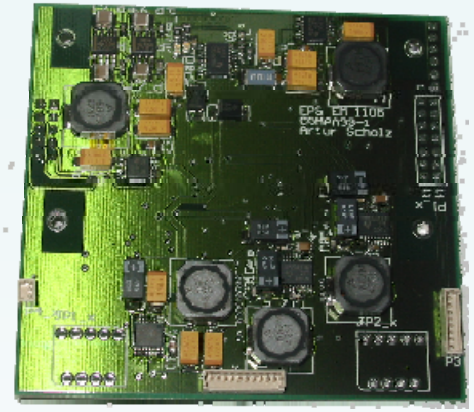
EPS/TCS Development Status

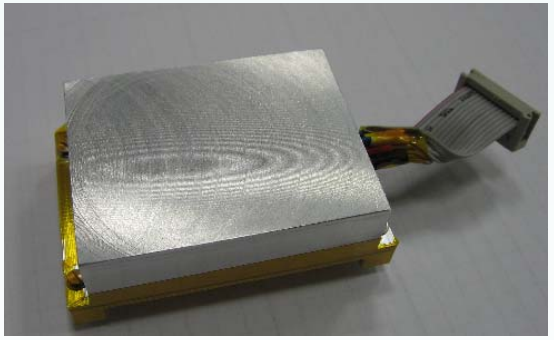
Hardware:

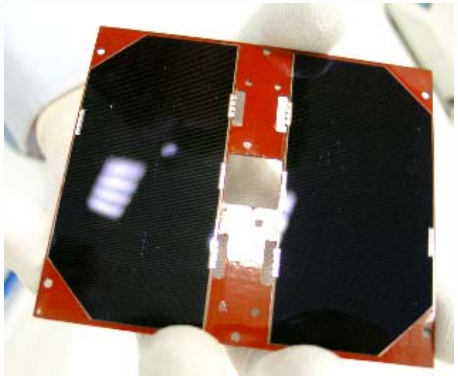
- EM, FM & FSM ready
- EM Battery Box ready and tested
- EM and FM solar cells integrated

Software:

- EM and FM software coded and tested
- WatchDog timer integrated and tested







EPS/TCS Outlook

Action Items:

- Build FM battery box

Optional Upgrades:

- Fix Single-Event Latch-Ups
- Control heater mode through ground commands

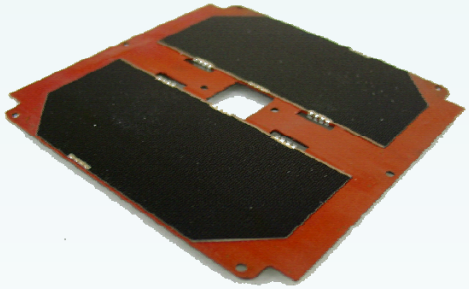
STR Requirements

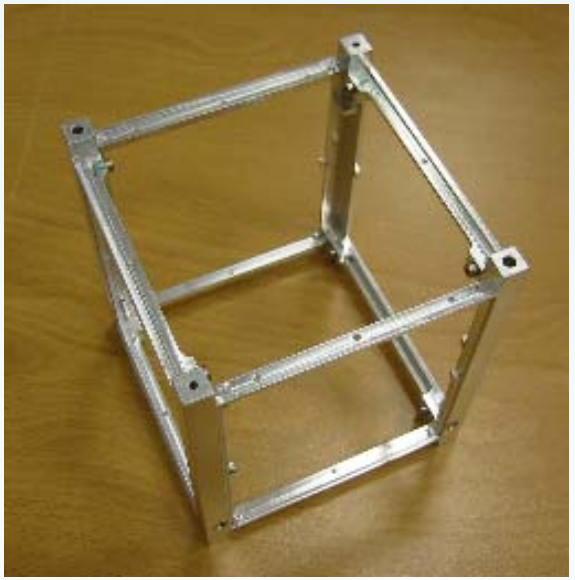
- Anodized 6061 aluminum frame
- Cubic shaped according to Cubesat specification
- Kill Switch and Remove before Flight Mechanism
- Antenna Deployment
- Stringent center of mass requirements and optimized inertial moments

STR Development Status

Structure:

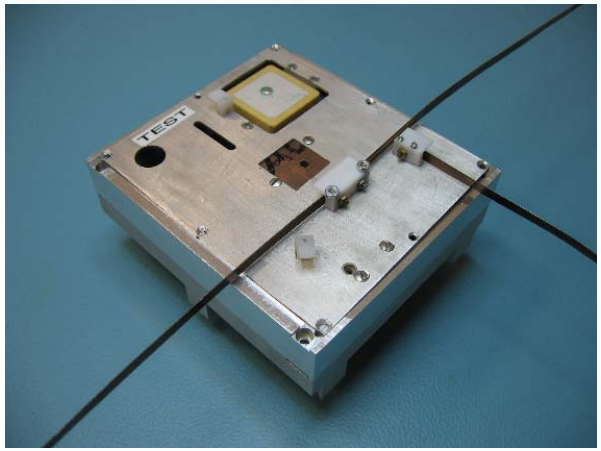
- EM ready
- FM structure ready
- FM sides ready
- FM parts in production





Mechanisms:

- All mechanisms developed and successfully tested



STR Outlook

Action Items:

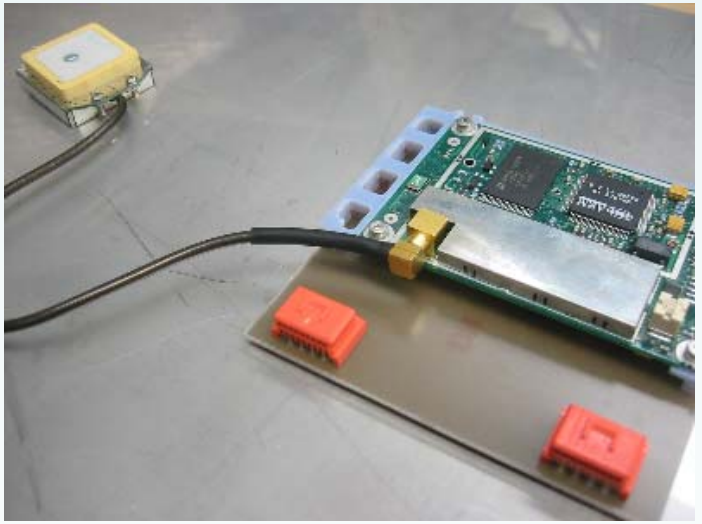
- Integration of mechanisms on side 1
- Integration of antennas on side 1

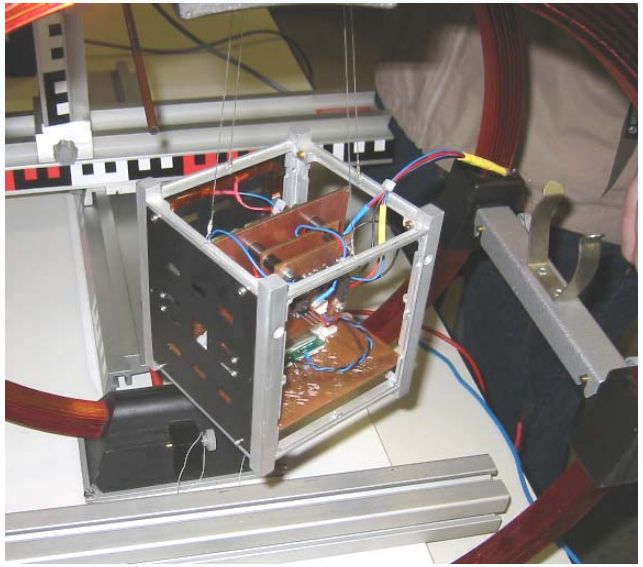
Optional Upgrades:

- none

ADCS Functional Testing

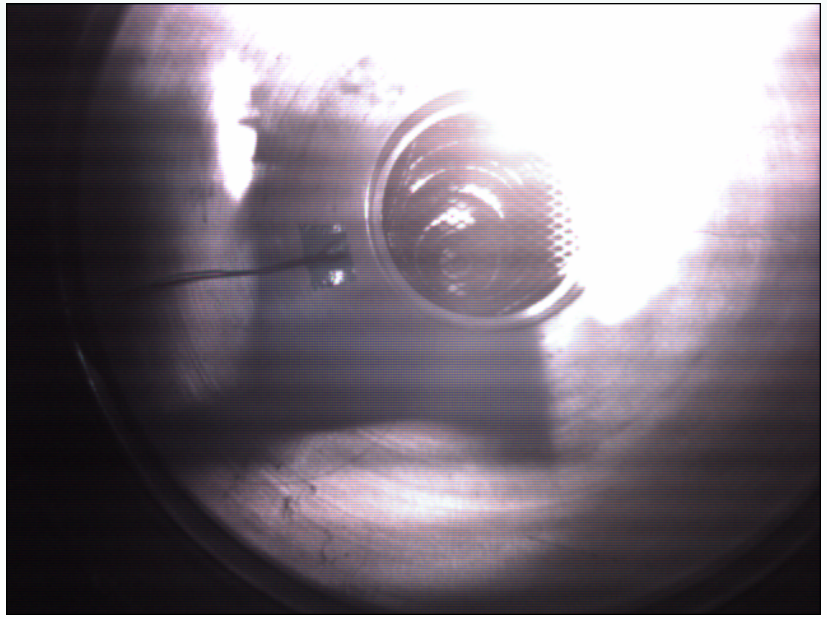
- A GPS stand-alone test has been carried out
- Coil driver test and tuning
- Verification of orbit propagation algorithm and reference vectors
- Functional demonstration of Actuators





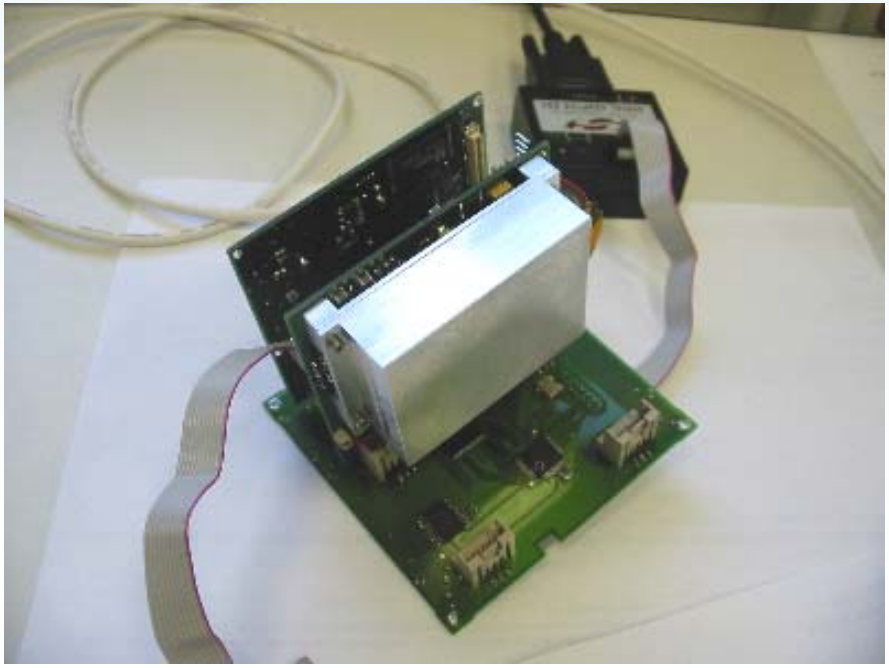
CDHS Functional Testing

- Through the Access Port Interface, virtually all commands and tasks can be tested on ground
- The data transfer and subsystem communication was examined and verified from low hardware level to software level



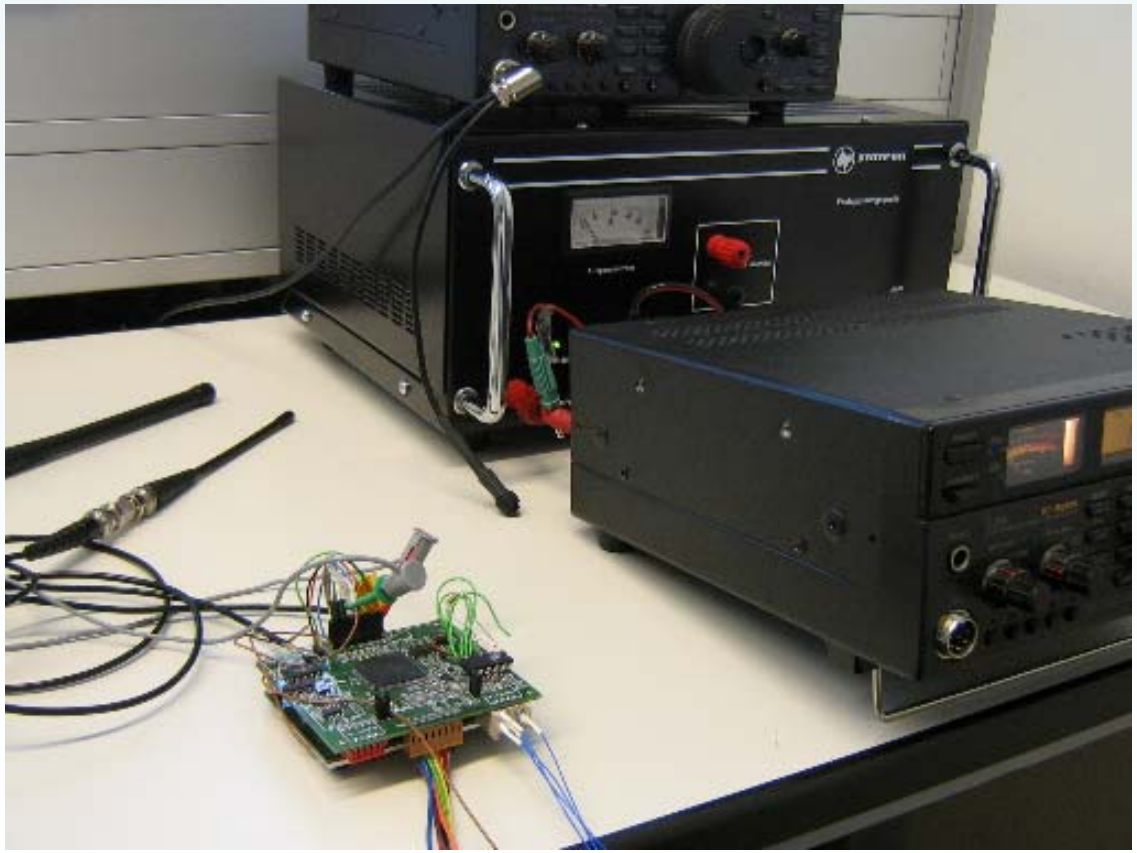
EPS/TCS Functional Testing

- Correct battery charging through solar cells was verified
- Recovery of frozen (-18°C) and deep discharged battery (<1 Volt) was verified
- Functionality of Heater system was tested
- Measurements (temperature, current and voltage) of EPS/TCS were verified



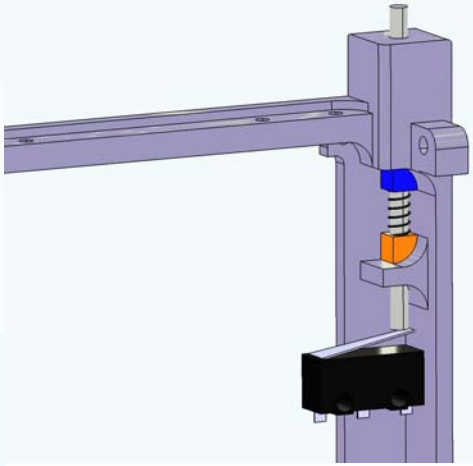
COM Functional Testing

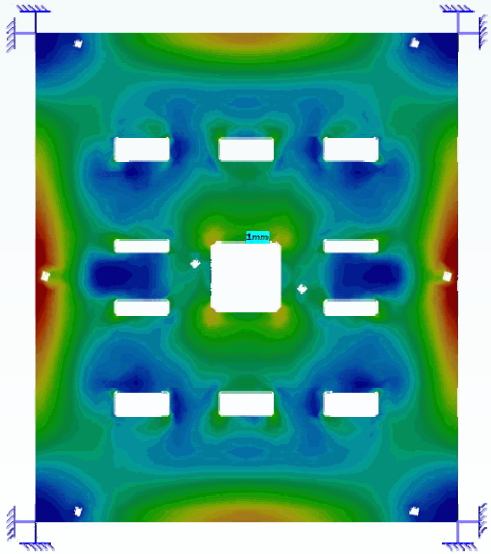
- Correct reception and interpretation of DTMF commands was verified
- Sending of FM packets was verified

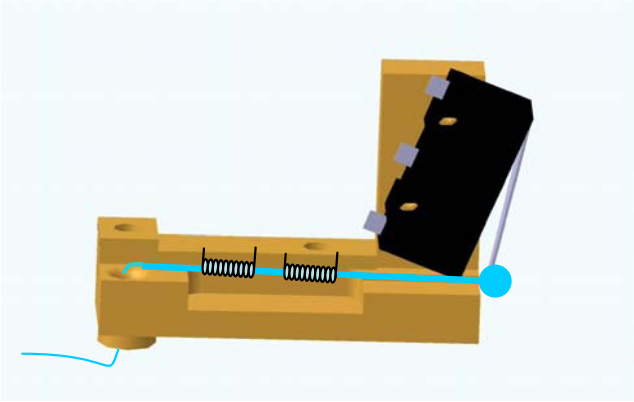


STR Functional Testing

- Antenna deployment was verified
- Kill Switch and RbF Switch were verified
- Vibration tests on component level were carried out to confirm the structural FEM analysis

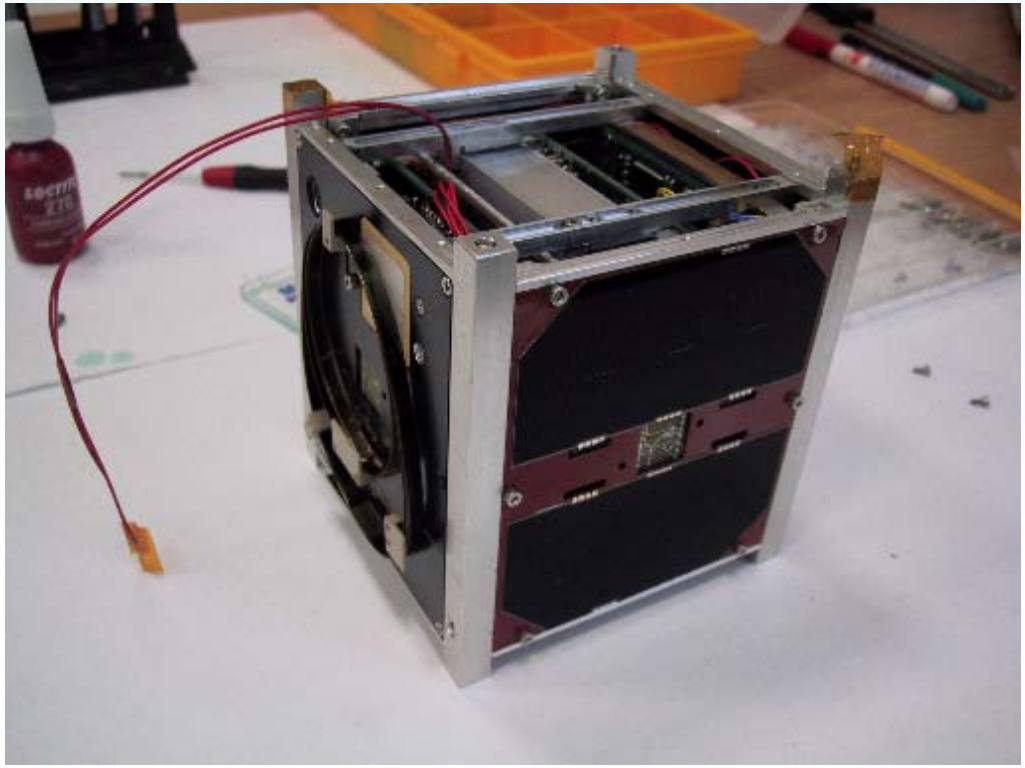






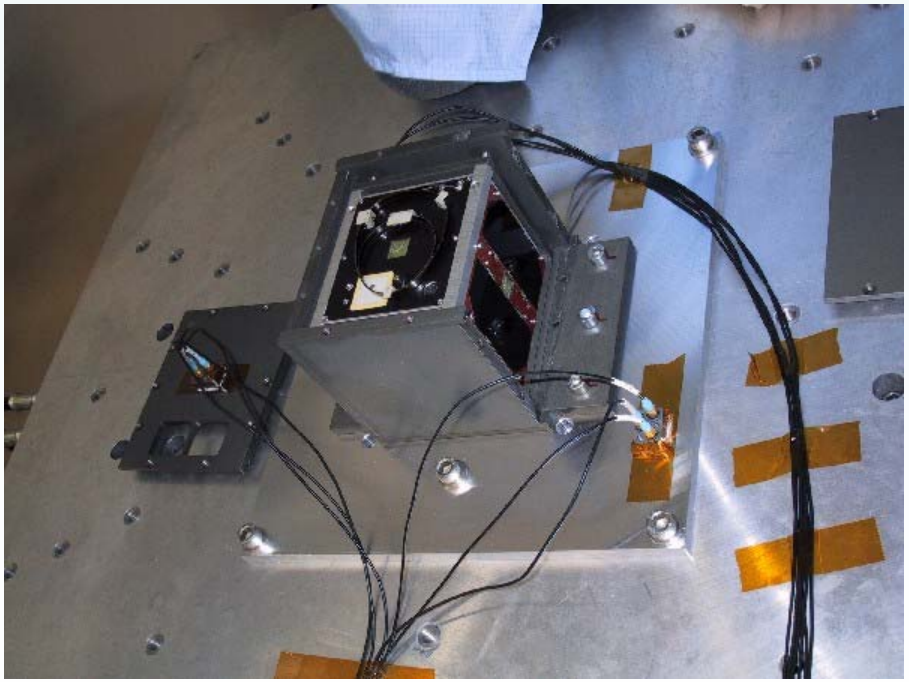
Satellite EM Integration

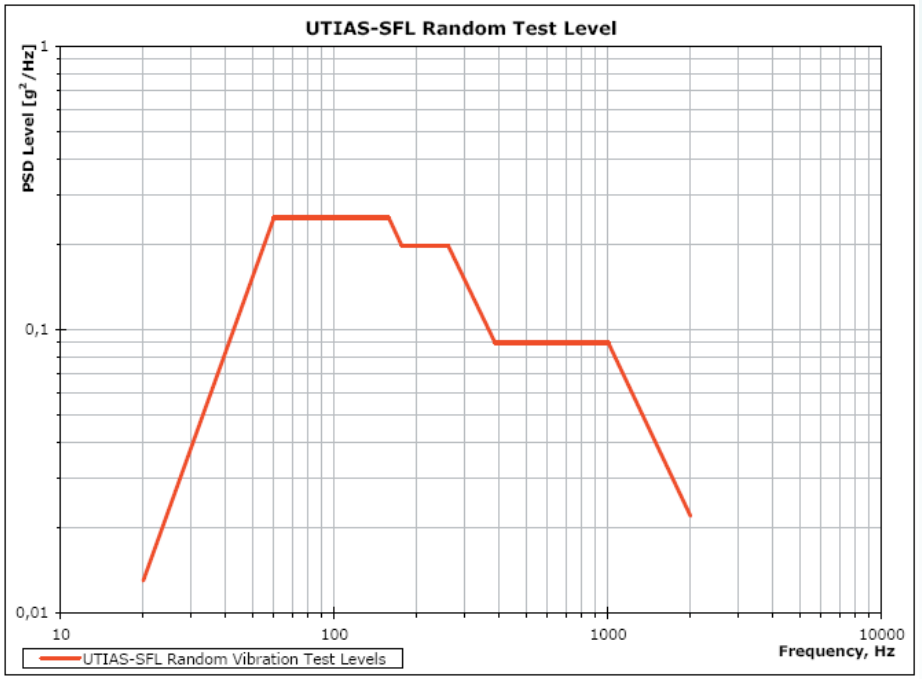
- The EM of COMPASS-1 for the conduction of the qualification tests was made up by the EM subsystems and mass dummies.
- A list of necessary modifications that became evident during assembly was produced and implemented in the development of the FM.

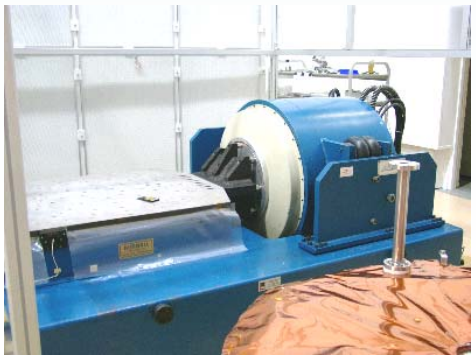


Vibration Test

- Qualification Levels (DNEPR, UTIAS) have been used for EM
- Resonance frequencies should determined and satellite was tested for survivability
- Test were carried out at CSL

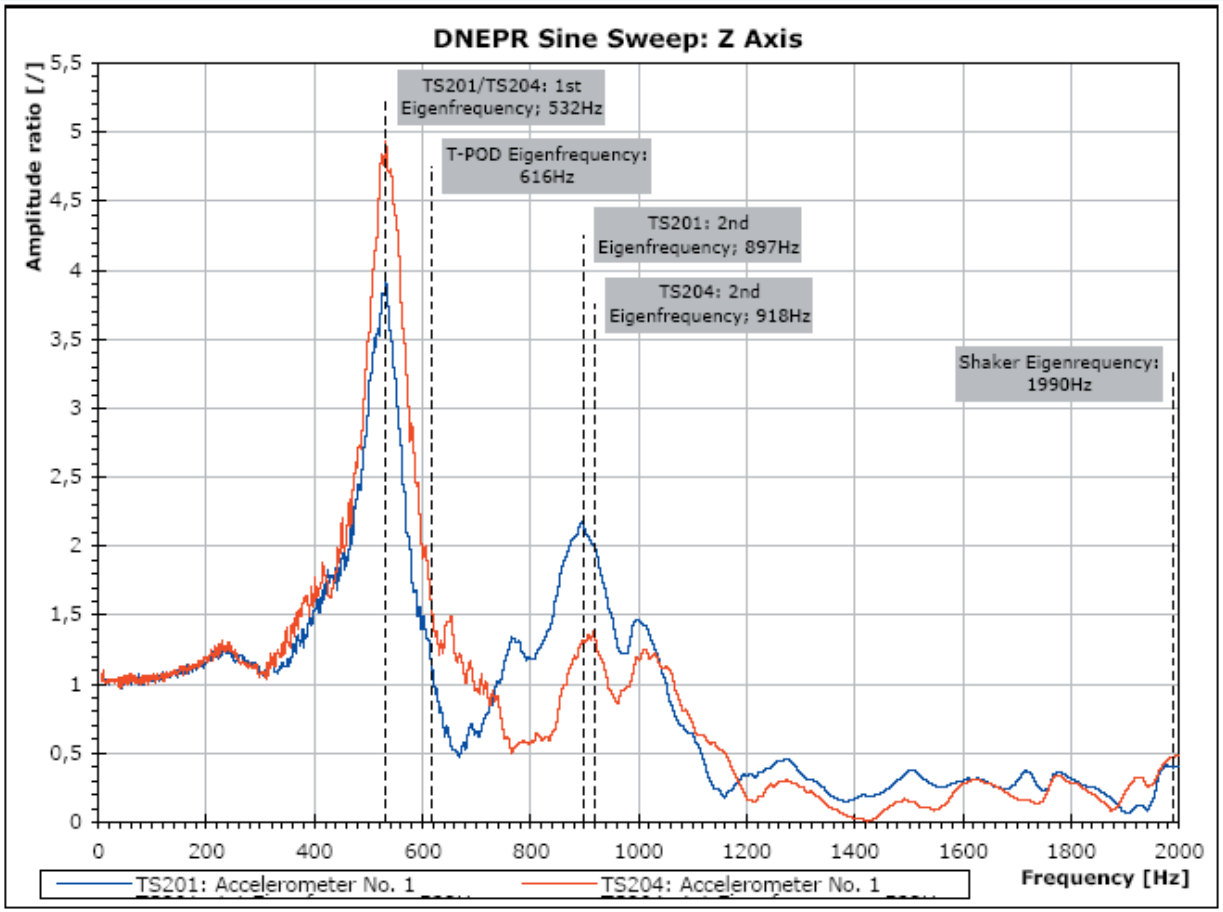


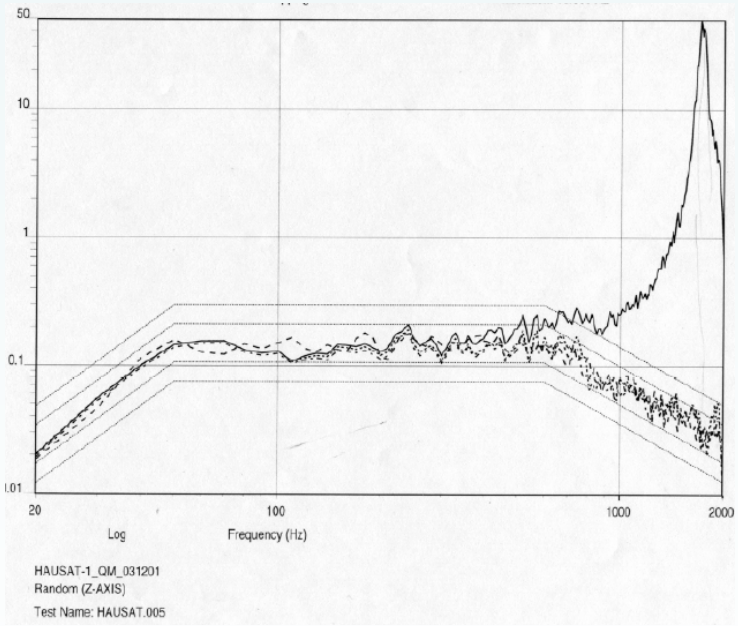




Vibration Test Results

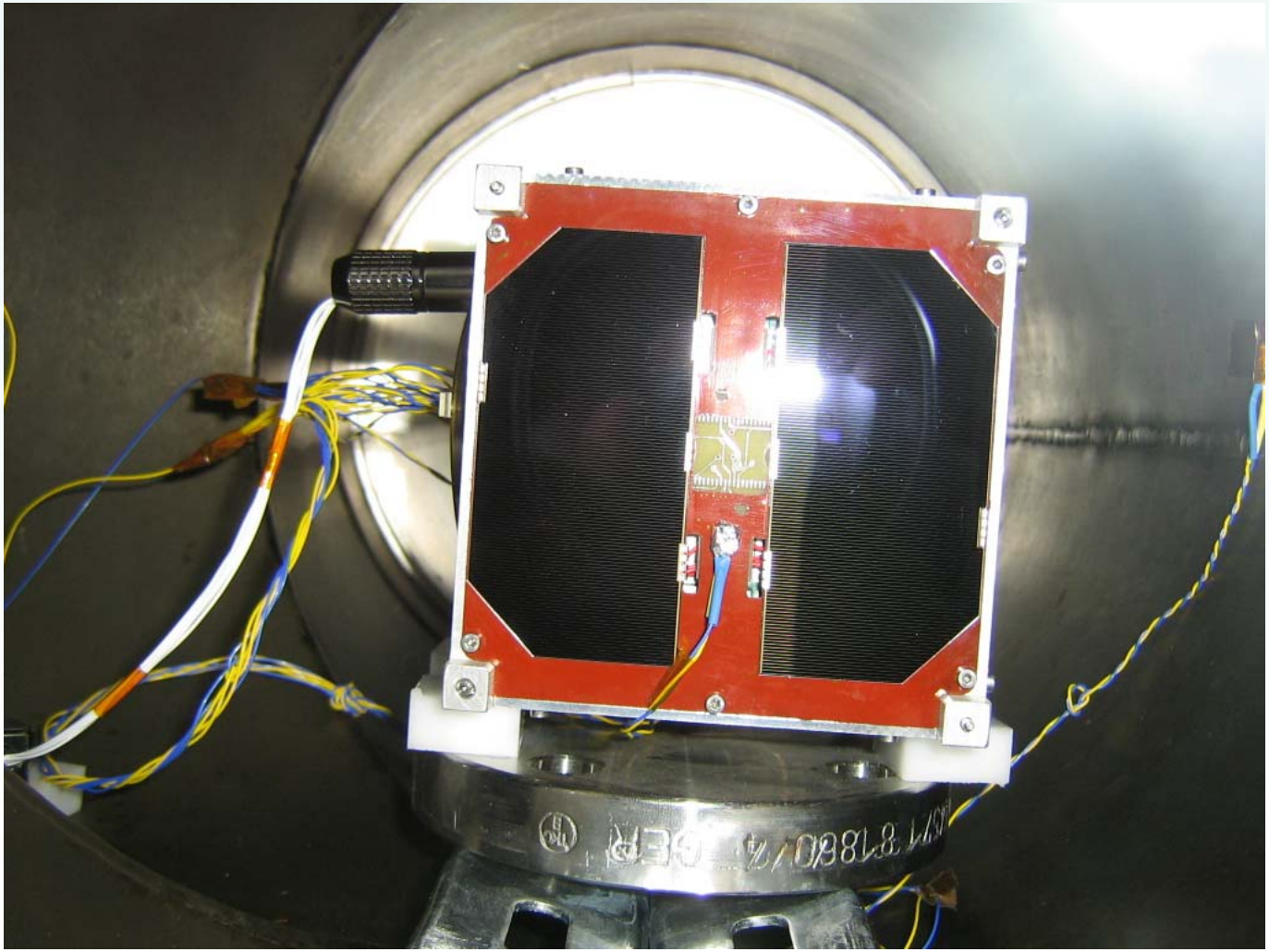
- Satellite survived without malfunctions
- Resonance frequencies for all axis are well above 35 Hz (as required by NASA)



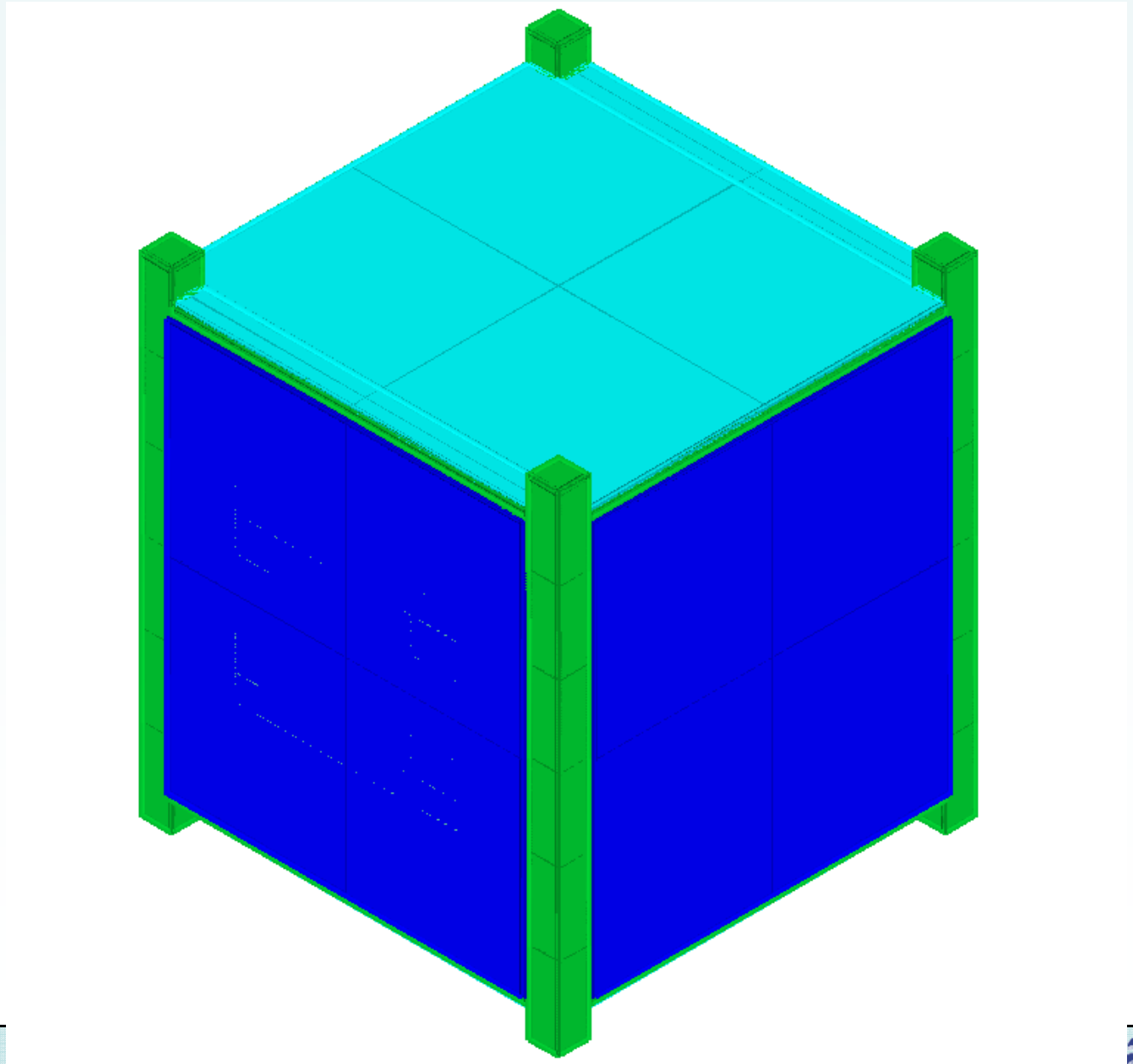


Thermal Test

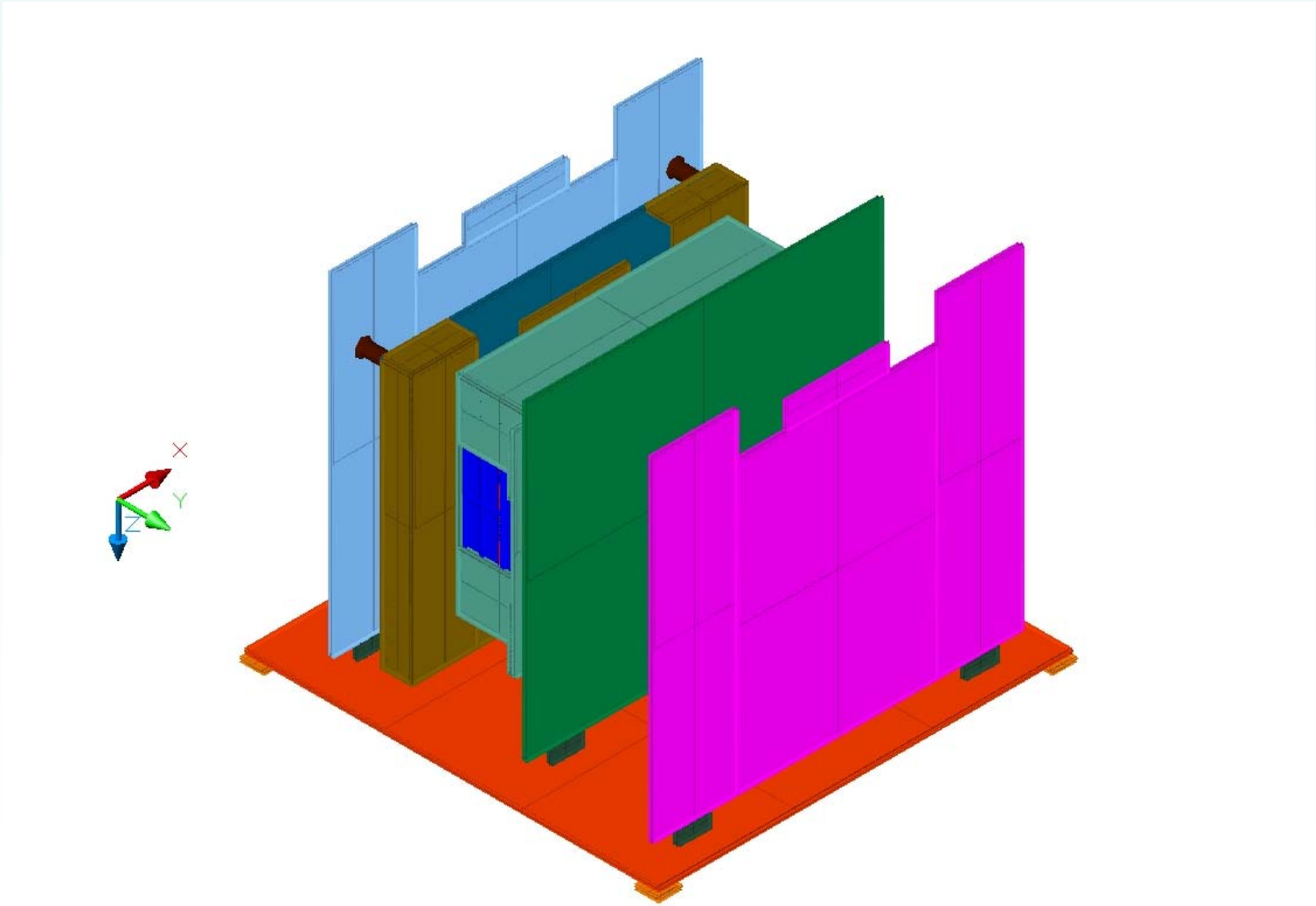
- A modified thermal test was conducted to compare results from numerical analysis with real measurements



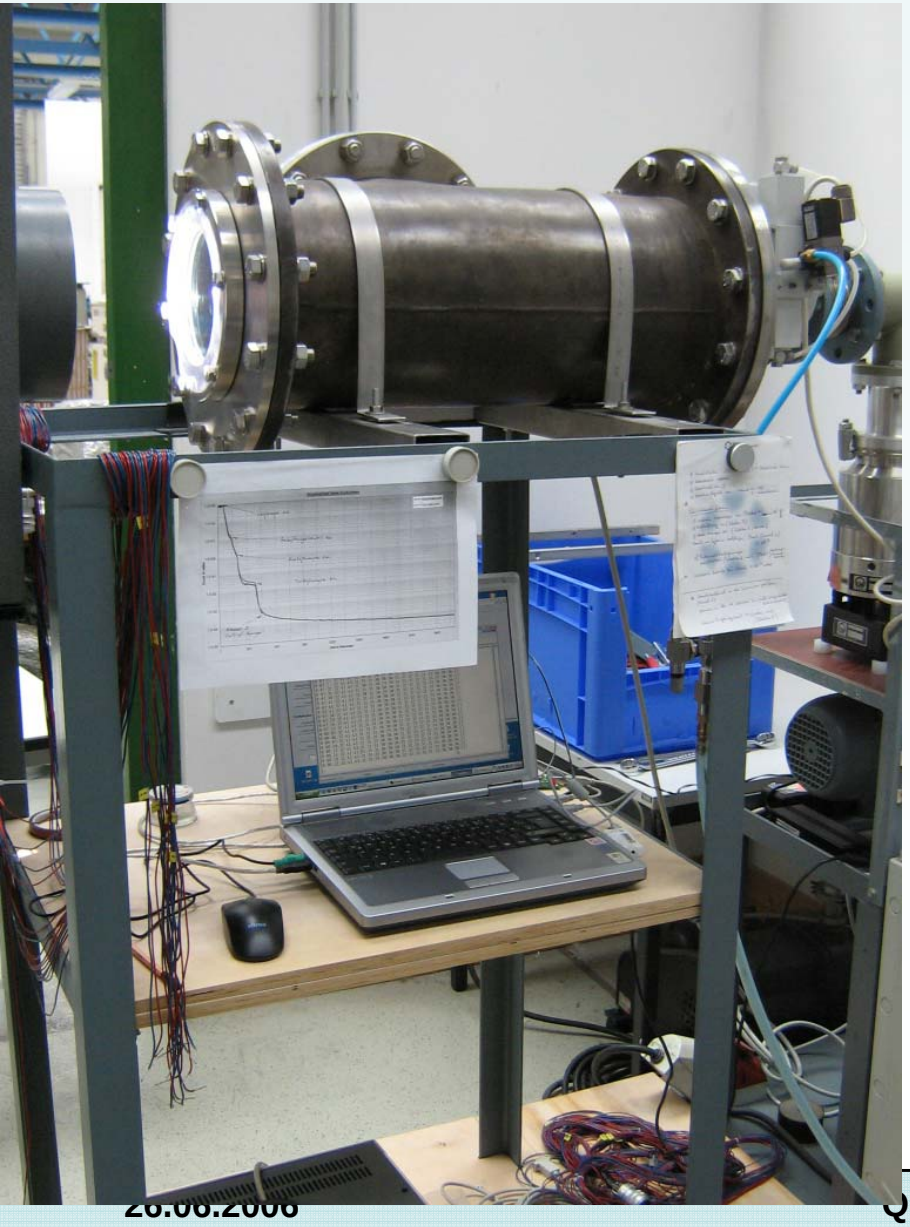
Exterior of Compass1 (Thermal Desktop 4.7)

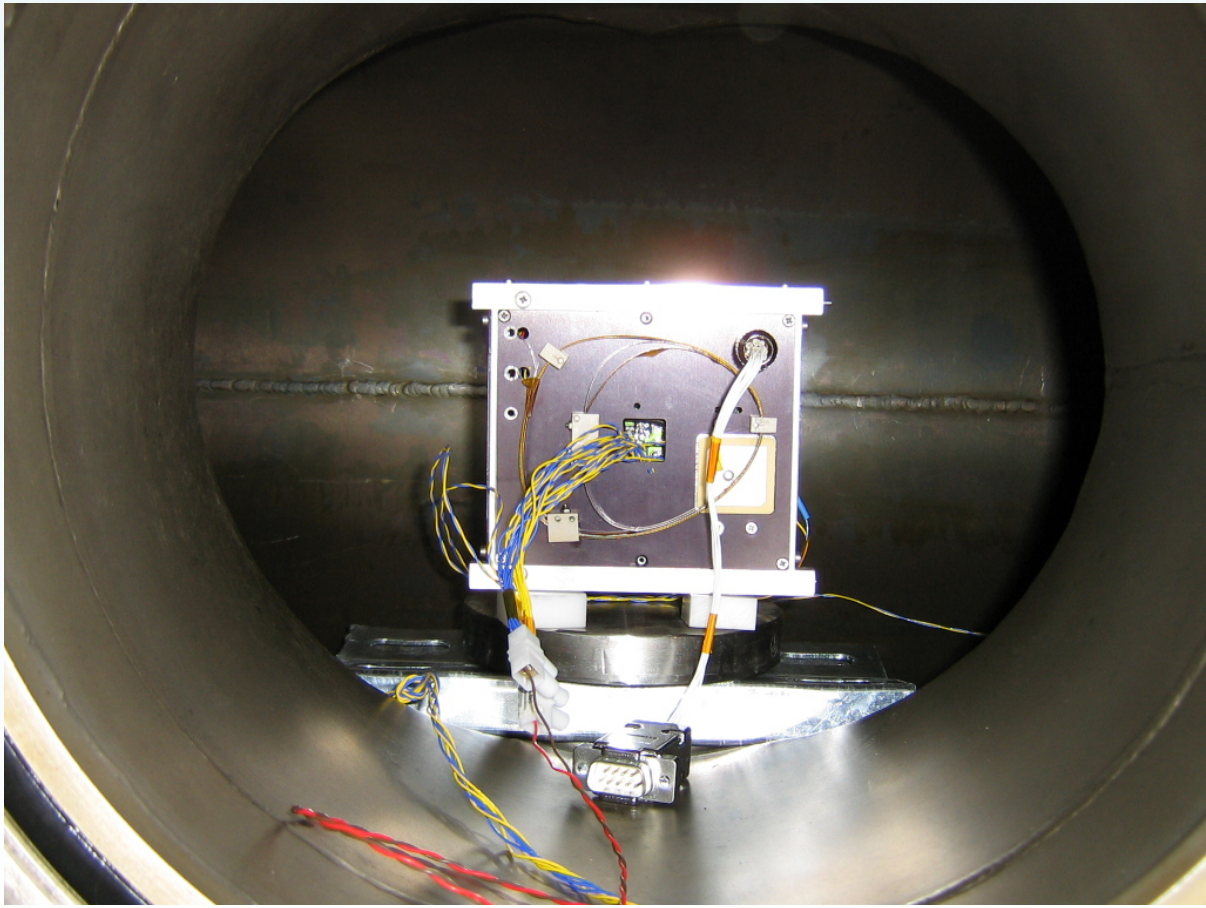


Interior of Compass1 (Thermal Desktop 4.7)

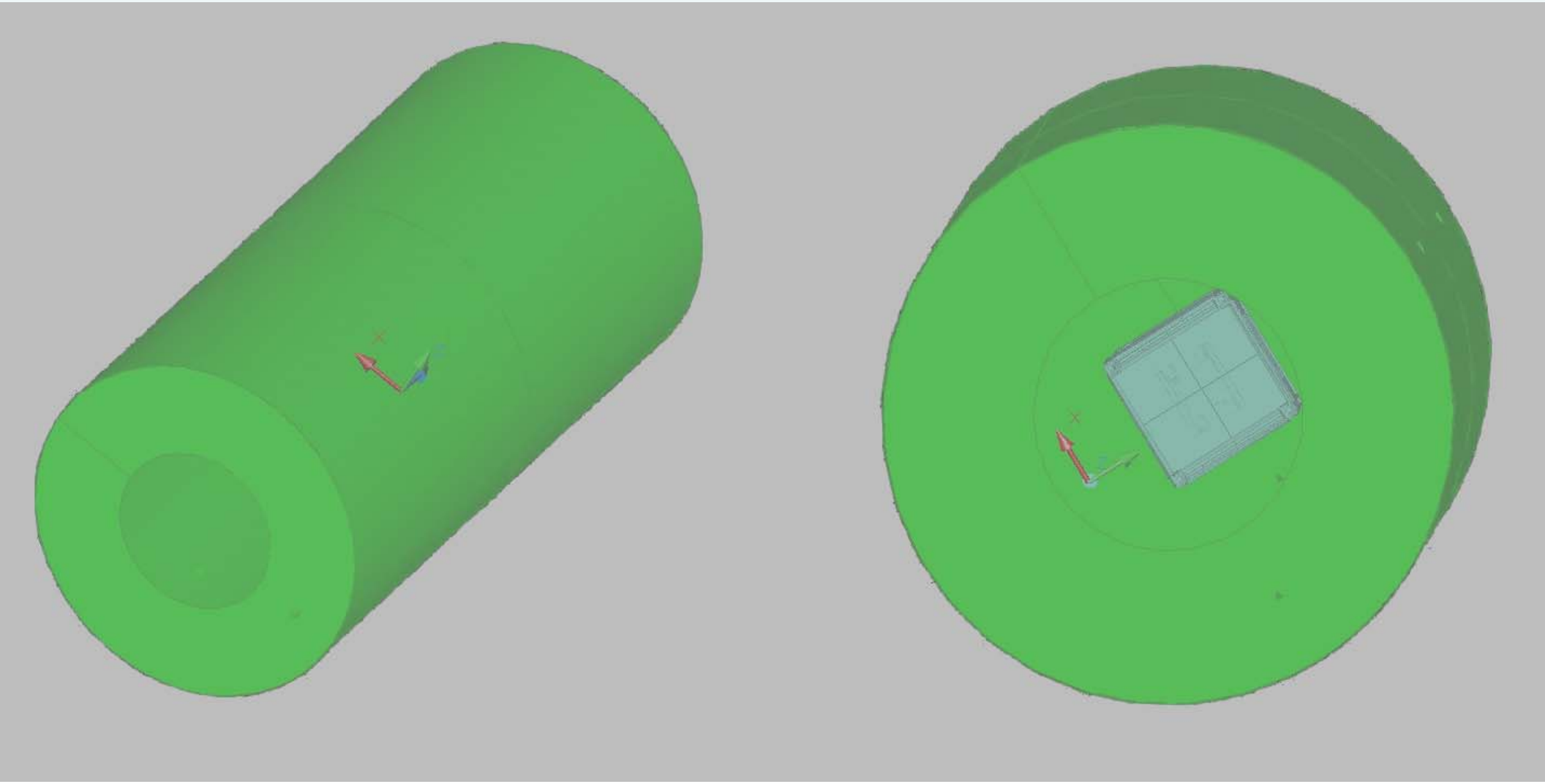


Vacuum Chamber FH-Aachen

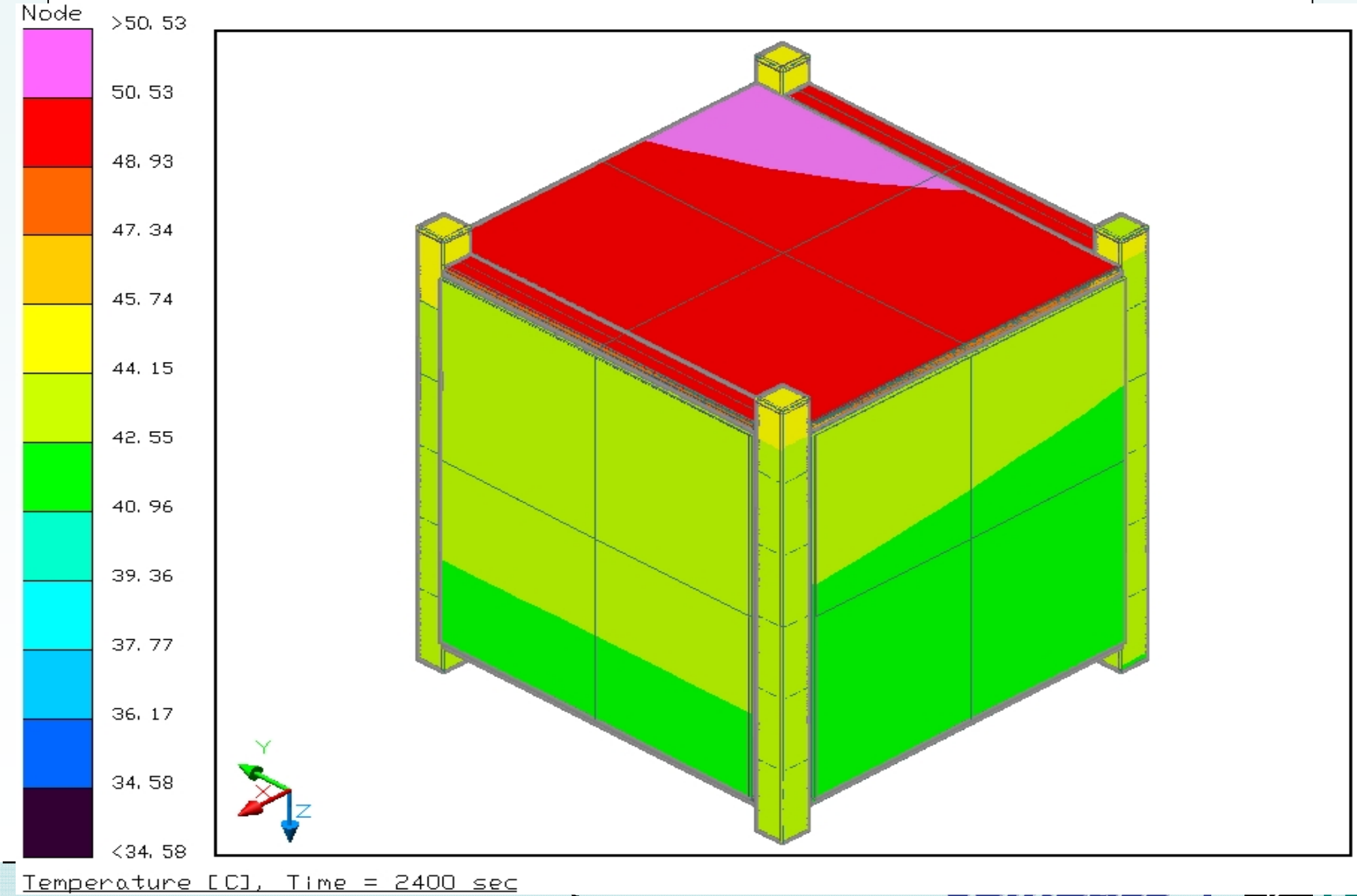




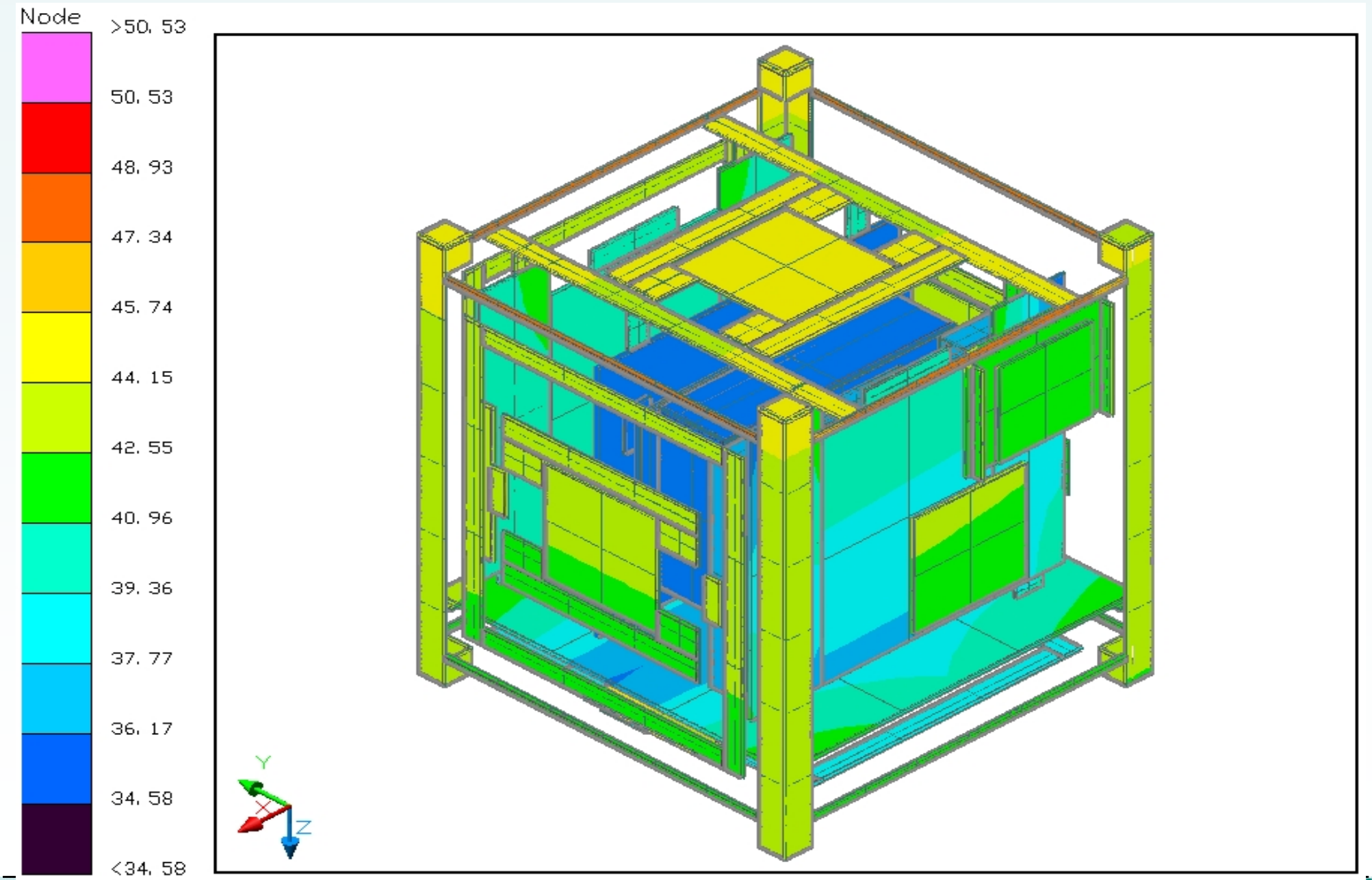
Vacuum Chamber in Thermal Desktop

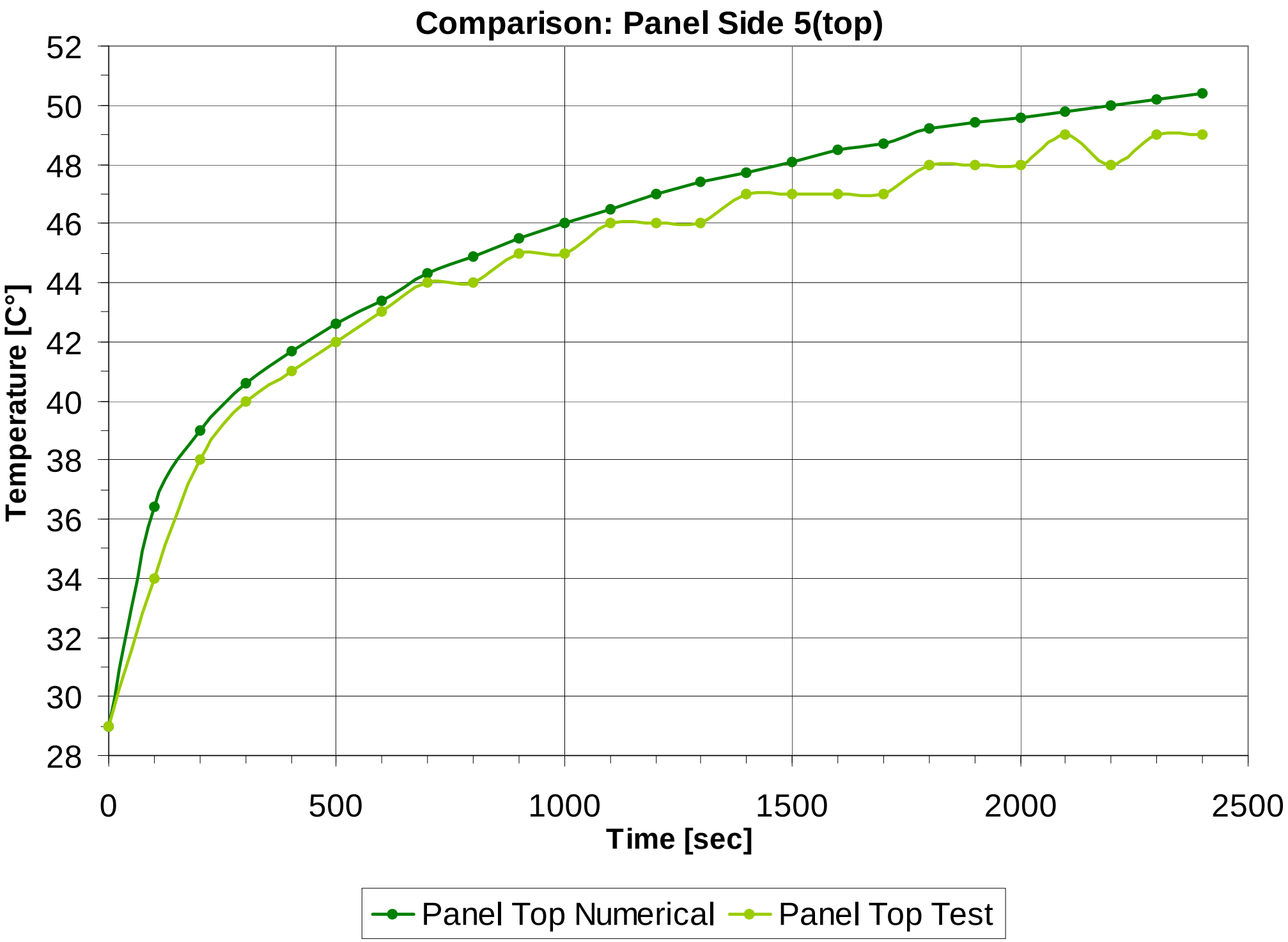


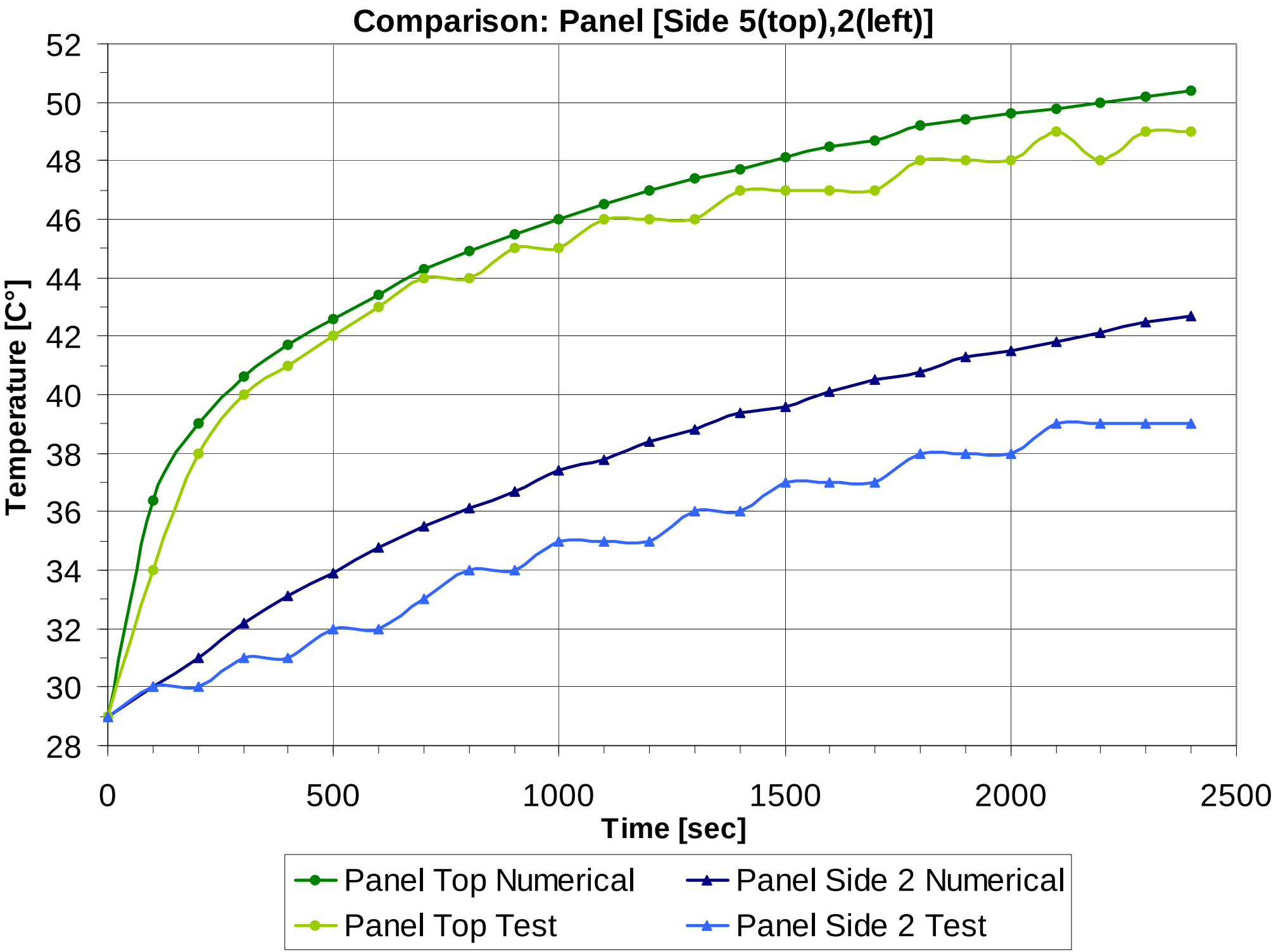
Transient results after 40 minutes(Exterior)

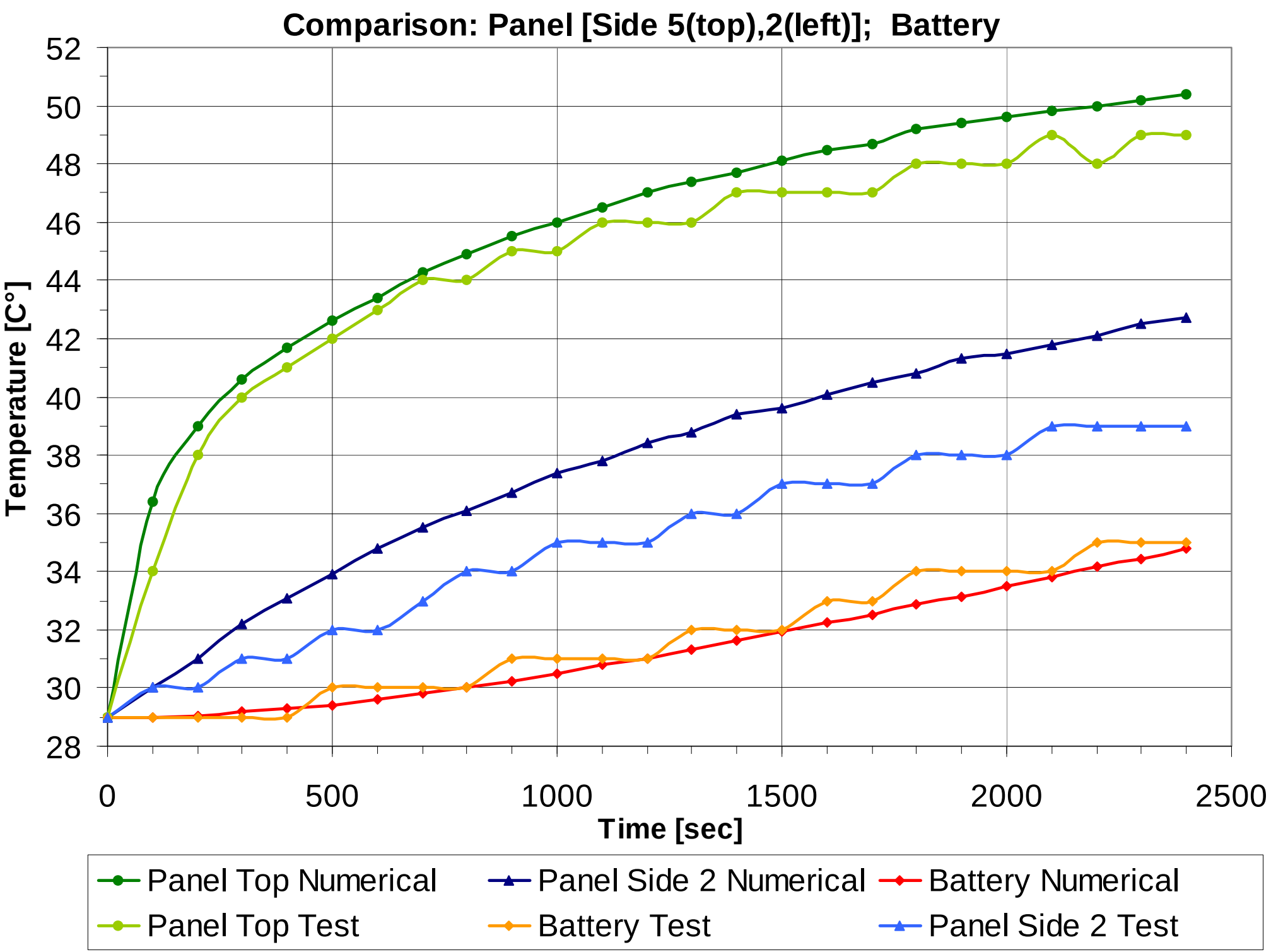


Transient results after 40 minutes (Interior)




Comparison: Panel Side 5(top)
52
50
48
46
44
42
40
38
36
34
32
30
28
Temperature [C°]
0
500
1000
1500
2000
2500
Time [sec]
Panel Top Numerical
Panel Top Test


Comparison: Panel [Side 5(top),2(left)]
Temperature [C°]
52
50
48
46
44
42
40
38
36
34
32
30
28
0
500
1000
1500
2000
2500
Time [sec]
Panel Top Numerical
Panel Side 2 Numerical
Panel Top Test
Panel Side 2 Test


Comparison: Panel [Side 5(top),2(left)]; Battery
Temperature [C°]
52
50
48
46
44
42
40
38
36
34
32
30
28
0
500
1000
1500
2000
2500
Time [sec]
Panel Top Numerical
Panel Side 2 Numerical
Battery Numerical
Panel Top Test
Battery Test
Panel Side 2 Test

Physical parameters of the Thermal Desktop Satellite Model

Material	Conductivity $\frac{W}{m \cdot K}$	Density $\frac{kg}{m^3}$	Specific Heat $\frac{J}{kg \cdot K}$
Aluminium 6061 T4	154	2700	896
Al 6061 T651	167	2700	896
Epoxy	0.49	1300	970
Copper	401	8900	380
PEEK	0.25	1320	2160
PIFE	0.25	2180	2000
POM Copolymer	0.31	1410	1470
Solar cells	40	5800	350

Element	Material
All Electronic Boards	PIFE
Heater and Coils	Copper
Frame; Comboard coating; Board holdings; Battery- box	Aluminium 6061 T651
Panels	Aluminium 6061 T4
Battery and Battery- box filling	Epoxy

Optical parameters of the Thermal Desktop Satellite Model

Element	α coefficient /	ε coefficient /
Battery box	0.15	0.18
Panel	0.59	0.79
Electronic boards	0.72	0.94
T-Pod Frame	0.15	0.095
Magnet coils	0.27	0.94
Sensors	0.93	0.92

Element	Material / Source
Battery box	Rough polished aluminium
Panel	Black anodised aluminium
Electronic boards	Electronic board paint
Solar cell frame	Estimated
T-Pod Frame	Polished aluminium
Magnet coils	Electronic board paint for ε ; $\alpha \rightarrow$ copper
Sensors	Polyethylene

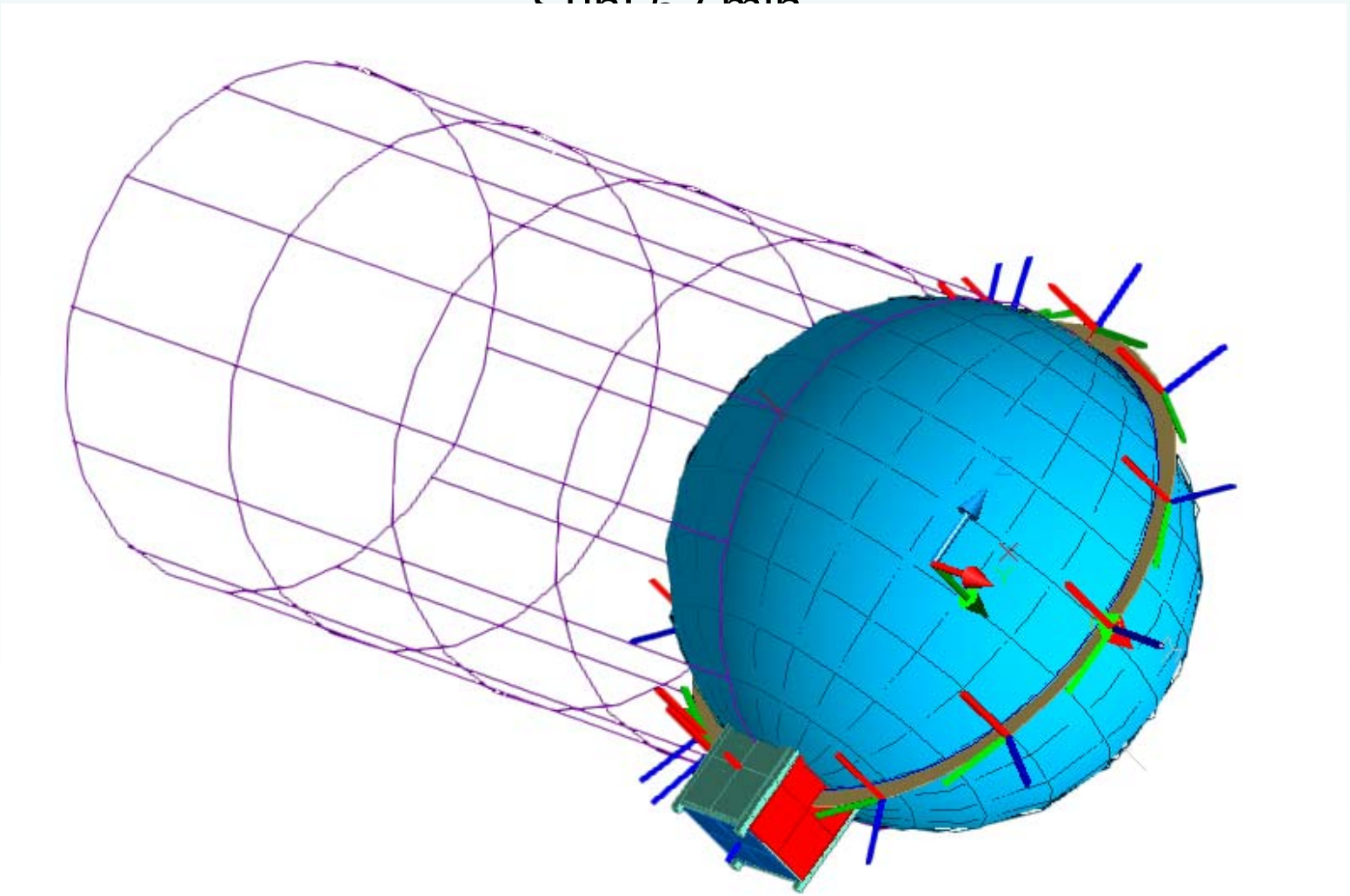
Orbit Thermal- Analysis

Altitude: 600 km

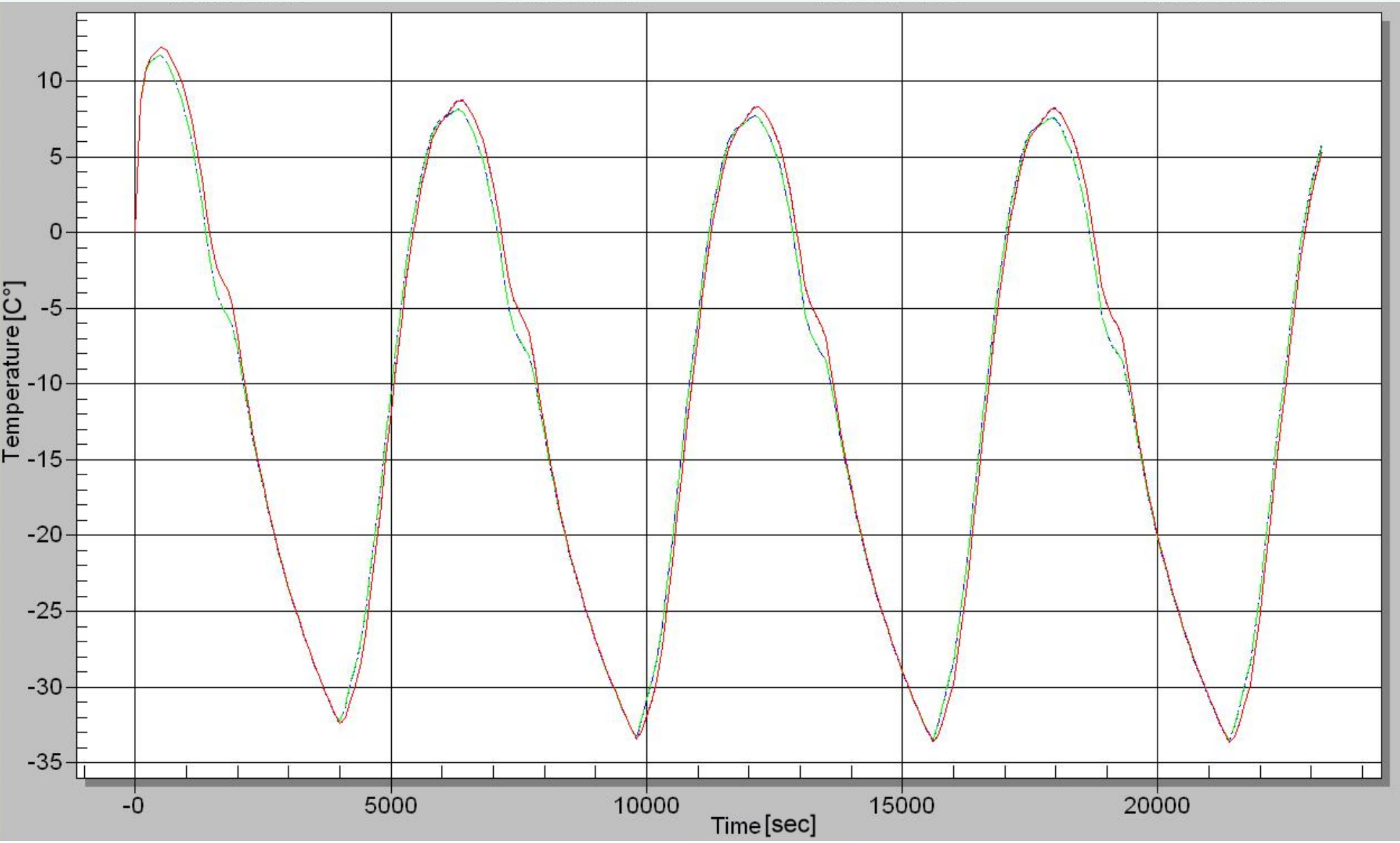
Inclination: 90°

Eclipse: 31 min

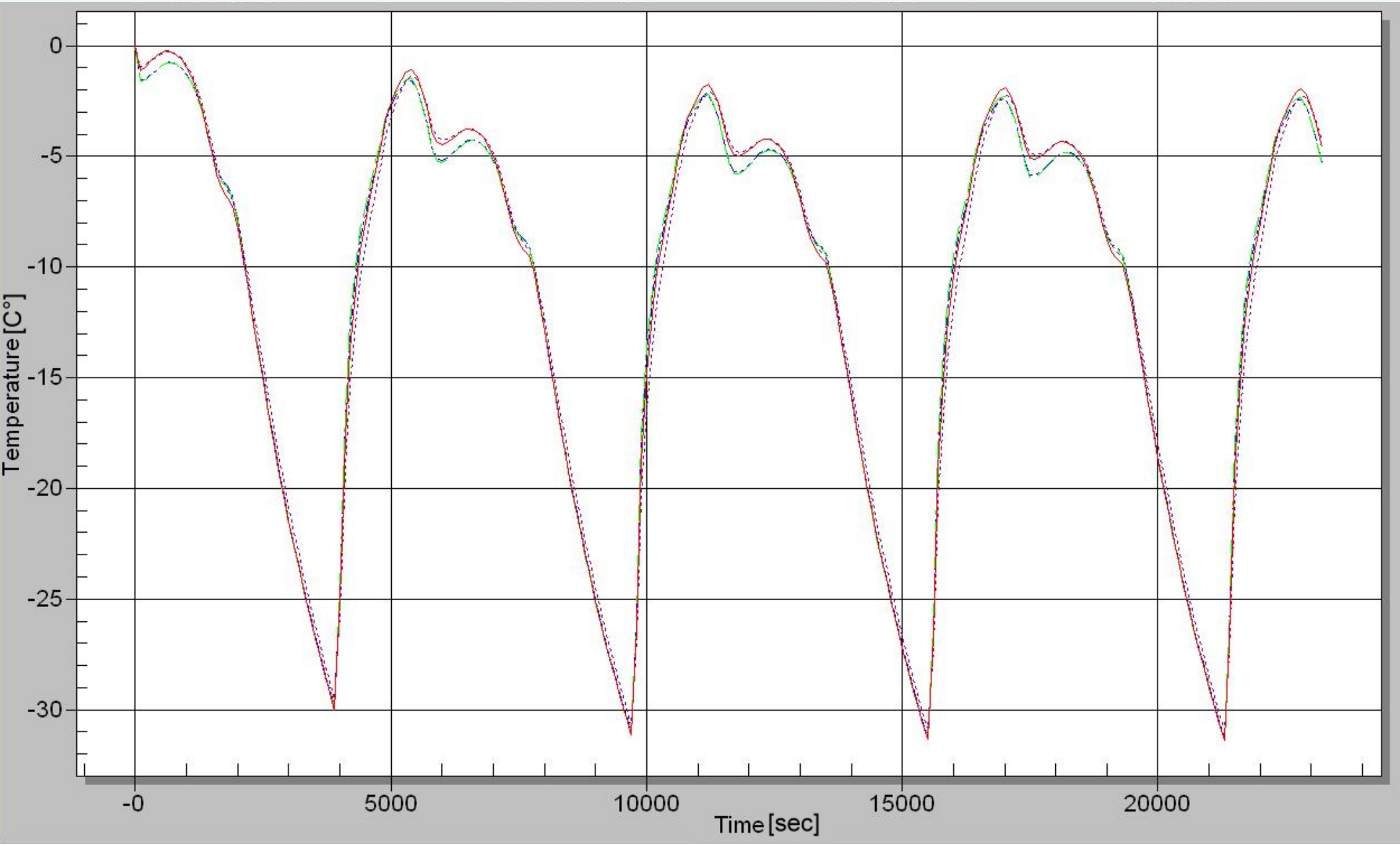
Sun: 63 min



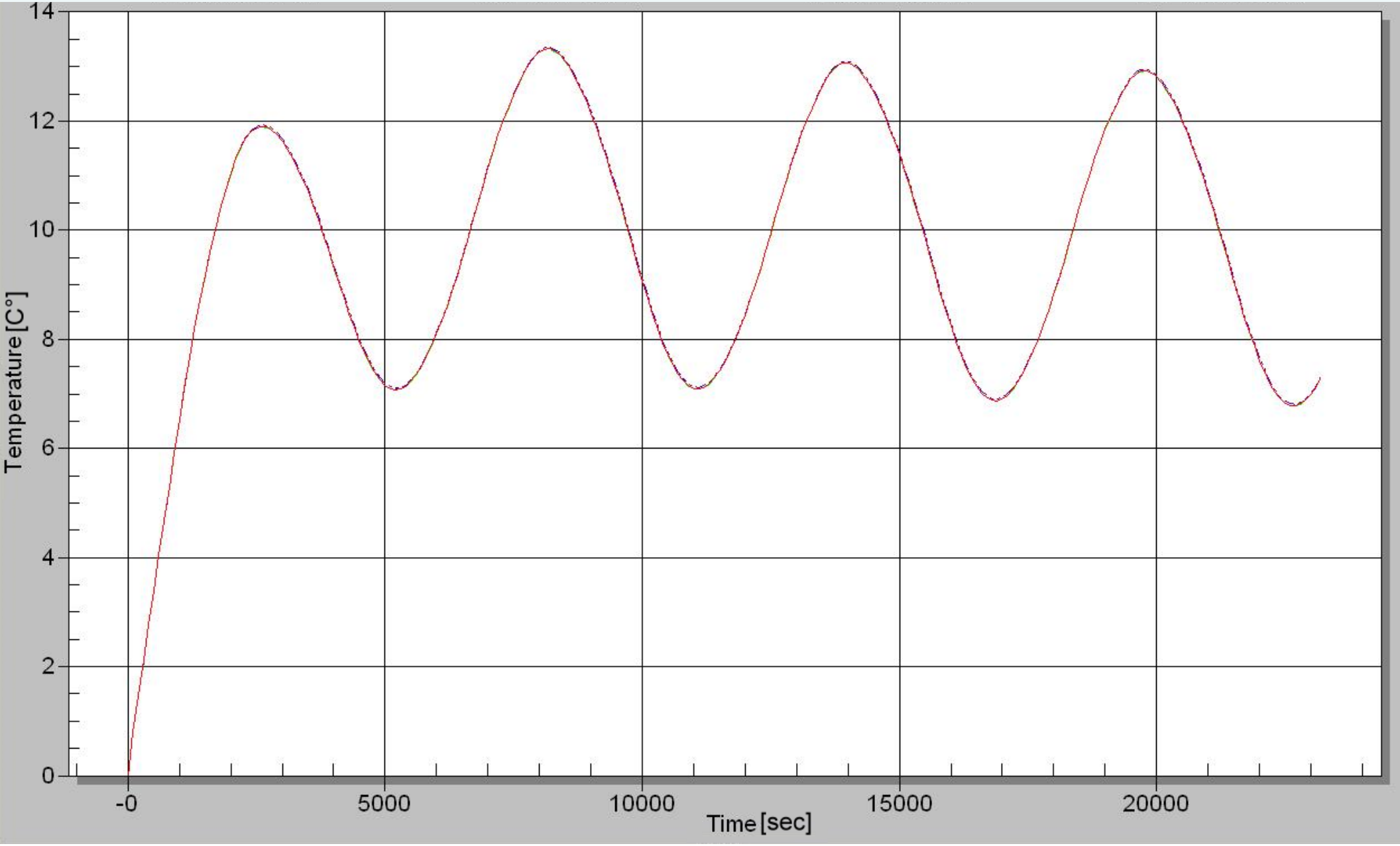
Temperature(i=90°) : Panel [side 5(top)]



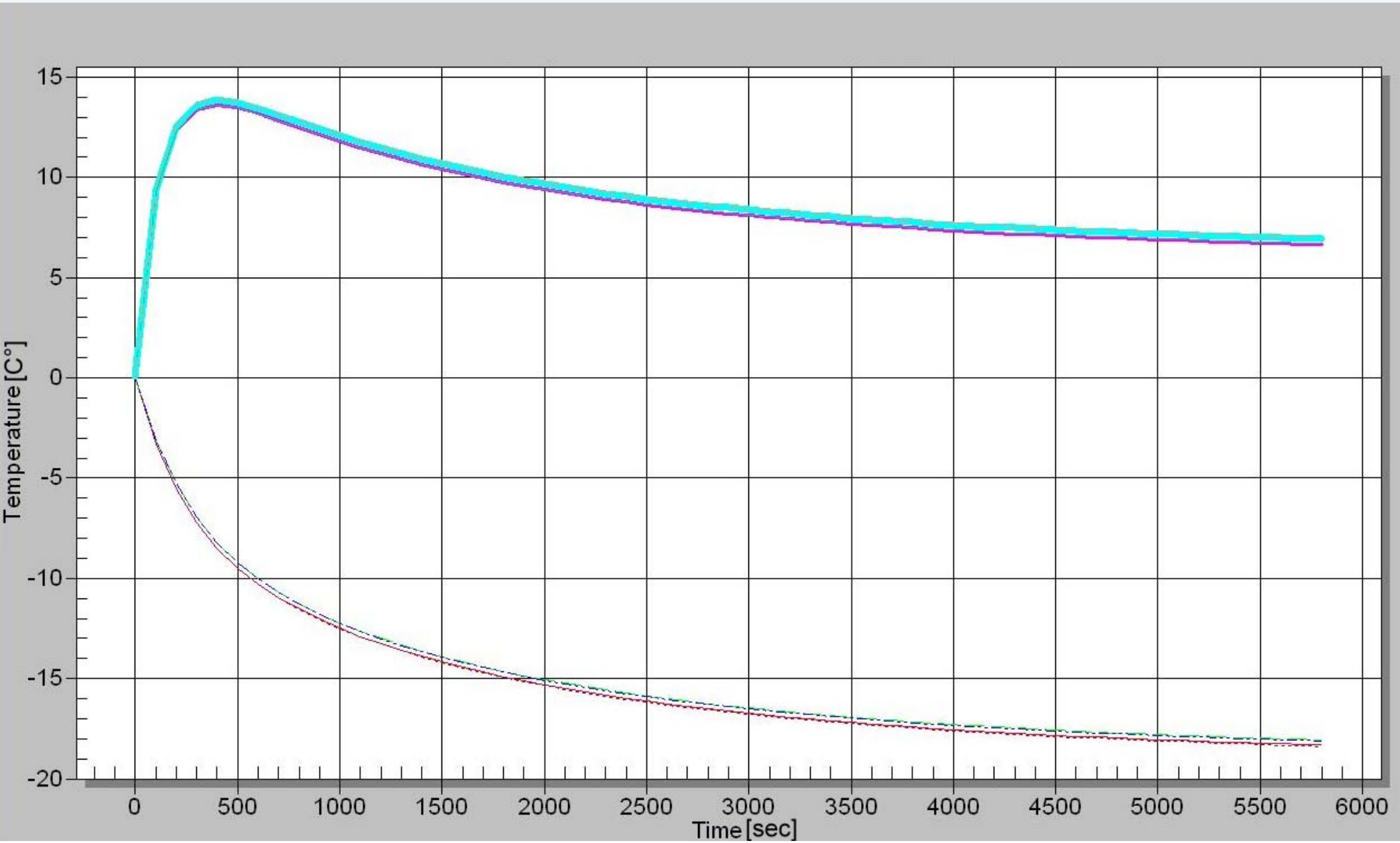
Temperature(i=90°): Panel [side 2(left)]



Temperature(i=90°): Battery
1 W heater power during the whole time

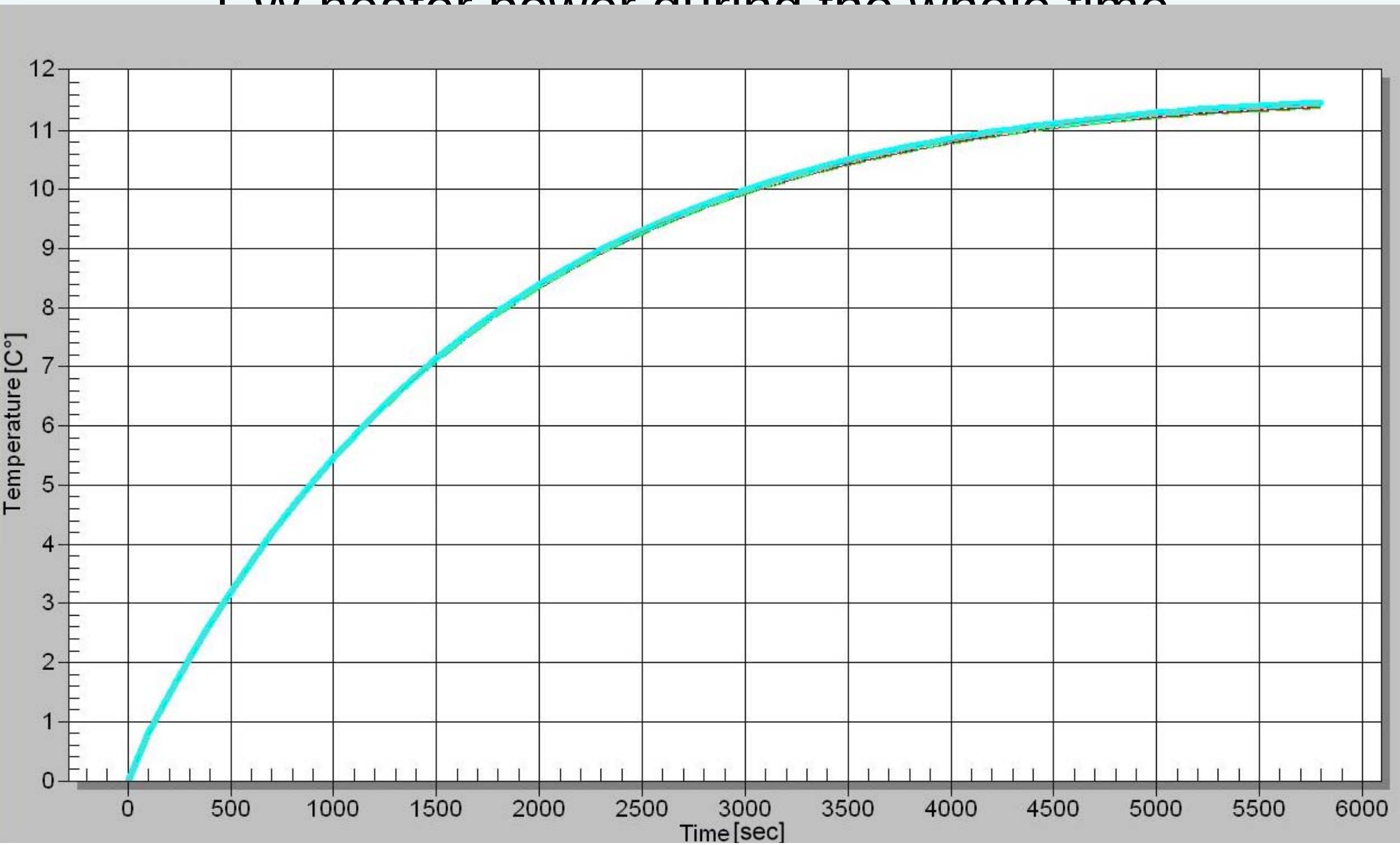


Temperature(sun synchronious, day night border) Panel (sun-side;shadow-side)

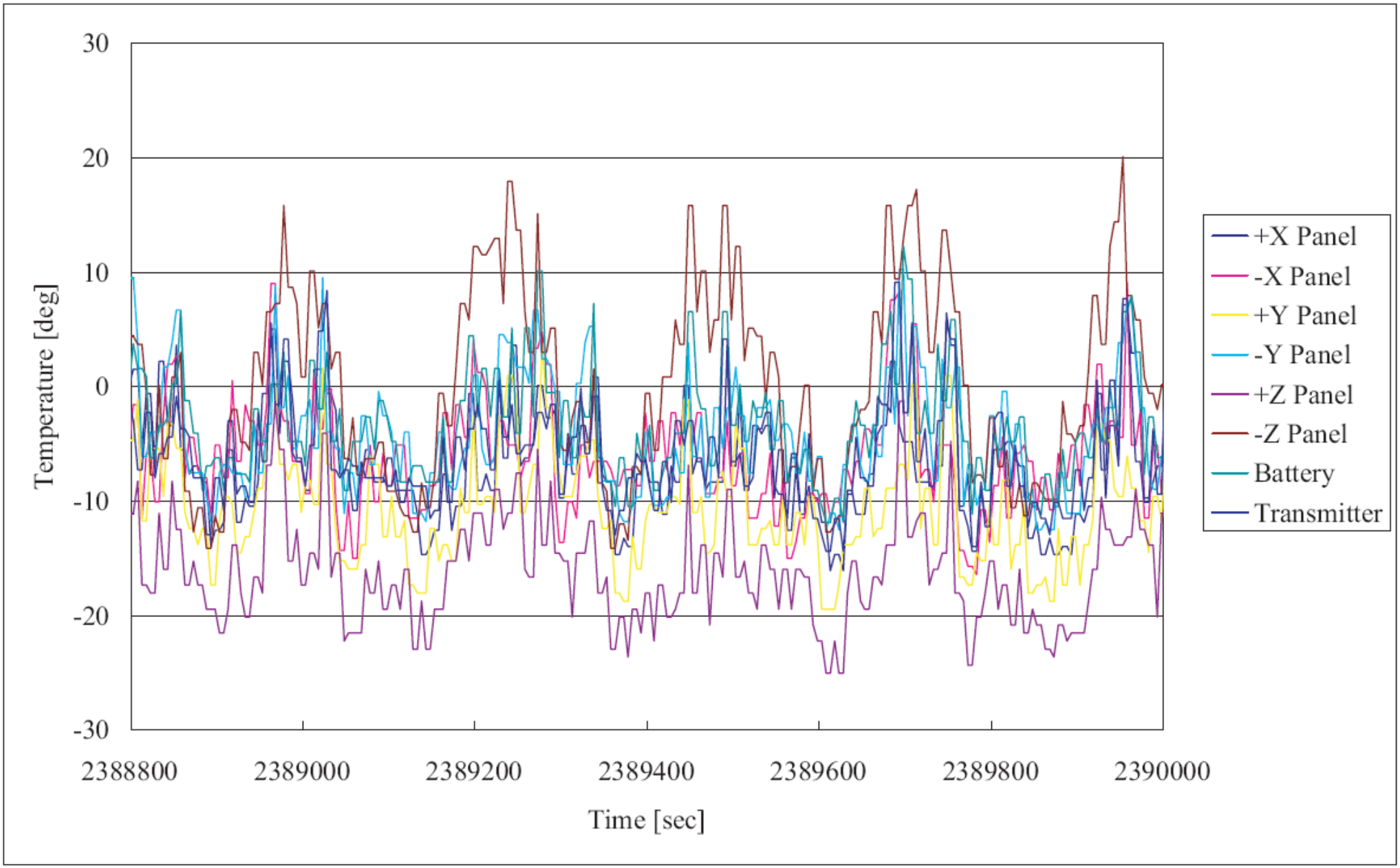


Temperature(sun synchronious, day night border) Battery

1 W heater power during the whole time



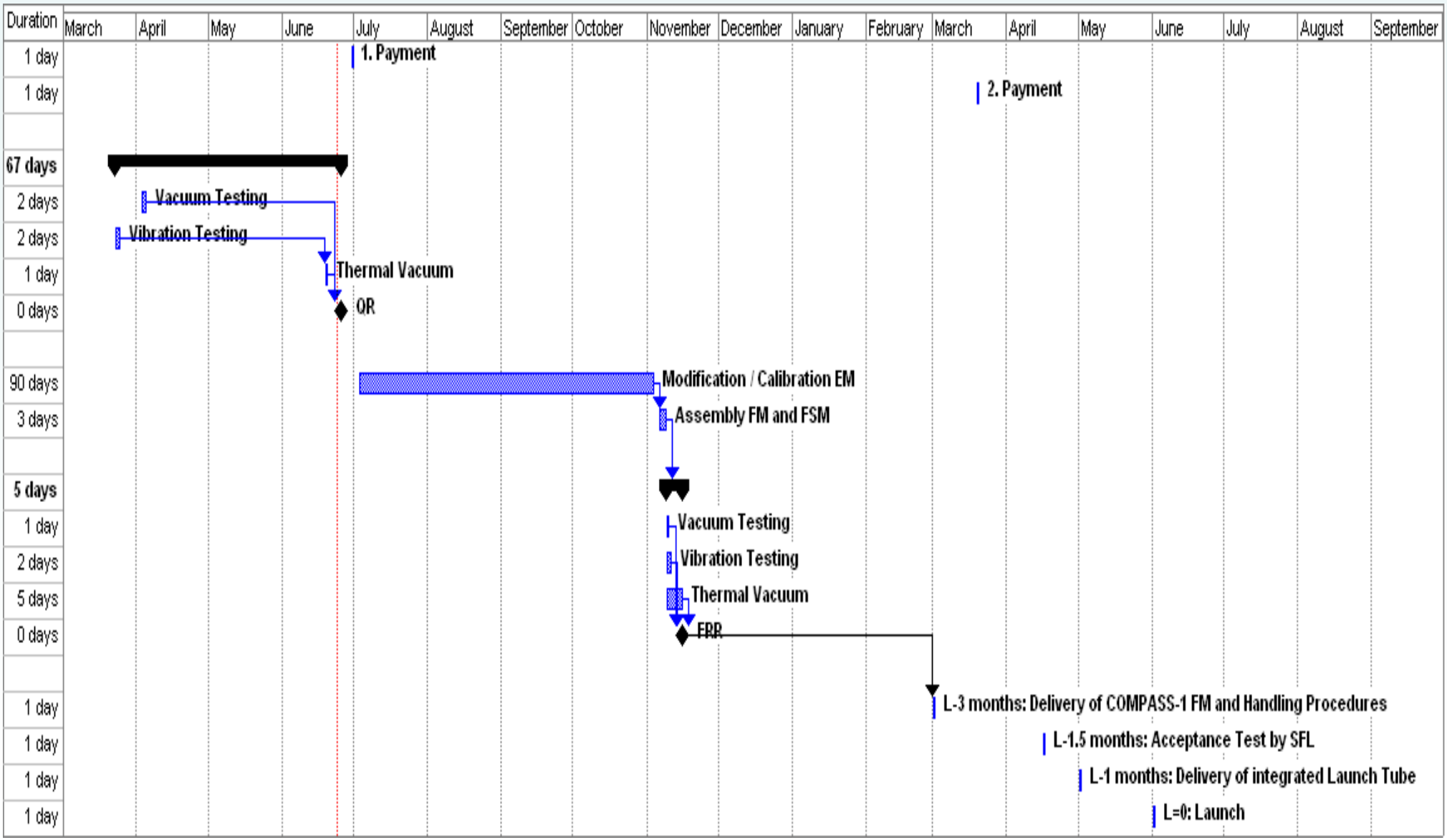
Measured Temperatures of XI-IV



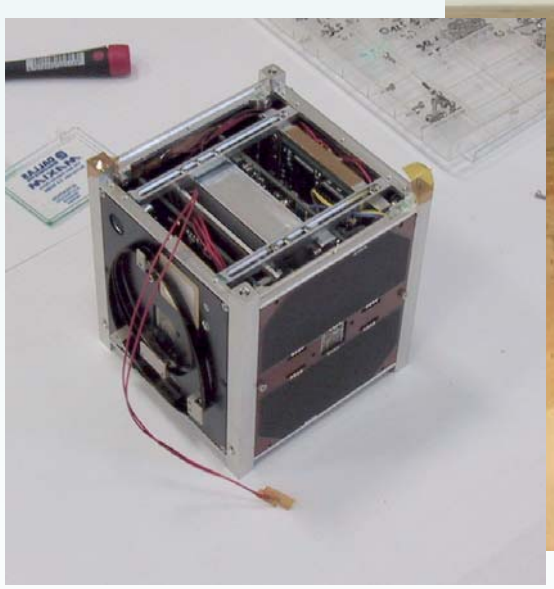
Launch Preparations Roadmap

- Prepare Mission Operations Facility
- Action Item List (FM and Acceptance Tests)
- Sign MoU

Launch Readiness Time Schedule



Thanks !



Support:

Backup Slides

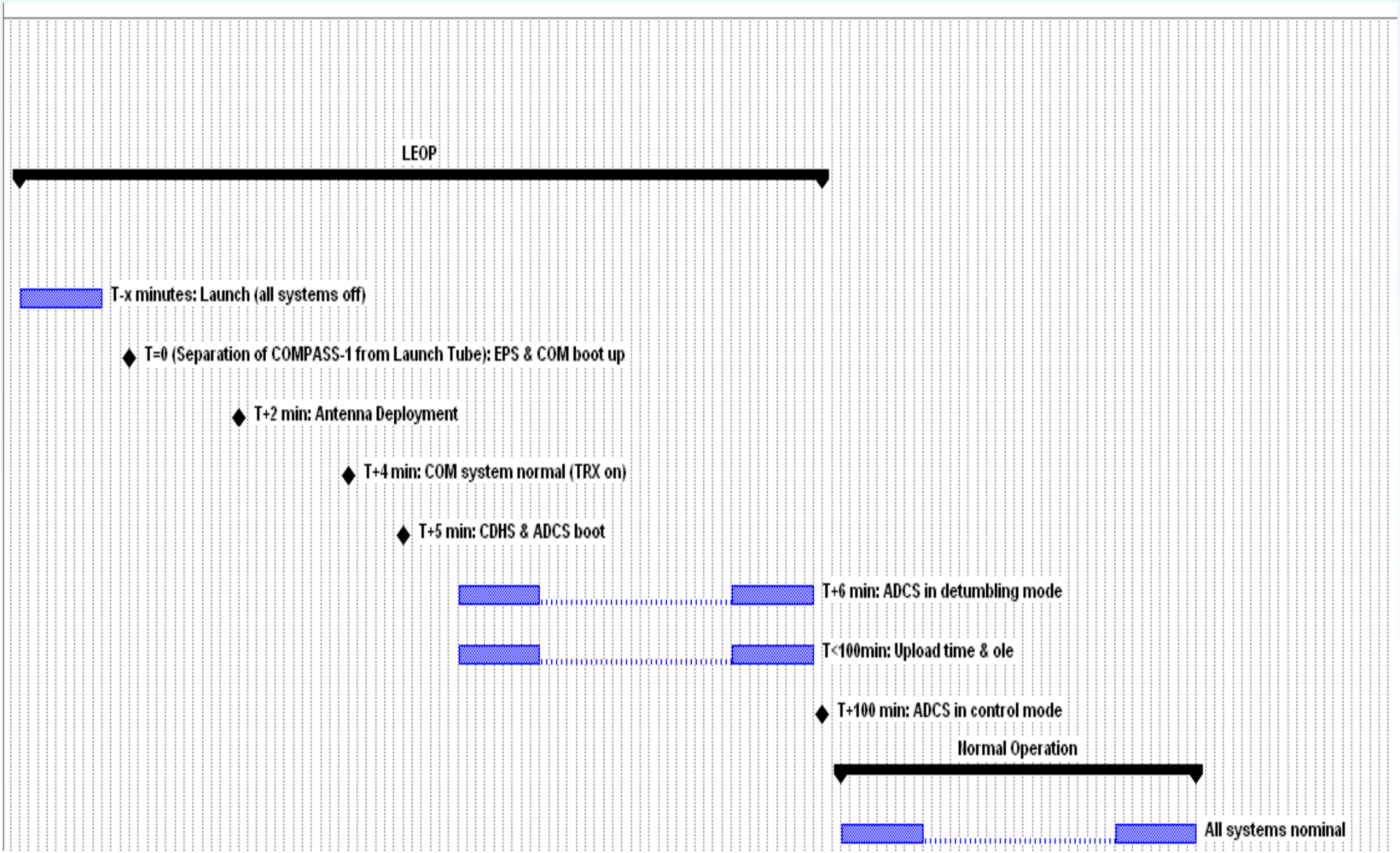
Mission Modes

EPS	TCS	COM	CDHS	ADCS
active MCU sensors **61 mW** **100%**	passive sensors **2 mW** **60%**	beacon TX2 **416 mW** **20%**	task mode TX2 **22 mW** **100%**	Control Magnetometer Sun Sensors Memory MCU Magnetorquer **336mW** **80%**
	active heater sensors **1012 mW** **30%**	FSK TX2 **2343 mW** **10%**		Detumbling Magnetometer Memory MCU Magnetorquer **443mW** **1%**
		RX TX2 **60 mW** **100%**		GPS GPS Memory MCU **1007mW** **2%**

Disabled in Powersafe 1

Switched off in Powersafe 2

Mission Sequence Schedule



Development Costs