ISTANBUL TECHNICAL UNIVERSITY

CANSAT 2011

TEAM HEZARFEN

258

POST FLIGHT REVİEW

June 12, 2011

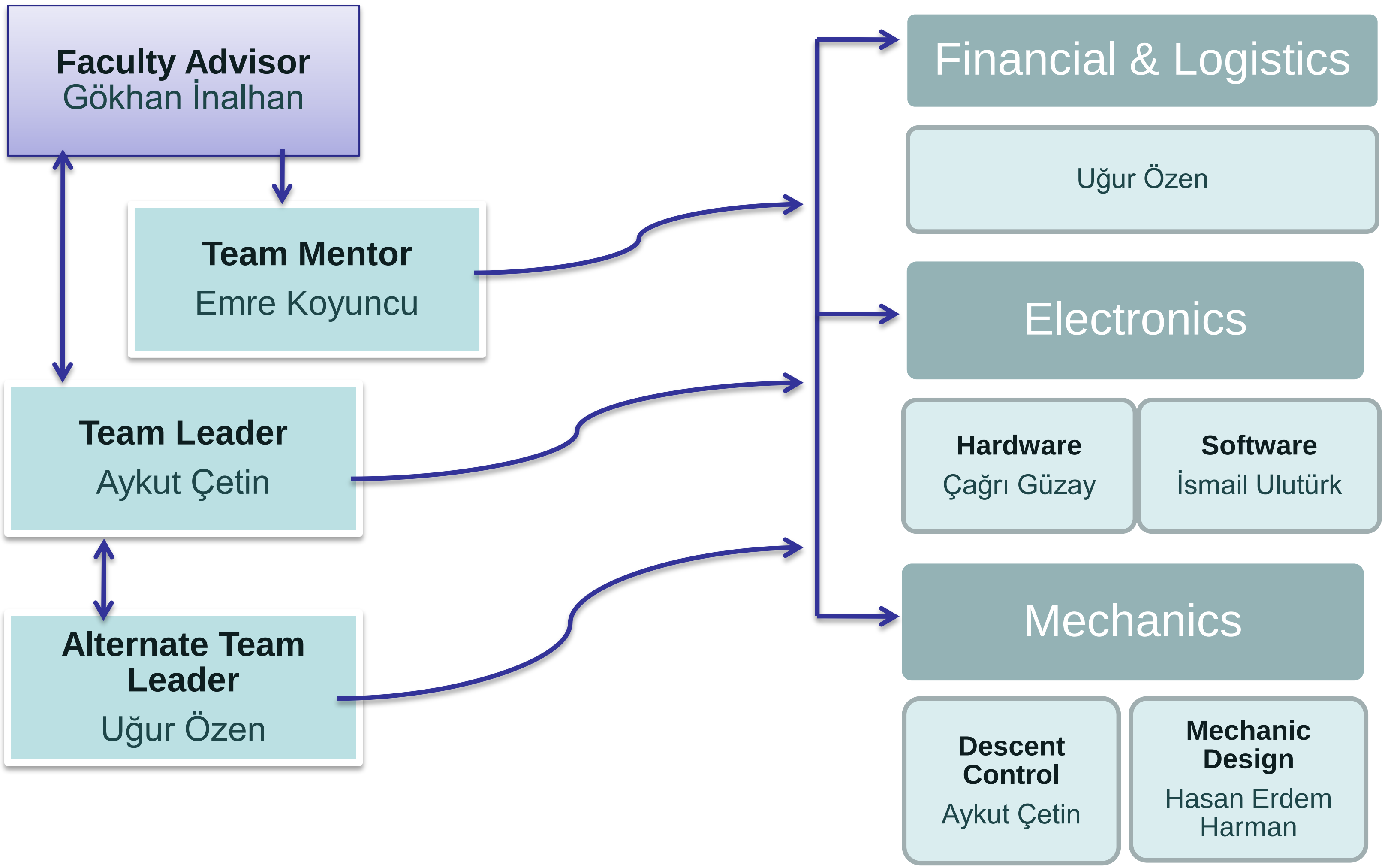
Presentation Outline

Content

TEAM HEZARFEN

NO	NAME	COURSE	POSITION
1	Emre Koyuncu	Graduate	Team Mentor
2	Aykut Çetin	Undergraduate	Team Leader Descent Control Authorized
3	Uğur Özen	Undergraduate	Alternate Team Leader Financial&Logistic Authorized
4	Çağrı Güzay	Undergraduate	Electronic-Hardware Authorized
5	İsmail Ulutürk	Undergraduate	Electronic-Software Authorized
6	Hasan Erdem Harman	Undergraduate	Mechanic Design Authorized

Team Organization



ADC	Analog digital converter
CDH	Communication and Data Handling
DCS	Descent Control System
EPS	Electric Power System
FSW	Flight Software
GPS	Global Positioning System
RF	Radio Frequency
SPI	Serial Peripheral Interface
TTL	Transistor - Transistor Logic

Systems Overview

İsmail ULUTÜRK

Mission Summary

The Main Obective:

→The main purpose of Cansat is that provide egg safety from launch to landing

Other Objectives:

→Launch Cansat

→Separate Cansat two parts; lander and carrier

→Control descent of lander speed of 3-5m/s

→Control descent of carrier speed of 4,5-6,5m/s

→Collection and saving flight data

→Prediction of lander location

Bonus Objective:

→Calculate lander collision force

Overview of the design

-160mm long lander

-110mm long carrier

- 68mm diameter of each

Mechanical Design:

Key desgin decisions:

-Carrier is placed on the top of lander.

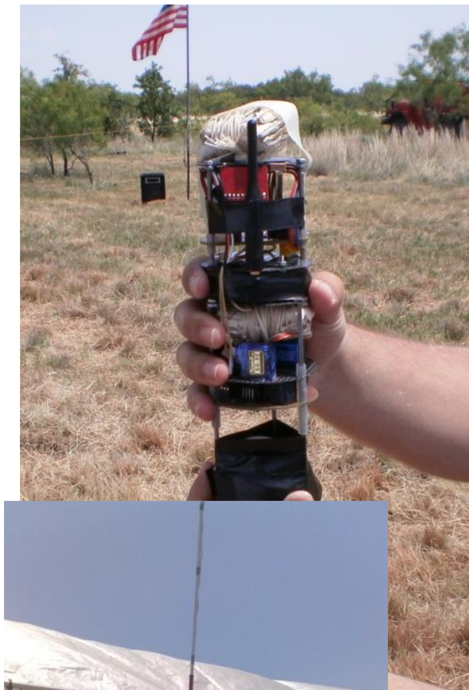
-Special dough to protect the egg

-The egg placed on the bottom of lander

- Interface design

Key features of the cansat:

- We use a special dough for protecting the egg.
- We use a servo and a rubber which are responsible for the carrier and lander interface.
- Rubber holds them together and servo let them sperate.
- We use steel bars and carbon-fiber plates to create the body.
- We use silicon tubes to hold the electronics stable on their location



Overview of the design

Electrical Design:

Key desgin decisions:

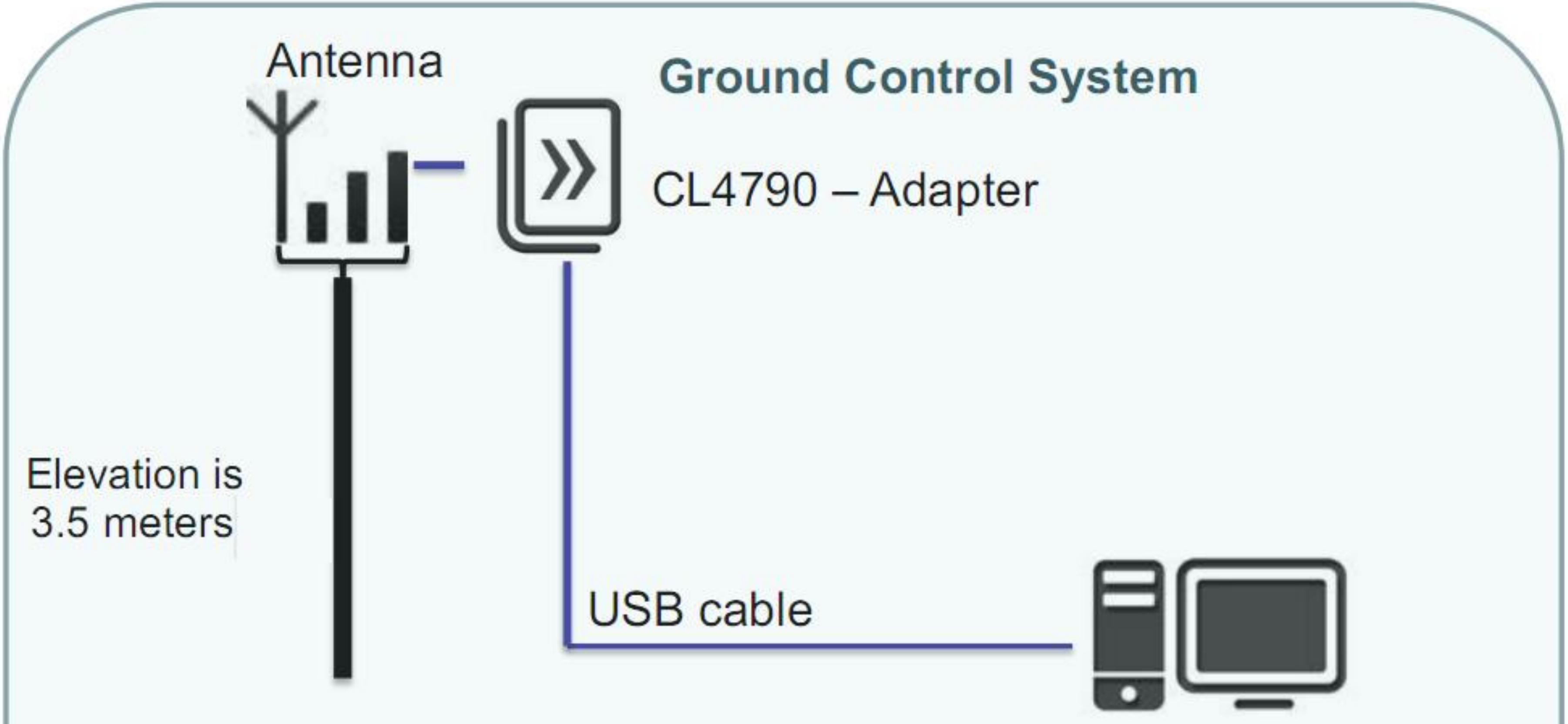
-We designed our cansat to make samplings as fast as possible using a multithreaded approach.

-We used dual-function integrated sensors as much as we can to gain from space.

-We created different analysis and GCS tools using mostly MATLAB to display, plot, simulate and process the data quickly.

-We mainly trusted MicroSD Cards for storage because of their storage capacity and commonness.

Component Summary



Matlab is used for realtime calculation and plotting of the data during the launch.

Component Summary

- **Sensor Subsystem:**
  - **Carrier**

PRE

VTI Technologies-SCP1000

Used for :

Determination of altitude without GPS

Determination of Lander's descent rate

TEM

VTI Technologies-SCP1000

Used for :

Determination of air temperature

Including temperature data to determine the altitude with pressure

GPS

Locosys - 20 Channel LS20126 GPS Receiver

Used for :

Positioning of the Lander

Obtaining other GPS data

Component Summary

- **Sensor Subsystem:**
  - **Lander**

PRE

Bosch – BMP085

Used for :

Determination of altitude

Determination of Carrier's descent rate

TEM

Bosch – BMP085

Used for :

Determination of air temperature

Including temperature data to determine the altitude with pressure

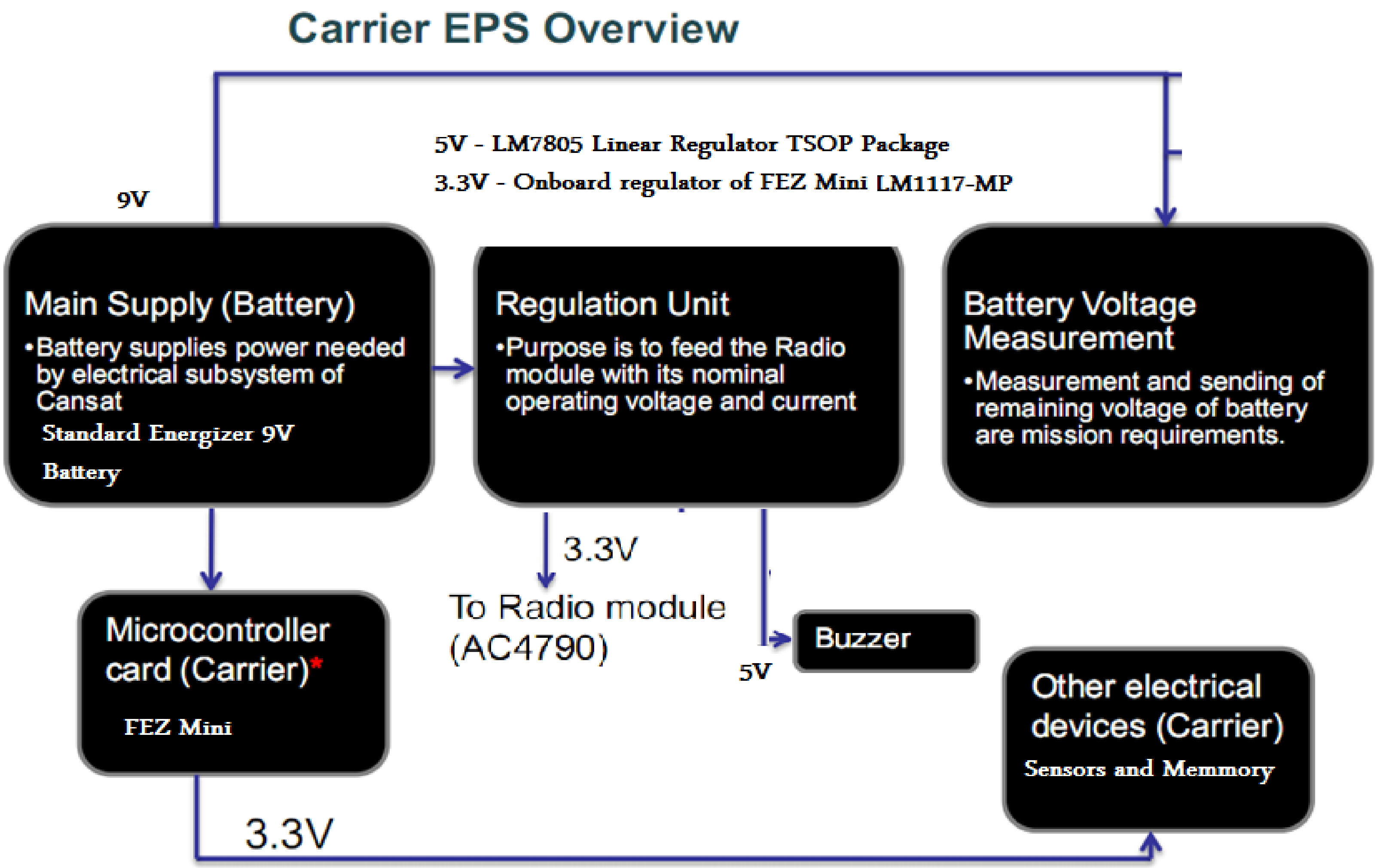
ACL

Freescale – MMA7260Q

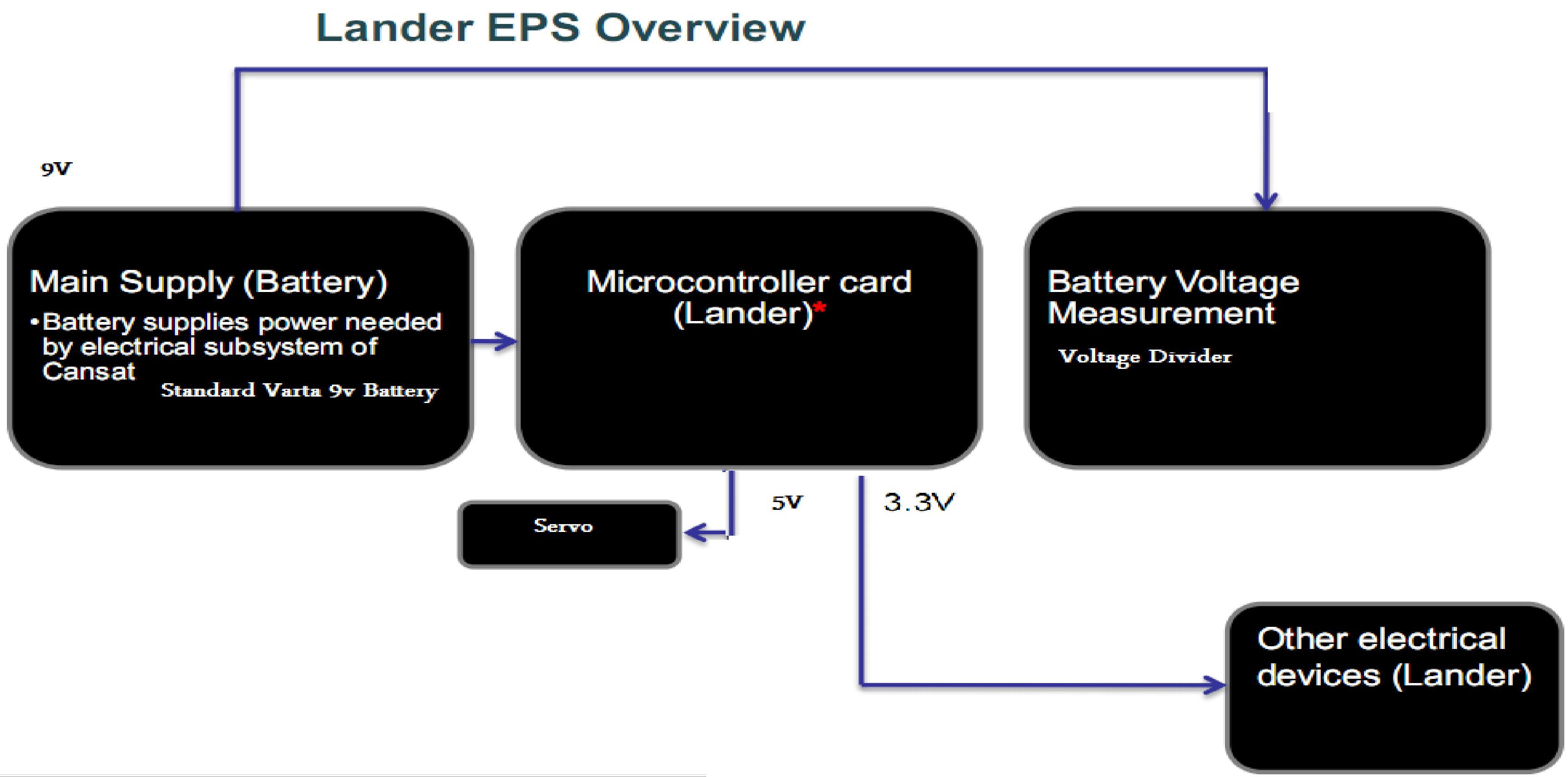
Used for :

Determination of impact force , occurred by landing of the Carrier

- **Electrical & Power Subsystem:**



- **Electrical & Power Subsystem:**

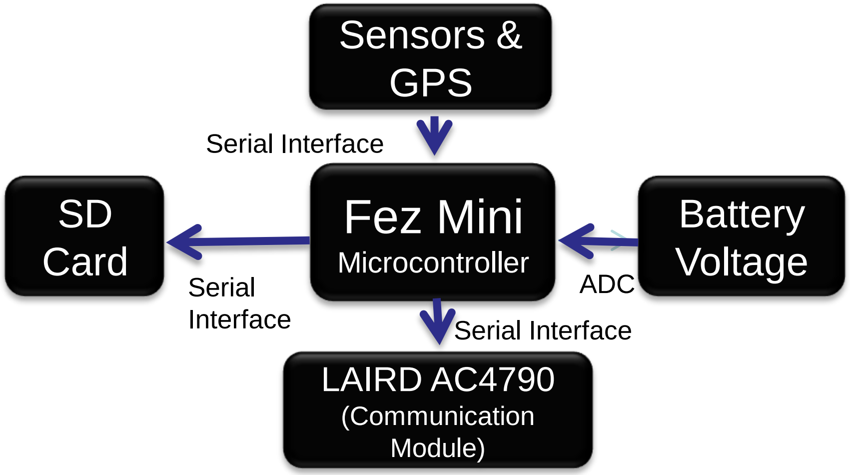


Voltage dividers are 5.1k Ohm and 10k Ohm resistors in series.

Component Summary

- **Flight Software:**
- **Carrier:**
  - IDE: Microsoft Visual Studio 2010 Ultimate
  - Framework: Microsoft .NET MicroFramework 4.1
  - Programming Language: C# 4.0
- **Lander:**
  - IDE: Arduino Development Environment
  - Programming Language: C++

- **Communication & Data Handling:**
  - Carrier:



- Fez Mini is the microcontroller board that will handle all communication and data.

- SD Card is used for storing a detailed flight log to be able to see where system fails on tests and providing backup for telemetry in case of a communication failure.

- Laird AC4790 is the radio module that will transmit and recieve messages to/from ground station.

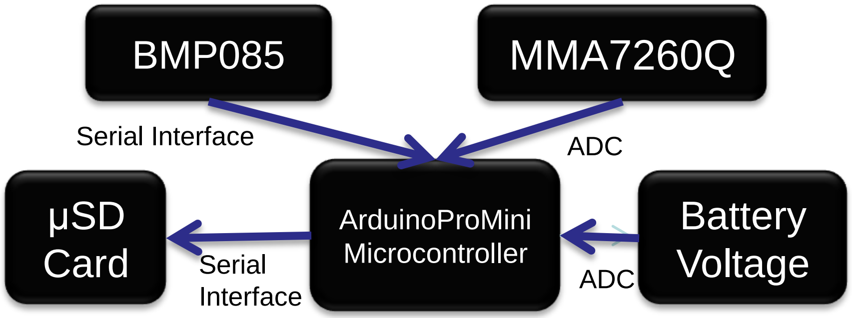
- Battery Voltage is measured through a voltage divider form an analog input.

- SCP1000 is used as both temperature and altitude sensor. It is interfaced via SPI by Fez Mini.

- Lycosys LS20126 is used as GPS, it is interfaced via Serial UART interface by Fez Mini.

Component Summary

- **Communication & Data Handling:**
  - Lander:



•Arduino Mini is the controller board that will handle all communication and the data

•MicroSD Card is used for storing a detailed flight log and sensor readings.

•Battery voltage is measured through a voltage divider.

• Bosch BMP085 is used as both temperature and pressure sensor. It is interfaced via a two wire interface by Arduino Mini.

•MMA7270Q is the accelerometer used to measure impact force, it is interfaced via an analog input.

Component Summary

Mechanical subsystem:

Carbon-fiber plates

Steel bars

Silicon tubes

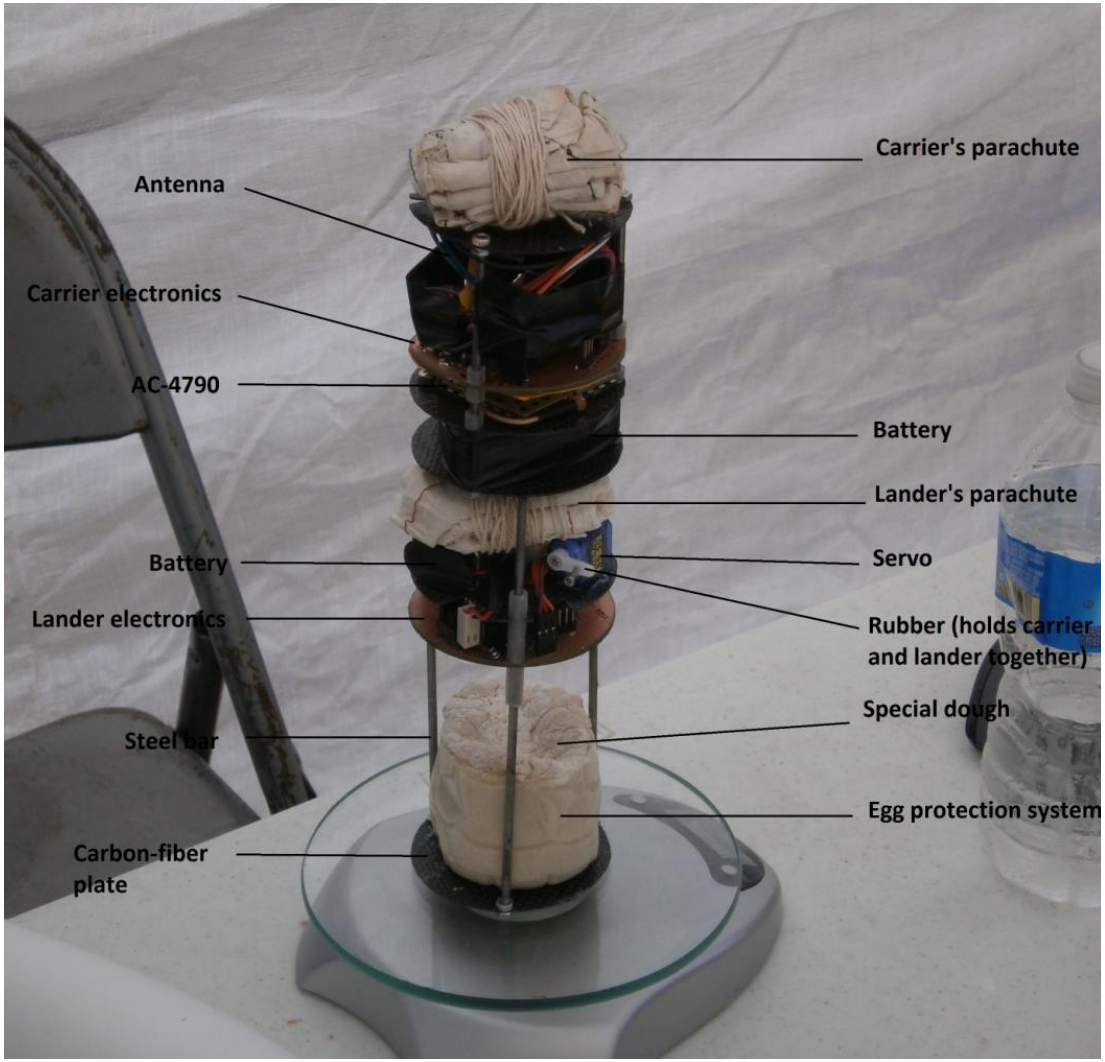
Servo and rubber

Special Egg Protection Dough

Descent control subsystem:

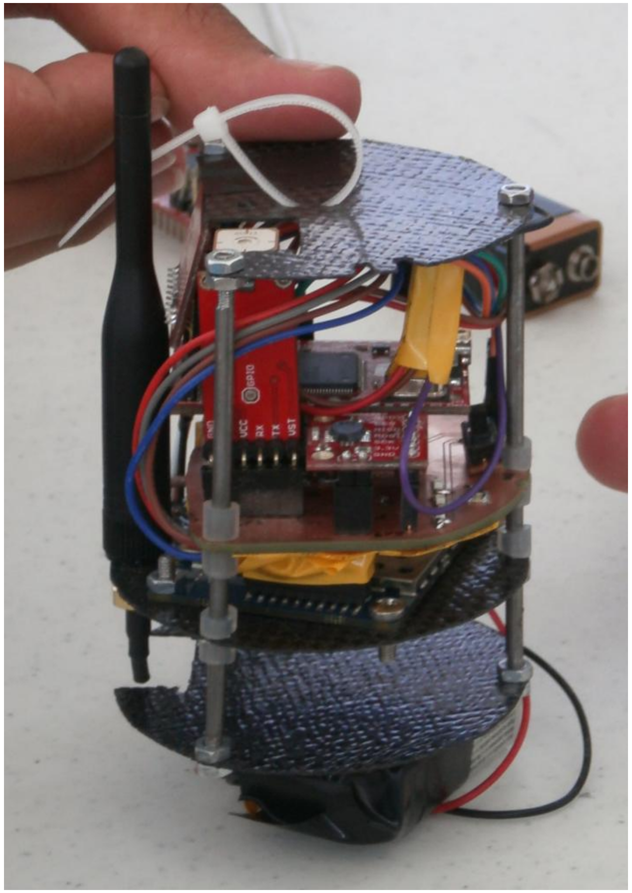
Parachutes

Physical Layout

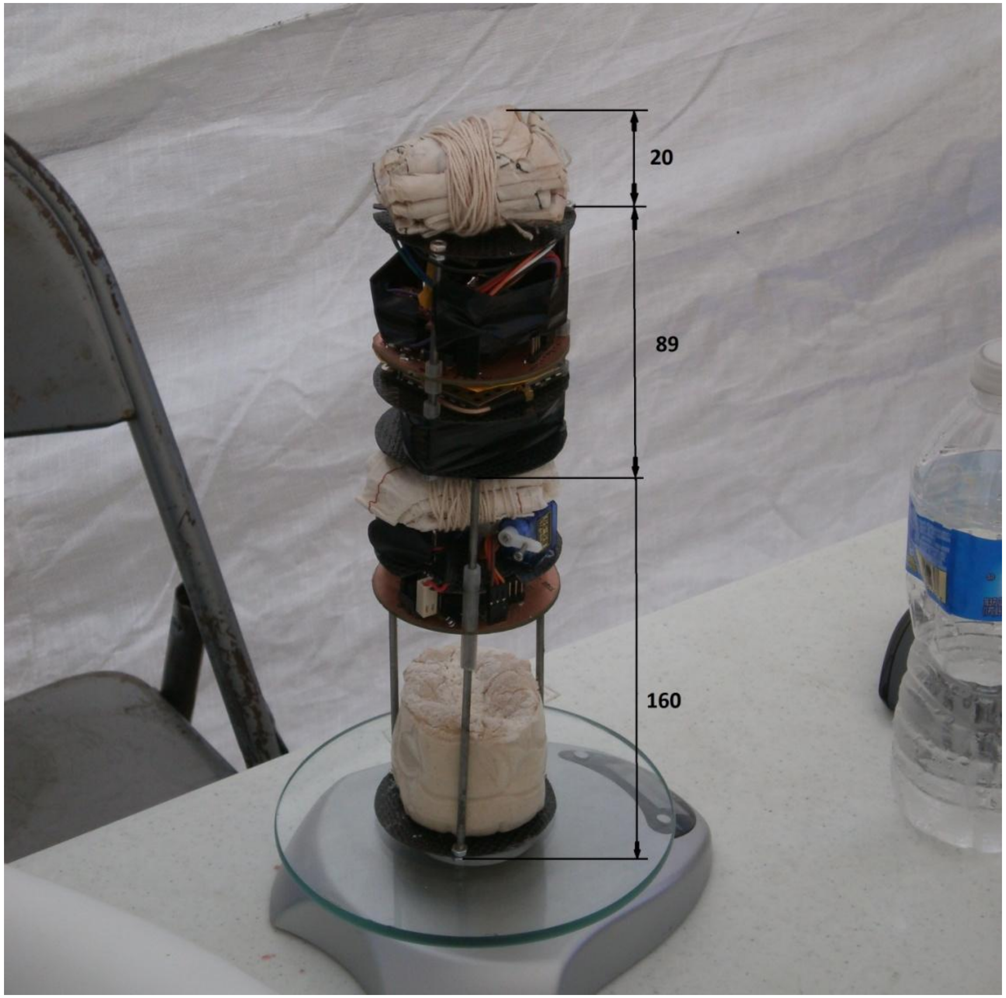


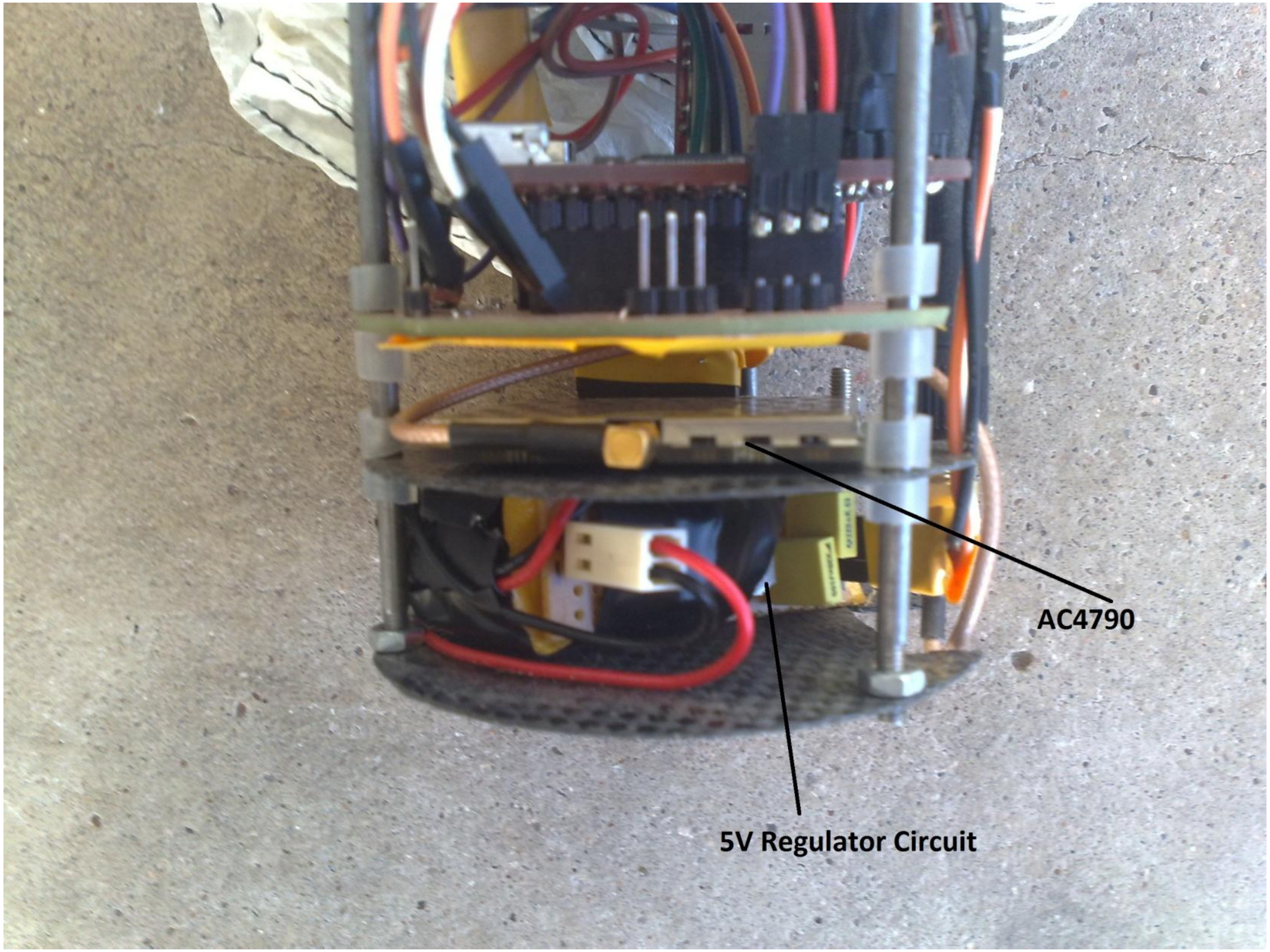
LANDER

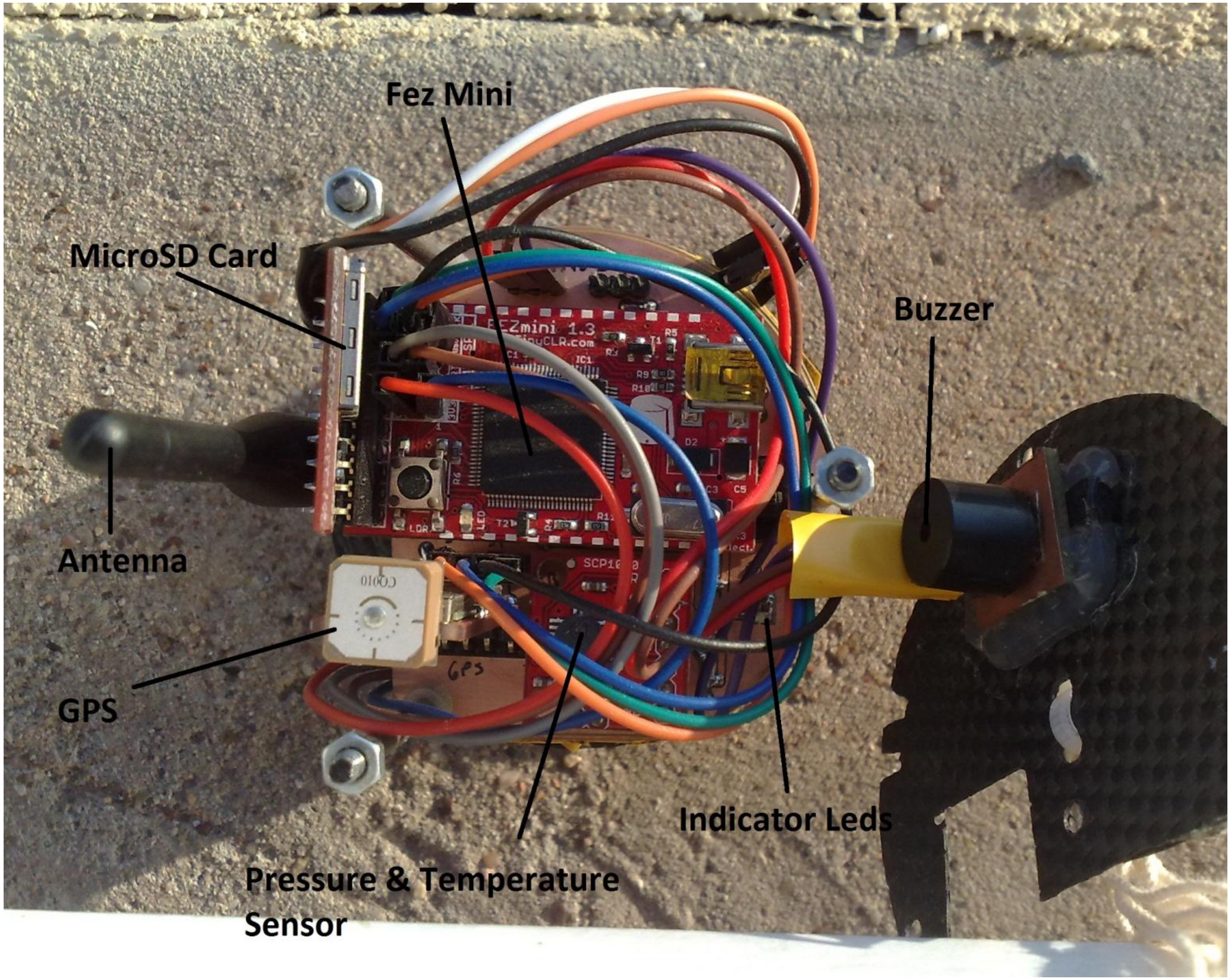
CARRIER

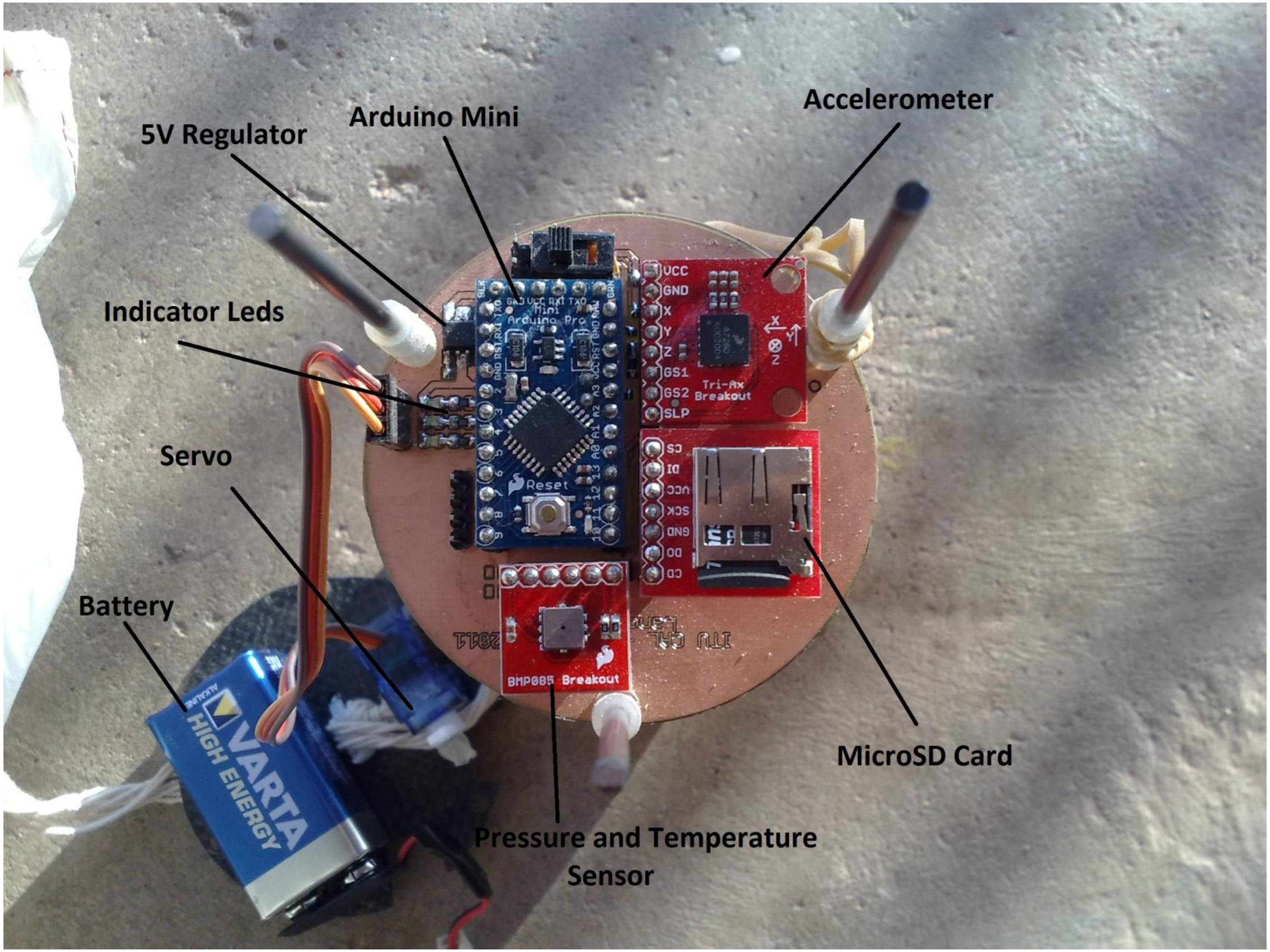


DIMENSIONS




AC4790
5V Regulator Circuit


Fez Mini
MicroSD Card
Buzzer
Antenna
GPS
Indicator Leds
Pressure & Temperature Sensor


Accelerometer
Arduino Mini
5V Regulator
Indicator Leds
Servo
Battery
MicroSD Card
Pressure and Temperature Sensor
VARTA
HIGH ENERGY
BMP085 Breakout
Tri-Ax Breakout
Arduino Pro Mini
Reset

Concept of Operations and Sequence of Events

İsmail ULUTÜRK

Overview of Mission Sequence of Events

Preflight briefing → Last mechanic control → Last electronic control → Coming competition area

Placing competition platform → Preparing materials → Making egg protection system → Dimension and weight controls

Power On cansat → Put cansat into rocket → Launch rocket → Cansat Leaves Rocket

Overview of Mission Sequence of Events

Measuring Altitude of cansat → Seperate cansat at 500meters → Collect data using sensors → Data saving on ground station

Calculate collusion force → Locate Cansat → Turn Off cansat → Analyzing& saving data

Prepare PFR → PFR

Red means there was a problem.

Overview of Mission Sequence of Events

Planned	Actual	Where is the problem?
Ground system radio link check procedures	Done Successfully	
Loading the egg payload	Done Successfully	
Powering on/off the CanSat	Done Successfully	
Launch configuration preparations	Done Successfully	
Loading the CanSat in the launch vehicle	Done Successfully	
Telemetry processing, archiving, and analysis	Problem	Connection Lost after takeoff.
Recovery	Problem	Took a long time because we lost connection.

Overview of Mission Sequence of Events

•We arrived at the site, having our CanSat already prepared and tested.

•We only prepared the dough on the site as the first thing in the morning because storing it for a long time is hard.

•Everything went according to plan until the takeoff, after the takeoff we lost connection and because of that we had a hard time to recover our CanSat.

Flight Data Analysis

İsmail ULUTÜRK

Flight Data Analysis

GPS data collected by GCS are shown below. (Carrier)

Longitude [degree]	Latitude [degree]	UTC time [sec]	Number of satellites tracked	Mean sea level altitude [m]
-99.14587500	32.10275667	170423	7	519
-99.14587500	32.10275667	170423	7	519
-99.14587500	32.10275667	170424	7	519
-99.14587500	32.10275667	170424	7	519
………	……….	……….	…………	………….
-99.14823000	32.10980833	170746	6	1176
-99.14841167	32.11133000	170807	7	1043

Flight Data Analysis

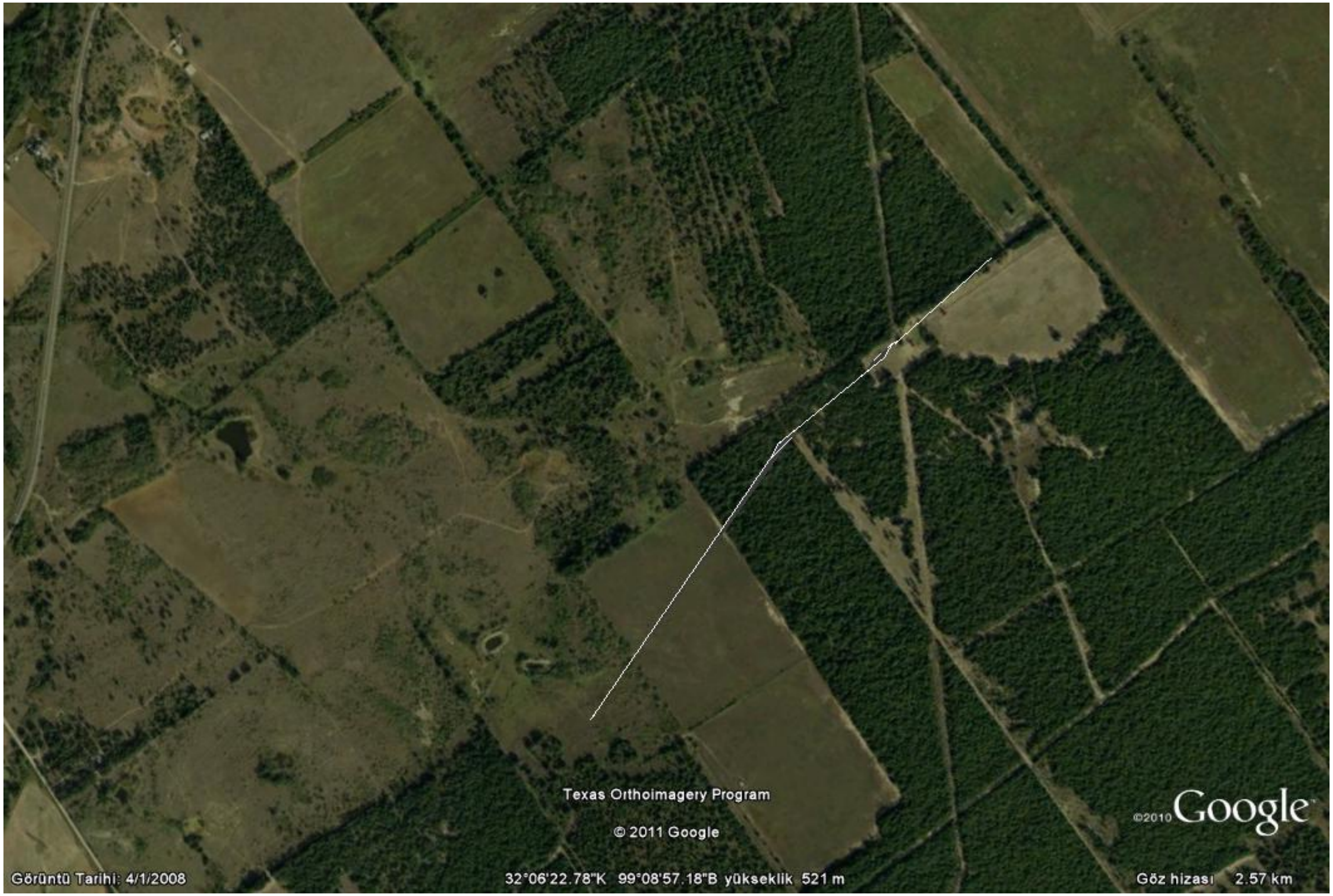
Flight path of the Cansat.

Flight Data Analysis

Flight path of the Cansat.

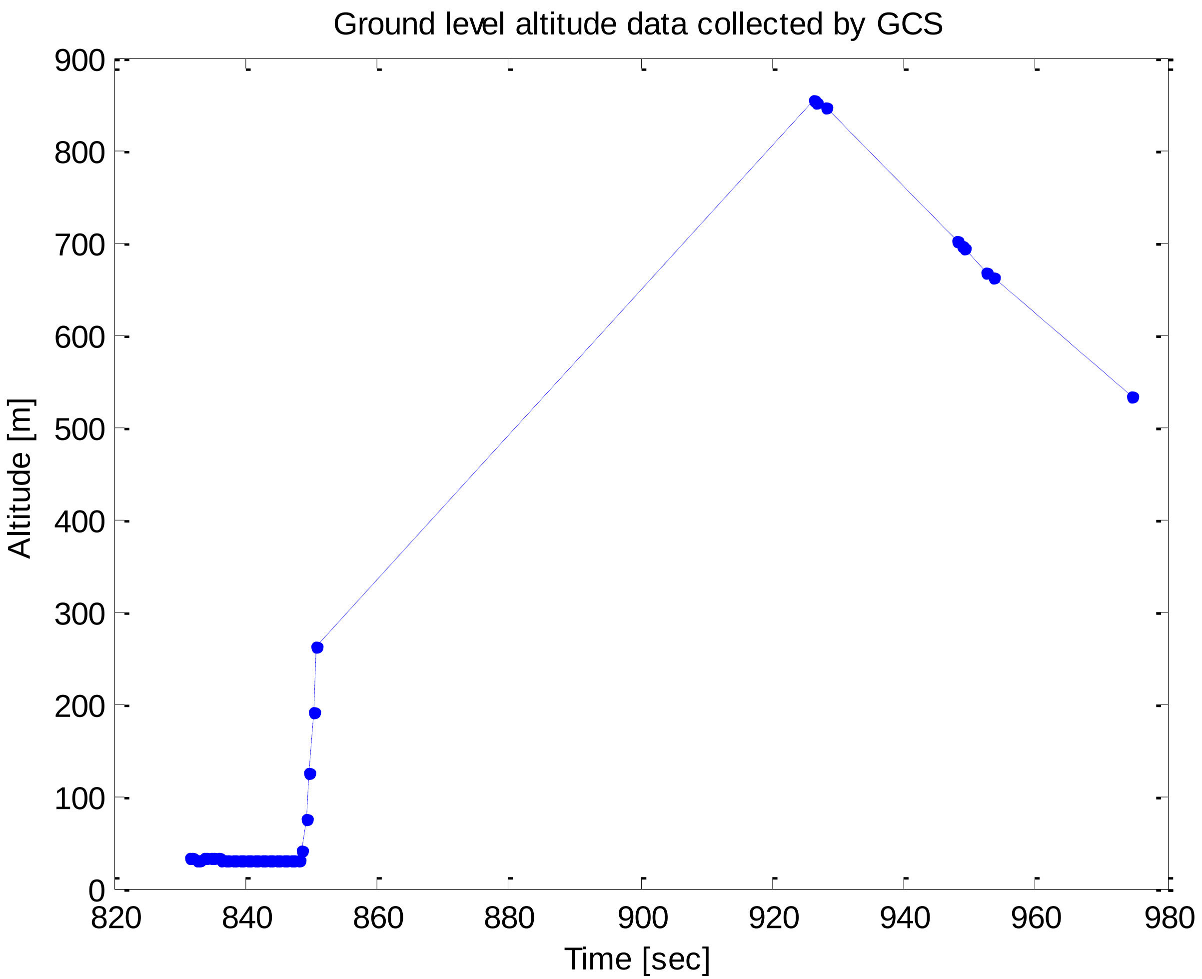
Flight Data Analysis

Flight path of the Cansat.



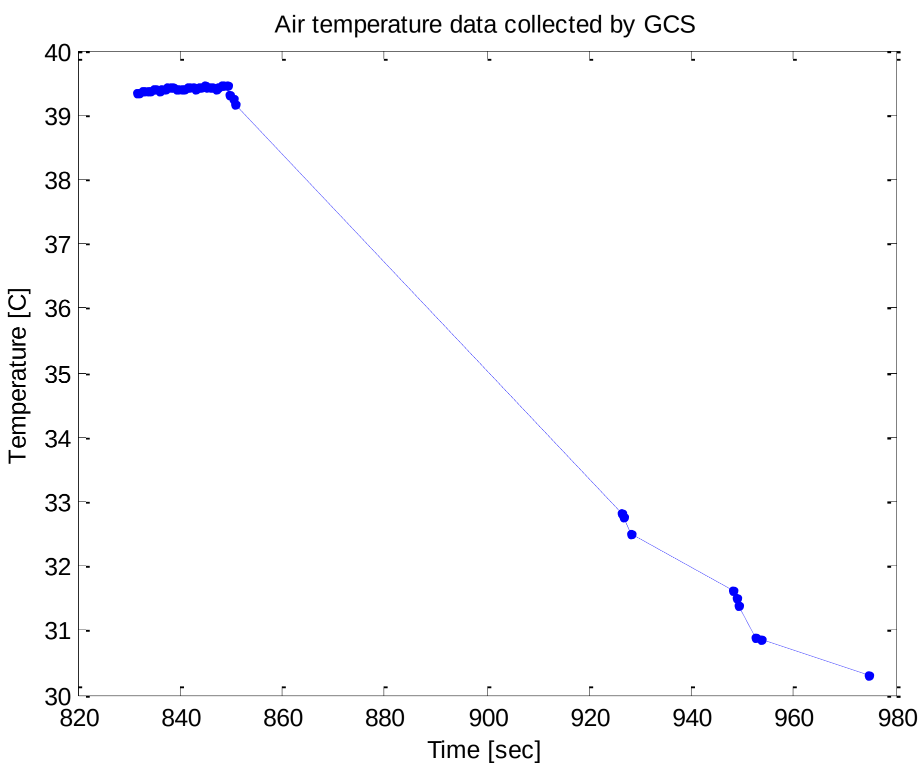
Flight Data Analysis

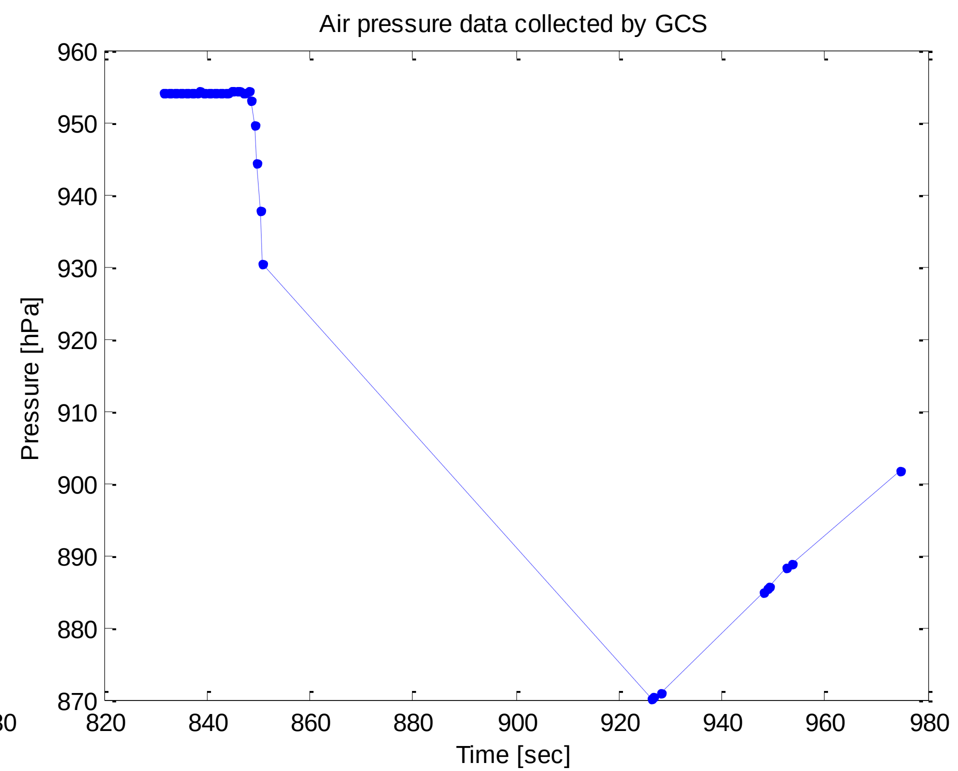
Ground level altitude data collected by GCS are shown graphically. (Carrier)



Flight Data Analysis

Air temperature and air pressure data collected by GCS are shown graphically. (Carrier)

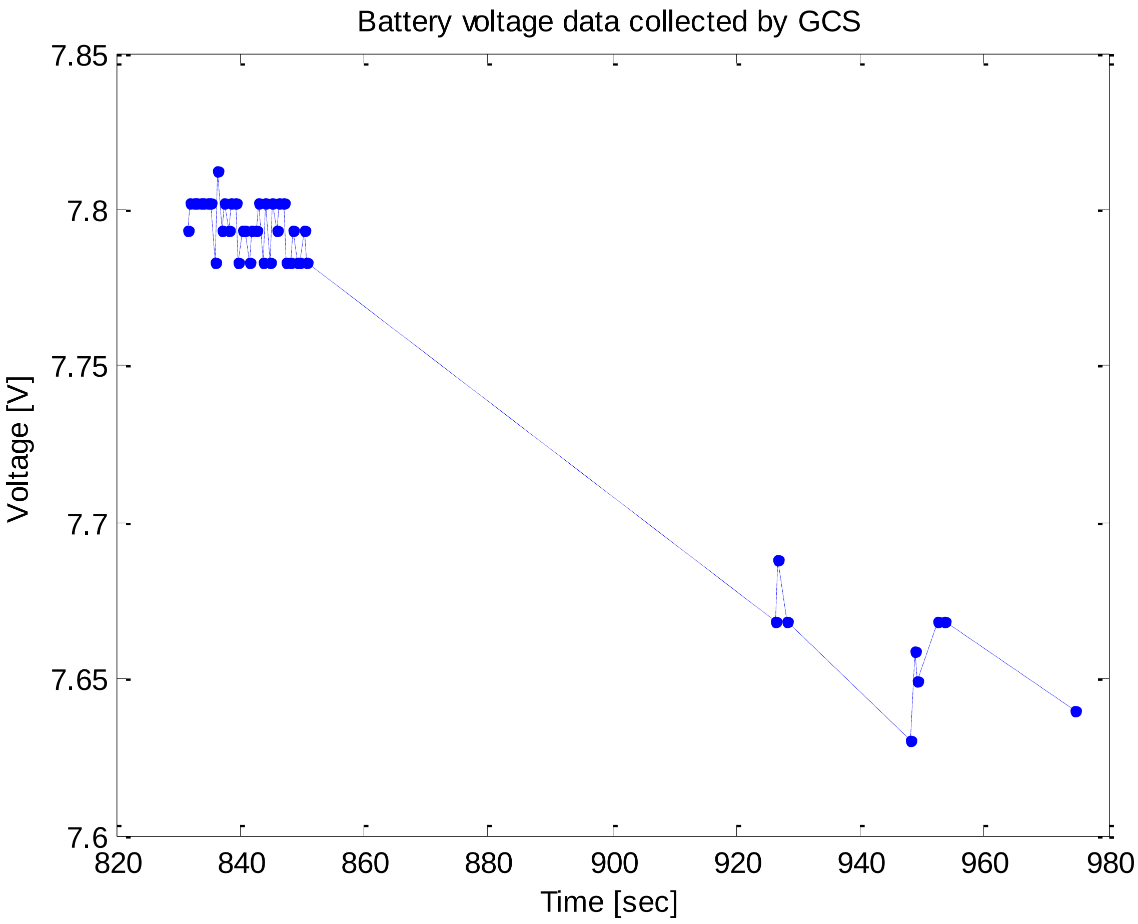




Ground level altitude is calculated via current air temperature and air pressure.

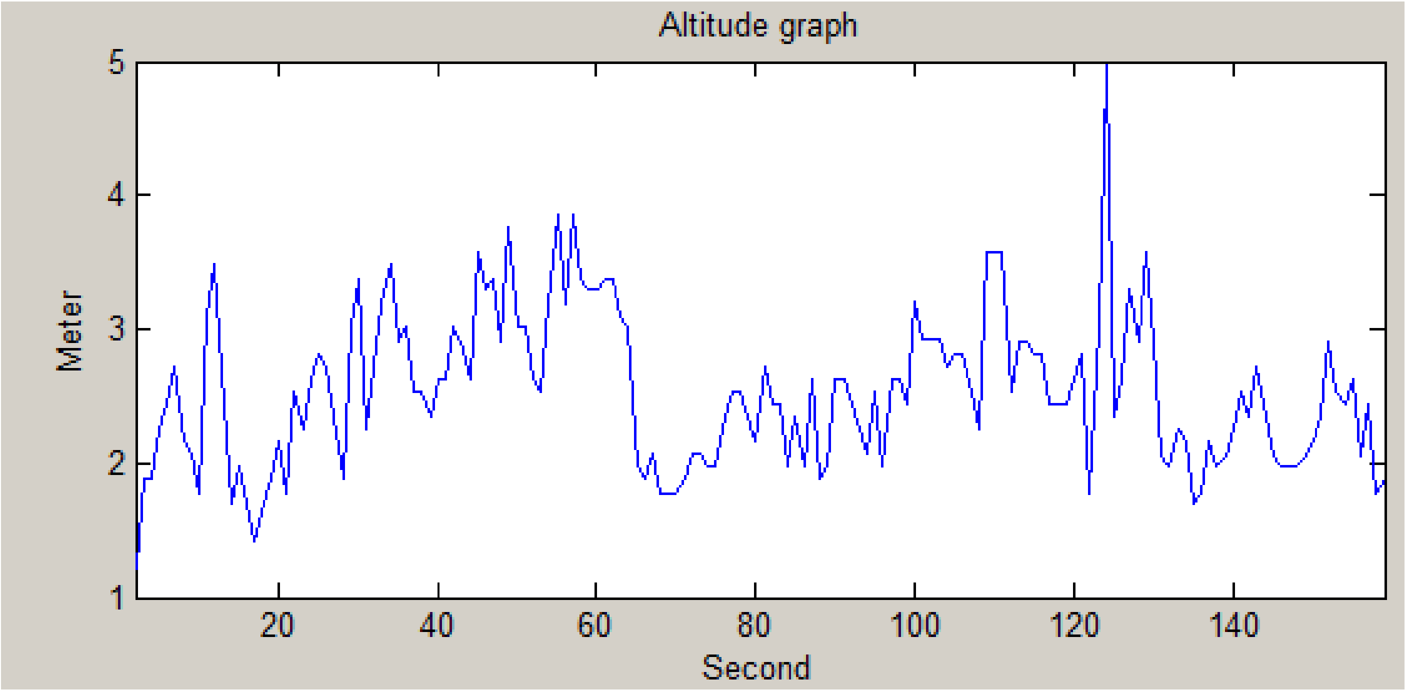
Flight Data Analysis

Battery voltage data collected by GCS are shown graphically. (Carrier)



Flight Data Analysis

Ground level altitude data collected by GCS are shown graphically. (Lander)

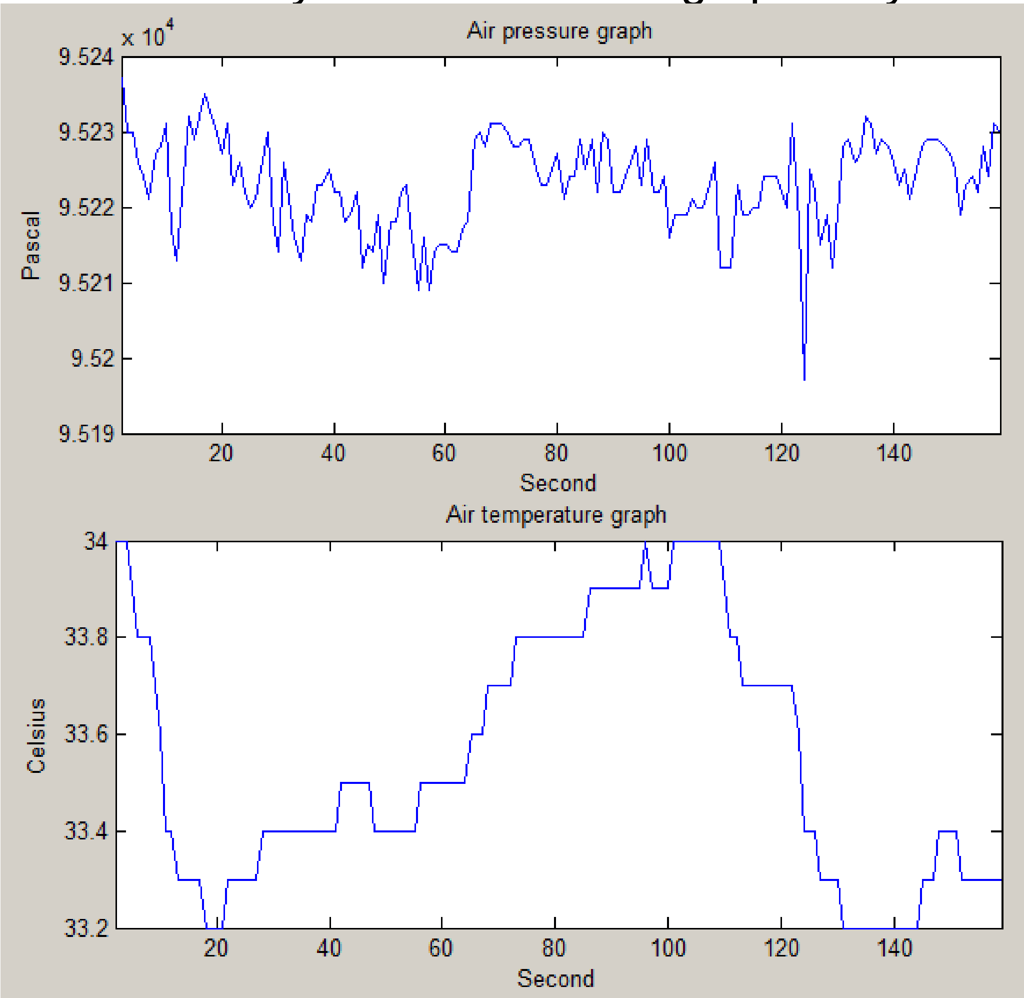


This measurement is taken just before launch.

Flight Data Analysis

Air pressure and air temperature data collected by GCS are shown graphically. (Lander)

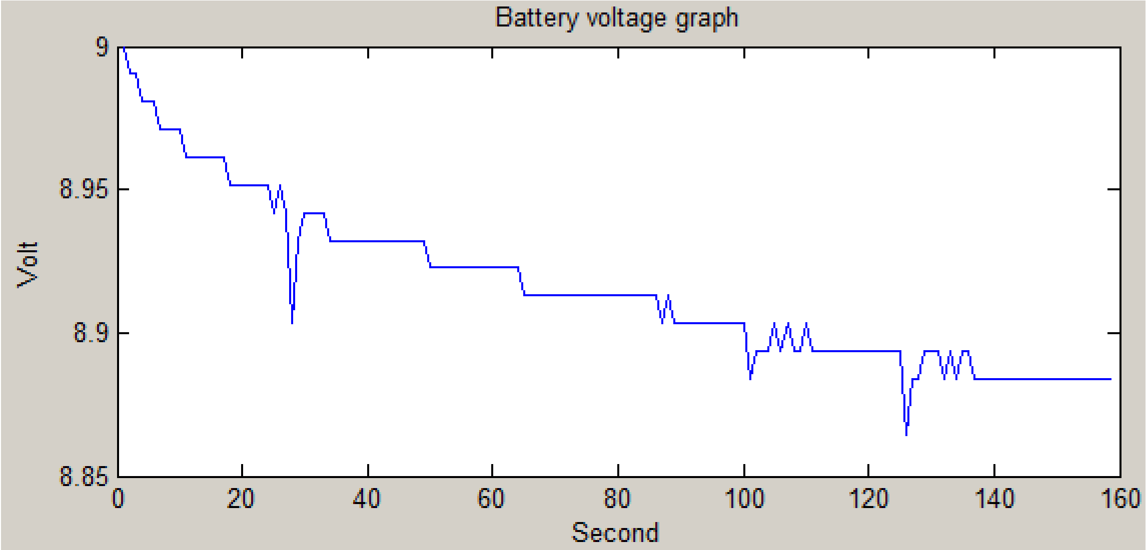
Ground level altitude is calculated via current air temperature and air pressure.



These measurements are taken just before launch.

Flight Data Analysis

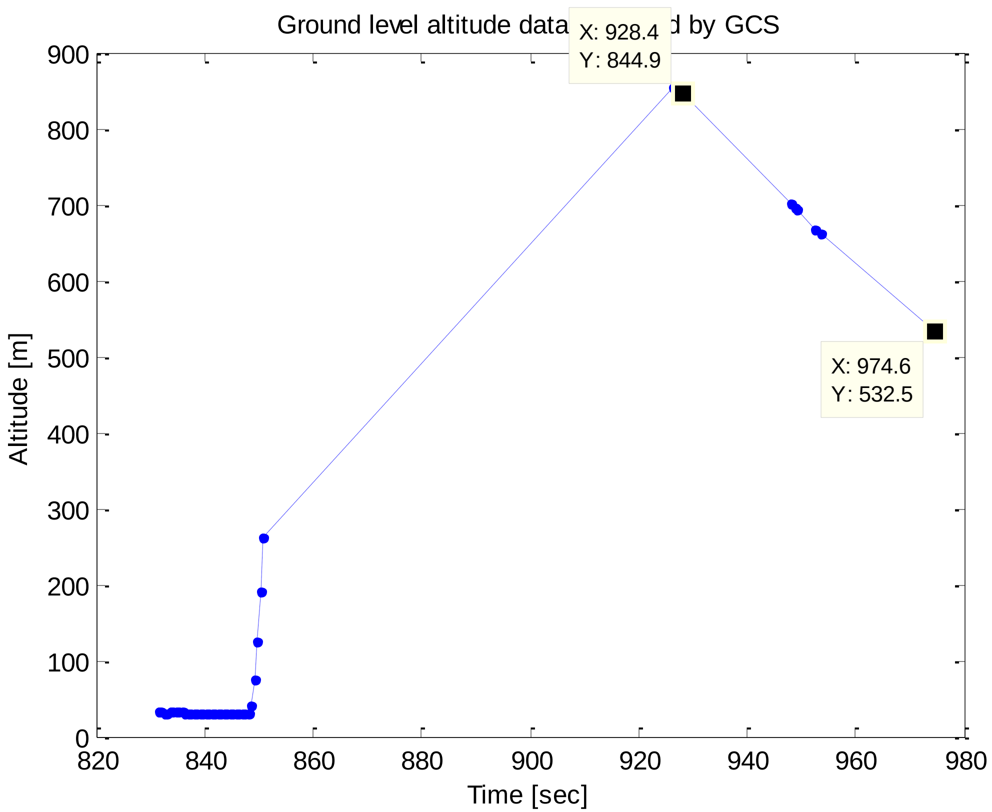
Battery voltage data collected by GCS are shown graphically. (Lander)



This measurement is taken just before launch.

Flight Data Analysis

Average descent rate is calculated as follows. (Carrier)



Numeric derivative of the line which is pointed by the datatips:

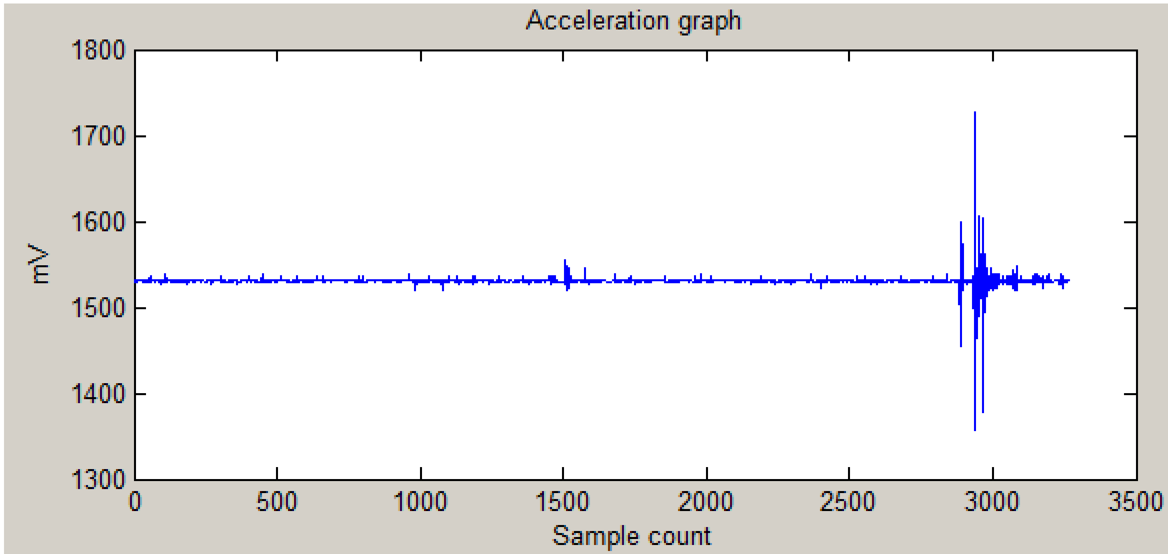
$$\frac{\Delta y}{\Delta x} = \frac{532.5 - 844.9}{974.6 - 928.4} = -6.76\ m/sec$$

Seperation altitude of the Lander is planned to be 525±25 meters. The last measurement is at 532.5 meters level. So:

- We won't be able to say seperation altitude.
- This average descent rate points to Carrier&Lander.

Flight Data Analysis

Impact force of the Lander.



Due to onboard storage failure of the Lander, acceleration measurement is not completed.

Mean sampling frequency (acceleration sensor):	386.6809 Hz

This measurement is taken just before launch.

Flight Data Analysis

Analysis:

- Carrier:
  - Pressure and temperature are measured from single sensor.
  - Altitude is calculated by air pressure and air temperature data[*].
  - GPS data are obtained by serial port. These data are used directly.
  - Battery voltage is measured with a simple voltage divider.
  - Average descent rate is calculated by simple numeric differentiation.

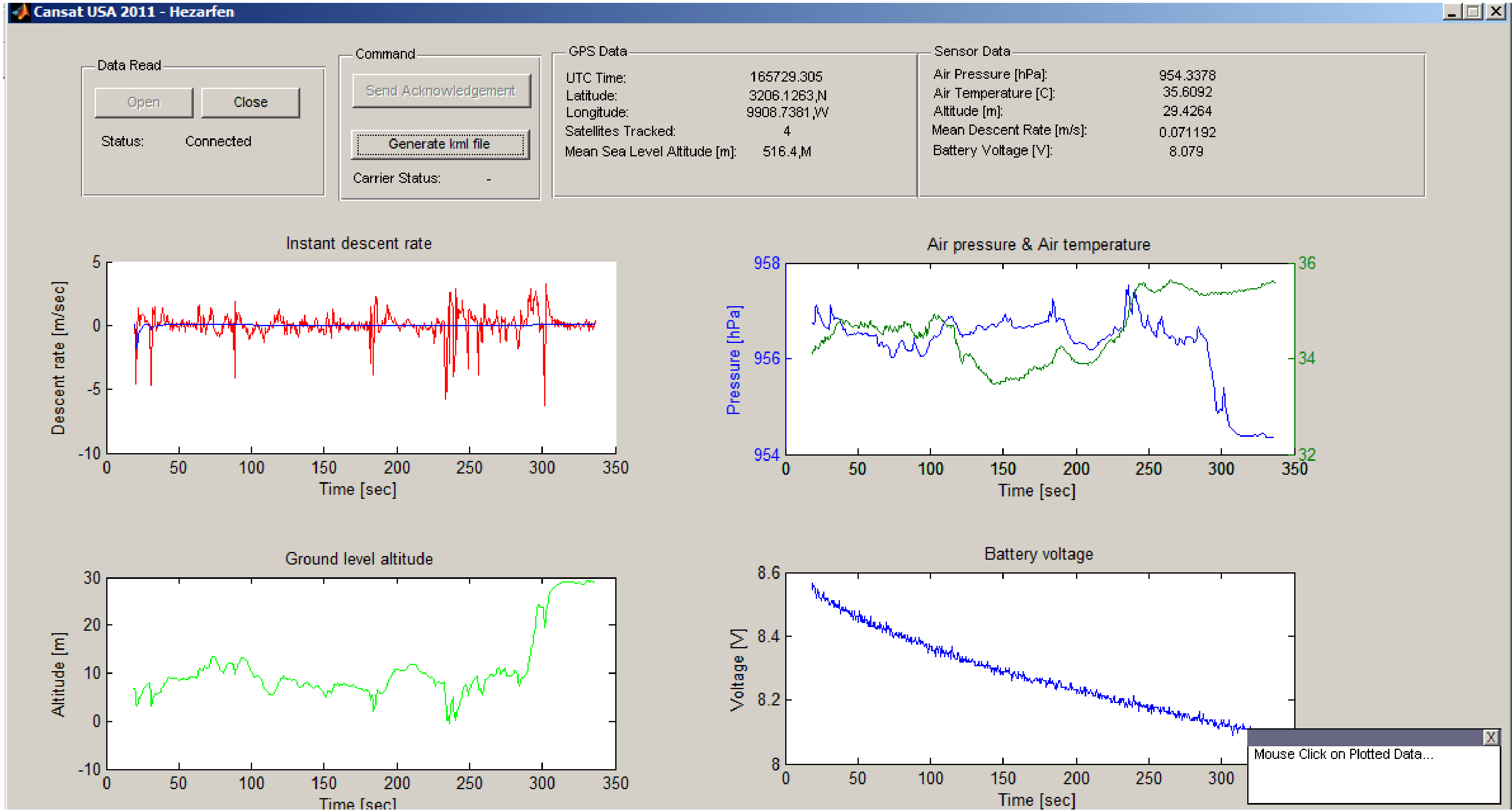
- Lander:
  - Pressure and temperature are measured from single sensor.
  - Altitude is calculated by air pressure and air temperature data.
  - Battery voltage is measured with a simple voltage divider.
  - Average descent rate is calculated by simple numeric differentiation.

All data are parsed and processed via a program written with Matlab. After that, these are visualized in a GUI (written with Matlab).

[*] Altitude formula is given at the end of this section.

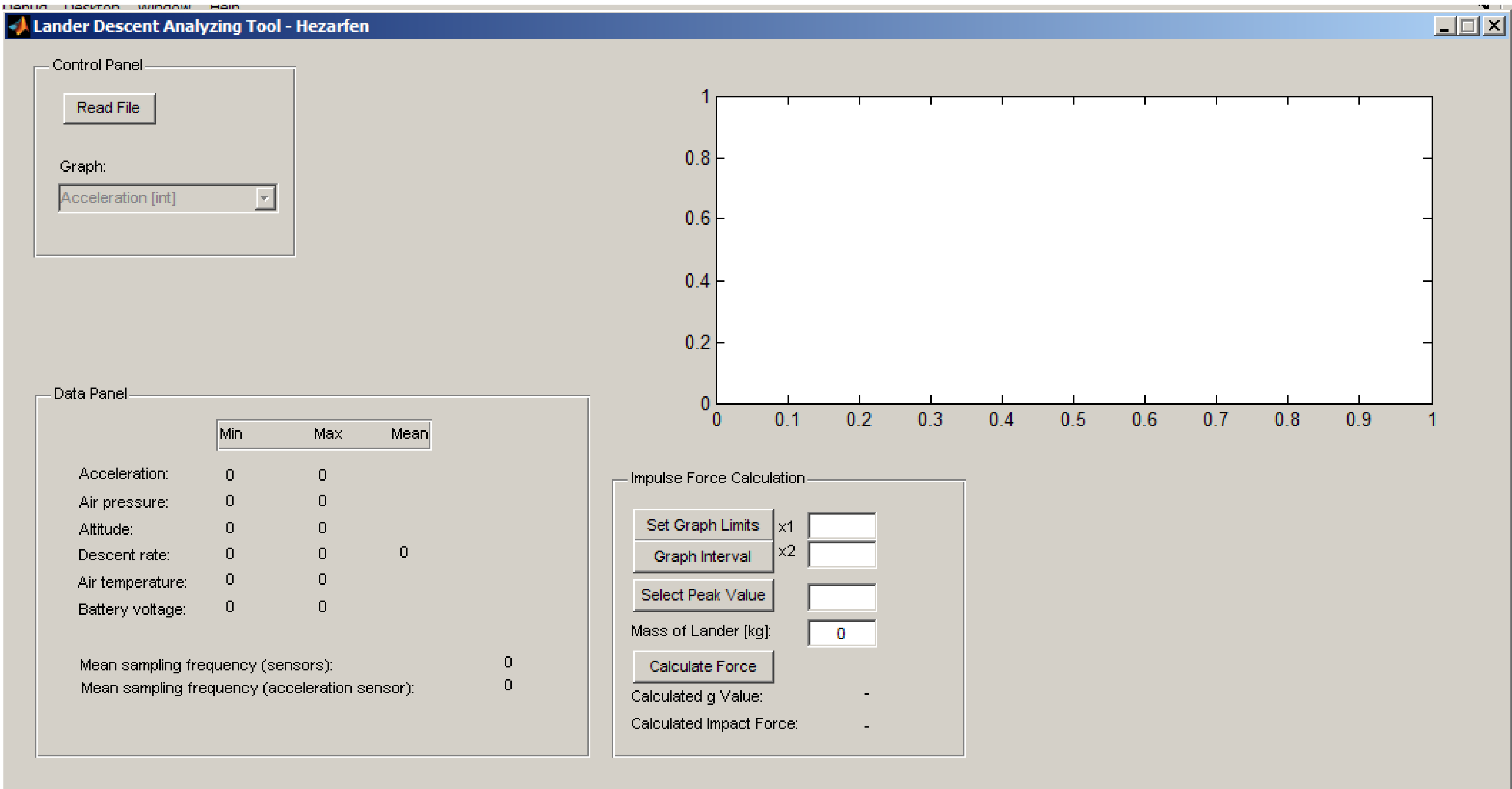
Flight Data Analysis

A screenshot of GCS software.



Flight Data Analysis

A screenshot of LDAT (Lander Descent Analyzing Tool) software.



Flight Data Analysis

All telemetry data are processed and graphed realtime in GCS. Also, upon retrieval of the Lander, LDAT is used. Role of this two programs is very crucial.

[*] Altitude formula:

$$P = P_0 \exp\left[\frac{-A\,z}{T}\right]$$

P: *Measured pressure* (Pa)

P_0: *Reference pressure* $(Sea\ level, Pa)$

A: *Coefficient* $(avg.\ 0.0342)$

z: *Altitude* $(in\ meters)$

T: *Temperature* $(in\ Kelvin)$

By arranging of variables,

$$z = \frac{T}{A}\ln\left[\frac{P_0}{P}\right]$$

Failure Analysis

İsmail ULUTÜRK

Failure Analysis

- **Lost connection between GCS and Carrier after launch.**
  - Link between the radios was lost. We made rangetests before and had a range longer than 1km on ground, so we think it might be caused by the acceleration of the rocket because it is the only new parameter to our tests.
    - We tested our circuit for short-circuits and broken connections, the circuit was still intact and working
- **Data on the Lander’s SDCard got corrupted.**
  - We couldn’t read the card. Because recovery took so long(~4 hours) by the time we got there the battery was depleted. We think depletion of the battery caused repetetive resets and that corruption on the filesystem of the card.
    - When we dumped the hex data of the card without filesystem we saw multiple log files.
  - A cut-off circuit could be used to shut the circuit on a safe level.

- **Carrier’s SDCard died.**
  - We couldn’t read the card. The card was not showing up when inserted. We tried low-level block read and block write operations but the card didn’t respond to commands specified by the SD Alliance. So we lost all our data stored on board on Carrier.
  - Problem might be caused again by the depletion of the battery, acceleretion of the rocket or because of the crash but SDCards are normally pretty rugged and robust so that is not very likely. It was working on our last tests, and it was working with a new card after recovery so we think we might got a faulty card.

Management

İsmail ULUTÜRK

Cansat Budget

Hardware Costs

	Category	Model	Quantity	Unit Cost	Determination
ELECTRONIC	Controller Board (Lander)	Arduino Pro Mini 328-3.3V/8MHz	1	19$	Actual
	Controller Board (Carrier)	Fez Mini	1	50$	Actual
	GPS Receiver (Carrier)	20Channel LS20126 GPS Receiver	1	60$	Actual
	Temperature + Pressure Sensor	SCP1000 with Breakout Board	1	35$	Actual
	Accelometer (Lander)	MMA7260Q	1	20$	Actual
	RF Transciever (Carrier)	AC4790-200M	1	51$	Actual
	RF Antenna (Carrier)	Laird 0600-00019	1	12$	Actual
	Pressure Sensor (Lander)	BMP085 with Breakout Board	1	20$	Actual
	Electronic Components	LEDs, Resistors, Connectors etc.	-	30$	Actual
	SDCard & Connector	Transcend 2GB MicroSD MicroSD Breakout from Sparkfun	2	45$	Actual
MECHANIC	Structure Materals	Silver steel	1	40$	Actual
	Parachute		2	10$	Actual
	Servo	Hitec HS-65HB Micro Carbonite	3	12$	Actual
	Egg protective mix	Dough with fermenter	1	7$	Actual
	SUBTOTAL			**425$**	

Cansat Budget

Ground System Costs

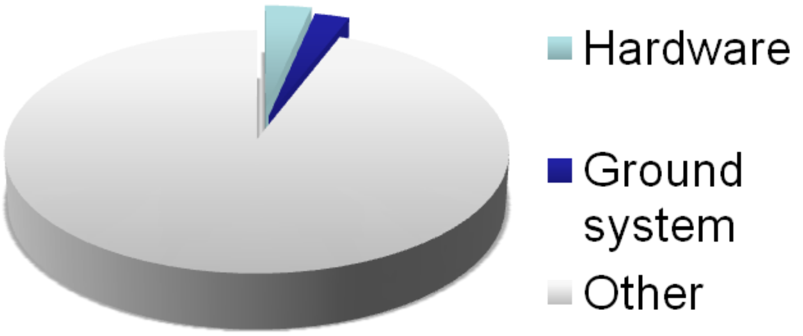
Category	Model	Quantity	Unit Costs	Determination
Antenna Cable	RG195 ANT Cable RPSMA Jack/Plug	1	56$	Actual
Wireless Adapter	Laird Tech. – CL4790	1	170$	Actual
Computer	Asus F3Sv	1	-	Actual
Miscallenous	Wires, expansion equipment		74$	Estimate
SUBTOTAL			**300$**	

Other Costs

Category	Quantity	Unit Costs	Total	Determination
Travel	5	1200$	6000$	Actual
Hotel	5	130$	650$	Actual
Van Rental	1	500$	500$	Actual
Food	5	250$	1250$	Actual
SUBTOTAL			**8400$**	

Income-Cost Equilibirium

Category	Cost
Hardware	425$
Ground System	300$
Others	8400$
Suprise Costs	1875$
Total Cost	11000$
Income	11000$



→Source of project income is ITU Controls & Avionics Lab., Elginkan Vakfı, Istanbul Ticaret Odası, TAI and Tubitak.

→The project can be fit with income and cost equilibirium

Conclusions

İsmail ULUTÜRK

What Worked / What Didn't

-Egg protection system using special dough proved itself. The egg had no cracks.

-The parachutes opened with no problem

-The body of both carrier and lander landed safely.

What Worked / What Didn’t

- Our egg protection system had excellent performance. We can say that it was the most successfull part of our CanSat.
- Our Lander deployment system successfully deployed the Lander, but because of the problems on both cards we can’t tell if we deployed it at the required altitude.
- Our mechanical structure worked as expected, both Carrier and the Lander was intact when we got them.
- Our descent control systems worked well, especially the small form factor of the parachutes really helped us, but because of our problems with the card, we won’t be able the tell if the descent rate was in the required range.

What Worked / What Didn’t

- Our telemetry system was working on ground and for some time after the launch, but then we lost connection. We did extensive range and stability test on our telemetry system for weeks, so the failure was a big let down. We suspect the cause to be the acceleration, but we should inspect further to say the last word.

- Our on-board data storage using MicroSD cards failed to some extent on Lander and completely on Carrier, that caused us almost all of the data collected. We trusted the robustness of SDCards and didn’t implement any back-up storage, such as a flash, which would have increased our flight performance greatly with very little extra effort.

- Not implementing a cut-off circuit in EPS most probably caused us both MicroSD Cards, so implementing that would have helped us greatly with little extra effort.

What Worked / What Didn't

- **Our sensor systems worked as expected but since we lost our data, that is almost meaningless at this point.**

- **We worked a lot on our analysis tools and and Ground Station to have real time plotting of the data and quick analysis of the data using different methods and filters, and they helped us a great deal to get the most from the data we have at hand.**

Lessons Learned

- **We should have found the money earlier. Getting the sponsors and the money late caused us some testing time.**
- **We should have done a more extensive testing, everything was working great on the table, so we should have included a rocket flight somehow to our test schedule.**
- **We shouldn't have trusted solely on one thing for storage just because it was the defacto standard for years in the industry ☺. We should have implemented extra back-up data storage devices for the Lander and the Carrier.**