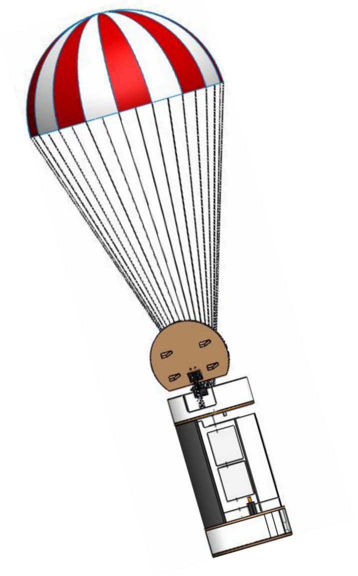
CANSAT 2018
POST FLIGHT REVIEW (PFR)



Team #5002

Manchester CanSat Project

INTRODUCTION

(Iuliu Ardelean and Lawrence France)

PRESENTATION OUTLINE

This review follows the sub-sections listed below:

Section	Presenter
INTRODUCTION	Iuliu Ardelean and Lawrence France
SYSTEMS OVERVIEW	Iuliu Ardelean and Lawrence France
CONCEPT OF OPERATIONS AND SEQUENCE OF EVENTS	Iuliu Ardelean and Lawrence France
FLIGHT DATA ANALYSIS	Iuliu Ardelean and Lawrence France
FAILURE ANALYSIS	Iuliu Ardelean and Lawrence France
LESSONS LEARNED	Iuliu Ardelean and Lawrence France

MANCHESTER CANSAT PROJECT

TEAM ORGANIZATION

ANNUAL CANSAT COMPETITION

Iuliu Ardelean
Team Leader

Nicole Zieba
Project Manager

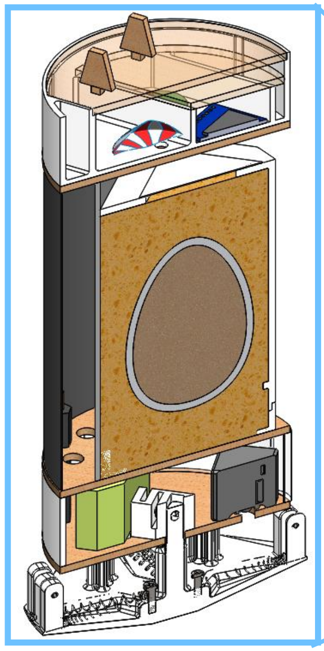
Mechanical Subsytem	Electrical Subsytem	Integration and Testing	Ground Control Station
Alex Shelley 3rd Year	**Iuliu Ardelean** 3rd Year	**Lawrence France** 4th Year	**Iuliu Ardelean** 3rd Year
Davis Joseph 4th Year	**Xisco Jover** 3rd Year		
Julia Stankiewicz 2nd Year	**Nicole Zieba** 4th Year		
Zair Chaudhry 3rd Year	**Lawrence France** 4th Year		
Nacho Salsas 3rd Year	**Robert Stana** 3rd Year		

SYSTEMS OVERVIEW

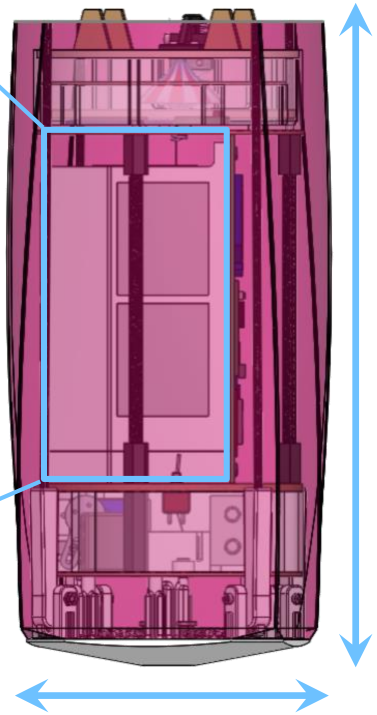
(Iuliu Ardelean and Lawrence France)

CANSAT DESIGN OVERVIEW

Stowed Payload

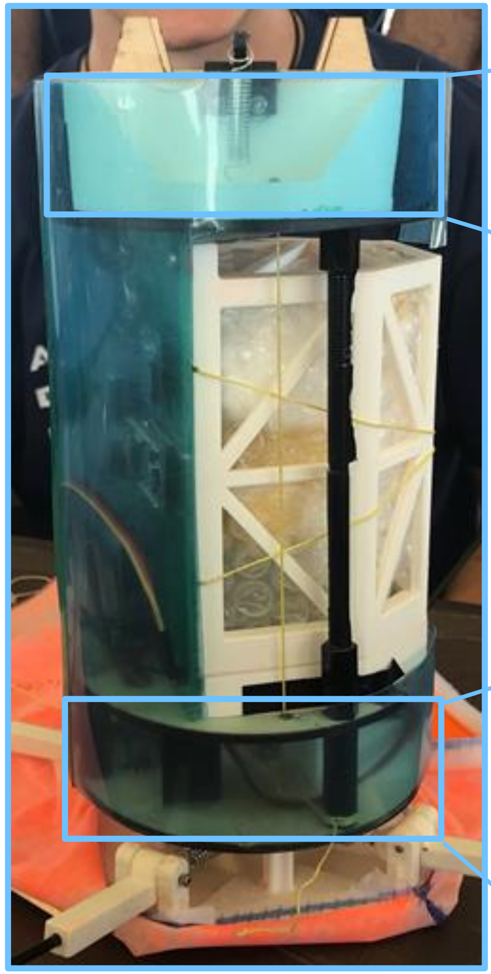


Egg with padding



248.5 mm

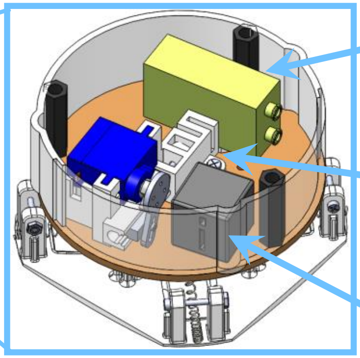
120 mm



Parachute Bay

Stowed Parachute

Camera Bay



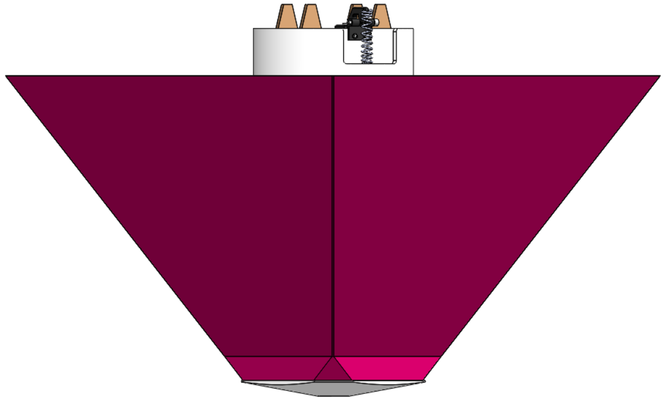
Battery

Central Control Unit (CCU)

Camera

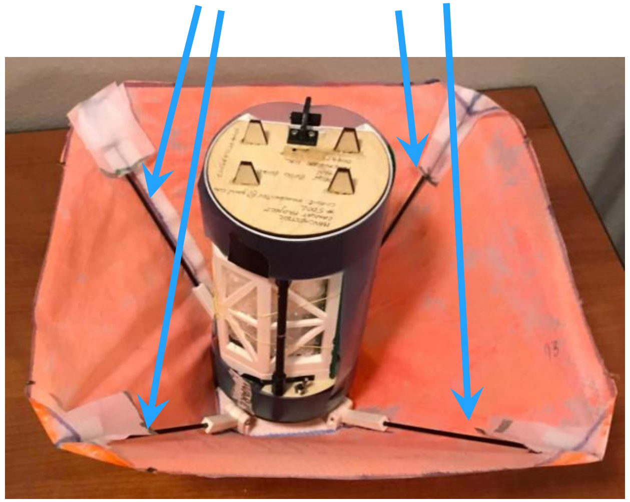
CANSAT DESIGN OVERVIEW

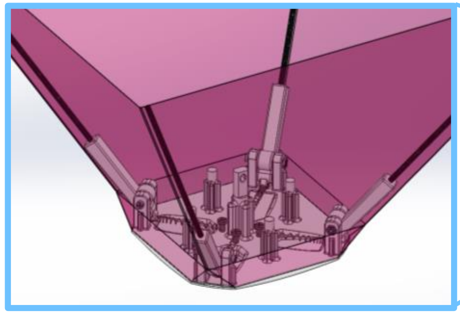
Deployed Heat Shield Payload

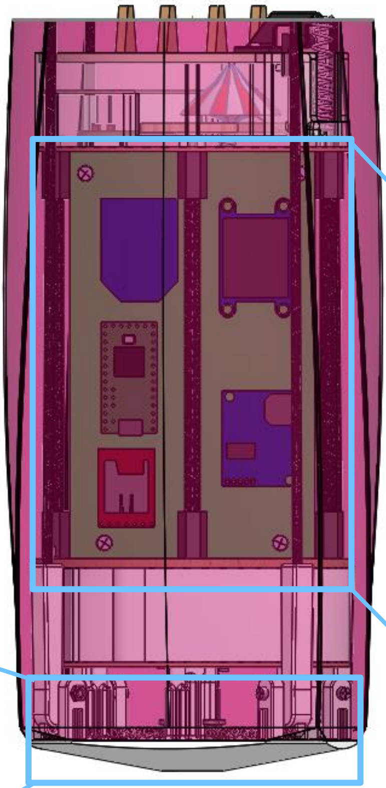


Heat Shield Assembly

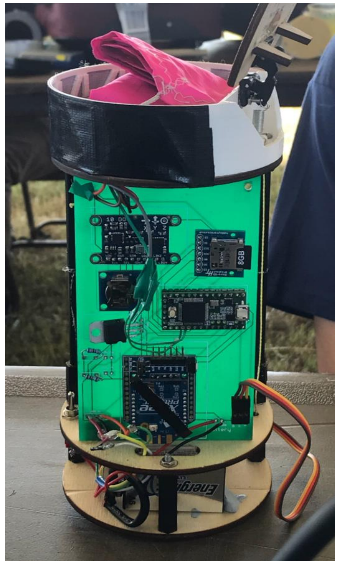
Carbon Fibre Rods

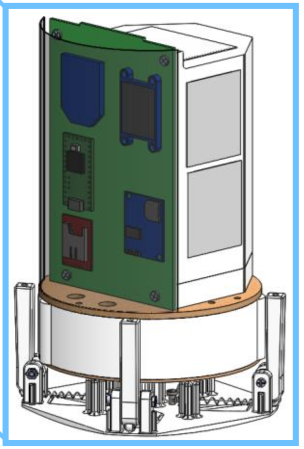






PCB





CANSAT DESIGN OVERVIEW

Available Volume (as per Competition Requirements):

Diameter : 125 mm
Height : 310 mm

CanSat Volume:

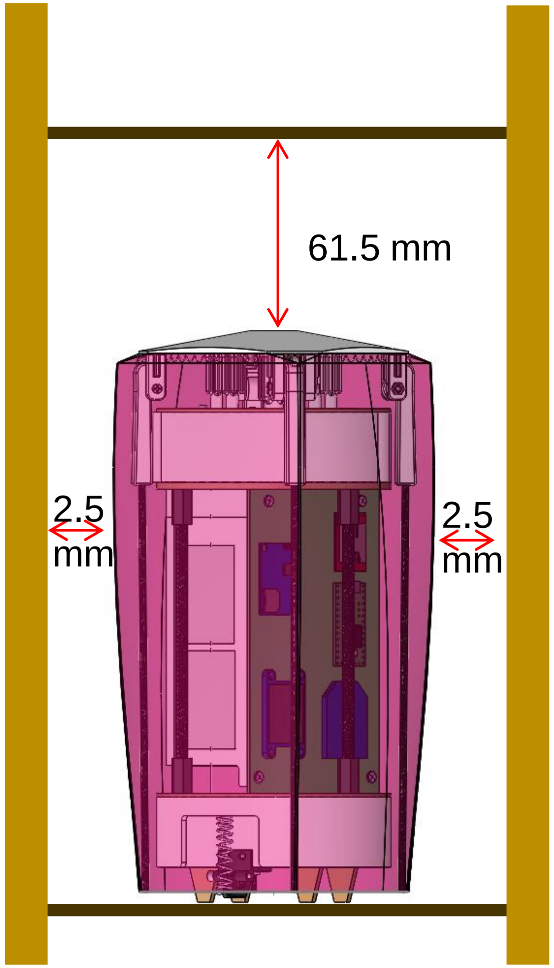
Diameter : 120 mm
Height : 248.5 mm
Clearance : More than 2.5 mm throughout

CanSat mass (measured):

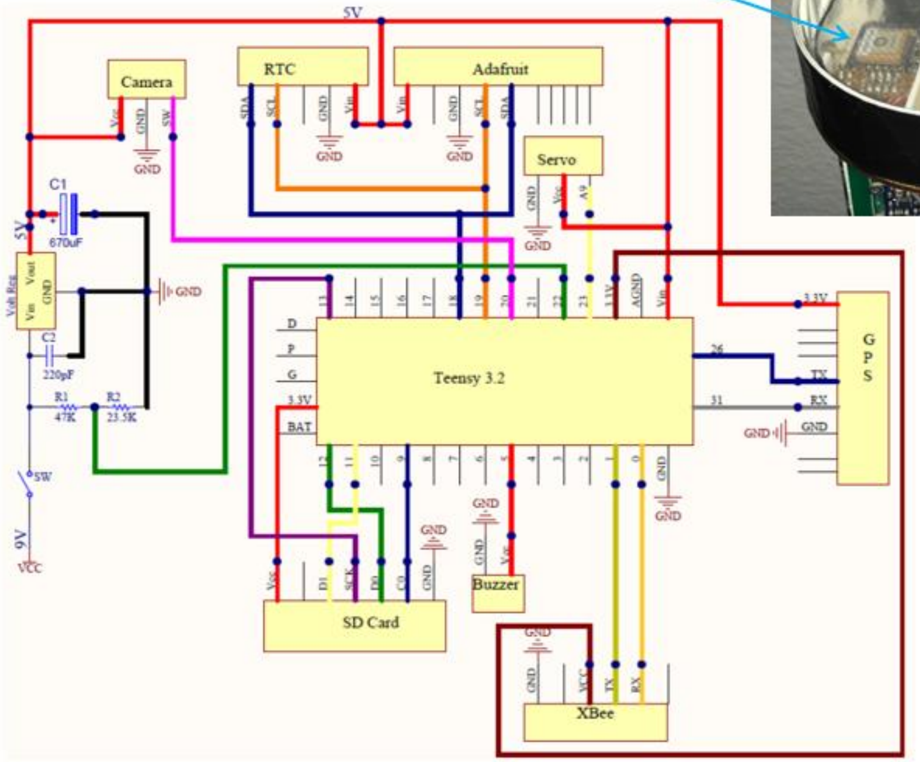
Without the egg : 448.00 g
With the egg : 509.9 g

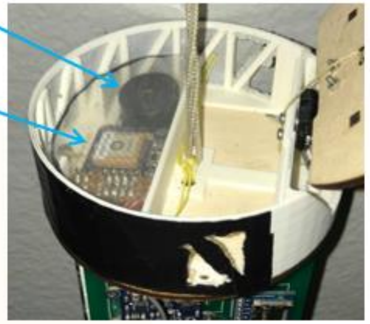
- No sharp protrusions
- Mass is within the required limit
- Dimensions account for ease of fit and deployment.

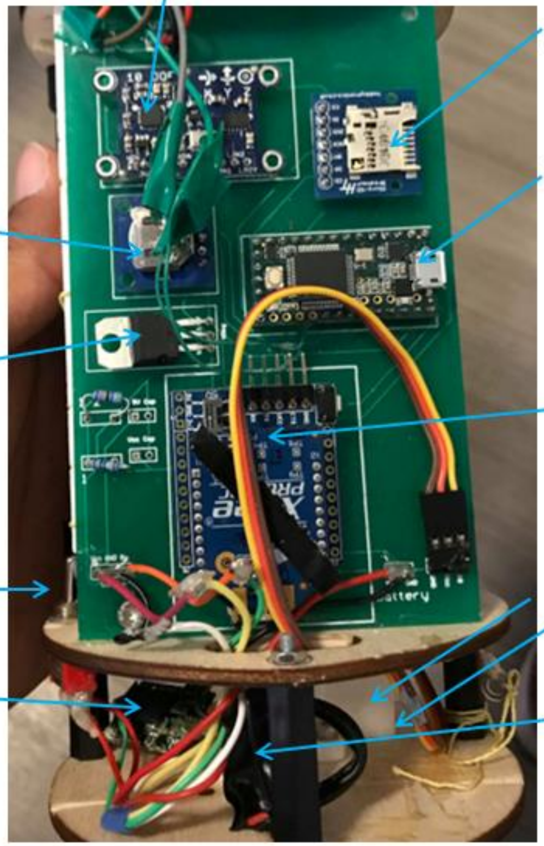
Stowed Payload inside Rocket



Electronics Overview







COST OF CANSAT

Electronic components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Adafruit 10-DOF IMU	Temp., Press., Alt, Tilt	No	1	**21.11****	**28.15****
Adafruit Ultimate GPS Breakout	GPS	No	1	**40***	**53.33***
Modified SQ11 Pawaca Camera	Camera	No	1	**14.99***	**19.99***
Teensy 3.2 USB Microcontroller	Microcontroller	No	1	**19.80***	**26.40***
Breakout for SD Card	On board data storage	No	1	**4.20***	**5.60***
16 GB SD Card	SD Card	No	1	**6.80***	**9.07***
DS1338	RTC	No	1	**3.08***	**4.11***
XBee Pro S2C	Transceiver	No	2	**52.42***	**69.87***
Energizer Lithium	Battery	No	1	**7.05***	**9.40***
Servo	Mechanisms	No	1	**4***	**5.33***
Switch	On/Off Switch	No	1	**0.61***	**0.81***
			Total	**174.06**	**232.03**

Legend			
Estimated	**XX**	**Actual**	**XX**

*Current Market Value
**Market Value of Discontinued Item

COST OF CANSAT

3D printed components					
Equipment	**Part Name/Specifications**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Egg Protection Base	Egg Containment	Yes	250 g (including failures/prototyping)	**@ £275 per 500 g cartridge = £137.50**	**183.33**
Egg Protection Cover	Egg Containment	Yes			
Nose Cone	HS	183.33			
CCU	Release/Deployment Mechanisms	Yes			
HS CF Pivots	HS	Yes			
Parachute Bay	Electronics/Parachute Storage	Yes			
			Total	**£137.50**	**183.33**

Legend			
Estimated	**XX**	**Actual**	**XX**

MANCHESTER CANSAT PROJECT

CanSat Budget – Hardware

ANNUAL CANSAT COMPETITION

Off the shelf components					
Equipment	**Part Name/Specifications**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Sponge	Egg Protection	Yes	-	0.50	0.67
Nuts and Bolts	M3 and M2	Yes	35	3	4.02
Carbon Fiber Rods	HS structure	Yes	4	1.62	2.17
Springs	HS release and deployment	Yes	5	0.80	1.07
Ripstop Nylon	HS deployment	Yes	1	1.00	1.34
String	HS	Yes	-	0.50	0.67
Nylon Spacers	10 mm and 30 mm	Yes	12	5.20	6.97
Servo Horn	Parachute Release Mechanism	Yes	1	0.50	0.67
CCU Rod	Parachute Release Mechanism	Yes	1	1.00	1.34
Hinge	Parachute Release Mechanism	Yes	1	0.32	0.43
Laser Cut Plywood Plates	HS Release Mechanism Bay, Camera Bay, Parachute Bay	Yes	4	3.25	4.35
Laser Cut Plywood	Feet	Yes	4	0.75	1.00
			Total	18.44	24.7

Subsystem	Cost (£GBP)	Cost ($USD)
Structures	£155.94	$208.03
Electronics	£174.06	$232.03
Tools	£0	$0
Total	£330	$440.06

Legend			
Estimated	XX	**Actual**	XX

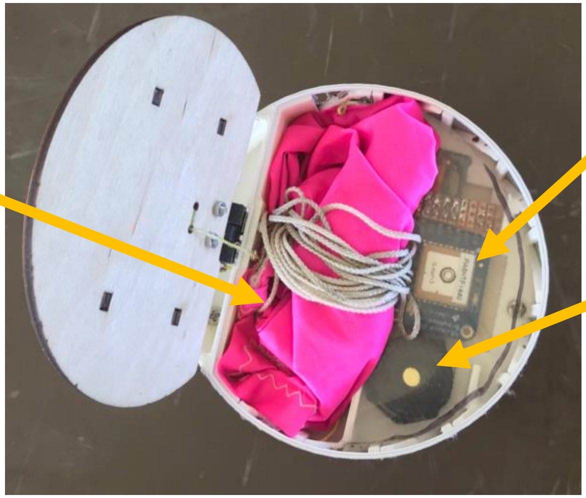
Most expensive parts included: XBee, Adafruit sensor, GPS and Camera.

The total cost of CanSat is well below $1000 as required by the competition guidelines.

PHYSICAL LAYOUT

Parachute Bay (top view)

Parachute

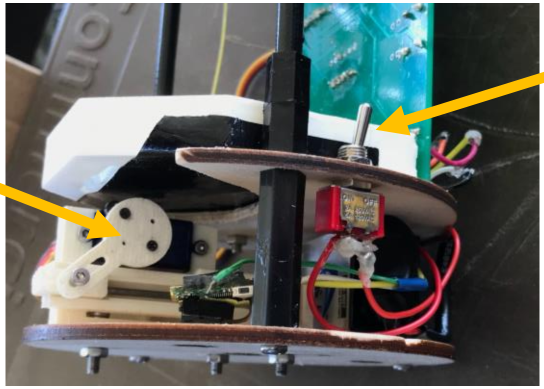


GPS

Buzzer

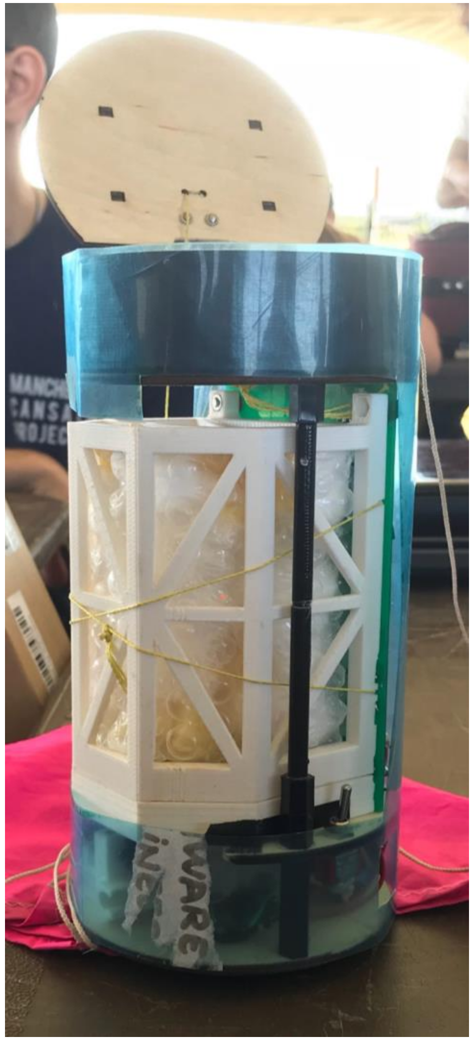
Camera Bay

Servo



Switch

Probe without Heat Shield



PCB

PHYSICAL LAYOUT

Probe and Nose Cone

CanSat with stowed Heat Shield (pre-folding)

CONCEPT OF OPERATIONS AND SEQUENCE OF EVENTS

(Iuliu Ardelean and Lawrence France)

COMPARISON OF PLANNED AND ACTUAL CONOPS

(CONOPS from CDR)

0. Pre - Launch	1. Launch	2. HS Deployment	3. CanSat Descent	4.1. HS Release
• CanSat Switched on • Telemetry transmitting start	• CanSat insertion in Rocket Payload Bay • Rocket ignition and ascension • Apogee Reached	• Rocket and nose cone separation • CanSat deployed from rocket Payload Bay • HS deploys • Rocket and nose cone descent	• CanSat descent with Heatshield deployed	• 300 m altitude sensed by Probe • HS released • Release captured by Camera

Actual release altitude: 310 m; margin was introduced to make sure that Heat Shield is going to deploy within the given limit; camera did not record the release of the HS, as it had been turned on at 300 m (as required).

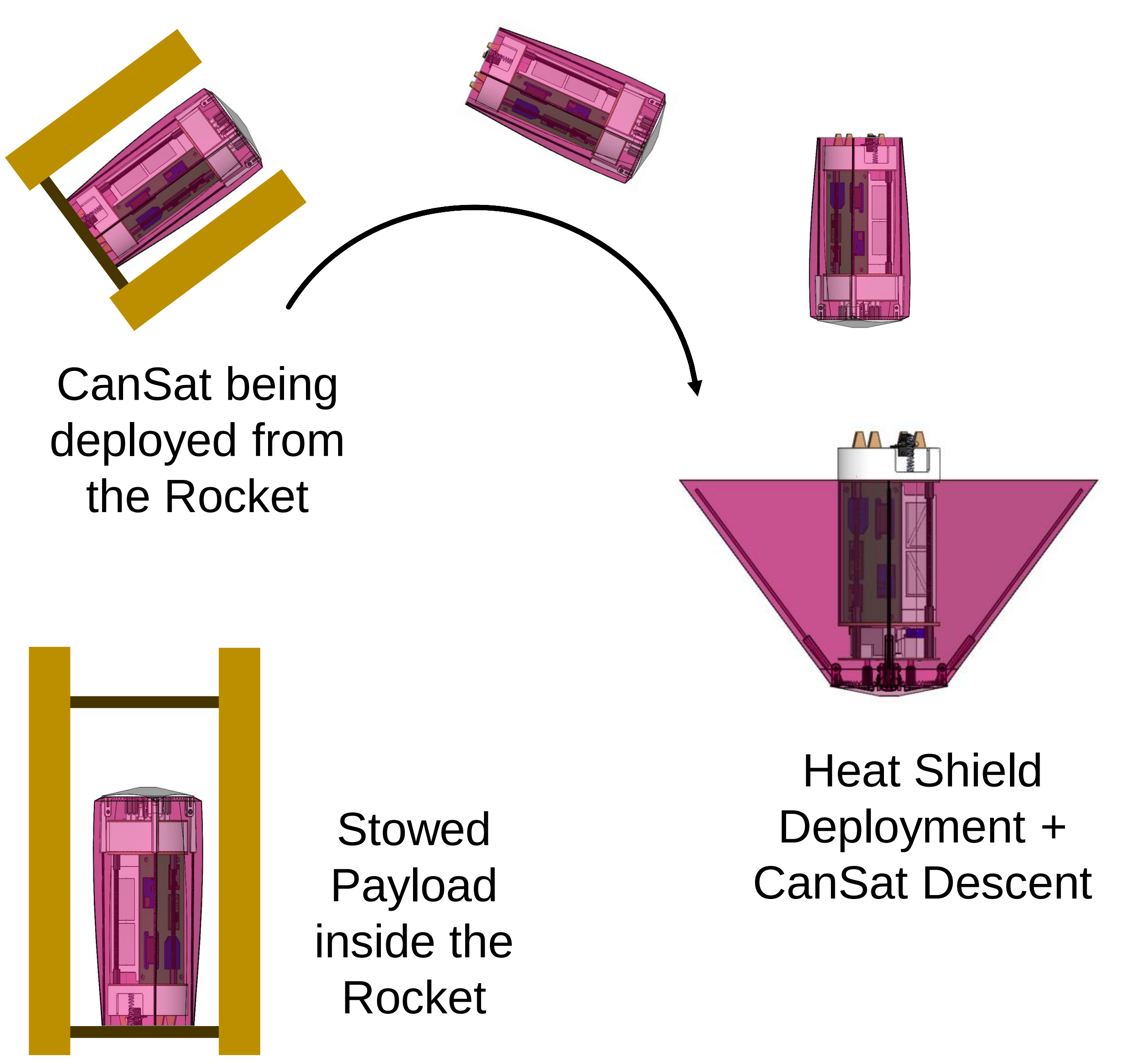
COMPARISON OF PLANNED AND ACTUAL CONOPS

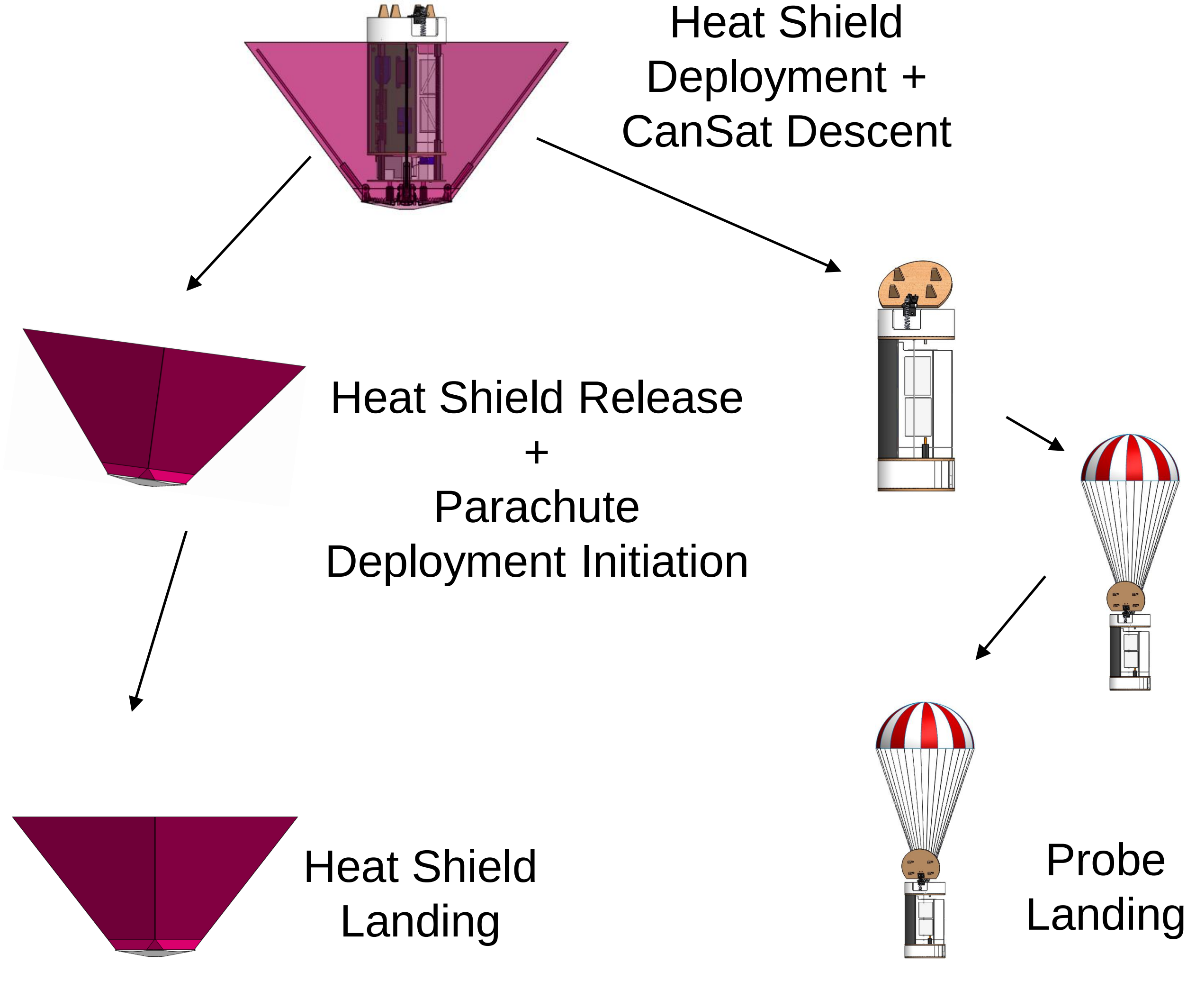
(CONOPS from CDR)

4.2. Parachute Deployment	5. Probe Descent	6. Landing	7. Recovery	8. Data Handover
• 300 m altitude sensed by Probe • Parachute deployed	• Probe descent with Parachute • HS tumble down on its own • Descent captured by Camera	• Telemetry transmitting Stop • Audio Beacon Activation	• Audio Beacon Operational • All systems recovered (including HS) • CanSat switched off	• Data formatted and saved to USB • USB handed over to officials • Data analysis and reduction for PFR

Actual parachute deployment altitude: 310 m; landing mode was turned on at 42 m making sure that Audio Beacon Activation requirement is completed; telemetry was not transmitted after the probe reached the altitude of 42 m; **HS was not recovered**.

COMPARISON OF PLANNED AND ACTUAL CONOPS





COMPARISON OF PLANNED AND ACTUAL SEQUENCE OF EVENTS

(Sequence of Events from CDR)

1. Arrival – 0800 – Full Team
2. Final Integration and Testing – CanSat Crew
3. Official Inspection – 1200 – NZ
4. Collect CanSat – NZ
5. CanSat integration with rocket – AS
6. Check Communications - IA
7. GCS & Rocket with CanSat transportation to Launchpad – NZ, AS, IA
8. Rocket Installation – Officials
9. GCS operational – GCS Crew
10. Launch Procedures Execution – NZ
11. Flight + GCS Operational – GCS Crew
12. All CanSat Launched
13. Recovery – Recovery Team
14. Handout CanSat for Final Judging – NZ
15. Terminate GCS Operation – IA
16. Submit USB with collected and received data – NZ
17. Begin PFR work

Actual sequence of events happened as planned.

Legend			
Unsuccessful	(red)	Successful	(green)

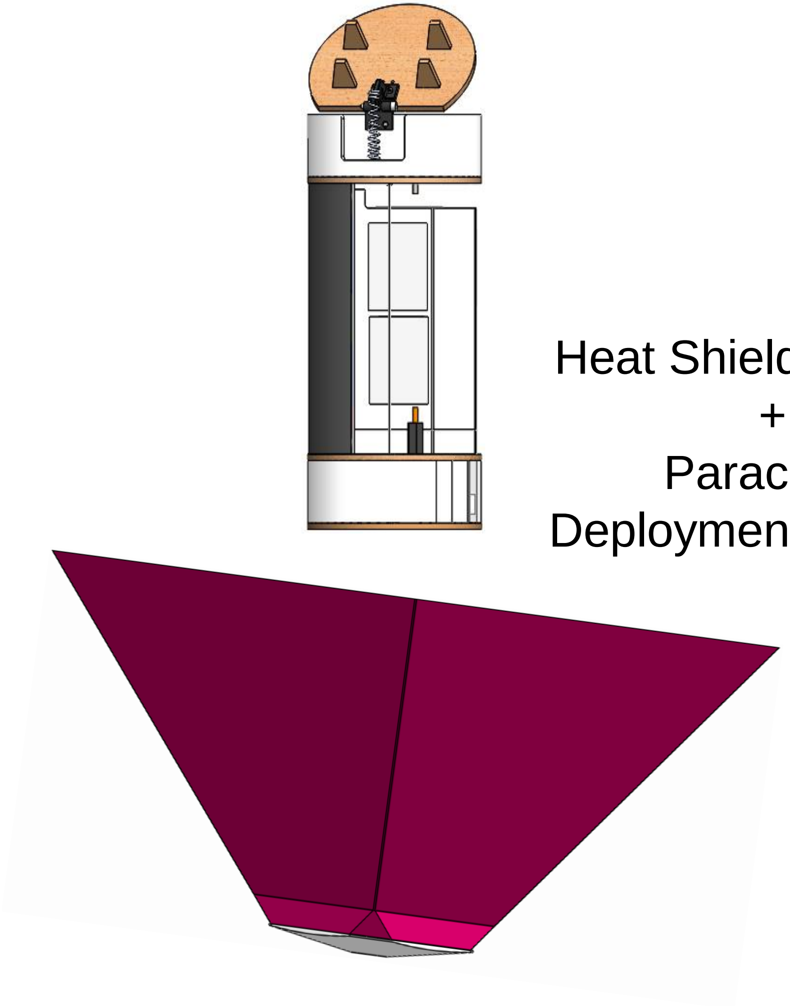
FLIGHT DATA ANALYSIS

(Iuliu Ardelean and Lawrence France)

HEAT SHIELD SEPARATION ALTITUDE

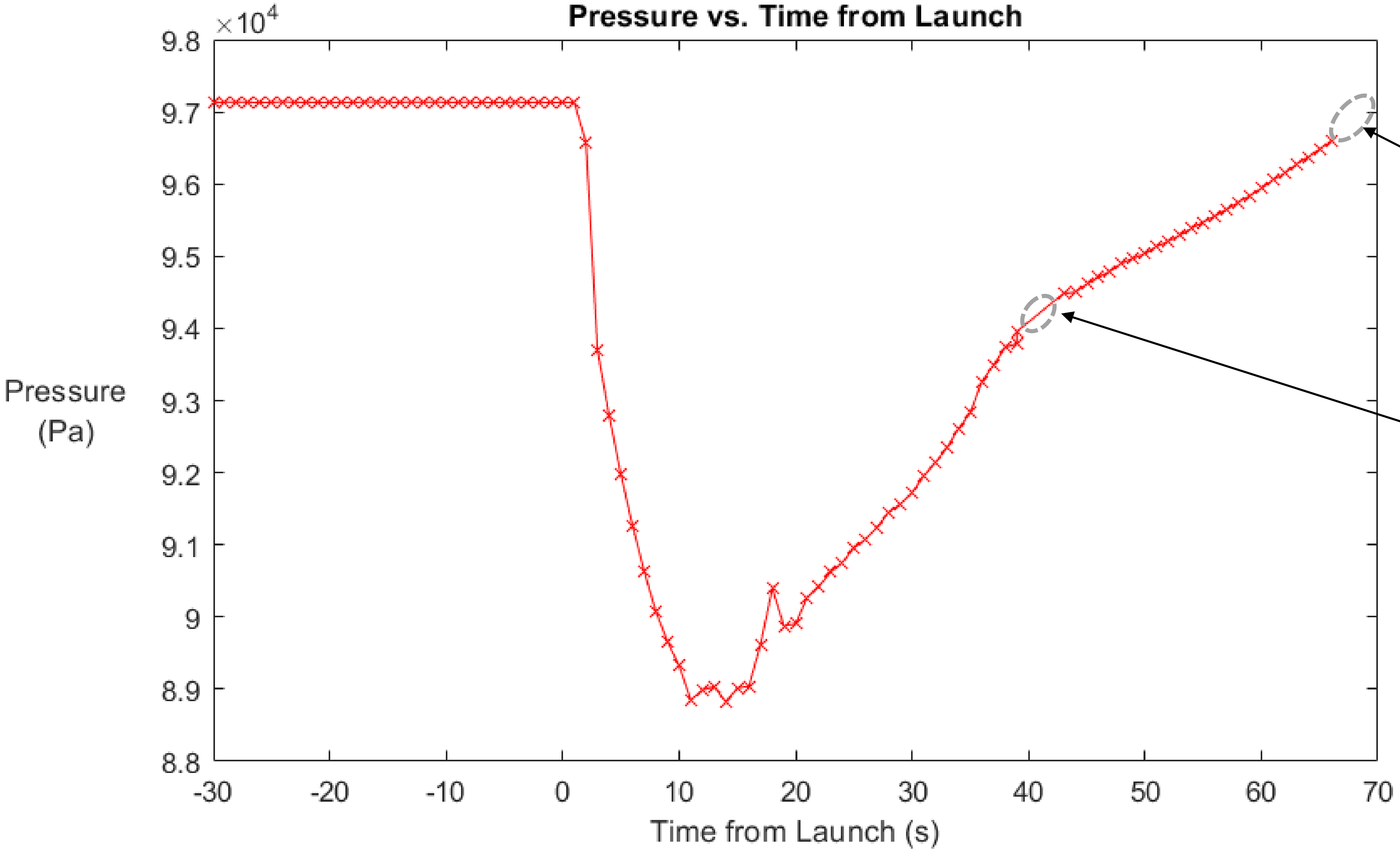
- Heat Shield separation altitude required in competition guidelines is 300 m.

- **The actual altitude at which separation took place was measured to be 310 m.**
  - HS release altitude set to be 310 meters in the code
  - This 10 m margin was included to account for the distance the CanSat could continue to fall before the heat shield has been properly removed (response time).



Heat Shield Release
+
Parachute
Deployment Initiation

PAYLOAD PRESSURE SENSOR DATA PLOT

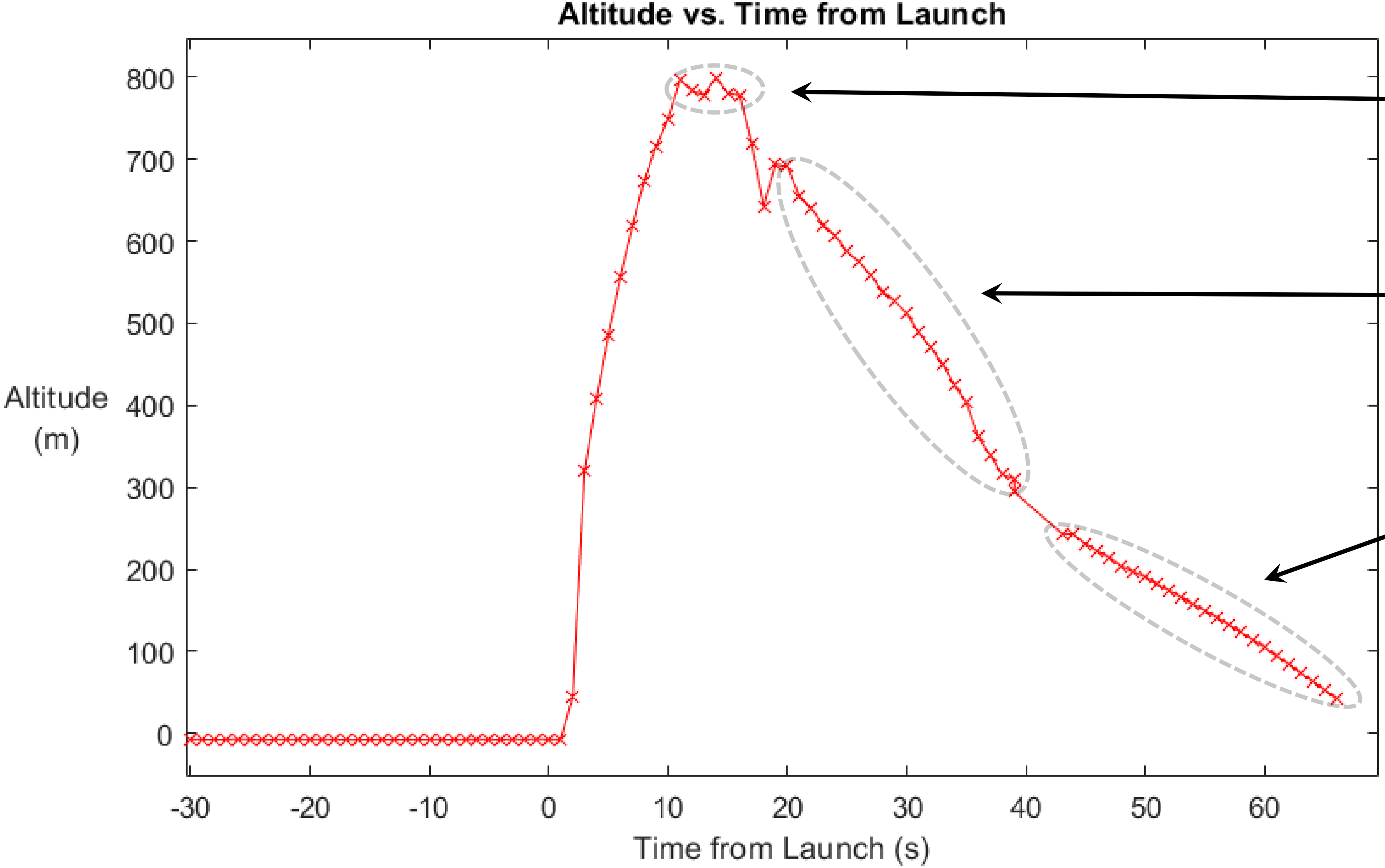


Pressure falls with altitude

CanSat stops transmitting at 43m due to code feature

Loss in data packages due to camera activation

PAYLOAD ALTITUDE PLOT

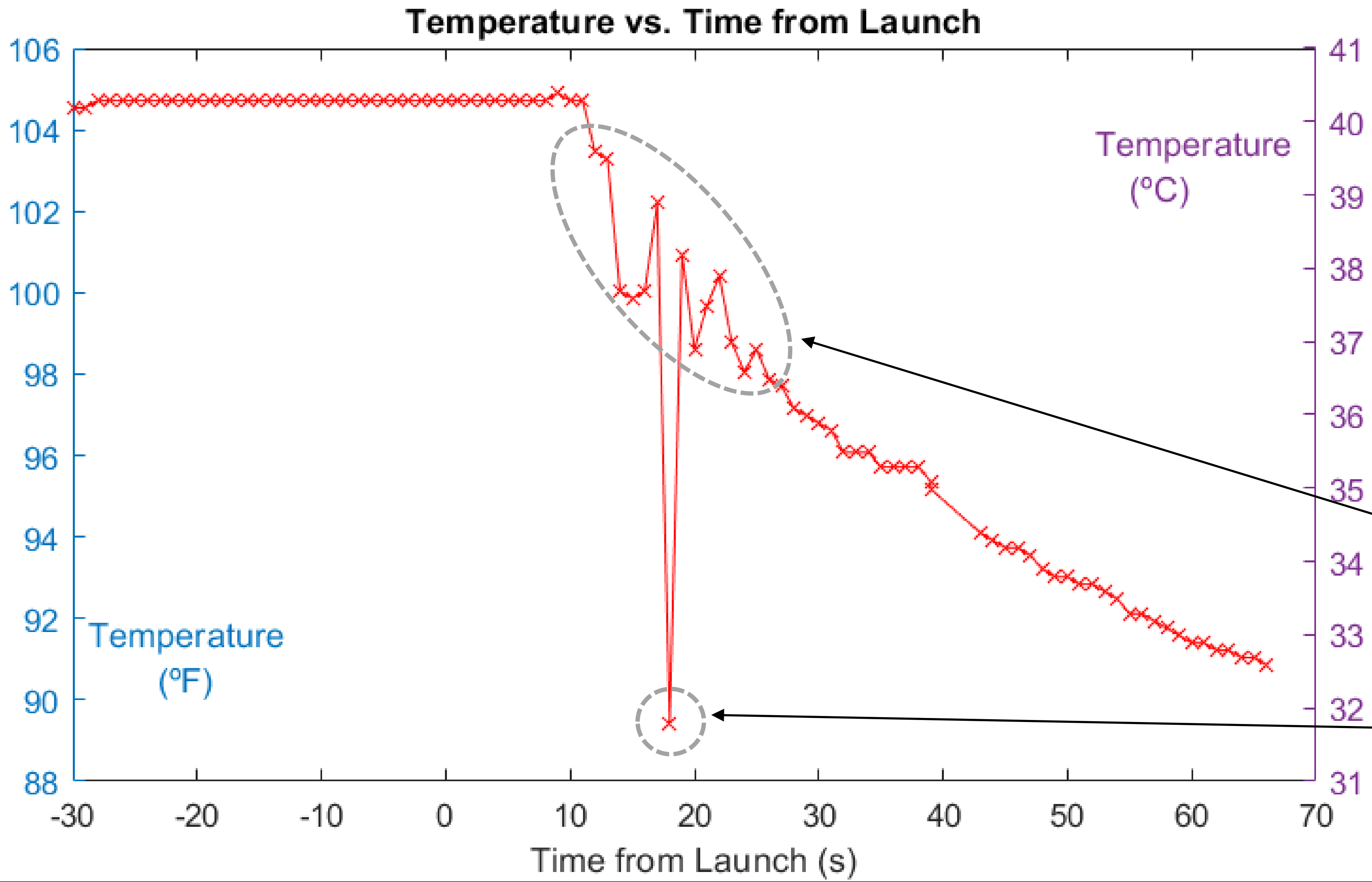


Apogee: 799m

Descent with heatshield: 18.2 m/s

Descent with parachute: 8.7 m/s

PAYLOAD TEMPERATURE SENSOR DATA PLOT



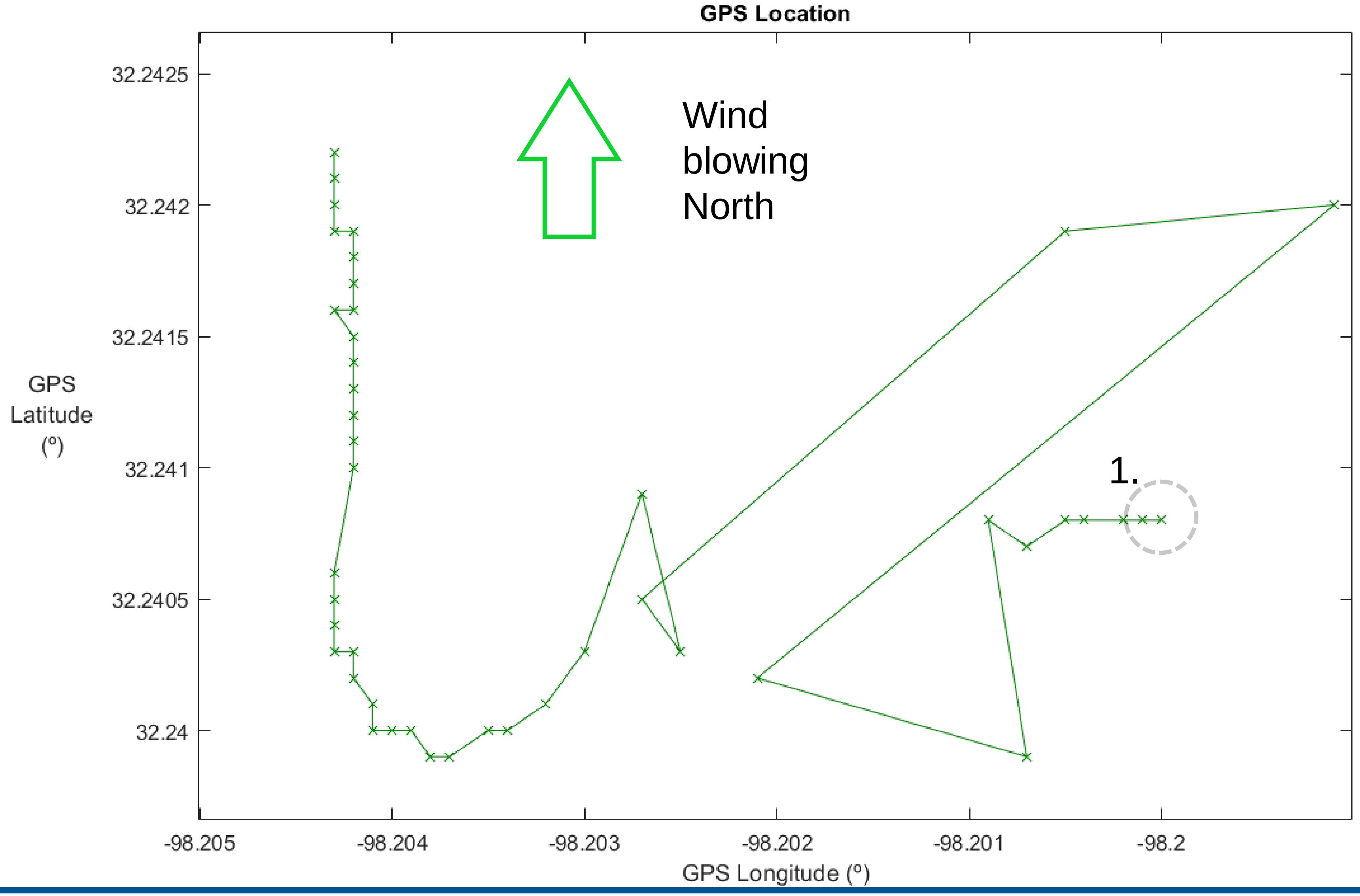
Probe is heated inside rocket to around 40ºC

Cools down naturally when exposed to open air flow

High Noise Region – immediately after launch.

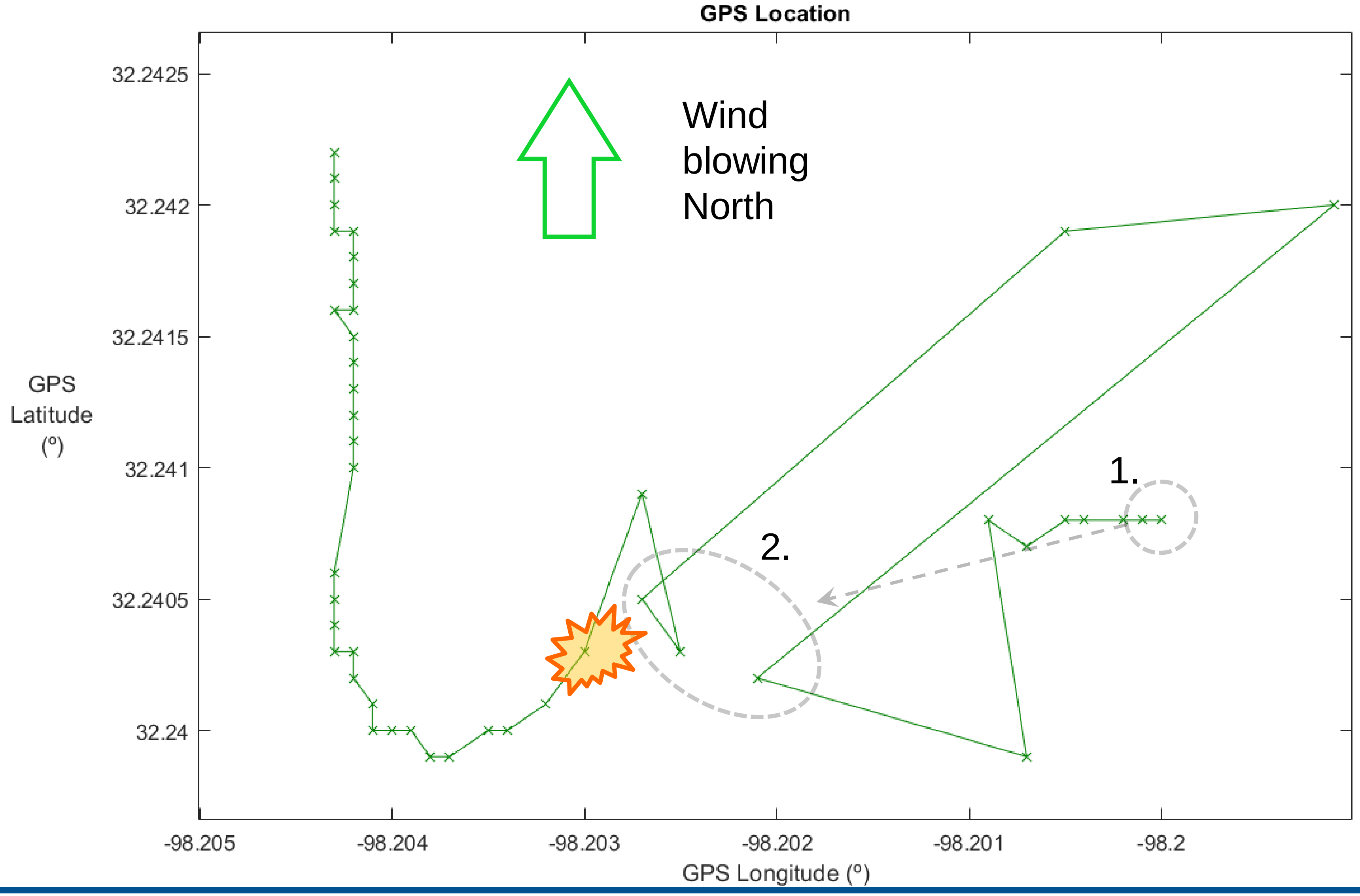
Anomaly

PAYLOAD GPS PLOT



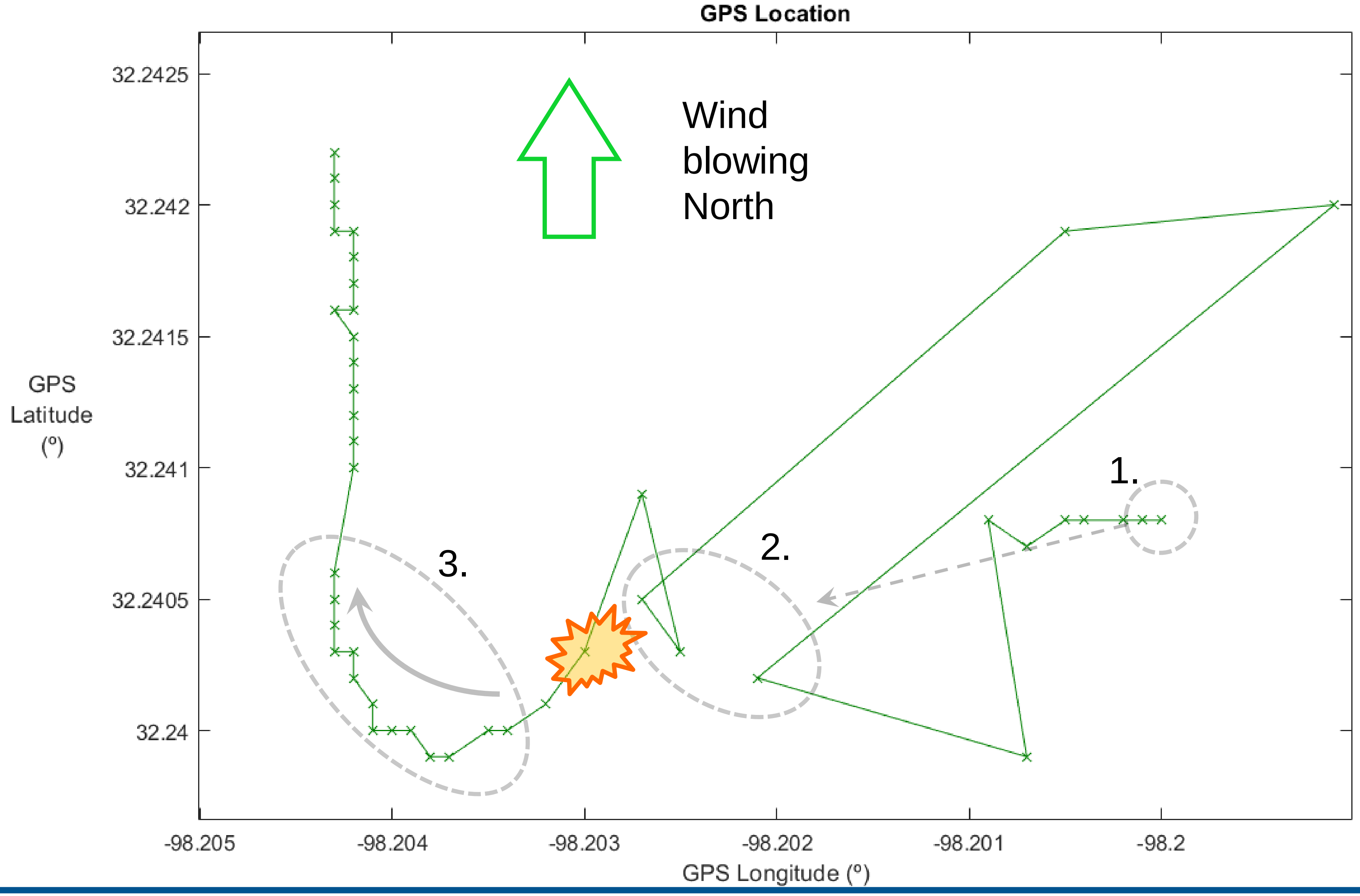
1. Launch site

PAYLOAD GPS PLOT



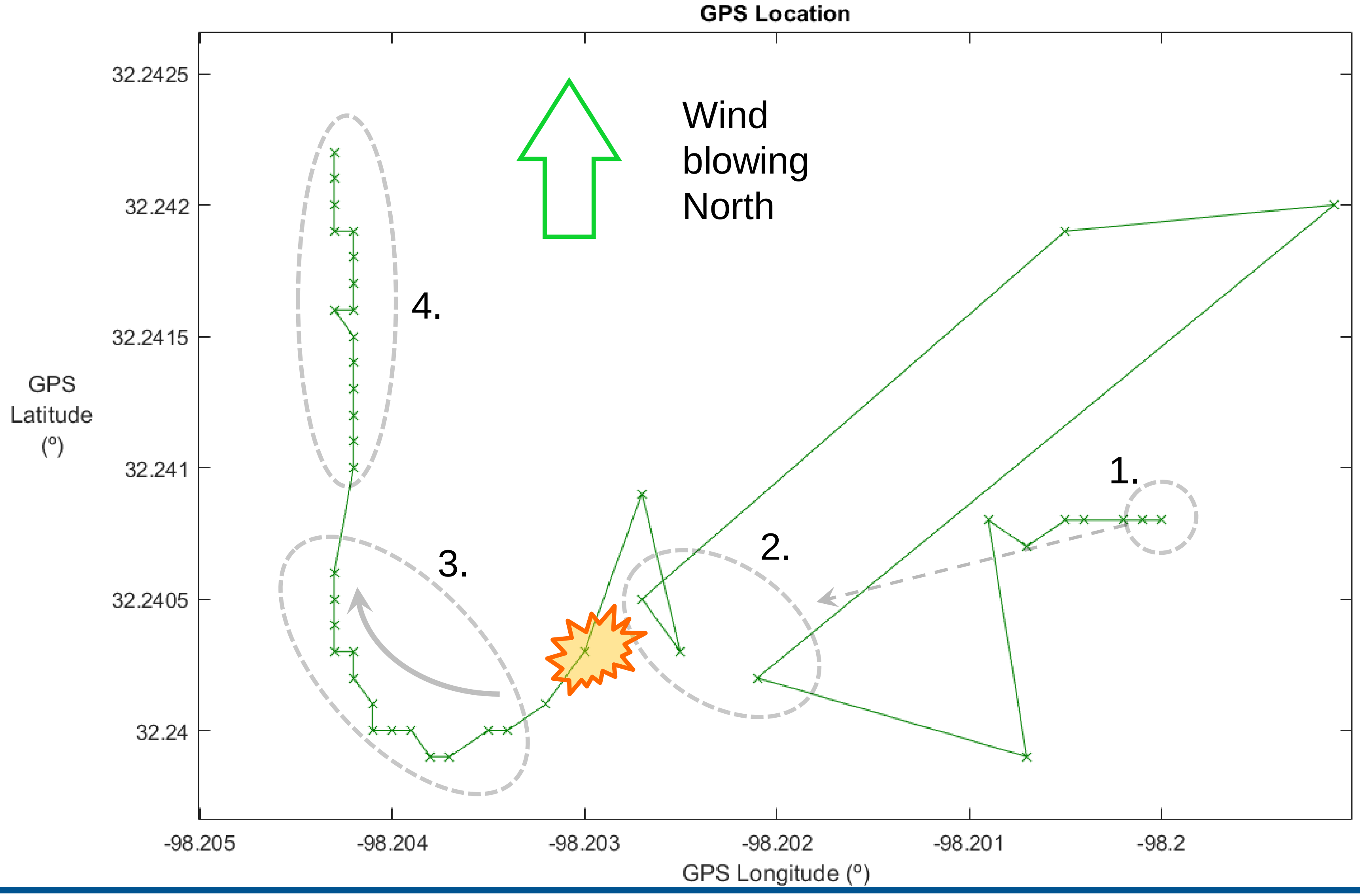
1. Launch site
2. Approximate location of apogee

PAYLOAD GPS PLOT



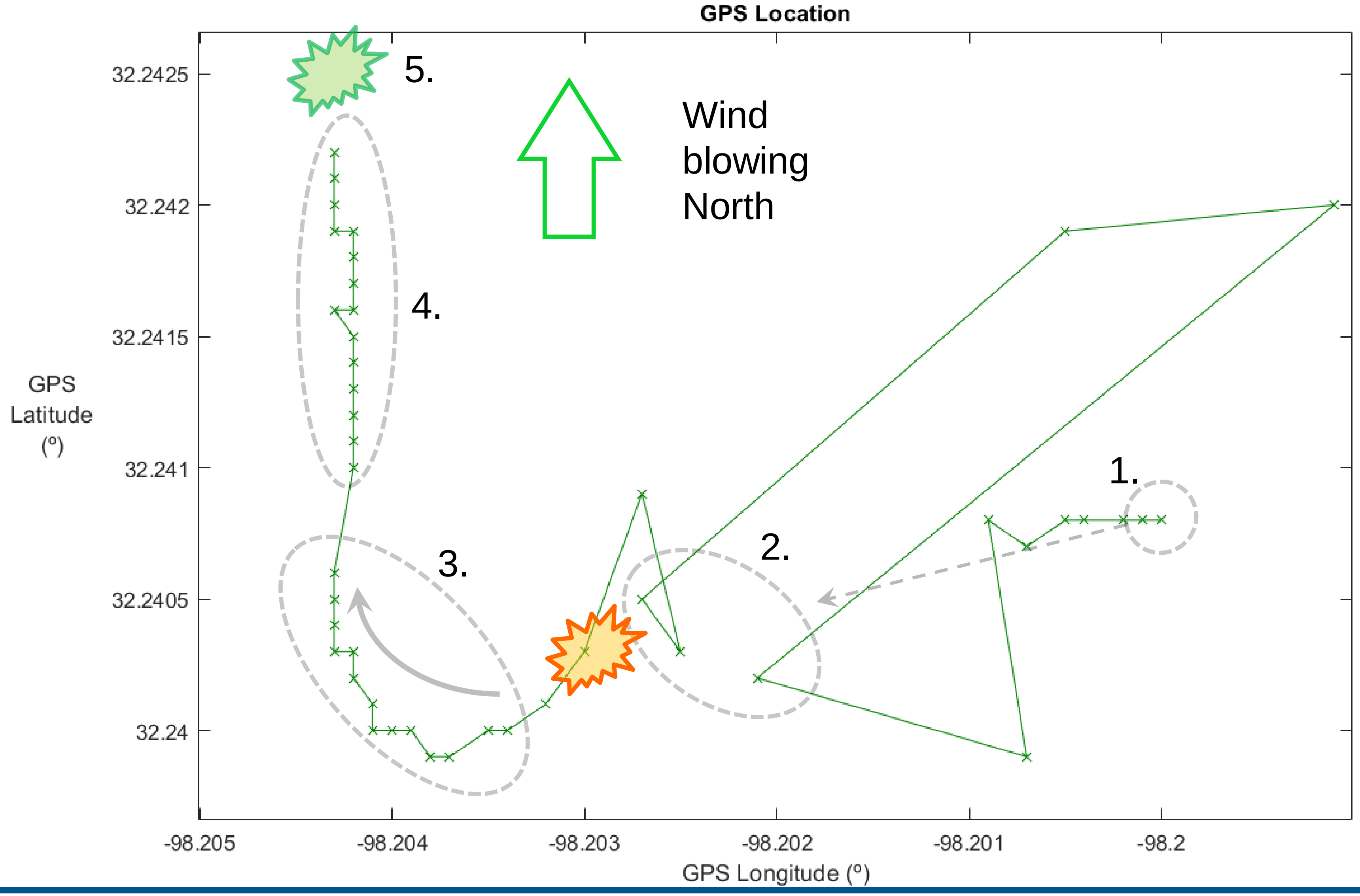
1. Launch site
2. Approximate location of apogee
3. Region of heatshield descent

PAYLOAD GPS PLOT



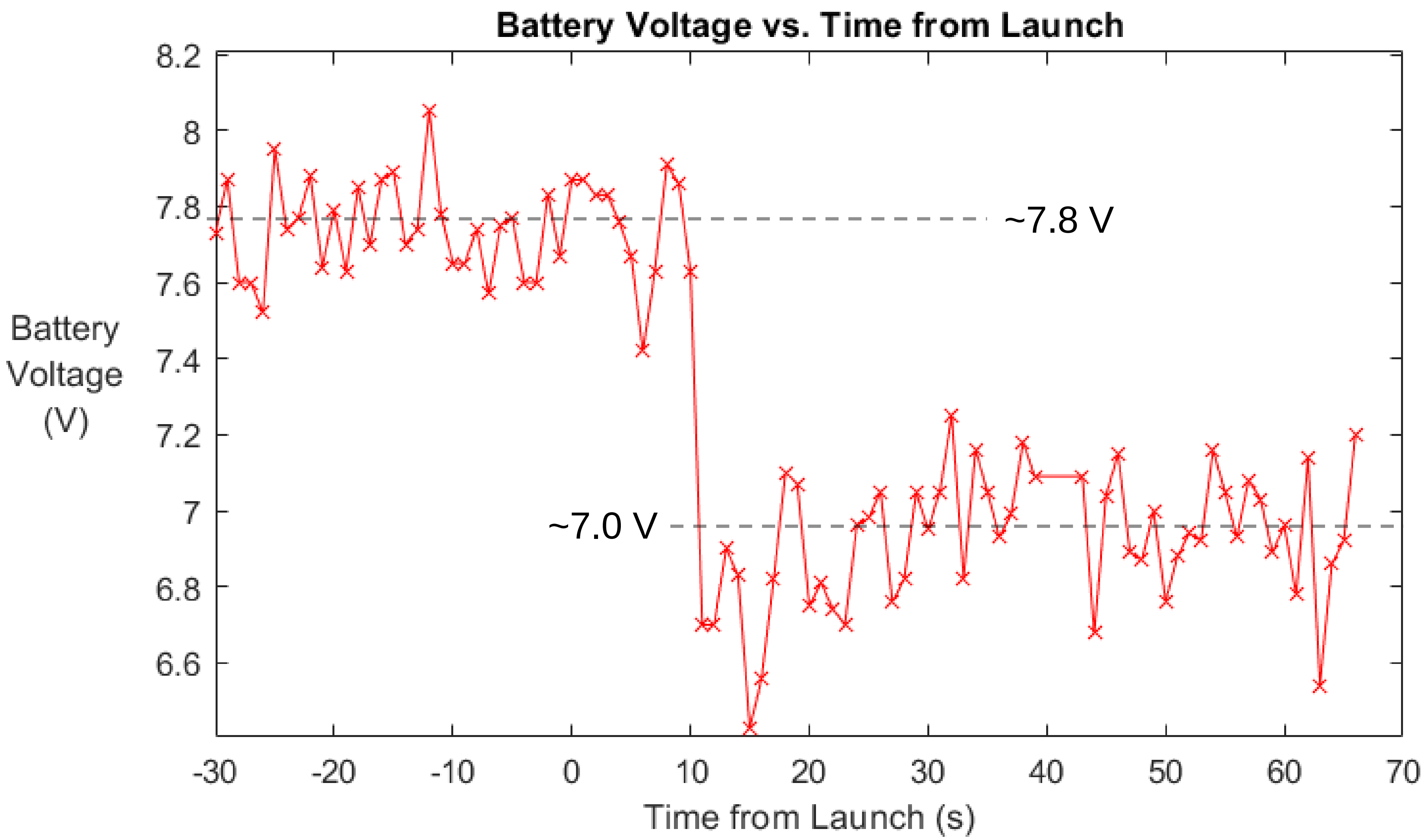
1. Launch site
2. Approximate location of apogee
3. Region of heatshield descent
4. Region of parachute descent

PAYLOAD GPS PLOT



1. Launch site
2. Approximate location of apogee
3. Region of heatshield descent
4. Region of parachute descent
5. Approximate landing site

PAYLOAD BATTERY POWER PLOT

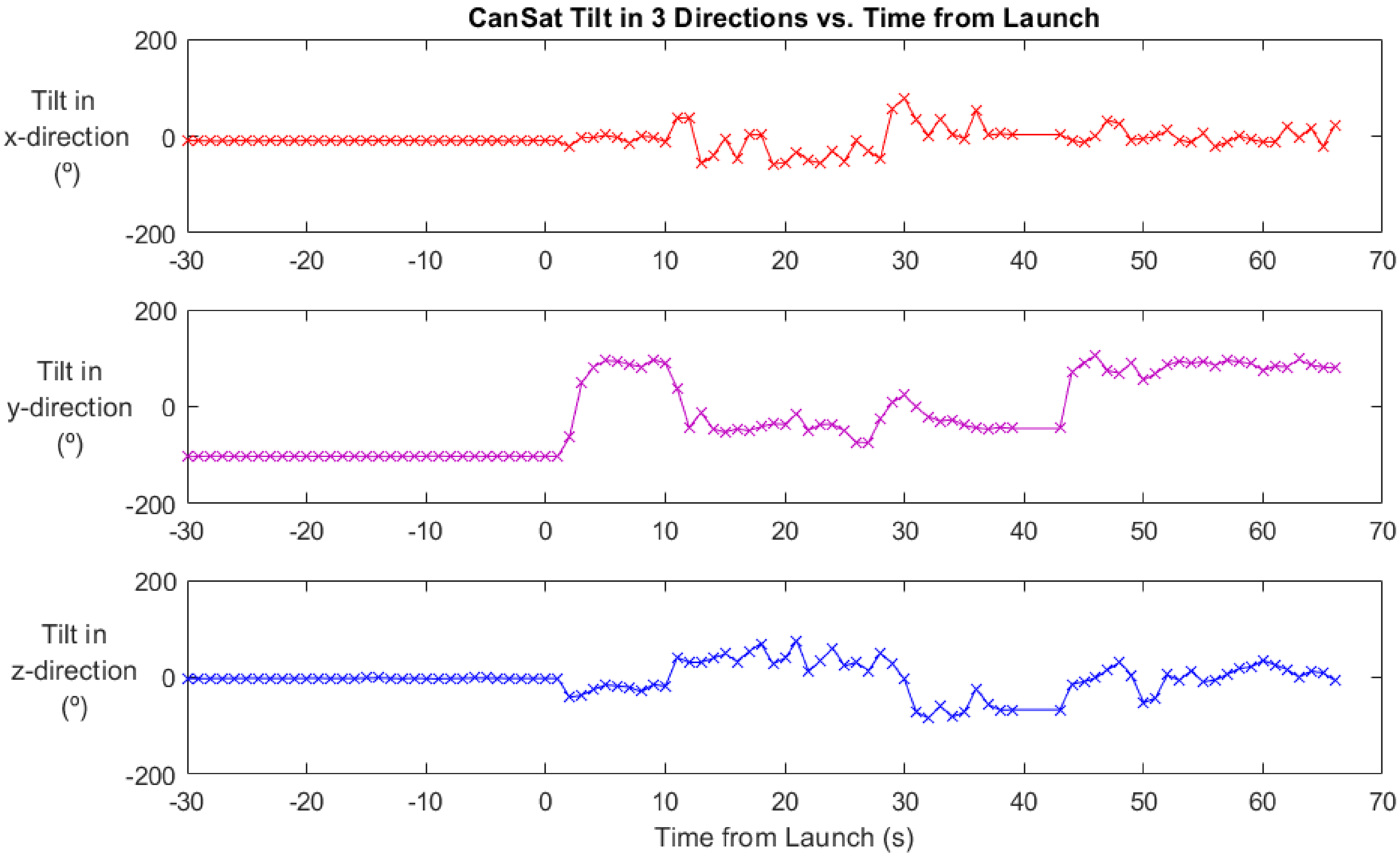


7.8V initially

Noisy: could use capacitors – large ones needed for voltage smoothening but not included due to their weight.

Servo power draw is at a maximum when heatshield is stowed – power draw falls to ~7.0 V as heatshield is deployed near apogee ~15s

TILT SENSOR PLOT



Heat shield not tumbling – non-sinusoidal y-axis tilt plot

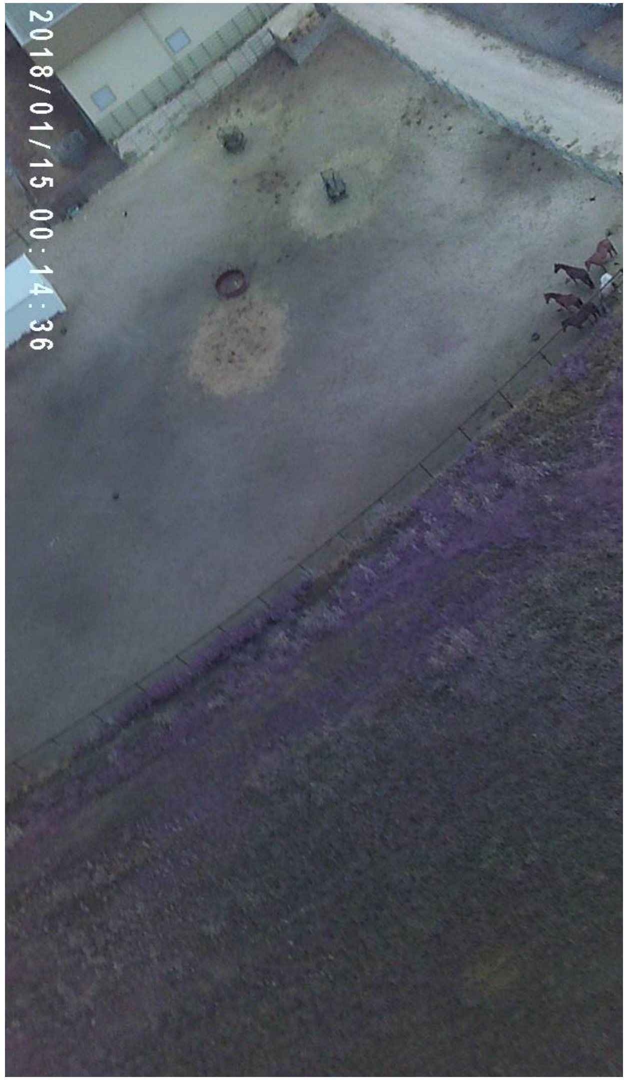
Nadir direction maintained under passive control – nose down orientation.

CanSat spinning about its y-axis - as shown in superimposition of x-axis with z-axis tilt.

Post parachute deployment z-axis tilt shows spinning oscillatory nature about the y-axis

CAMERA VIDEO

https://www.youtube.com/watch?v=Z9TzMFuRZG0



FAILURE ANALYSIS

(Iuliu Ardelean and Lawrence France)

IDENTIFICATION OF FAILURES, ROOT CAUSES, CORRECTIVE ACTIONS

FAILURE	ROOT CAUSE(S)	CORRECTIVE ACTION
Probe descended at 8 m/s with parachute (requirements stated 5 m/s).	Insufficient parachute cross-sectional area (to mitigate against high wind speeds)	Use parachute of larger diameter
Parachute hatch hinge broken	• Weak point of structure (~3 mm). Parachute tangled with the parachute hatch hinge. High velocity impact. • Impact with ground at angle. Impact taken by parachute hatch. Force transmitted to hinge.	• Spread load over 2 hinges rather than 1. • Different materials and configuration hinges.

LESSONS LEARNT

(Iuliu Ardelean and Lawrence France)

WHAT WORKED AND WHAT DID NOT

WORKED
Probe and Egg retrieved intact.
Deployment and release of heatshield, and deployment of parachute, were successful at correct altitudes.
Bonus camera footage captured @ 720p HD for 22 seconds.
85/110 telemetry packets received over full range of operation (~800 m).
CanSat was within total mass budget @ 509 g.
GPS coordinates aided probe recovery.
Camera capture terminated in code at 42 m.

WHAT WORKED AND WHAT DID NOT

DID NOT WORK
The heatshield was not recovered from site.
Probe descent rate with parachute slightly high (~8.7 m/s instead of 5 m/s).
Deployment of the heatshield was not captured by the camera.
Telemetry stopped at 53 m.

CONCLUSIONS

Successes

- **Mission successful**
    - CanSat within mass budget at 509 g (including egg payload).
    - Heatshield deployed successfully.
    - Heatshield released successfully .
    - Parachute deployed.
    - Audio beacon operational upon landing.
    - CanSat retrieved with egg intact.
    - Bonus camera footage captured (22 s).
    - 85 telemetry packets received at GCS.

- **Mission stages concordant with FSW**

CONCLUSIONS

Challenges

- Manufacturing is equally challenging as designing.
- The least complex design the better. Introducing more active components introduces the risk of failure and increases weight.

CONCLUSIONS

Further Achievements

- UK Competition
  - Held the first inter-university CanSat competition in the UK, between Manchester and Bristol in April.
  - We have inspired a handful of UK universities to join the UK competition.
  - We are planning to expand the UK competition across Europe.
  - Received support from Airbus to support growth of the UK competition.

- Inspired a number of BEng and MSc dissertations in University of Manchester.
- Delivered around a dozen different workshops/lectures on various space engineering related topics, including:
  - CAD + FDM 3D printing
  - Object-Oriented Embedded Programming
  - Soldering
  - Real-Time Data Acquisition + Machine Learning