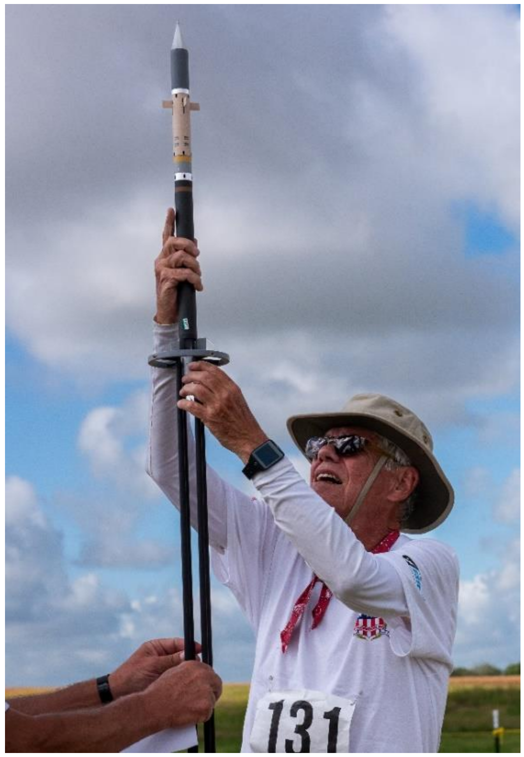
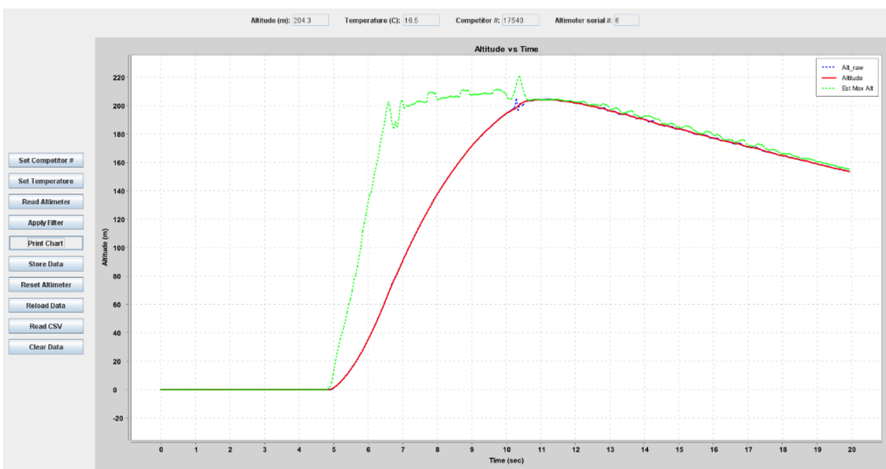
Rev 1.1
11-July-2026





"ZETA II" ALTIMETER SYSTEM TECHNICAL REPORT & USER GUIDE

RELEASE HISTORY

Version	Date	Comments
1.0	1-June-2026	Initial release
1.1	11-Jul-2026	Enhanced launch detection algorithm to help avoid false triggering. ZetaPost can plot acceleration histories as well as altitude histories. READCSV module can read .PF2 files as well as CSV files. Update ZetaPost installation instructions.

CONTRIBUTORS

Chris Flanigan

John Brohm

Bernard and Avis Cawley

Mike Caplinger

Dan Wolf

Will Marchant

Sean Guzek

Zeta Rocketry Company

http://www.zetarocketry.com

No Warranty

This electronic device and its associated software are provided "as is" without warranties of any kind, either express or implied, including but not limited to warranties of merchantability or fitness for a particular purpose. The manufacturer shall not be liable for any direct, indirect, incidental, or consequential damages resulting from the use of this product.

By using this product, you acknowledge and accept these conditions. You agree to hold the manufacturer harmless from any claims, damages, or liabilities arising from the use of this product. If you do not accept these conditions, do not use the product.

Zeta II – Quick Start Guide

Before Flight – Check the Battery

- The altimeter uses a single cell (1S) LiPo battery (3.7V nominal).
- Before connection, confirm that the battery has the correct polarity (see Figure 3.1-1). The altimeter will not function if the battery has its polarity reversed.
- Verify that the battery is charged.

Start the Altimeter

- Plug-in the battery. The LED will start blinking.
- If the LED displays sequences of **three rapid blinks**, the altimeter has not been reset. **DO NOT FLY**! The altimeter must be reset before flight.
- If the LED displays **slow blinks** (1 second on, 1 second off), this indicates the preparation period. **OK TO PROCEED**.

Pre-Flight Preparation

- The preparation period lasts 90 seconds. During the preparation period, insert the altimeter into the rocket and close the altimeter compartment. The altimeter does not record any data during the preparation period.
- After completing the preparation period, the altimeter begins to take data. The LED will change to **continuous-on**. However, you shouldn't be able to see this because your altimeter is already in the rocket.
- Wait an additional 10 seconds for the altimeter to initialize the ground reference data points.
- **100 seconds after plugging in the battery, the altimeter is ready to fly.**
- At any point prior to flight, you can restart the pre-flight preparation time by unplugging the battery and starting over.

Post-Flight Check

- If the LED displays **continuous-on**, the altimeter did not reach the "launch detect" altitude of 30 meters and did not record flight data.
- If the LED displays sequences of **three rapid blinks**, the altimeter has recorded flight data.

(continued)

Zeta II – Quick Start Guide
(continued)

Postprocessing

- Start the ZetaPost program on a laptop or similar computer.
- Connect the altimeter to the laptop using a MicroUSB data cable.
- **SET TEMPERATURE** – enter the temperature at the launch site
- **READ ALTIMETER** – read and download the data from the altimeter
- **APPLY FILTER** – remove noise and smooth the data
- **PRINT CHART** – save the display to a PNG file for printing
- **STORE DATA** – store the data to a ZTA file
- **RESET ALTIMETER** – erase current data and reset the altimeter for a new flight
- Disconnect the altimeter from the laptop.

TABLE OF CONTENTS

NOMENCLATURE

ρ	Air density
B	Ballistic coefficient
A	Cross-section area
C_d	Coefficient of drag
F_s	Sampling frequency (Hz)
g	Acceleration due to gravity
H	Altitude
m	Mass
P	Pressure
P_o	Reference pressure
V	Velocity
V_t	Terminal velocity

ACRONYMS, ABBREVIATIONS, AND INITIALISMS

AM/SG	Adaptive median / Savitzky-Golay
CAD	Computer aided design
CSV	Comma separated value format
EDIC	Electronic Devices in Competition
EMA	Estimated maximum altitude
FAI	Federation Aeronautique Internationale
FRAM	Ferroelectric random-access memory
ICAO	International Civil Aviation Organization
LED	Light emitting diode
MF	Median filter
NAR	National Association of Rocketry
PNG	Portable network graphics format
SMA	Simple moving average
VDC	Volts (direct current)
ZTA	Zeta storage file format

UNITS

hPa	Hectopascal
Hz	Hertz (cycles per second)
m	Meter
Pa	Pascal

1 INTRODUCTION

1.1 OVERVIEW

This document describes the Zeta II altimeter system for use in NAR and FAI Spacemodelling competition.

1.2 APPLICABLE DOCUMENTS

- FAI Sporting Code, Section 4 – Aeromodelling, **Volume S: Space Models**, 2026 Edition - Version 1.
  https://www.fai.org/sites/default/files/document/file/SC4_volume_S_Space_2026_0.pdf
- FAI Sporting Code, Section 4 - Aeromodelling, **Volume EDIC: Electronic Devices in Competition**, 2026 Edition.
  https://www.fai.org/sites/default/files/2026-03/sc4_vol_edic_26.pdf
- **Manual of the ICAO Standard Atmosphere**, International Civil Aviation Organization (ICAO), Document 7488/2.
- **Altimeters for NAR Competition: Technical Specification**, National Association of Rocketry, V1.0 (pending), 2026.
- Flanigan, Chris, **"Evaluation of Filters for Competition Altimeters**", vNARCON R&D Report, February 2026.
  https://drive.google.com/file/d/1HAmcKeismdBxkAZ3xPdkw27IfPIErdpk/view?usp=sharing

2 ALTIMETER

2.1 TECHNICAL CHARACTERISTICS

The technical characteristics of the altimeter and battery are summarized in Table 2.1-1. The altimeter contains a high accuracy pressure sensor with a measurement accuracy of ±0.5 meters. The altimeter also includes a 3-axis accelerometer for use in reviewing flight behavior.

Table 2.1-1. Technical characteristics of the altimeter.

PHYSICAL CHARACTERISTICS	
Width	15.3 mm
Length	25 mm
Thickness	3.5 mm
Mass (altimeter only)	1.67 grams
ELECTRONICS	
Microcontroller	ATSAMD21E18, 32-bit Cortex M0+, 48 MHz[1]
External Memory	FRAM (256 Kbit)[2] non-volatile memory
Pressure Sensor	BMP580[3] (±0.5 m, 700 hPa...1100 hPa)
Accelerometer	LIS3DH 3-axis, ±16 G digital accelerometer[4]
Sampling Rate	20 Hz
Signaling Mode	LED
Computer Interface	MicroUSB data cable
BATTERY	
Type	1-cell lithium-polymer (LiPo), 40 mAh
Voltage	3.7 V nominal
Mass (battery only)	1.37 grams
Connector	2-pin JST-PH-2.0
Power-On Time	>2.5 hours using 40 mAh 1-cell LiPo battery
SOFTWARE	
Altimeter Software	V1.2 (28-May-2026)
Postprocessing Software	V1.1 (27-May-2026)

[1] https://www.microchip.com/en-us/product/ATSAMD21E18
[2] https://www.fujitsu.com/uk/Images/MB85RC256V-20171207.pdf
[3] https://www.bosch-sensortec.com/en/products/environmental-sensors/pressure-sensors/bmp580
[4] https://www.st.com/resource/en/datasheet/lis3dh.pdf

This altimeter is intended for subsonic flight. It does not have features such as "Mach Lock" for transonic or supersonic velocities.

2.2 PHOTOGRAPHS

Views of the Zeta II altimeter are shown in the following photos.

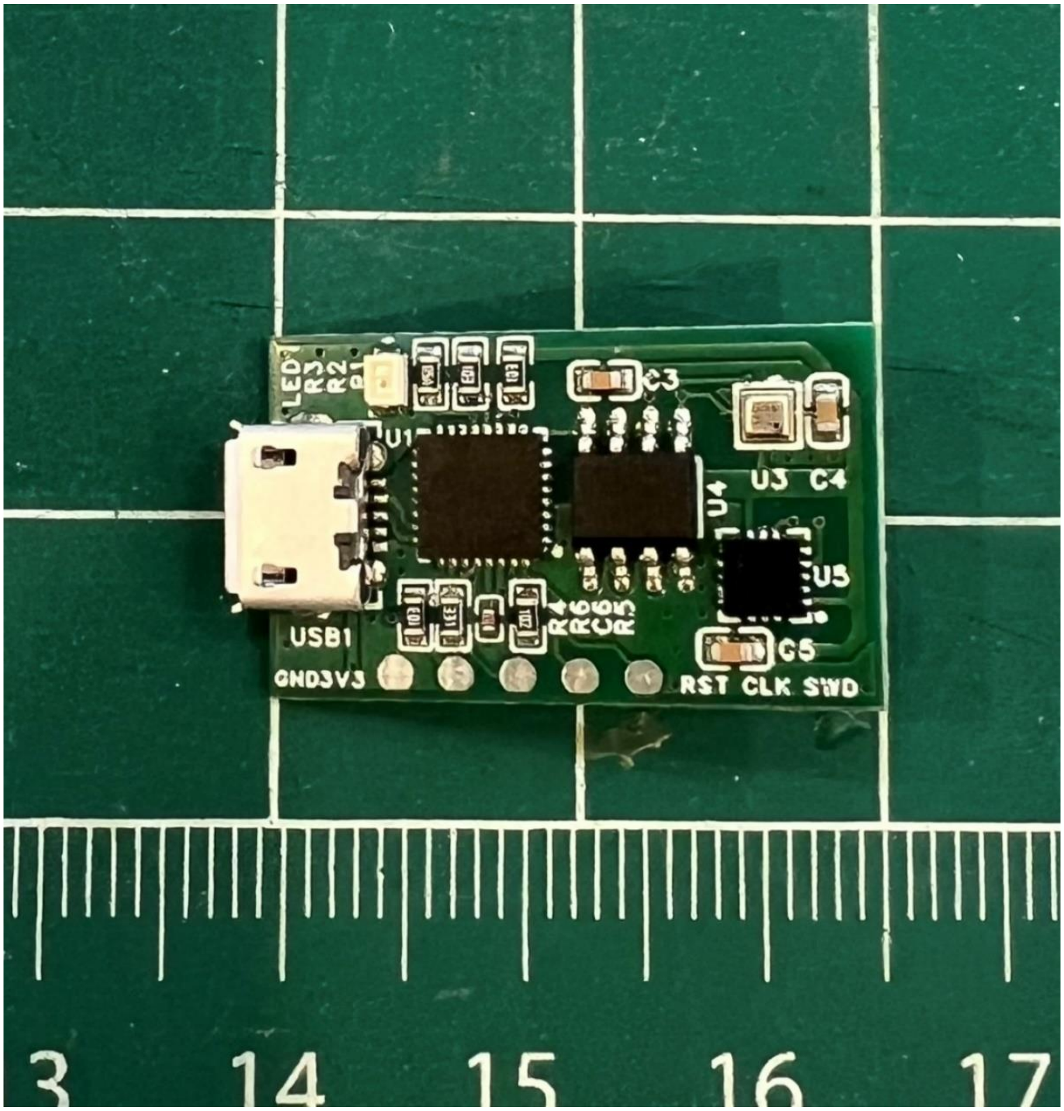


Figure 2.2-1. Top view of the Zeta II altimeter.

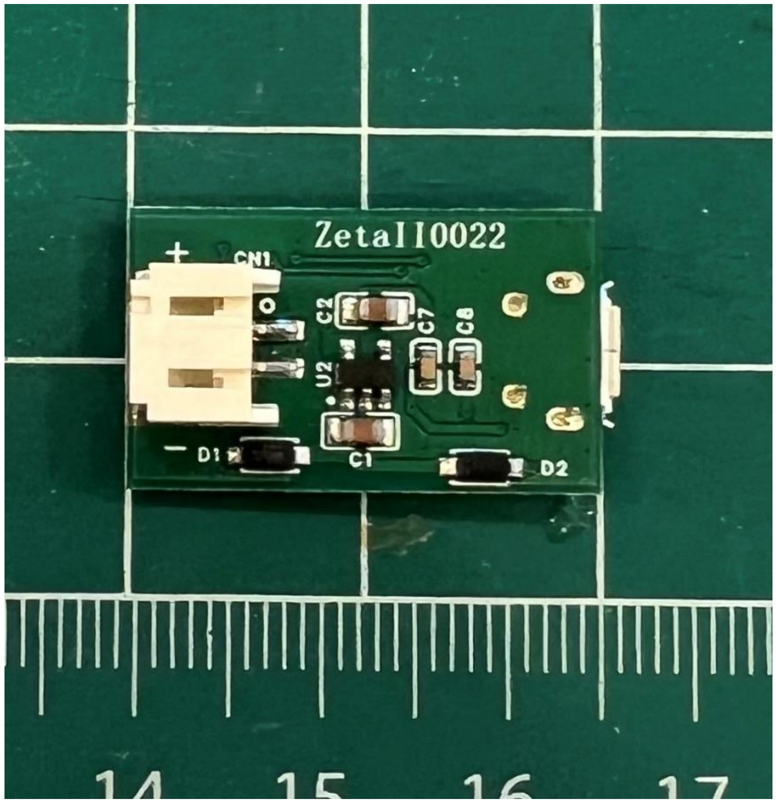


Figure 2.2-2. Bottom view of the Zeta II altimeter.

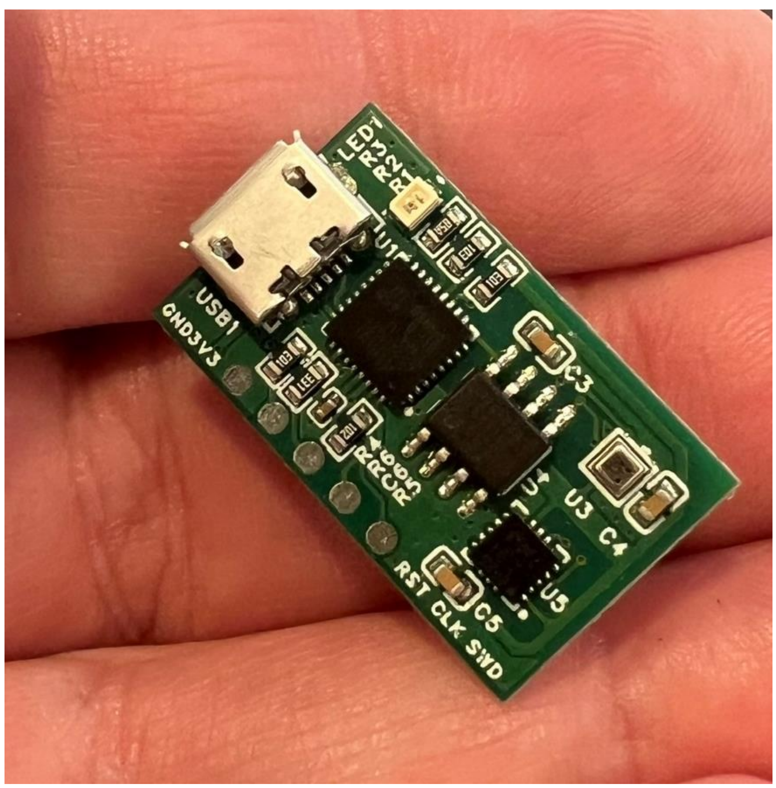


Figure 2.2-3. The Zeta II altimeter complies with the FAI volume requirement.

2.3 MECHANICAL CAD MODEL

A simplified CAD model is available for 3D printing mockups to perform fit checks. The CAD model includes the board and volume representations of the major components (USB connector, microcontroller, memory, accelerometer, pressure sensor, and battery connector). The CAD model is shown in Figures 2.3-1 and -2.

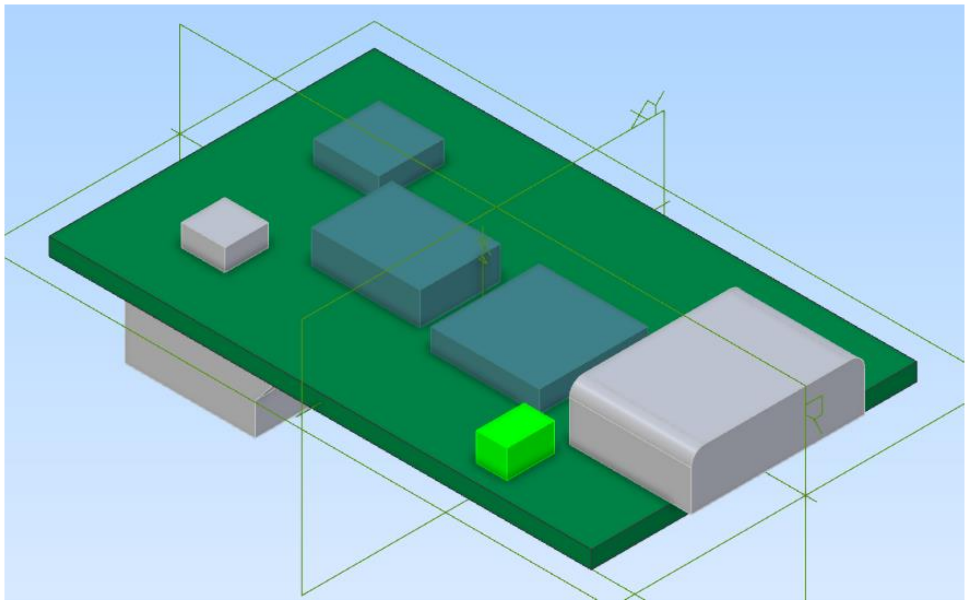


Figure 2.3-1. Simplified CAD model of the Zeta altimeter (isometric view).

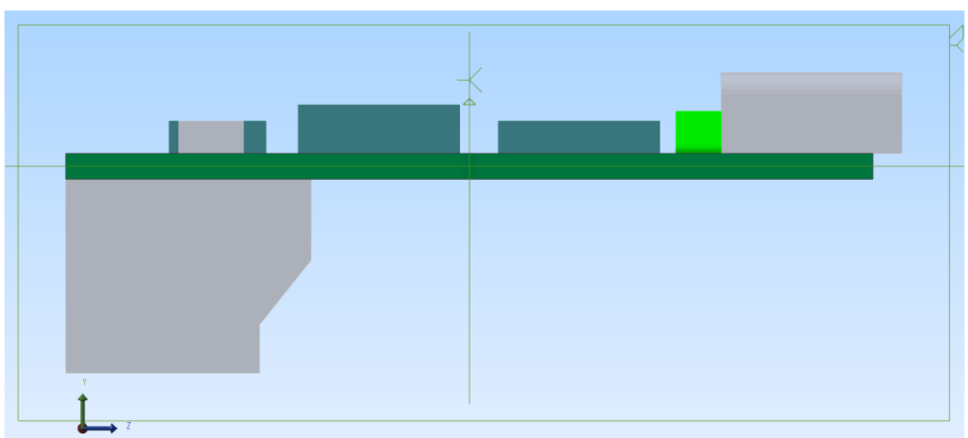


Figure 2.3-2. Simplified CAD model of the Zeta altimeter (side view).

2.4 ACCELEROMETER ORIENTATION

The Zeta II altimeter includes a 3-axis accelerometer. The acceleration data can be used to assess flight performance and identify anomalies. The orientation of the accelerometer is shown in Figure 2.4-1.

Figure 2.4-1. Orientation of the 3-axis accelerometer.

3 FLIGHT OPERATION

3.1 PREPARATION

The altimeter is activated by plugging in the battery. The required battery polarity is shown in Figure 3.1-1. The positive (red) wire is on the left when viewed from the bottom of the board. This follows the polarity standard used by Adafruit and Sparkfun. **Some batteries come with the battery wires in the opposite polarity. If so, you must switch the wires to achieve the correct polarity.** See https://www.youtube.com/watch?v=Qe9g5ZMZni4.

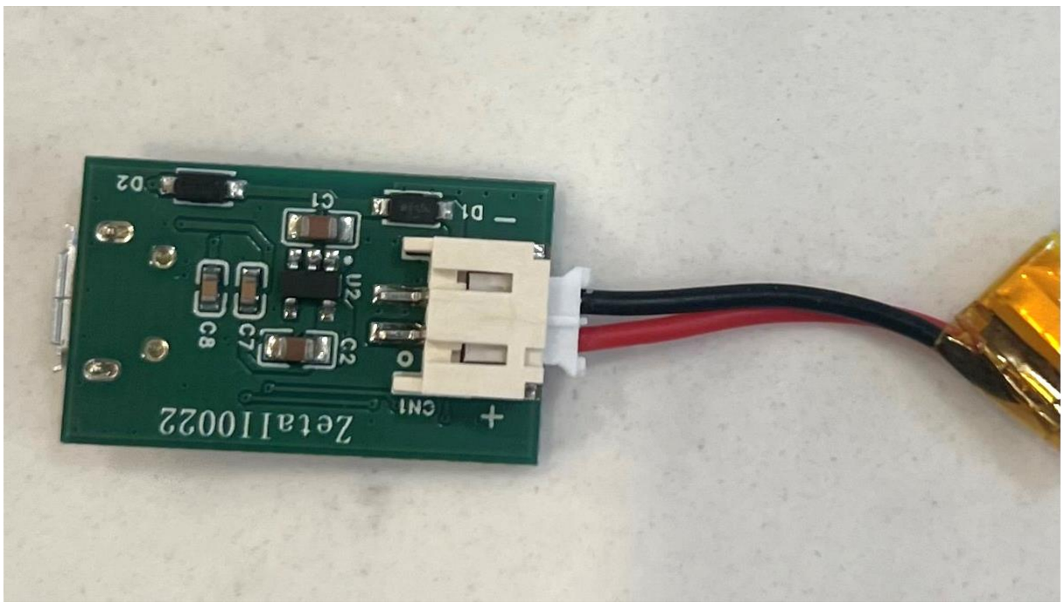


Figure 3.1-1. The required battery polarity is marked on the Zeta board.

When you need to unplug the battery, it is highly recommended to use a battery puller[5] or battery remover tool[6] (see Figure 3.1-2). Do not pull on the wires to remove the battery.

---

[5] https://www.adafruit.com/product/6391

[6] https://www.sparkfun.com/sparkfun-jst-battery-removal-tool.html

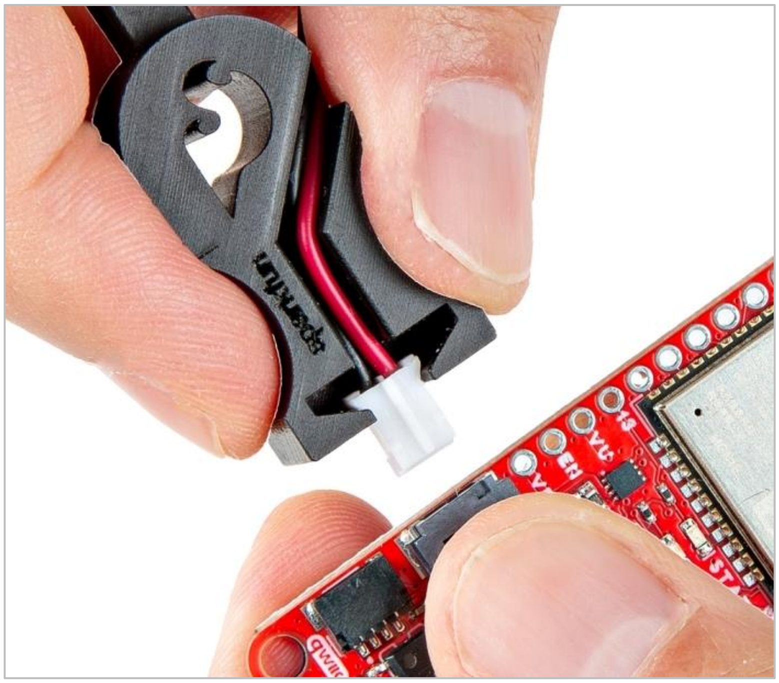


Figure 3.1-2. Use a "battery puller" to unplug the battery from the altimeter.

After power up, the altimeter enters a 90 second "prep" period. During this time, the competitor inserts the altimeter into the model. The altimeter does not record any data during the prep period.

The altimeter must be shielded from strong light; exposure to strong light may result in bad data or no data. Placing the altimeter in a standard paper body tube is sufficient. If using a transparent payload section, the altimeter must be oriented or protected such that the pressure sensor is not exposed to direct sunlight.

Following the prep period, there is a brief time for the altimeter to initialize the ground reference points. Initialization takes six seconds, but it is prudent to wait ten seconds to provide some margin.

100 seconds after activation, the altimeter is ready for flight.

3.2 FLIGHT

Data is stored in a rolling buffer until launch is detected. Launch is detected when an altitude of 30 meters or greater is measured for five consecutive samples. **Data is retained for 6 seconds prior to launch detect and for 30 seconds**

following launch detect (36 seconds total). Maximum altitude (apogee) will occur during this time window. The recording window is illustrated in Figure 3.2-1.

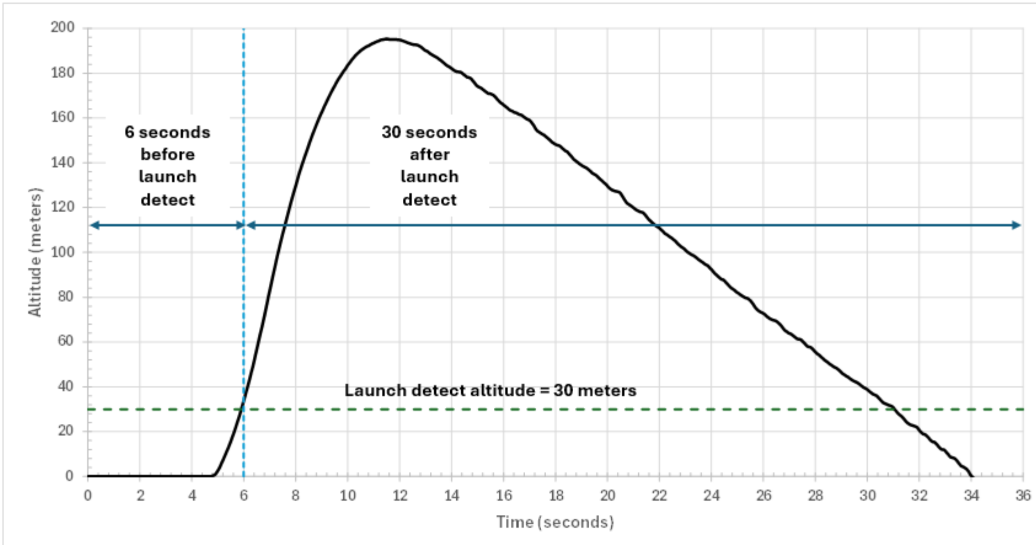


Figure 3.2-1. The Zeta altimeter records data for 6 seconds prior to launch detect and 30 seconds after launch detect.

If the flight is very short (less than 36 seconds), do not disturb the rocket or the altimeter until the recording time is complete.

After completing data recording, the flight data is written to FRAM (non-volatile) memory. The battery may be unplugged at this point to conserve battery charge. The data is retained even after the battery is unplugged.

3.3 DISPLAY OF STATUS

The status of the altimeter is displayed by a blinking pattern as described in Table 3.3-1.

Table 3.3-1. Display of status.

Blink Pattern	Status
Triple blink before flight 3 rapid blinks, then 0.5 seconds off	Altimeter has **not** been reset. **Do not use until the altimeter has been reset.**
Slow blink 1 second on, 1 second off	Preparation time (90 seconds). The altimeter does not record data during this period.
Solid on	The altimeter is armed and taking measurements. The most recent 6 seconds of data defines sthe reference altitude (launch pad). The altimeter is ready for flight 100 seconds after plugging in the battery.
Triple blink after flight 3 rapid blinks, then 0.5 seconds off	The altimeter has recorded flight data.
Rapid single blinks	The battery voltage has dropped below safe operating value. Replace with a charged battery.

4 ALTIMETER PROCESSING

After the flight is complete, the flight data is downloaded and processed using a laptop computer or similar device. The software is written in Java and operates on Windows, Mac, and Linux computers. . The main program interface is shown in Figure 4-1. If desired, accelerations can also be plotted as shown in Figure 4-2. Each data curve can be toggled on/off for clarity.

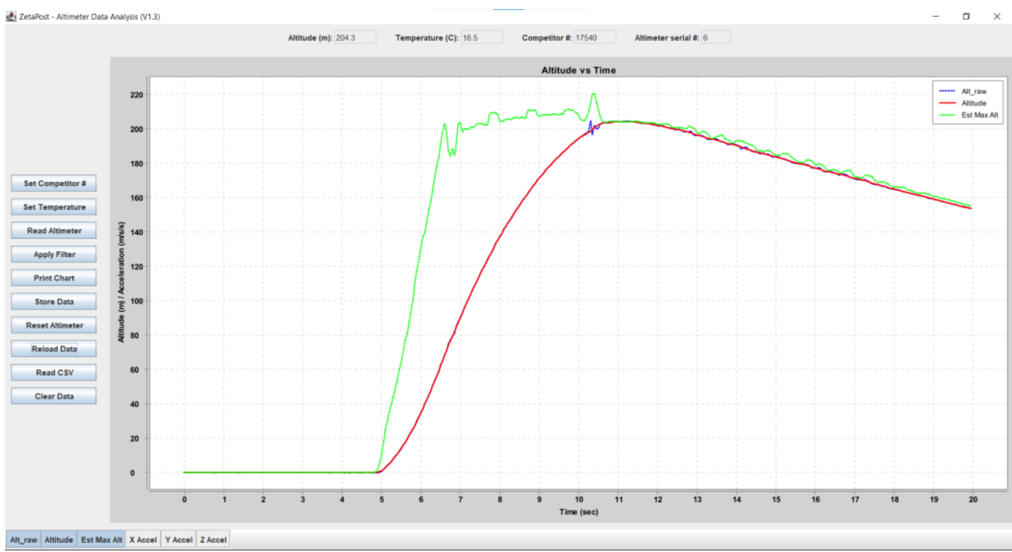


Figure 4-1. The ZetaPost program processes data from the Zeta II altimeter.

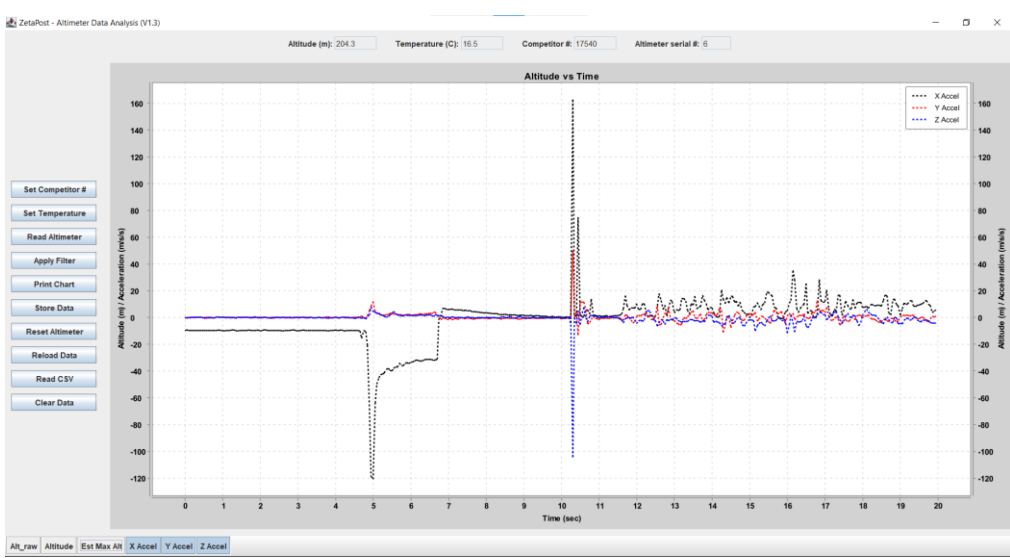


Figure 4-2. The ZetaPost program can display accelerations separately or superimposed on the altitude data.

To begin, connect the Zeta altimeter to the laptop using a cable with a MicroUSB connector. **Check that the cable is a "data" cable and not a "charging only" cable.**

4.1 SET COMPETITOR

The competitor's number can be stored in the altimeter using this command. The competitor's number is retained in non-volatile memory.

4.2 SET TEMPERATURE

Pressing the "Set Temperature" button sets the temperature at the launch site.

The uncorrected altitude data from the altimeter will be multiplied by a temperature correction factor:

$$\text{Corrected Altitude} = \left(\frac{273.15 + \text{T}}{288.15}\right) * \text{Uncorrected Altitude}$$

where T is the ambient temperature in degrees Celsius. This is the small-perturbation, constant-lapse (or mean-temperature) approximation used in aviation to scale pressure altitude for nonstandard temperatures.

4.3 READ ALTIMETER

Pressing the "Read Altimeter" button reads the flight data from the altimeter and loads it into the postprocessor. See Appendices A and B for more details about processing of the altitude data.

4.4 APPLY FILTER

Pressing the "Apply Filter" button applies filters to the data to eliminate noise spikes and smooth the data. See Appendix C for additional information about the filtering algorithm.

After filtering the data, the "estimated maximum altitude" (EMA) is calculated and plotted. This algorithm uses altitude and velocity data during ascent to estimate the maximum altitude that the rocket is likely to achieve (see Appendix D for additional details). Any significant difference between the EMA prediction and the actual altitude of the flight should be checked carefully. EMA is intended as a plausibility check and not as the official reported altitude.

4.5 PRINT CHART

Pressing the "Print Chart" button captures the content of the display and writes it to a PNG (Portable Network Graphics) file.

4.6 STORE DATA

Pressing the "Store Data" button stores the data in a text file. The format of the text file is provided in Appendix F.

4.7 RESET ALTIMETER

Pressing the "Reset Altimeter" button sets the altimeter status to "ready for new flight". Any prior flight data is erased.

If you perform a "Read Altimeter" command after resetting the altimeter, you will see a "test pattern" as shown in Figure 4.7-1. This is normal and correct.

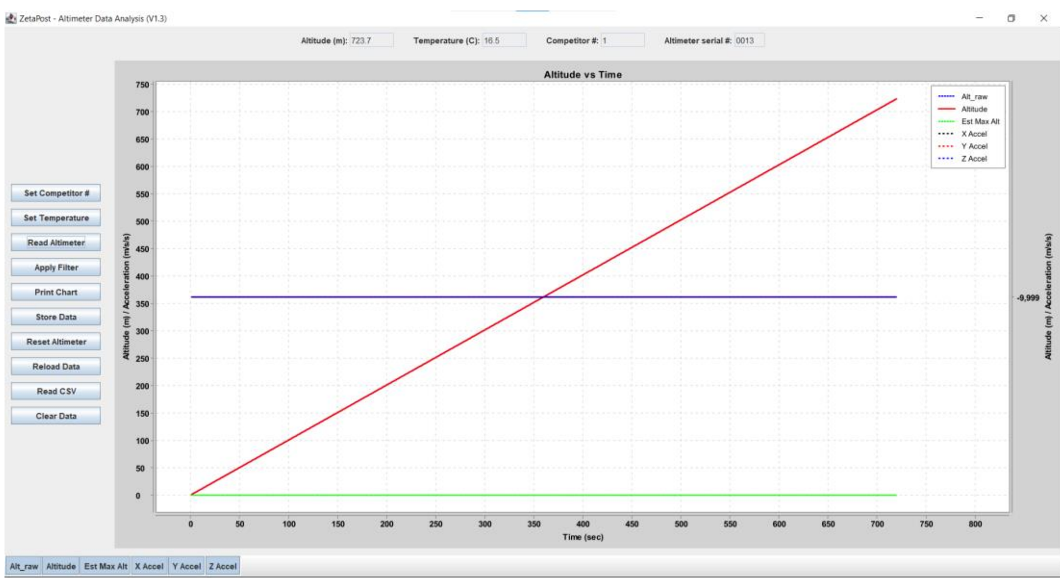


Figure 4.7-1. A "test pattern" will be displayed if you perform a "Read Altimeter" command after resetting the altimeter.

4.8 RELOAD DATA

Pressing the "Reload Data" button will reload results that have been previously stored to a text file using the "Store Data" command.

4.9 READ CSV

Pressing the "Read CSV" button will read flight data from a CSV (comma separated value) file or from a PerfectFlite PF2 file. This allows the ZetaPost program to be used with data from other altimeters or data sources.

The CSV file must have the following properties:

- The first record is assumed to be a header record and is skipped.
- There must be one row of data per time sample.
- Data values must be separated by a comma.
- The first value in each row is time.
- The second value in each row is altitude.
- Any additional data values in a row are ignored.

Up to 2,000 data rows will be read from the CSV file. Any additional rows are not processed.

4.10 CLEAR DATA

Pressing the "Clear Data" button clears data from the program. This step must be done before reading new data or reloading old data.

Note that "Clear Data" applies only to data in the program. It has no effect on the altimeter (see "Reset Altimeter").

5 VERIFICATION

5.1 BENCH TESTING

The Zeta II altimeter was placed in a simple vacuum chamber along with two reference altimeters:

- A PerfectFlight Pnut altimeter[7], certified for NAR competition and approved by the American Rocketry Challenge[8], the world's largest student rocket competition.
- A vendor-independent altimeter consisting of an Arduino board[9] and a BMP390 pressure sensor breakout board.[10]

The vacuum chamber test setup is shown in Figure 5.1-1.

Vacuum tests were performed to simulate different altitudes and rise rates. The results from the Zeta II altimeter had excellent agreement with the data from reference altimeters as shown in Figures 5.1-2 through 5.1-4. [Note: the altitude traces are intentionally time-shifted for clarity when comparing the three datasets.]

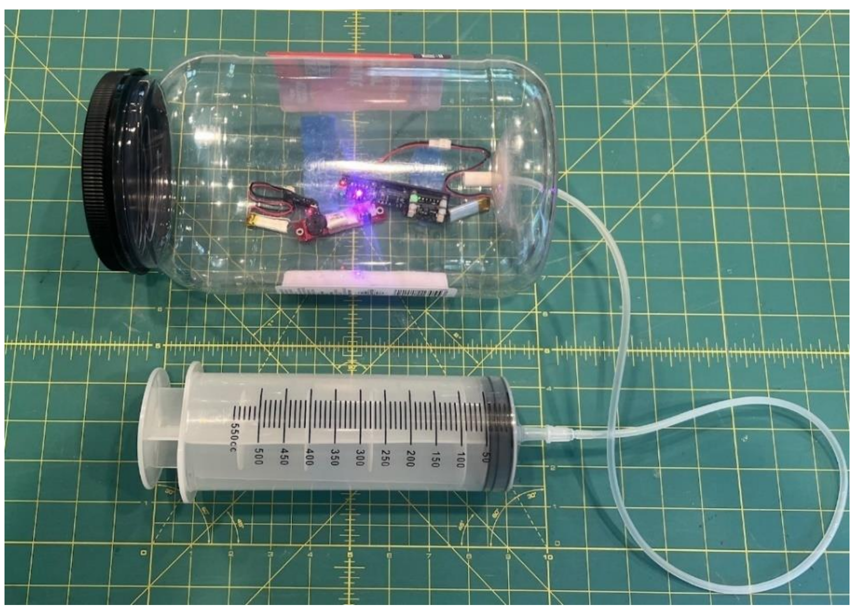


Figure 5.1-1. A simple vacuum system was developed to perform pressure/altitude accuracy tests.

---

7 http://perfectflite.com/pnut.html
8 https://www.rocketrychallenge.org/
9 https://www.adafruit.com/product/3500
10 https://www.adafruit.com/product/4816

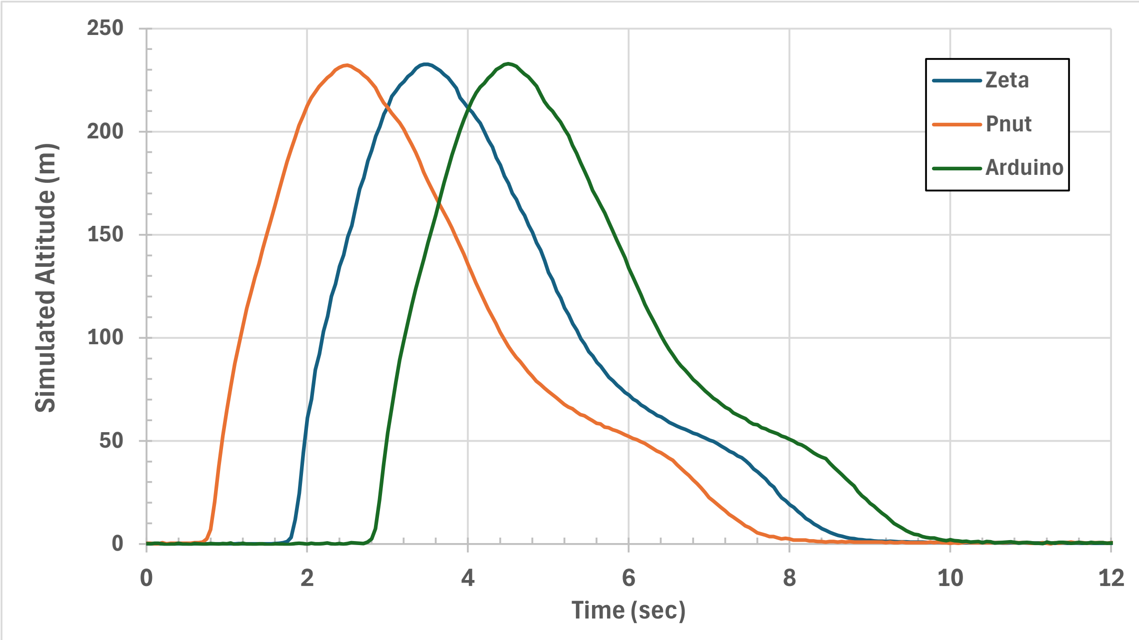


Figure 5.1-2. Simulated altitude of approximately 235 meters.

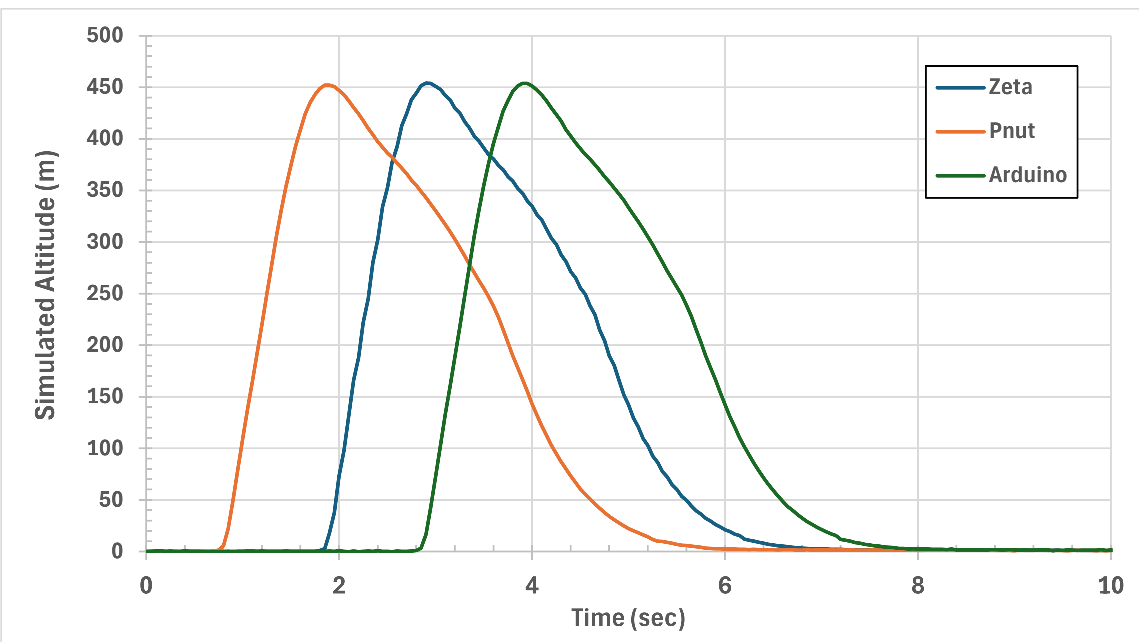


Figure 5.1-3. Simulated altitude of approximately 450 meters.

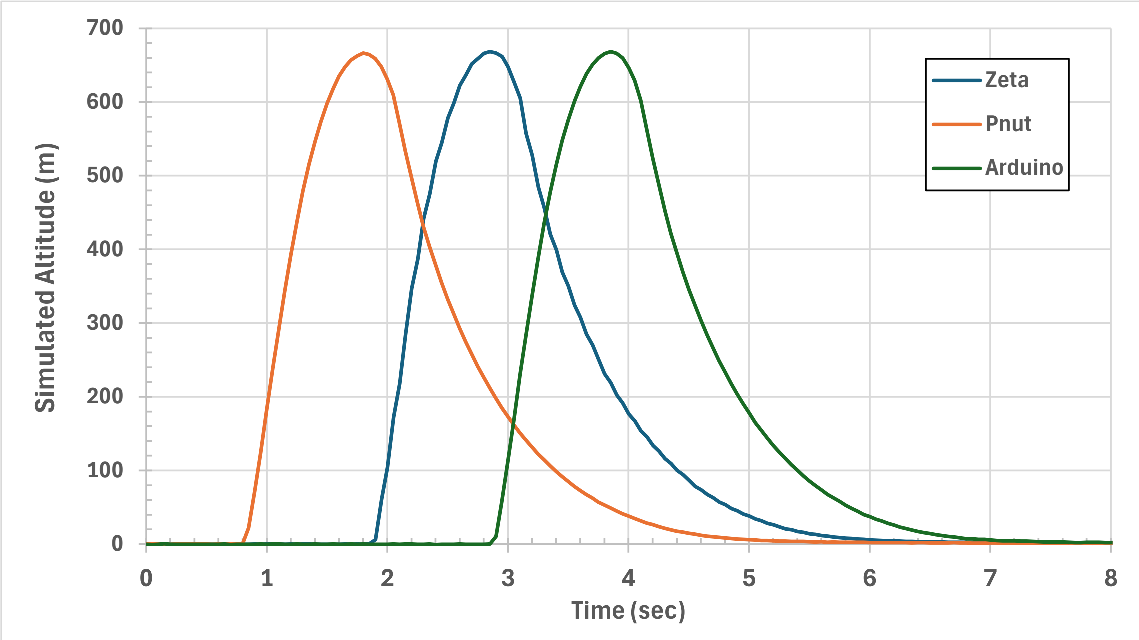


Figure 5.1-4. Simulated altitude of approximately 680 meters.

5.2 FILTER TESTING

The Zeta II uses an Adaptive Median filter to remove noise and a Savitzky-Golay filter to smooth altitude results and provide accurate 1st derivative terms (velocity) for the Estimated Maximum Altitude check. The AM/SG filter has been shown to robustly remove ejection charge noise and other effects in the altimeter history [Reference 7].

Two examples using actual flight data are described here. One flight exhibited a large noise spike at ejection as shown in Figure 5.2-1. Numerical simulation using GNU Octave[11] showed that the AM/SG filter successfully removed the ejection spike as shown in Figure 5.2-2.

In the second example, the altitude history had multiple noise spikes following ejection (see Figure 5.2-3). The AM/SG method successfully removed the noise spikes as shown in Figure 5.2-4.

Additional examples are provided in Reference 7.

[11] https://octave.org/

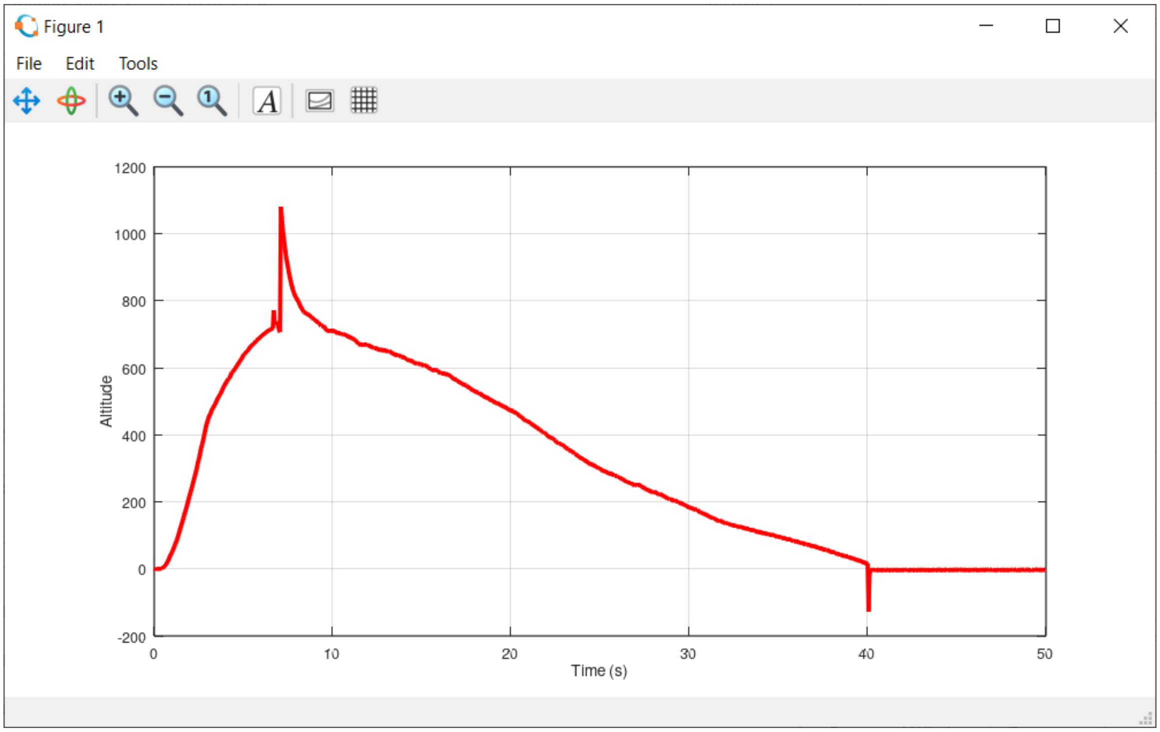


Figure 5.2-1. A flight reported a large noise spike at ejection.

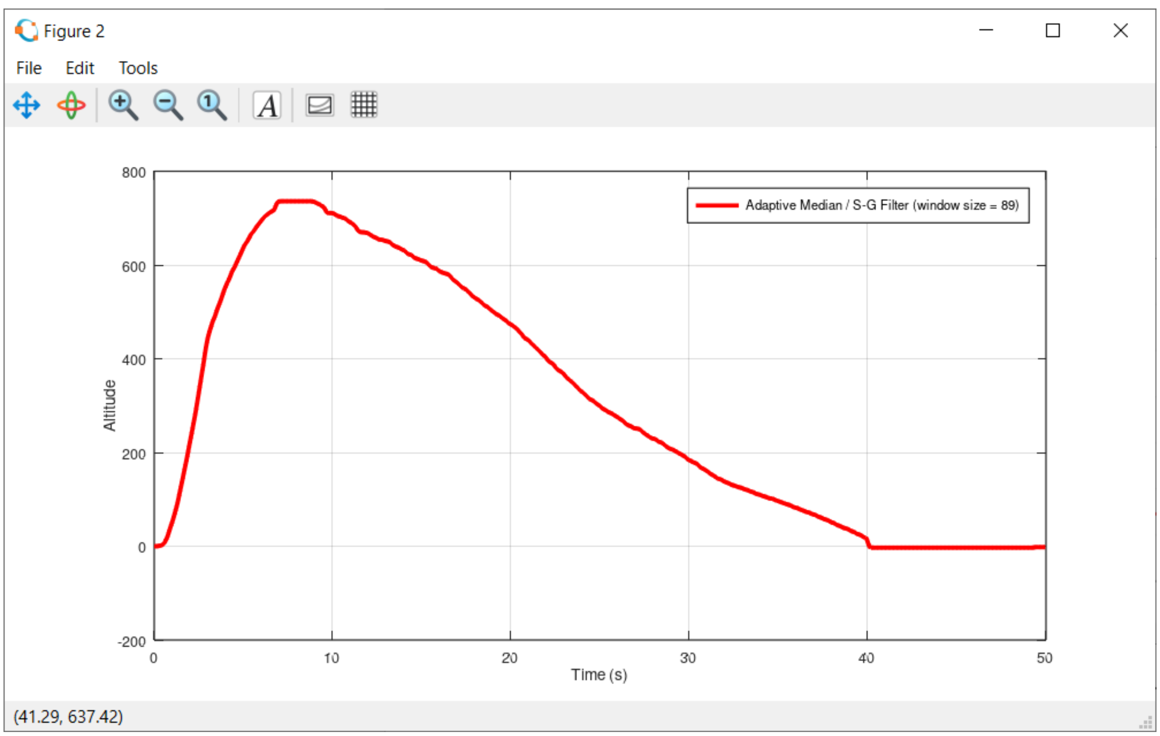


Figure 5.2-2. AM/SG filtering and smoothing removed the large noise spike.

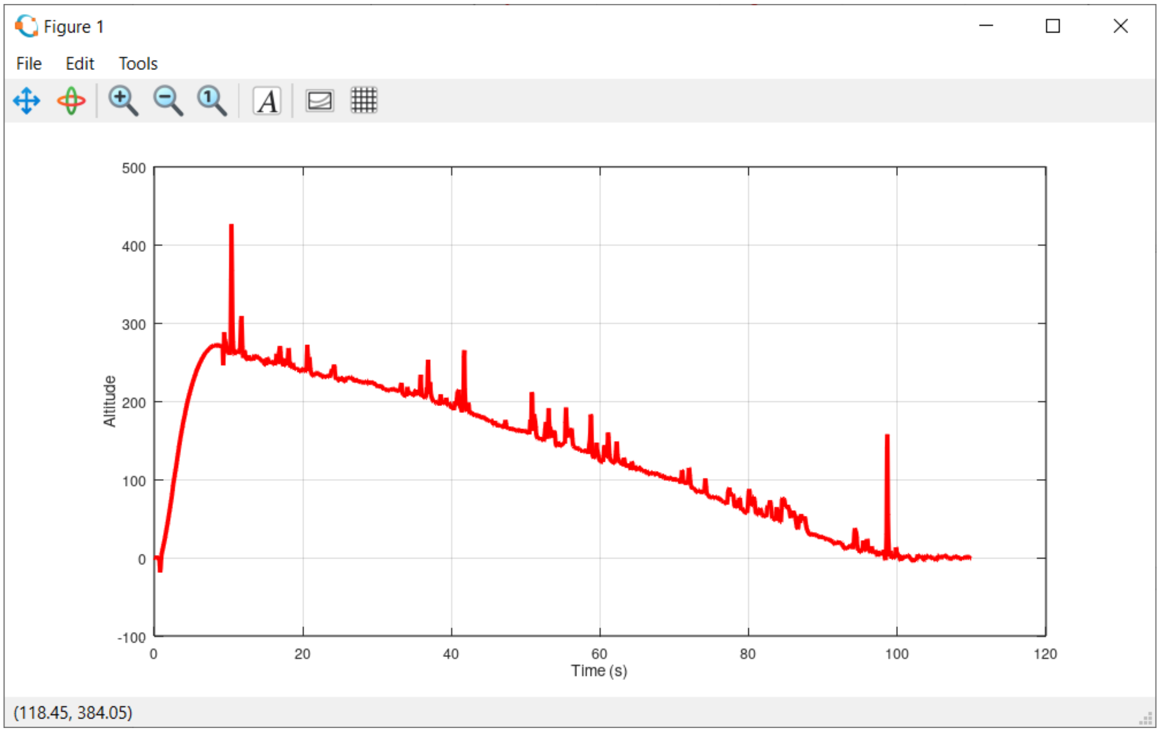


Figure 5.2-3. An example flight had multiple noise spikes after ejection.

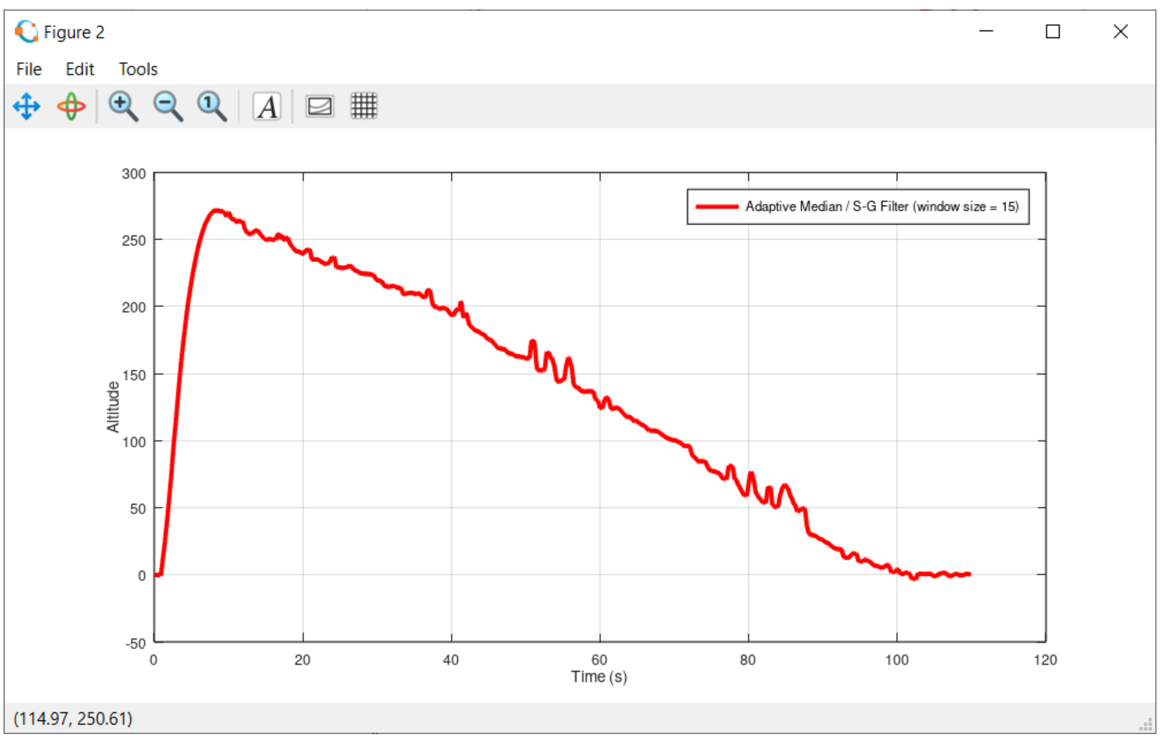


Figure 5.2-4. AM/SG filtering and smoothing removed the noise spikes.

5.3 S1B – ALTITUDE EVENT

A sample flight of an S1B model is shown in Figures 5.3-1. There was no significant difference between the raw data and the filtered data.

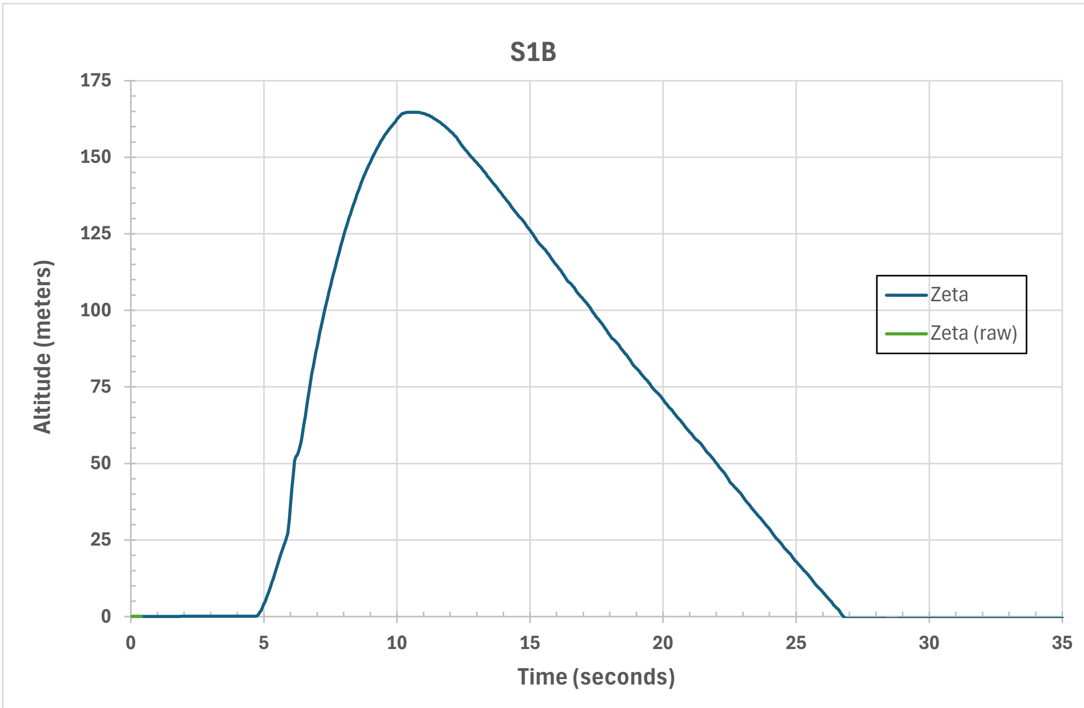


Figure 5.3-1 Example flight for an S1B flight.

5.4 S5C – SCALE ALTITUDE EVENT

A sample flight of an S5C model is shown in Figures 5.4-1 (raw data) and 5.4-2 (after filtering and smoothing). The raw data reported a large negative spike at ejection, probably caused by pressure from the ejection charge. The Zeta's filter successfully removed the noise spike.

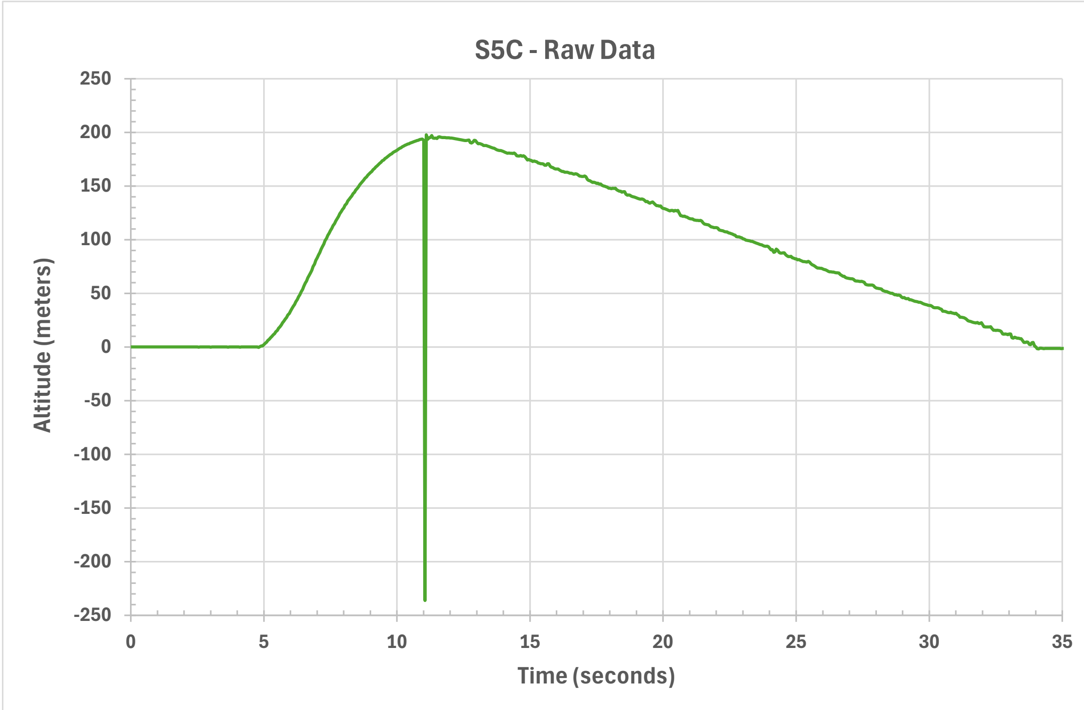


Figure 5.4-1. The S5C flight reported a large negative spike at ejection.

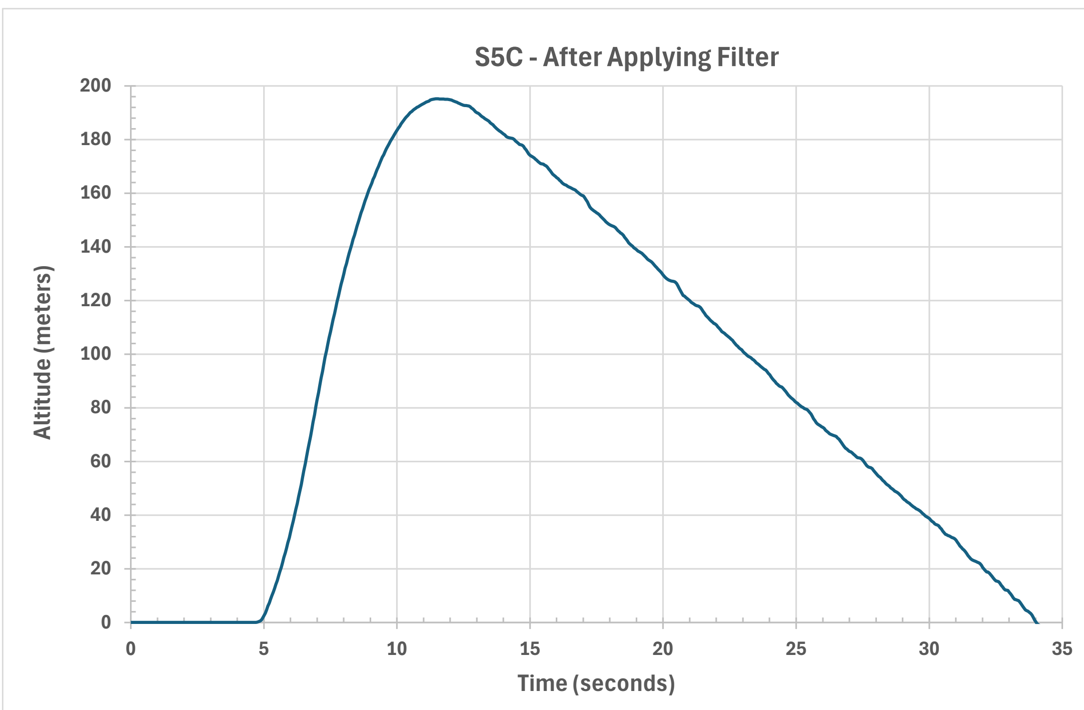


Figure 5.4-2. The Zeta filters successfully removed the noise spike.

REFERENCES

1. FAI Sporting Code, Section 4 – Aeromodelling, **Volume S: Space Models**, 2026 Edition - Version 1 (effective 1-Jan-2026)
   https://www.fai.org/sites/default/files/document/file/SC4_volume_S_Space_2026_0.pdf

2. FAI Sporting Code, Section 4 - Aeromodelling, **Volume EDIC: Electronic Devices in Competition**, 2026 Edition (effective 1-Jan-2026)
   https://www.fai.org/sites/default/files/2026-03/sc4_vol_edic_26.pdf

3. **Manual of the ICAO Standard Atmosphere**, International Civil Aviation Organization (ICAO), Document 7488/2.

4. Datasheet for BMP580 pressure sensor:
   https://cdn-shop.adafruit.com/product-files/6411/BMP580.pdf

5. Datasheet for LIS3DH accelerometer:
   https://www.st.com/resource/en/datasheet/lis3dh.pdf

6. Datasheet for FRAM memory:
   https://cdn-learn.adafruit.com/assets/assets/000/043/904/original/MB85RC256V-DS501-00017-3v0-E.pdf?1500009796

7. Flanigan, Chris, "**Evaluation of Filters for Competition Altimeters**", vNARCON R&D Report, February 2026.
   https://drive.google.com/file/d/1HAmcKeismdBxkAZ3xPdkw27IfPIErdpk/view?usp=sharing

APPENDIX A

Processing of Data from the Altimeter

The program reads the following data from the altimeter:

- Time
- Altitude (raw)
- Pressure
- X-axis acceleration
- Y-axis acceleration
- Z-axis acceleration

The program stores the raw altitude in an array named “alt_raw”. Pressure values are stored in an array named “pressure”. The pressure values are never modified.

The altitude values are multiplied by the temperature correction factor. The apogee value is determined.

If the reference temperature is later modified, the altitude values are multiplied by the ratio of the temperature correction factors of the previous and updated temperatures. The apogee value is updated.

If the APPLY FILTER command is executed, the altitude values are processed to remove noise and smooth the results. The apogee value is updated using the filtered altitude values.

APPENDIX B

Calculating Altitude from Pressure

To convert air pressure (P) measured by a pressure sensor into altitude (h), the barometric formula is used. In metric units, for the troposphere (0–11 km), a commonly used approximation (assuming standard atmosphere) is:

$$H = 44330\left(1 - \left(\frac{P}{P_o}\right)^{0.1903}\right)$$

where:

H = altitude in meters

P = measured pressure in pascals (Pa) or millibars (hPa) (units cancel)

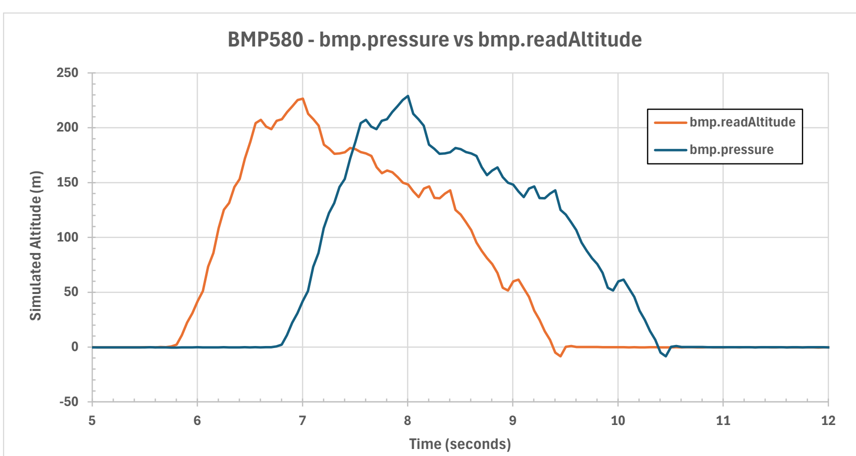
P_0 = sea-level standard pressure = 101325 Pa (or 1013.25 hPa)

This formula is widely used in avionics, drones, and embedded altimeters.

The BMP580 pressure sensor software has two functions related to pressure and altitude:

- bmp.pressure – returns the atmospheric pressure (hPa)
- bmp.readAltitude – returns the altitude (m)

A check was performed to verify that the results from "bmp.readAltitude" were the same as an altitude calculated using the pressure from "bmp.pressure". As shown in the following chart, the results were identical within bit truncation. [Note: the altitude traces are intentionally time-shifted for clarity when comparing the two datasets.]



APPENDIX C

Filtering and Smoothing

The Zeta II system uses an **Adaptive Median** filter to remove spike noise and a **Savitzky-Golay** filter to smooth the data and provide 1st derivative (velocity) values for calculating the Estimated Maximum Altitude.

"A median filter is a non-linear digital filtering technique used to remove noise from images, signals, and videos while preserving edges. It works by replacing each value in a dataset with the median of its neighboring values within a defined window."[12]

"The standard median filter is one of the most commonly used and effective methods for removing spike (impulsive) noise from signals and images."[13]

A Median filter is a windowed approach somewhat similar to the Simple Moving Average (SMA). The SMA uses the average of the values within the window, while a median filter uses the median value of the values within the window.

The results from a median filter depend on the window size relative to the duration of a noise spike. The window should be an odd number and be large enough such that the number of points in the noise spike is less than half the window. For example, if the noise spike is five samples long, the median filter window size should be 11 or greater. However, using an overly large window may affect real data.

A median filter can be used in an adaptive mode. Start with a baseline window size (perhaps 11 points), then increase the window size by two points per pass until the results stabilize (i.e., no significant change in apogee).

The Savitzky–Golay filter uses a windowed approach similar to the Median filter. The SG filter fits a polynomial of a specified order to the points within the window. The polynomial fit provides both a smoothed altitude value and its first derivative (velocity). ZetaPost uses a 9-point, cubic polynomial, constant time step version of the Savitzky-Golay filter.

---

[12] https://en.wikipedia.org/wiki/Median_filter

[13] https://www.sciencedirect.com/science/article/abs/pii/S0926985112001474

APPENDIX D

Estimated Maximum Altitude

Estimated Maximum Altitude (EMA) can be used to check the validity of measured altitude data. If the reported altitude is noticeably different than the estimated maximum altitude, the flight data should be carefully examined for unusual features or errors.

The estimated maximum altitude can be calculated for a rocket that is coasting after motor burnout. The rocket will decelerate due to gravity and drag. If drag is neglected, the maximum altitude of the rocket can be calculated from the kinematic equation:

$$H_{max} = H + \frac{V^2}{2\,g}$$

where "g" is the acceleration due to gravity (typically 9.80665 m/s^2).

By neglecting drag, the estimated maximum altitude calculated using altitudes and velocities immediately after burnout will be too high. As the rocket nears apogee and velocity decreases towards zero, the neglected drag term becomes small, and the simplified (no-drag) estimated maximum altitude calculation will be accurate.

A more complete version of the EMA calculation including drag effects is available at the NASA Glenn Research Center website[14] (see figure). Assuming constant air density, the equations for estimated maximum vertical altitude are:

$$H_{max} = H + \frac{V_t^2}{2\,g}\,ln\left(\frac{V^2 + V_t^2}{V_t^2}\right)$$

where V_t (terminal velocity) is:

[14] https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/flight-equations-with-drag/

$$V_t = \sqrt{\frac{2\,m\,g}{C_d\,A\,\rho}}$$

The rocket’s mass, cross-section area, and drag coefficient are needed to determine the terminal velocity. These values are related to the ballistic coefficient (B):

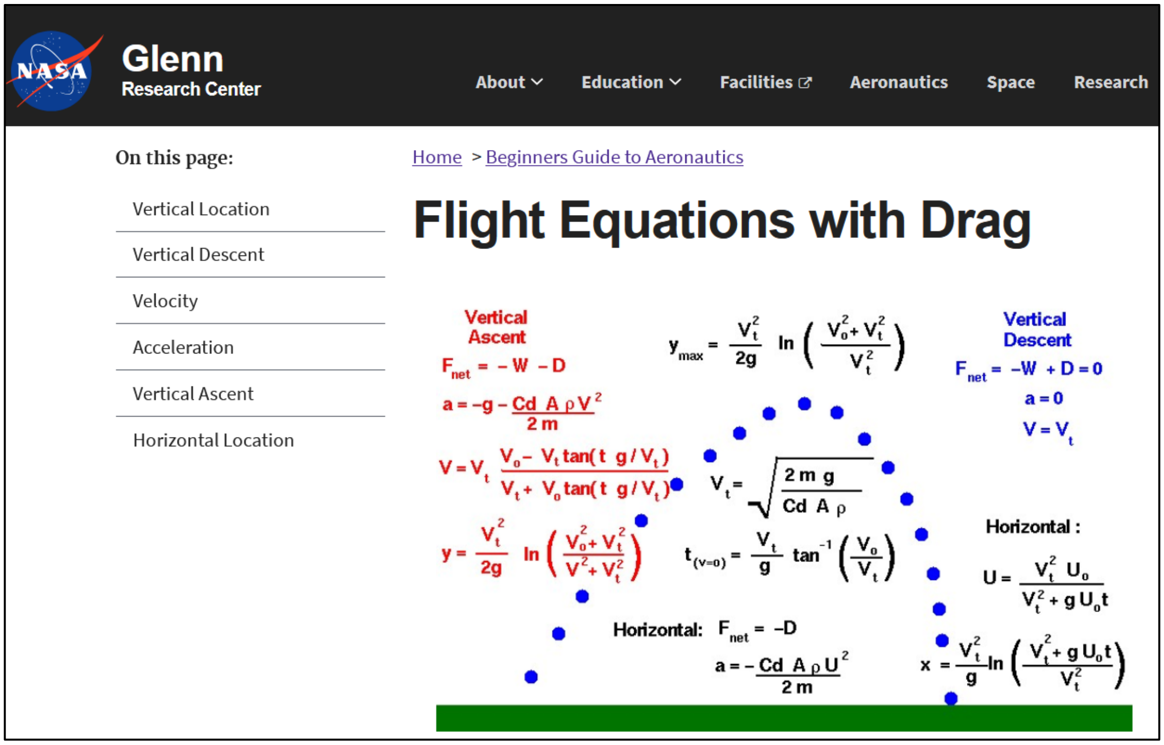
$$B = \frac{m}{C_d\,A}$$

Combining equations:

$$V_t = \sqrt{\frac{2\,B\,g}{\rho}}$$

Ballistic coefficients for typical FAI altitude models are shown in the following table. For S1B and S5C, a ballistic coefficient of 50 may be used as a representative value.

	S1B				S5C				S2P			
Diameter	**25**	mm	0.025	m	**30**	mm	0.03	m	**66.04**	mm	0.06604	m
Radius	12.5	mm	0.0125	m	15	mm	0.015	m	33.02	mm	0.03302	m
X-Sect Area	490.8739	mm^2	0.000491	m^2	706.8583	mm^2	0.000707	m^2	3425.343	mm^2	0.003425	m^2
Mass	**9**	grams	0.009	kg	**25**	grams	0.025	kg	**350**	grams	0.35	kg
CD	**0.4**				**0.6**				**0.5**			
Ballistic Coef (BC)			**45.8**	kg/m^2			**58.9**	kg/m^2			**204.4**	kg/m^2
BC = M / (Cd A)												



Glenn Research Center

About · Education · Facilities · Aeronautics · Space · Research

On this page:

- Vertical Location
- Vertical Descent
- Velocity
- Acceleration
- Vertical Ascent
- Horizontal Location

Home > Beginners Guide to Aeronautics

Flight Equations with Drag

APPENDIX E

BMP580 Pressure Sensor Settings

BMP580 Configuration for 20 Hz, No IIR Filter

Parameter	Setting	Value
IIR Filter	Bypass (off)	`BMP5XX_IIR_FILTER_BYPASS`
Pressure OSR	2x	`BMP5XX_OVERSAMPLING_2X`
Temperature OSR	1x (minimum required)	`BMP5XX_OVERSAMPLING_1X`
ODR	20 Hz	`BMP5XX_ODR_20_HZ`
Power Mode	Normal	`BMP5XX_POWERMODE_NORMAL`

The Zeta II altimeter does not use the IIR filter in the BMP580 sensor. All filtering of the altimeter data is performed in the ZetaPost program.

The BMP580 sensor automatically reads temperature as well as pressure at each data measurement. The temperature value from the BMP580 is not recorded by the altimeter and is not used.

APPENDIX F

File Format of Stored Data

- Documentation records (start with “$”)
- Rest of file is CSV
- Data description header record (Time, Pressure, etc.)
- Data records, one record per data sample

```
$ ZetaPost - Altimeter Data Analysis (V0.9)
$ File written: 2026-05-11T08:51:44.200330
$ Altimeter serial number: 6
$ Altimeter firmware version: 1.0
$ Competitor number: 17540
$ Temperature (deg C): 15.0
$ Apogee (meters): 195.2
Time,Pressure,AltRaw,Altitude,EstMaxAlt,Veloc,X_Accel,Y_Accel,Z_Accel
0.000,1015.020,-0.0,0.0,0.0,-0.1,-9.06,-1.53,1.53
0.050,1015.022,0.0,0.0,0.0,-0.1,-9.41,-1.29,1.53
0.100,1015.027,0.0,-0.0,-0.0,-0.0,-9.30,-0.94,1.41
0.150,1015.027,-0.0,-0.0,-0.0,-0.0,-9.65,-1.06,1.53
0.200,1015.021,0.0,-0.0,-0.0,-0.0,-9.65,-1.41,1.06
0.250,1015.024,0.0,-0.0,-0.0,-0.0,-9.30,-1.77,1.53
0.300,1015.025,-0.0,-0.0,-0.0,0.0,-9.53,-1.65,1.88
0.350,1015.024,0.0,-0.0,-0.0,0.0,-9.41,-1.53,1.41
0.400,1015.026,-0.0,-0.0,-0.0,0.0,-9.65,-1.29,1.53
0.450,1015.029,-0.0,-0.0,-0.0,-0.0,-9.41,-1.18,1.29
0.500,1015.027,-0.0,-0.0,-0.0,-0.0,-9.41,-1.06,1.06
0.550,1015.026,-0.0,-0.0,-0.0,-0.0,-9.53,-1.53,1.41
0.600,1015.026,-0.0,-0.0,-0.0,-0.0,-9.41,-1.65,1.41
0.650,1015.017,0.1,-0.0,-0.0,-0.0,-9.53,-1.41,1.88
0.700,1015.030,-0.0,-0.0,-0.0,-0.0,-9.77,-1.18,1.06
0.750,1015.018,0.1,-0.0,-0.0,-0.0,-9.30,-1.41,1.18
0.800,1015.022,0.0,-0.0,-0.0,0.0,-9.41,-1.29,1.53.
.
.
.
```

APPENDIX G

ZetaPost Installation and Execution

ZetaPost is written in Java. The ZetaPost installer files include everything needed to run the application, including the Java runtime environment. No separate Java installation should be needed.

Check http://www.zetapost.com for the latest installation instructions and Frequently Asked Questions (FAQs).

Windows

ZetaPost is provided as an unsigned ".exe" jpackage installer file with a bundled jlink runtime. Before installing the program, it is recommended to suspend virus check programs.

Execute the installer file to install ZetaPost. Windows may display a warning such as:

- "Windows protected your PC"
- "Microsoft Defender SmartScreen prevented an unrecognized app from starting"

If so:

- Click **More Info**.
- Verify that the publisher says "Unknown publisher" (which is normal for an unsigned app).
- Click **Run Anyway**.

macOS

ZetaPost is provided as an unsigned ".dmg" jpackage installer file with a bundled jlink runtime. Before installing the program, it is recommended to suspend virus check programs.

To install from an unsigned .dmg, do the following:

- Double-click the .dmg.
- Drag the "ZP" application into **Applications**.

To execute the program:

- Open **Applications** in **Finder**.
- Control-click (or right-click) the application.
- Choose **Open**.
- macOS will warn that the app is from an unidentified developer.
- Click **Open** to confirm.

If that doesn't work:

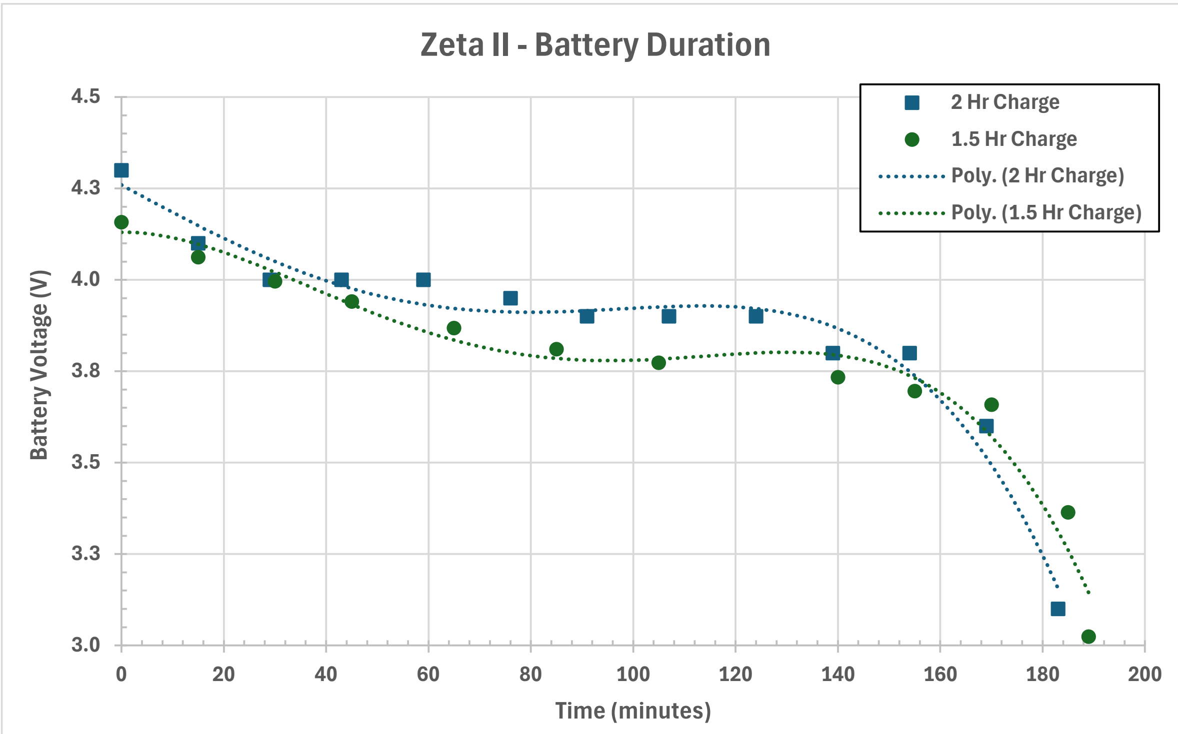
- Go to **System Settings**, **Privacy & Security**.
- Scroll down to the **Security** section.
- You should see a message that the app was blocked.
- Click **Open Anyway**.
- Confirm again.

After you've approved it once, you generally won't have to repeat these steps.

APPENDIX H

Battery Duration

The battery voltage was monitored during operation of the altimeter. Beginning with a fully charged 1-cell 40 mAh battery, the operating life was approximately 2.5 hours.



Lithium-Polymer (LiPo) Battery Safety

The Zeta II altimeter is powered by a single-cell lithium-polymer (LiPo) battery. LiPo batteries provide excellent energy density and low mass. They must be handled carefully to avoid damage, fire, or personal injury.

Battery Requirements

- Use only a 1-cell (1S) LiPo battery with a nominal voltage of 3.7 V.
- Verify battery polarity before connecting the battery. Reverse polarity may damage the altimeter.

Charging

- Charge LiPo batteries only with a charger specifically designed for 1-cell LiPo batteries.

- Do not exceed the manufacturer’s recommended charge rate.
- Never leave a charging LiPo battery unattended.
- If the battery becomes excessively hot, puffs or swells, emits odor, or shows signs of damage during charging, immediately disconnect it and move it to a safe location.

Handling and Storage

- Do not puncture, crush, bend, or short-circuit the battery.
- Avoid pulling on the battery wires when disconnecting the battery
- Store batteries in a cool, dry location away from flammable materials.
- For long-term storage, maintain the battery at an appropriate storage charge level (typically about 3.7–3.85 V per cell).

Inspection

Before each use, inspect the battery for:

- Swelling or puffing
- Damaged wires or connectors
- Torn insulation
- Signs of overheating

Do not use damaged batteries.

Transportation

LiPo batteries are subject to shipping and transportation regulations. Follow all applicable postal, courier, airline, and competition safety requirements when transporting batteries.

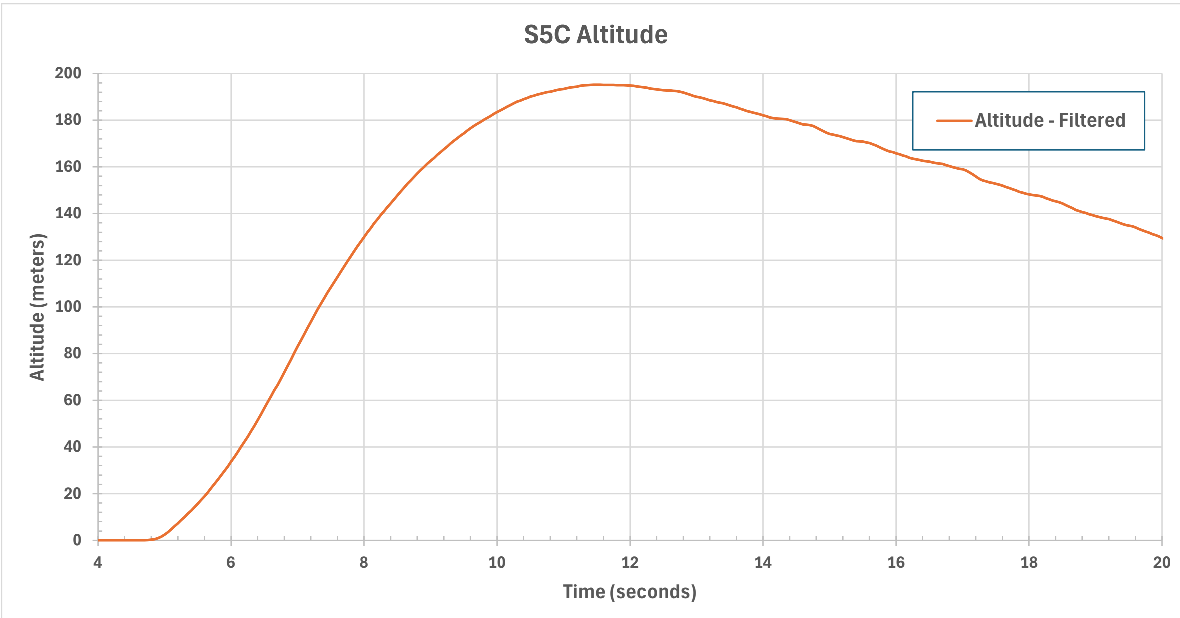
Disposal

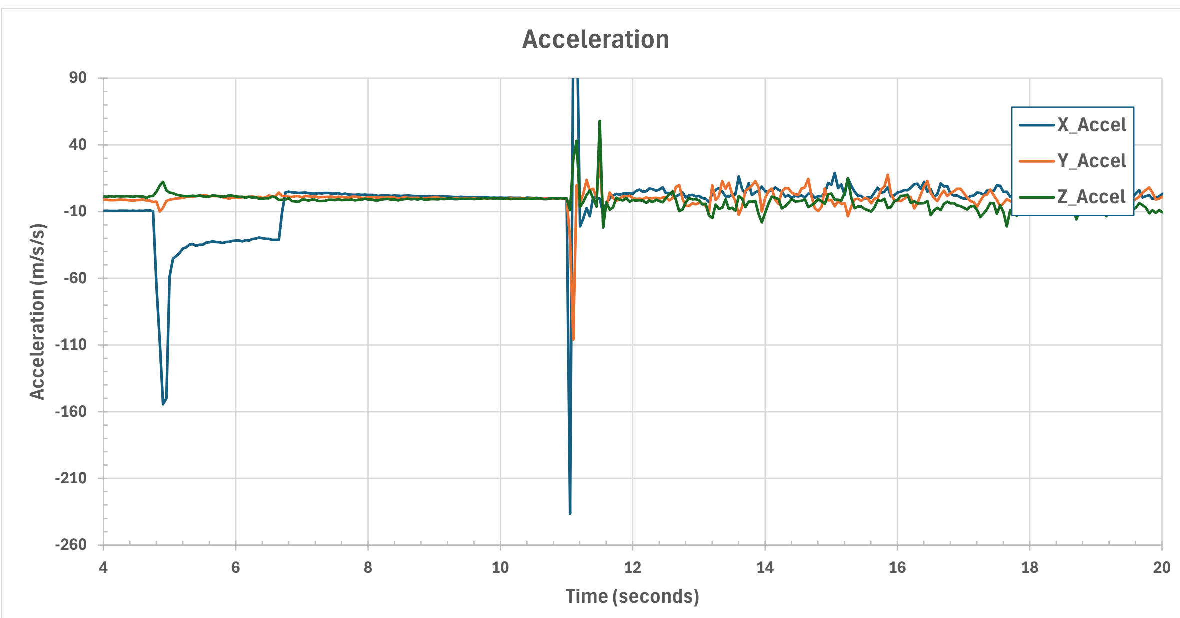
Do not dispose of LiPo batteries in household trash. Dispose of batteries in accordance with local regulations for lithium battery recycling and hazardous waste disposal.

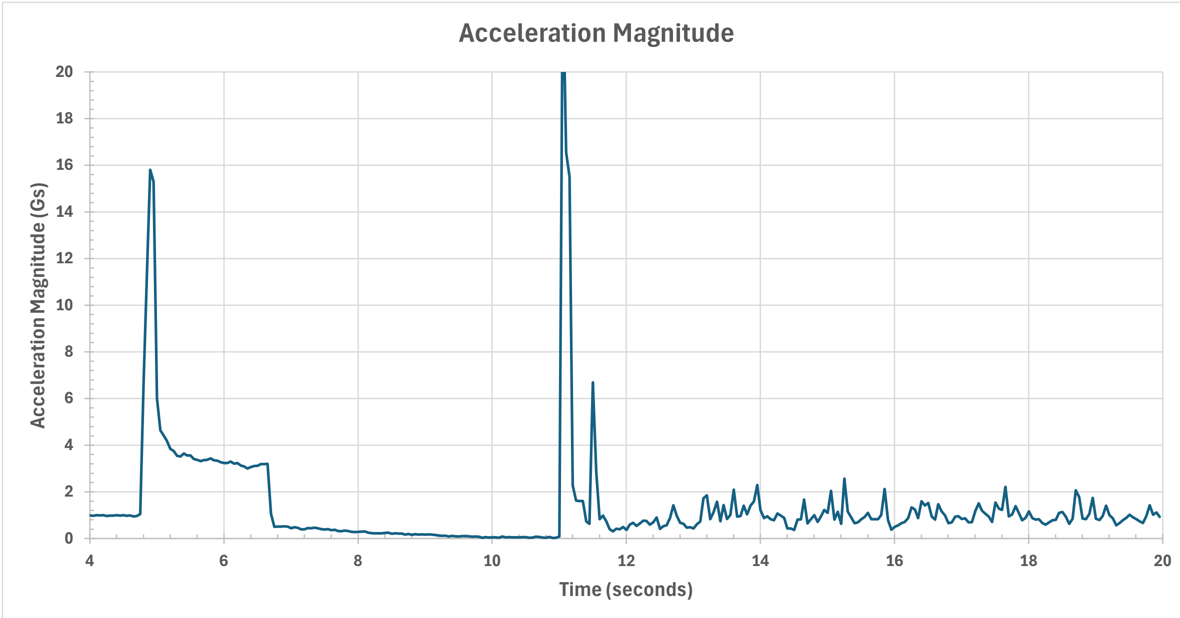
APPENDIX I

Additional Plotting

The information in a .ZTA file can be imported into Excel or similar spreadsheet program for additional plotting or processing.






Acceleration Magnitude
Acceleration Magnitude (Gs)
20
18
16
14
12
10
8
6
4
2
0
4
6
8
10
12
14
16
18
20
Time (seconds)