2.4GHz XCVR Module for Model Rocket Payload

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Background

- Astrocam rockets never worked right
  - Mechanical system to trigger picture
  - Pictures wouldn't take or came out dark
- Spawned fun idea to build custom model rocket with electronic payload
- Final goal to have payload with altitude data and video downlink
  - Would like pictures and video above clouds
- Will be an iterative process until complete
  - Each iteration will add to or refine electronics and bigger rockets capable of higher altitudes

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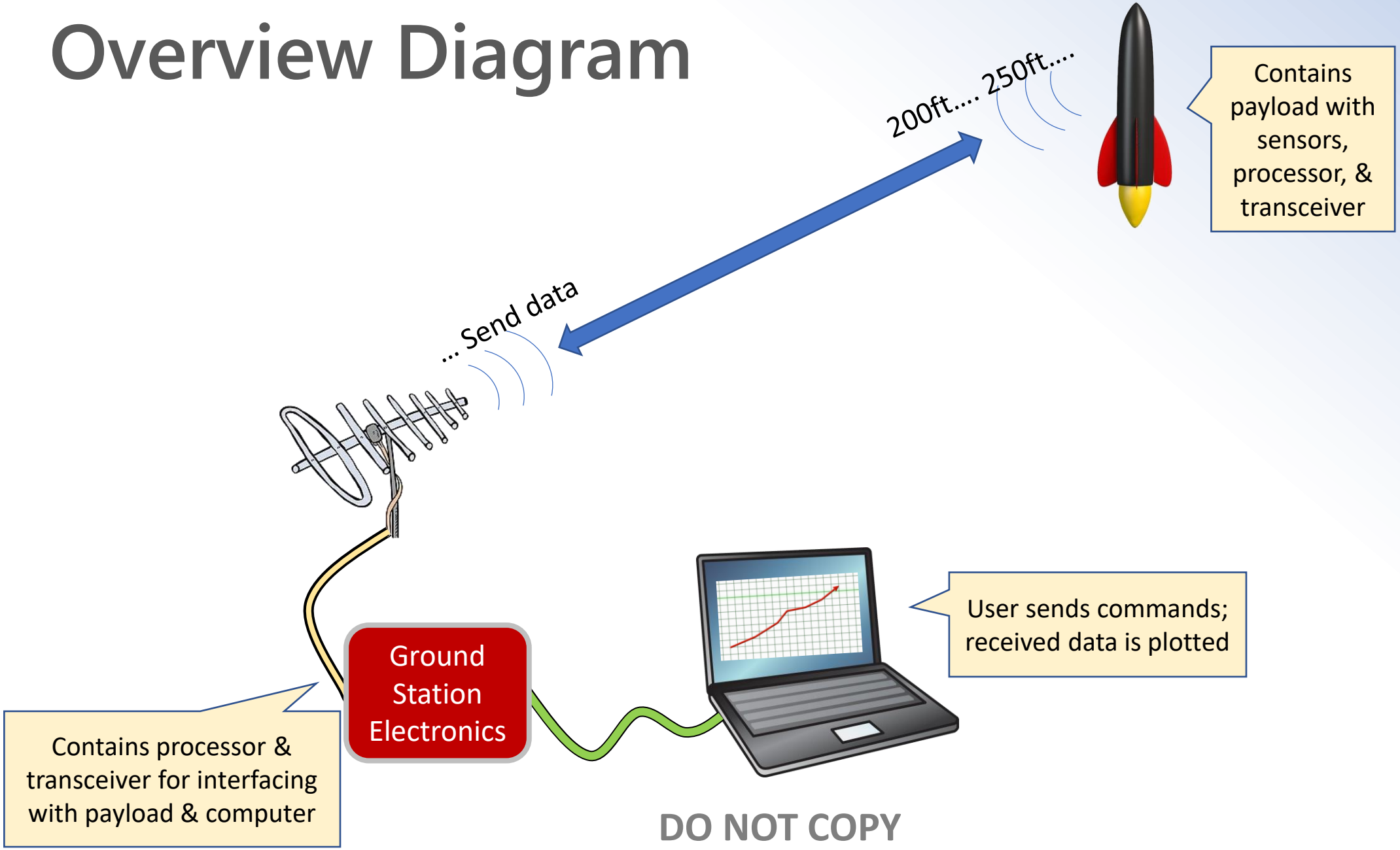
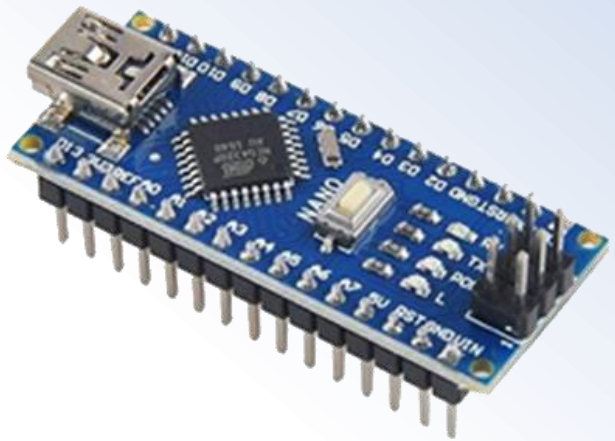
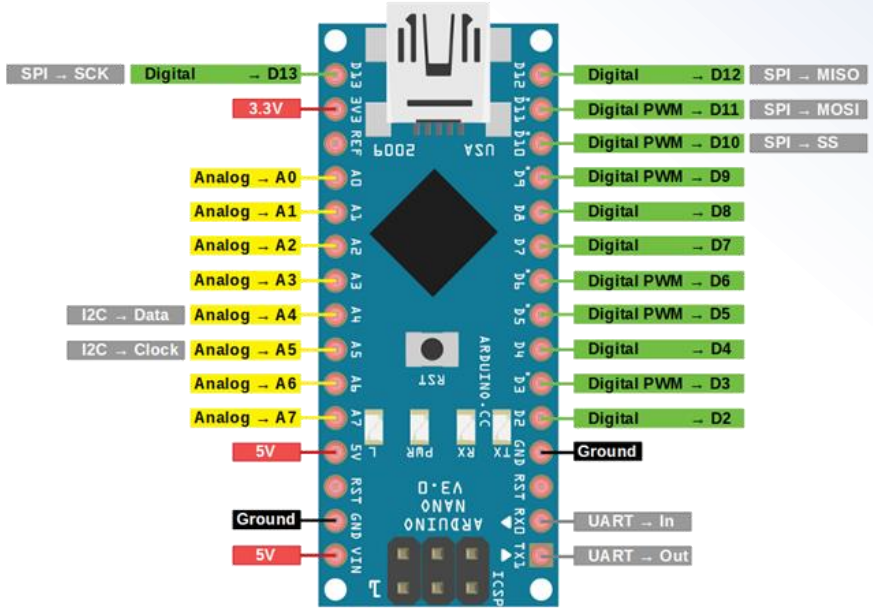
Overview Diagram



Payload

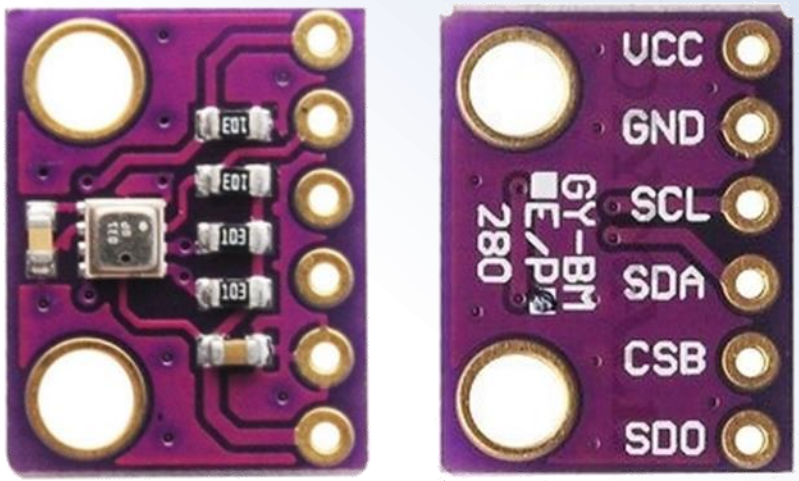
- Arduino Nano
  - Interface with peripherals
    - BMP280 sensor
    - nRF24L01 module
  - Receive and execute commands from ground
  - Form data packets
  - Transmit data to ground
  - Backup data in memory (1KB EEPROM)
  - Voltage: 7-12 volts
  - Weight: 5 grams





Payload

- BMP280 Barometric Pressure Sensor
  - Pressure readings can be converted to altitude
    - H = 44330 * [1 - (P/p0)^(1/5.255)]
    - H = altitude (m)
    - P = measured pressure (Pa)
    - p0 = reference pressure at sea level (check weather online for value at site and day of launch)
  - Also has temperature sensor
  - I2C and SPI interfaces
  - Voltage: 3 volts (used 3.3V source from Arduino)
  - Weight: 1 gram

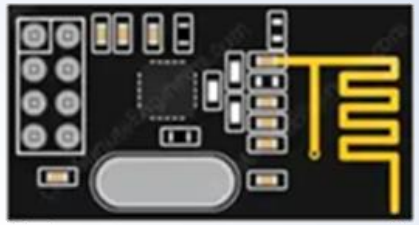


BMP280

Payload

- nRF24L01 Transceiver module
  - 2.4GHz ISM band
  - Antenna etched onto board
  - Gaussian Frequency-Shift Keying (GFSK)
  - Up to 2Mbps data rate
  - SPI interface
  - 0dBm, advertised range 800+ meters; Experiments on YouTube have shown up to many kilometers with line of sight and directional antenna
  - Voltage: 3.3V
  - Weight: 4 grams

nRF24L01+ Pinout



Payload

- nRF24L01 Transceiver module (cont'd)
  - Variable data payload size
  - Optional CRC
  - Auto acknowledge & re-transmit (turned this off to prevent data from backing up)
  - RF24 open source code library for Arduino makes interfacing with XCVR easy

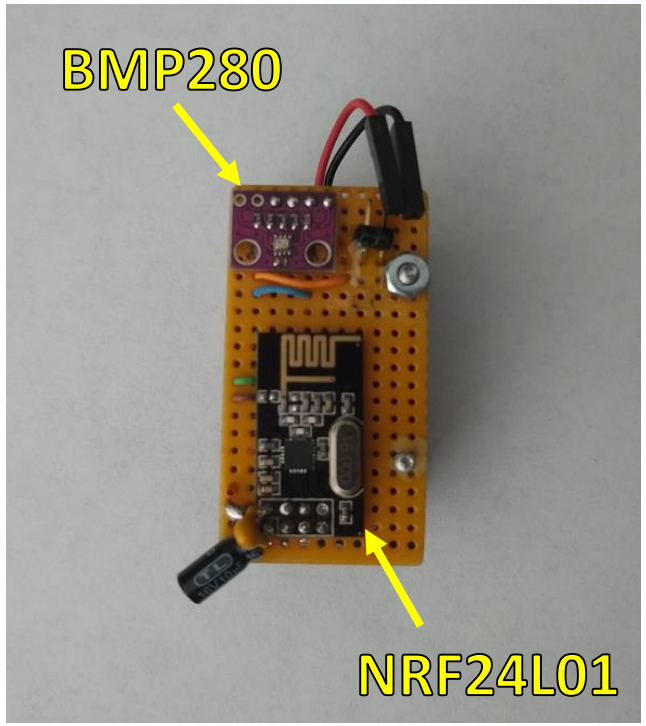
Preamble	Address 3-5 byte	Payload 1 - 32 byte	CRC 0/1/2 byte

Preamble	• Preamble is used to detect 0 and 1 levels. It is stripped off (RX) and added (TX) by nRF24L01.
Address	• The address field contains the receiver address. • The address can be 3, 4 or 5 bytes wide • The address fields can be individually configured for all RX channels and the TX channel • Address is automatically removed from received packets.[16]
Flags	• PID: Packet Identification. 2 bits that is incremented for each new payload • 7 bits reserved for packet compatibility with future products • Not used when compatible to nRF2401/nRF24E1
Payload	• 1 - 32 bytes wide.
CRC	• The CRC is optional. • 0-2 bytes wide CRC • The polynomial for 8 bits CRC check is $X^8 + X^2 + X + 1$ • The polynomial for 16 bits CRC check is $X^{16} + X^{12} + X^5 + 1$.

Table 12 Data packet description

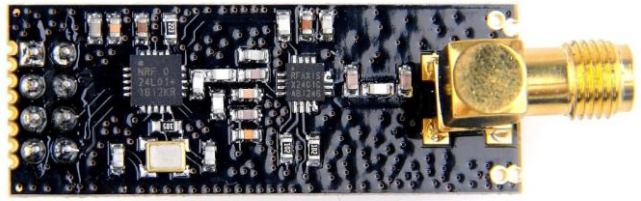
Payload

- Assembled Payload
  - Weight
    - Battery: 45 grams
    - Electronics: 10 grams
    - Board, wires, battery holder, etc: 15 grams
    - Total: 70 grams
  - Dimensions
    - Height: 2.25 in.
    - Length: 1.25 in.
    - Width: 1.5 in.

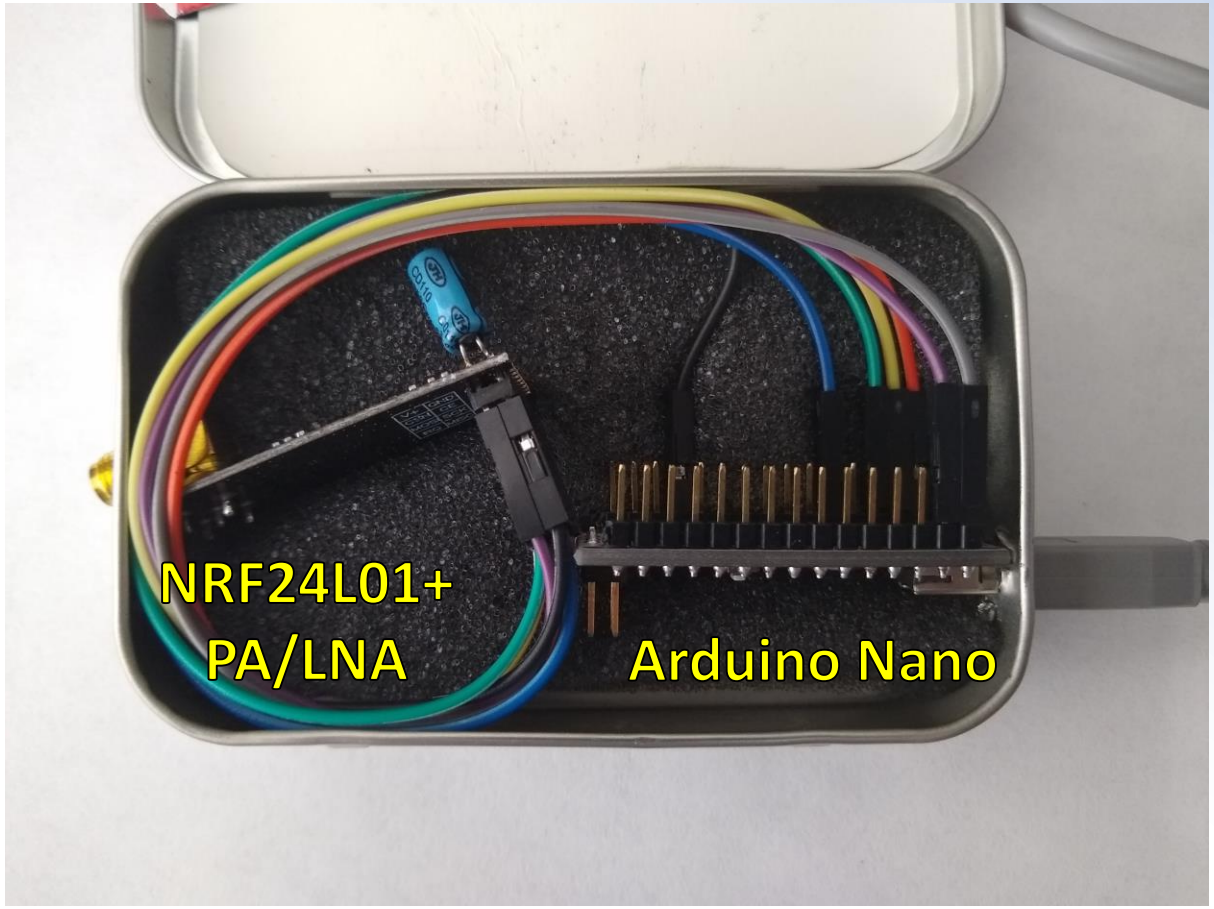


Ground Station

- Arduino Nano
  - Same hardware as payload
  - Middleman between computer and payload; forwards commands & data over RF link & USB
- NRF24L01+ PA/LNA 2.4GHz Transceiver
  - Similar to XCVR used in payload, but with 10dB LNA, 20dB PA, and SMA connector for offboard antenna
- 2.4GHz 18dB Yagi
  - Directionality and gain to improve reception at high altitudes



Ground Station

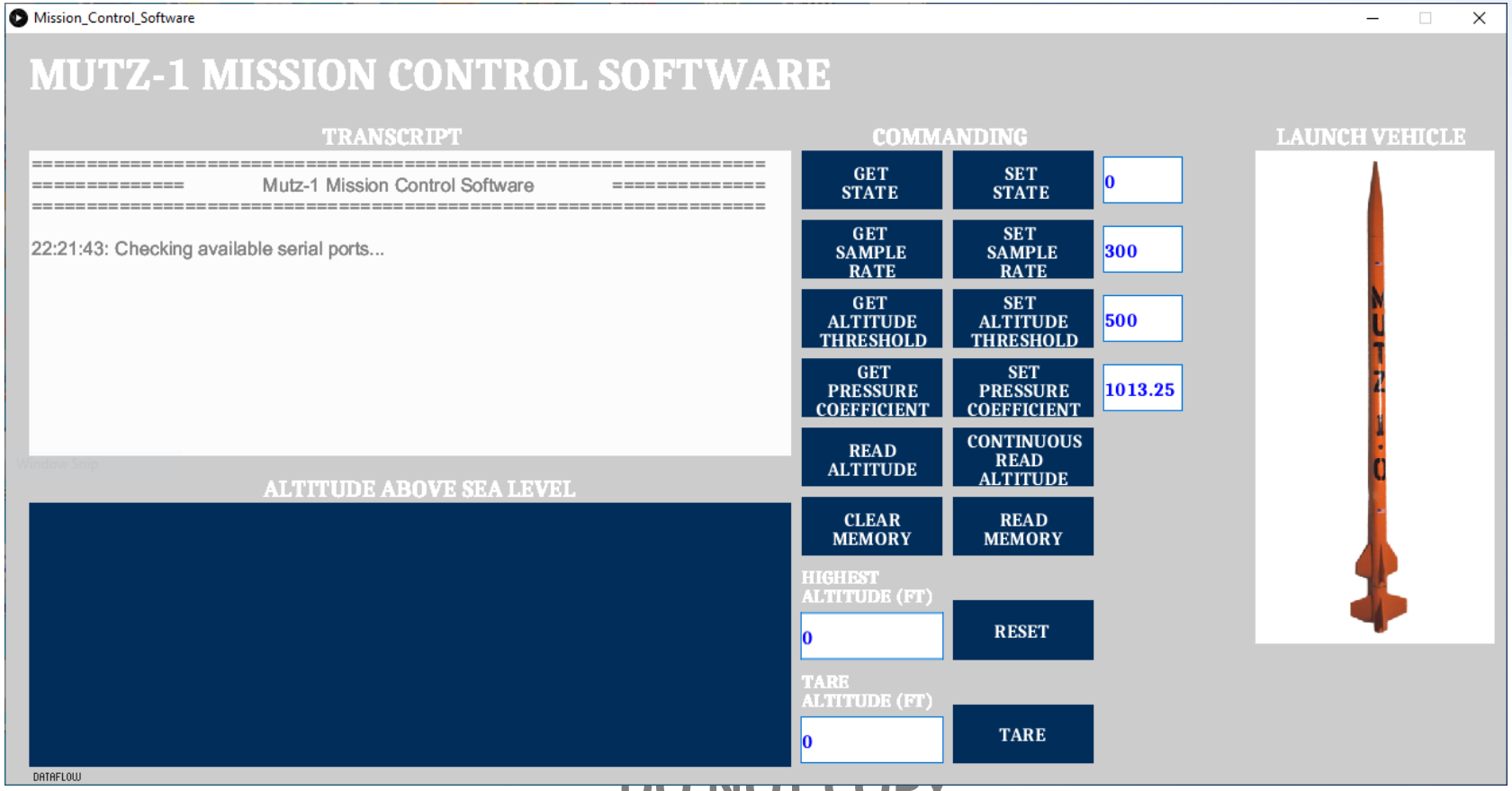


Mission Control Software

- Payload is controlled through software
- Received altitude data from payload and plots on graph

Transcript logs commands & data

Altitude data plotted here



Command & Telemetry Format

Mission Control to Payload Commands	Description	Command ID (1 byte)	Field 1 (1 byte)	Field 2 (1 byte)	Field 3 (1 byte)	Field 4 (1 byte)	Payload Response
Clear Memory	Overwrites all values in EEPROM with 0's	A	X	X	X	X	N/A
Read Memory	Reads all contents in EEPROM	B	X	X	X	X	1k x float (4 bytes)
Read Altitude	Returns one live altitude reading from sensor. Value is transmitted in meters; mission control software converts to feet.	C	X	X	X	X	float (4 bytes)
Read Launch State	Returns launch readiness state	D	X	X	X	X	byte
Set Launch State	Sets launch readiness state. 1: Enable launch readiness, Others: Disable launch readiness	E	byte	X	X	X	N/A
Set Altitude Threshold	Sets the minimum altitude that needs to be reached before data starts to be recorded into memory. Value is in feet	F	float (byte 0)	float (byte 1)	float (byte 2)	float (byte 3)	N/A
Set Sample Period	Sets the period in milliseconds to sample and record altitude sensor data into memory. This will only take affect after the Launch Altitude Threshold has been reached.	G	int to float(byte	int to float(byte	int to float(byte	int to float(byte	N/A
Get Altitude Threshold	Returns current value of altitude threshold from payload in feet	H	X	X	X	X	float (4 bytes)
Get Sample Period	Returns current value of sample period in milliseconds	I	X	X	X	X	float (4 bytes) to int
Set Continuous Read	Sets continuous sensor reading and reporting. 1: Enable continous reading, Others: Disable continuous reading. If enabled, ground station and mission control should continously monitor for data.	J	byte	X	X	X	N/A
Set Pressure Coefficient	Set coefficient for pressure to altitude conversion. This value is dependent upon pressure at sea level at launch location at that time.	K	float (byte 0)	float (byte 1)	float (byte 2)	float (byte 3)	N/A
Get Pressure Coefficient	Returns pressure coefficient	L	X	X	X	X	float (4 bytes)
*X fields are don't cares							

Rocket

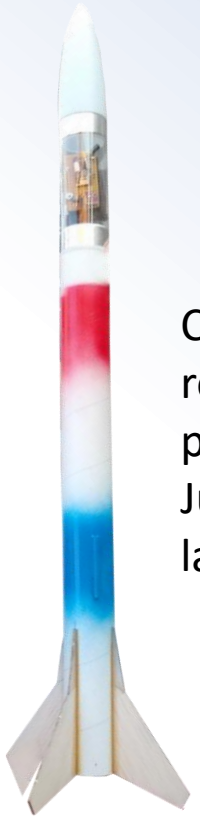
- Original rocket planned for launch
- Estes Mammoth E2X
- Modified with payload section (not shown in photo)
- Booster makes a 2-stage rocket capable of 2600 feet (no payload)
- Recommended Engines: E16-4, E16-6, E16-8, F15-6, F15-8
- Length: ~5ft

- One of the largest rockets we can get without needing high-powered rocketry license

- High winds in desert 20+ mph prevented July 4th launch, BUT…

Rocket

- Alternate rocket, Estes Olympus, was built overnight for lower wind conditions within city
- Recommended Engines: D12-3, D12-5, E12-4, E12-6
- Maximum Estimated Altitude: 1400 ft (max engine, no payload)
- Length: ~2.5ft



Completed rocket painted for July 4th launch date

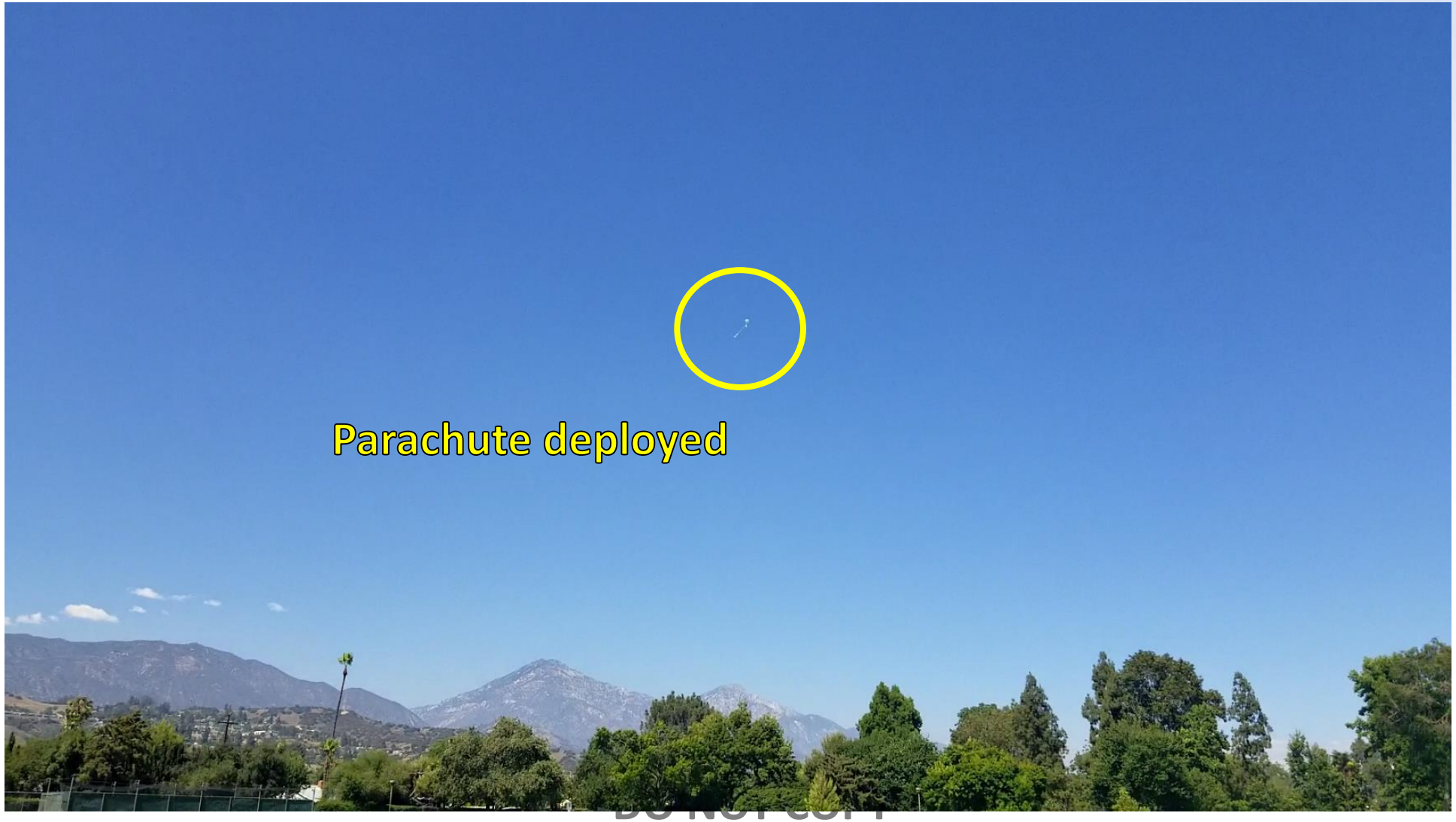
Launch Site

- Griffith Park, Claremont

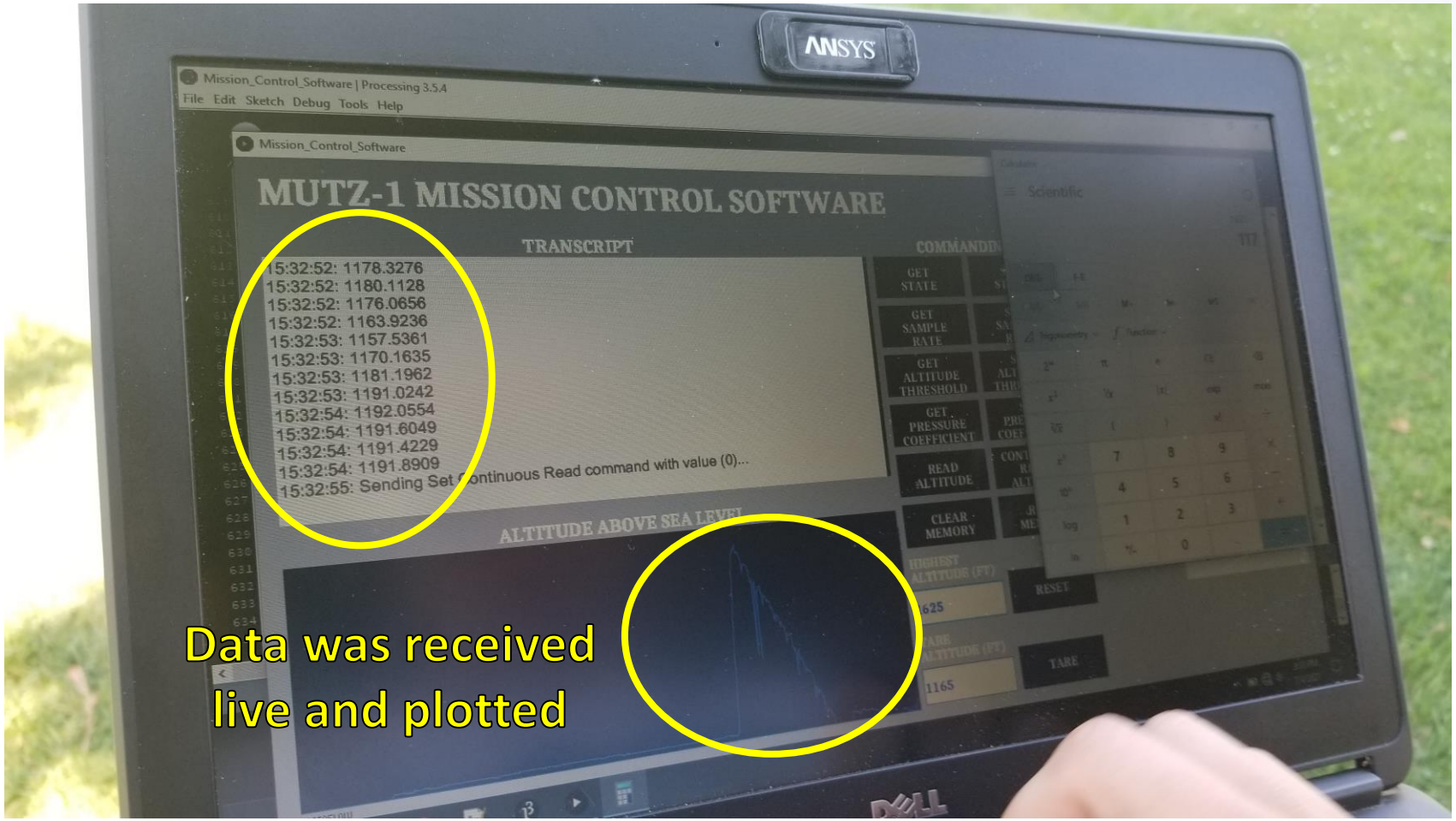
Preparing for Launch

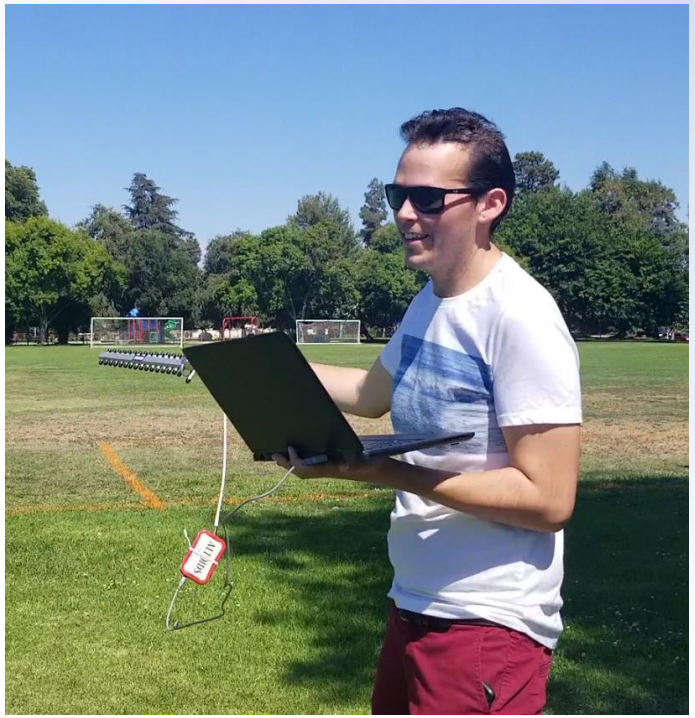
Liftoff!

Recovery



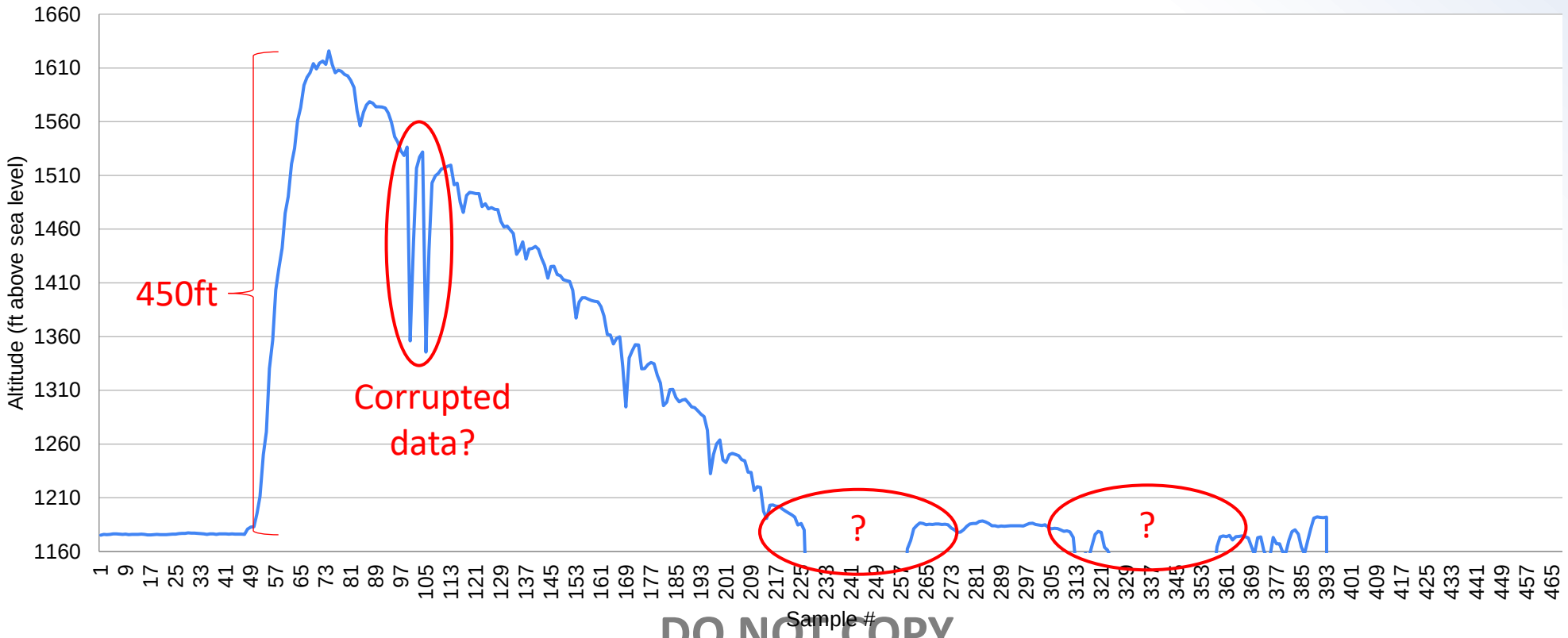
Received Data





Results

- Received altitude data had just a few anomalies, but otherwise looks very good
- Good to keep in mind that sensor is a pressure sensor and altitude data is calculated
- Will compare data from next launch see how data trends



Post-Launch

Future Plans

- Higher altitudes
- Inertial measurement unit (IMU)
- Improved telemetry
- Lighter payload
- Investigate camera & higher data rates
- ESP32-CAM to possibly replace Arduino
  - Built-in WiFi & camera

- **Next Launch**: September 18, 2021
  - Original rocket with same payload

BOM

Part	Price Per Unit	Quantity	Total	Source	Notes
Arduino Nano	$3.60	2	$7.20	Amazon	Pack of 5; used 2
9V Duracell Battery	~$7.00	1	$7.00	Ace Hardware	
Perf Board	$0	1	$0	Spare Parts	
9V Battery Holder	$0	1	$0	Spare Parts	
BMP280 Sensor	$1.32	1	$1.32	Amazon	Pack of 5; used 1; 1 part DOA
NRF24L01+ XCVR	$1.14	1	$1.14	Amazon	Pack of 10; used 1
NRF24L01+ PA/LNA XCVR	$4.80	1	$4.80	Amazon	Pack of 2; used 1
Techtoo 2.4GHz 18dBi Yagi	$32.84	1	$32.84	Amazon	
SMA to RP-SMA Adapter Kit	$7.99	1	$7.99	Amazon	Pack of 4 different adapters; used 1
Altoids Case	$0	1	$0	Spare Parts	
Screws & Nuts	~$3.00	X	$3.00	Home Depot	
Estes Olympus Rocket	$16.41	1	$16.41	Hobby Lobby	
Estes Mammoth E2X Rocket	$41.99	1	$41.99	~	
Estes Booster Stage	$15.00	1	$15.00	~	
E16-X Rocket Engine	~$15.00	1	$15.00	Pacific Coast Hobbies	Pack of 2; used 0 this launch
D12-X Rocket Engine	$4.37	1	$4.37	Hobby Lobby	Pack of 2; used 1
Total			**$158.06+**		Plus other miscellaneous items