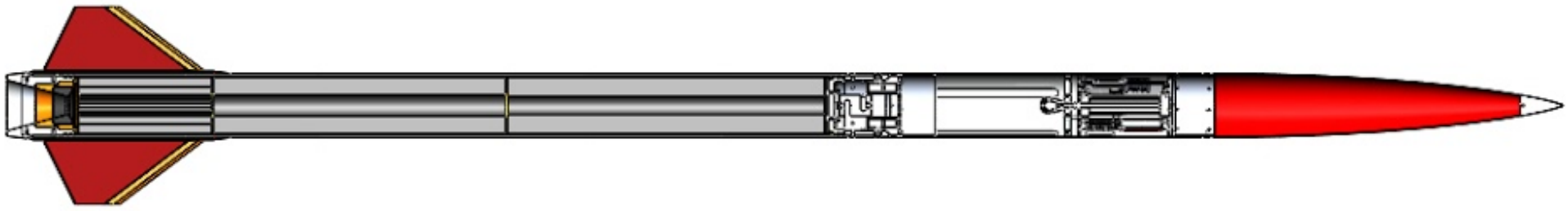
Supplemental Information for FAA Form 7711-2:



Major System Overview

Propulsion

a. Ammonium Perchlorate Composite Propellant (APCP); HTPB binder, 7.5% Aluminum; 82.5% total Solids
b. 70 inches of propellant in three 5.125” dia grains; one 12” finocyl grain, one 28” BATES grain, and one 30” BATES grain. Grains are cast in canvas phenolic casting tubes and bonded into a canvas phenolic liner with high-temp epoxy.
c. Parameters:

Table 1 - Propulsion Parameters

Kn: 170-331	Max Pc: 928.5 psi	Web: 1.69 in
Burn Time: 8.1 sec	Propellant Length: 70 in	Propellant Mass: 73.73 lb
Classification: P9100	Delivered ISP: 225 sec	Volume Loading: 84.4%
Initial Thrust: 1786 lb	Thrust/Weight: 24.1	Impulse: 74042 Ns

(Burnsim 3.1.8.0 and verified with 01/25/19 Static Test Data)

d. Motor is 79” long, 6” dia., .25” wall 6061-T6 Aluminum extruded tubing. Nozzle is made up of a three-piece assembly consisting of a graphite throat set in a composite phenolic carrier and retained inside the motor case with 5/16” countersunk FH machine screws bolted to an Aluminum nozzle carrier.

Ignition

a. Ignition is achieved with an E-match inserted into a small (.5” dia, .75” long cylinder) piece of APCP solid rocket propellant. The piece of propellant is attached to the end of an 80” long wooden dowel.
b. When the vehicle has been brought to vertical and the avionics armed, the propellant piece is inserted up the motor core using the wooden dowel and secured to the ground.
c. The E-match is connected to a wired relay-operated ignition system. When all personnel are clear and a countdown has been given, the E-match/propellant piece is

fired, building chamber pressure and temperature to the point at which combustion can be sustained.

Vehicle Structure

a. Airframe consists of the 79” motor case, coupled to 36” long G12 fiberglass avionics/parachute bay, coupled to the nose cone.
b. Rocket is 147” in overall length.
c. Nose cone is a 5.5 ratio G10 ¾ power series nose cone with a 4” stainless steel tip, and 6.0” OD.
d. Fins are a 6” ID custom carbon fiber layup which slides over motor case; retained on aft end by fitting against 6061-T6 Al boattail (boattail is attached to nozzle carrier with ¼” FH screws). Fin collar is made of phenolic tube and fiberglass overwrap; fins made of G10 with 6-layer carbon fiber layup and phenolic leading edges.
e. Fins are .125” (uncanted) trapezoidal design with 2.33” beveled phenolic leading edges and 1” beveled trailing edges.
f. Top of fins are located 128” from nose tip.

Avionics

a. Pyxida (custom flight computer) -- for telemetry, not in control of parachute deploy
b. Telemega 2.0 Altimeter (accelerometer and barometer-based)
c. Marsa33LHD Altimeter (accelerometer-based)
d. Altimeters b. and c. are redundant - either can deploy parachutes.

Recovery

a. Drogue (custom sewn disk-gap-band, 38.5” disk dia, 4” vent, 3” gap, 12” band) deployed at apogee (110 fps descent); deployed by a pyrotechnically actuated piston.
b. Main (semi-ellipsoidal 9.5’ dia, 4% spill hole) deployed at 2000 ft (34 fps descent); deployed by a pyrotechnic charge which allows the main parachute to be extracted by the drogue.

Upper Electronics

a. Instrumentation package in nose cone records temperature at points along nose cone with thermocouples and high frequency vibrations with accelerometers.
b. Custom data acquisition PCB stores data.
c. Directional RF beacon for backup tracking
d. Sensors and board mounted on acrylic structure bolted to a 6061-T6 Al bulkhead.

Lower Electronics

a. Instrumentation package directly forward of motor records: pressure in motor with pressure transducer; main parachute tensile loads with a load cell; high frequency vibrations with accelerometers; visuals with cameras.

b. Custom data acquisition PCB stores data.
c. Mounted to an ABS support structure which is attached to the motor's 6061-T6 Al forward closure with 5/16" screws.

Support Equipment

Launch Tower

20' tall, permanent steel structure located at Friends of Amateur Rocketry (FAR) -- Guides initial ascent by contact.

Communications

a. Tracking equipment includes laptops, antennas, GPS receiver, extra batteries, and backup laptops.
b. Handheld radios used for communications between team members and onsite FAR members. Radios chosen to eliminate frequency collisions.
c. Launch site has a public announcement (PA) system for announcements.

Infrastructure

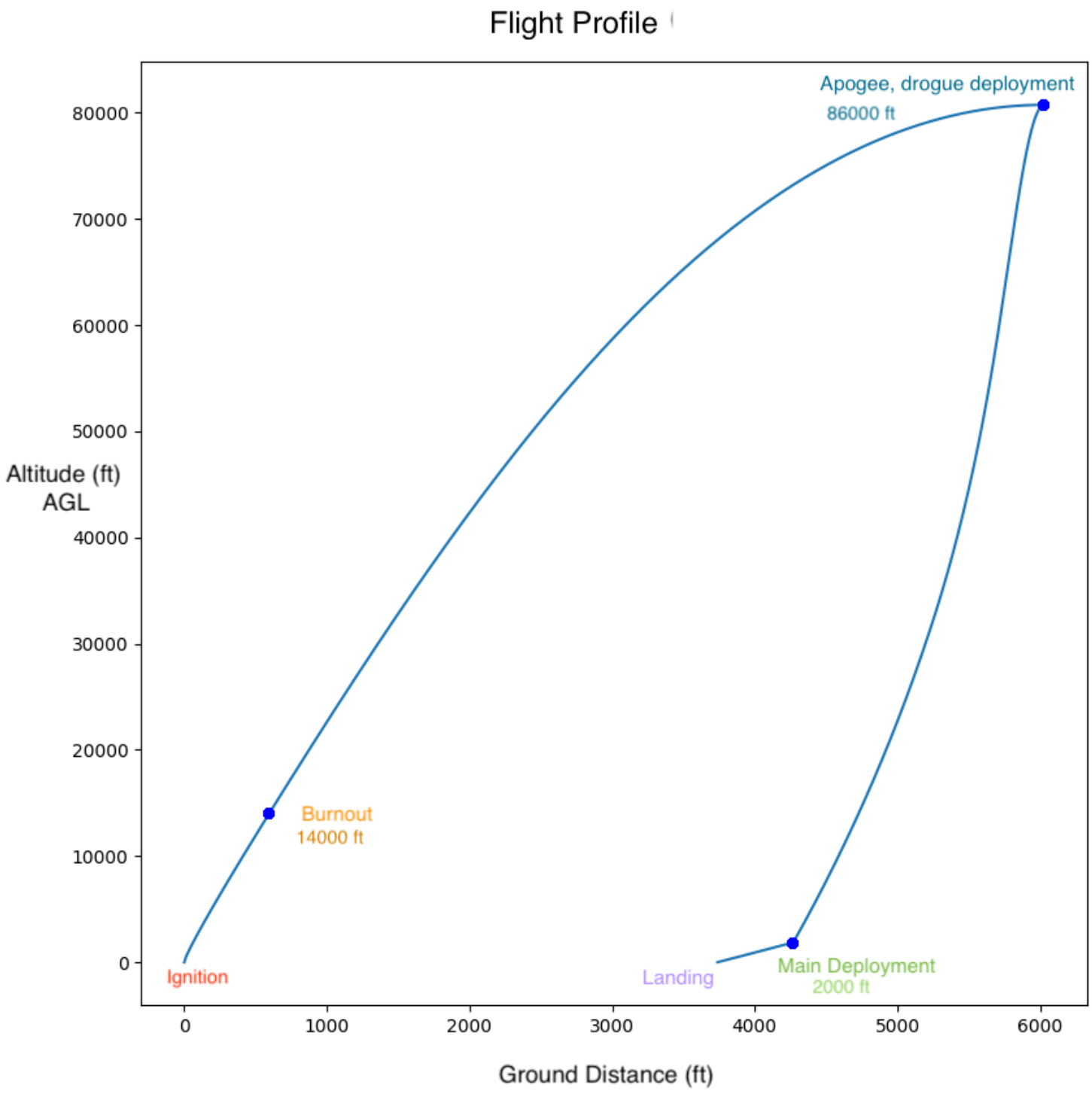
The site has permanent bunkers to take shelter during the rocket launch. Roofed areas provide sun shelter during vehicle integration. First aid kits are also available at the launch site, as well as restrooms.

Launch Control

Launch control consists of two sets of electronics - a receiver, 'pad box,' at the launch pad and a transmitter, 'launch box,' at the launch line--connected with a radio. Both sets of electronics are controlled by one key. The key must be out of the pad box and in the launch box in order for both to be armed. Once the transmitter is turned on, a red light turns on to indicate the signal is being received. In addition, the launch box has an arm switch and fire button, both must be pressed in order to initiate launch. The pad box connects to a relay which controls the circuit for the igniter. The igniter and radio run on separate batteries.

Flight Profile & Sequence of Events

1. Igniter is initiated remotely.
2. Motor ignites, burns for 8s and shuts down at Mach 2.88 and 14000 ft AGL.
3. After motor burnout out, rocket undergoes unpowered ascent to apogee at 86000 ft AGL after 68s.
4. At apogee, drogue parachute is deployed, rocket descends at 110 fps for 4 min.
5. At 2000 ft AGL, main parachute is deployed, rocket descends at 34 fps until impact with ground.



Highest Altitude and Maximum Range

The vehicle was simulated in RASAero 2 using prevailing winds in March from WeatherSpark. Using the initial conditions in the chart below, the simulated maximum altitude attainable by the vehicle is 85486 ft, and the maximum range (from high wind and no recovery plot) is 29500 ft.

Table 2 - Launch Parameters at FAR

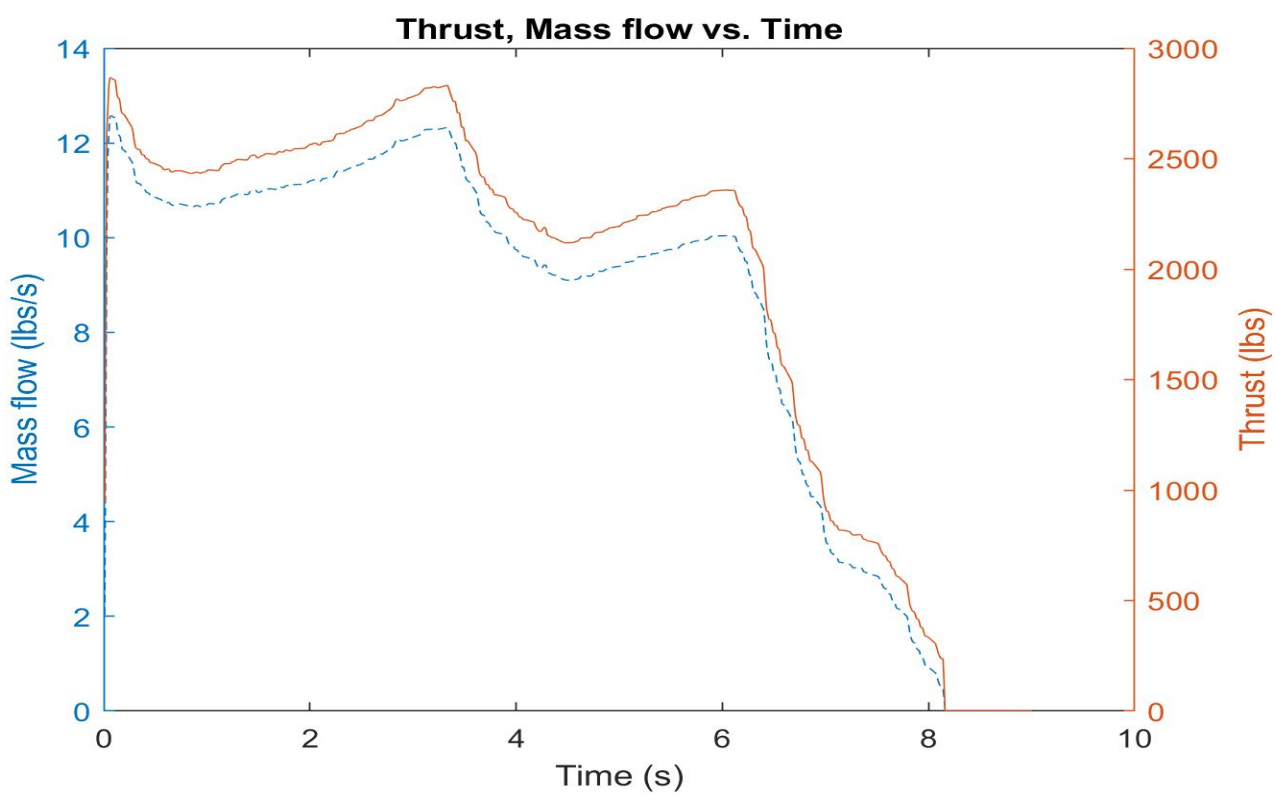
Parameter	Launch Tower Ht.	Launch Site Altitude	Landing Site Altitude	Temperature	Baro Pressure	Latitude	Longitude
Nominal Value	20 ft	2063 ft	2063 ft	63°F	29.68 Hg	35.346695 °N	-117.808343 °W

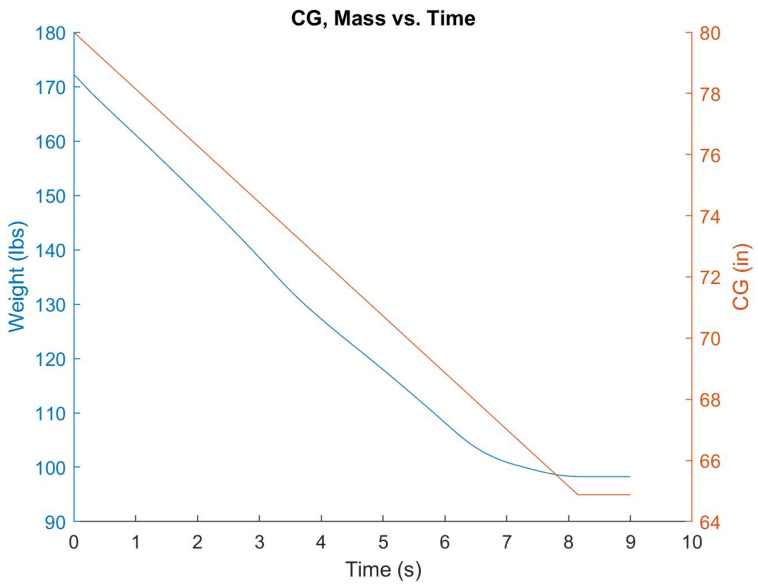
Table 3 - Predicted Altitudes/Ranges

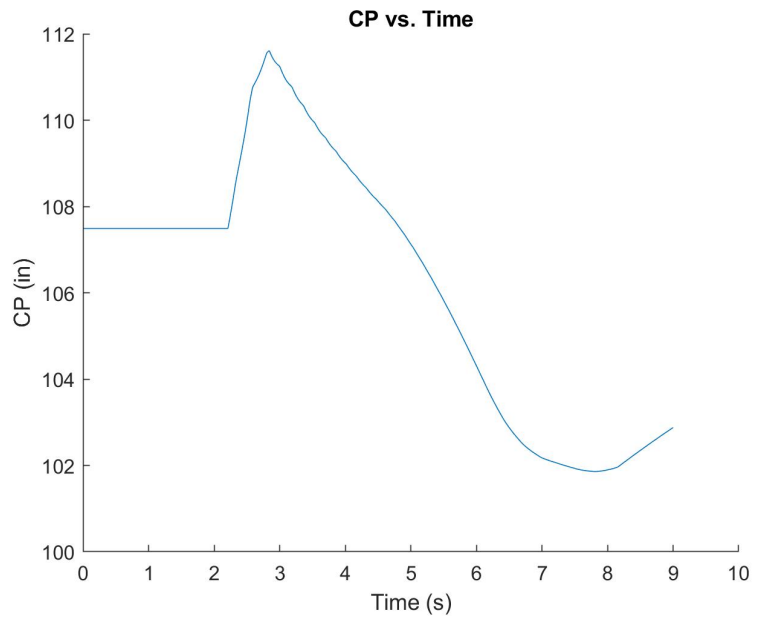
Conditions	Launcher Configuration	Altitude (ft AGL)	Range (ft)
No Winds	0 deg Elev	85486	0
Late March Winds 11 AM	3 deg Elev	78331	10132
Late March Winds 4 PM	5 deg Elev	76821	15471
Late March Winds 4 PM	2 deg Elev	78644	7700

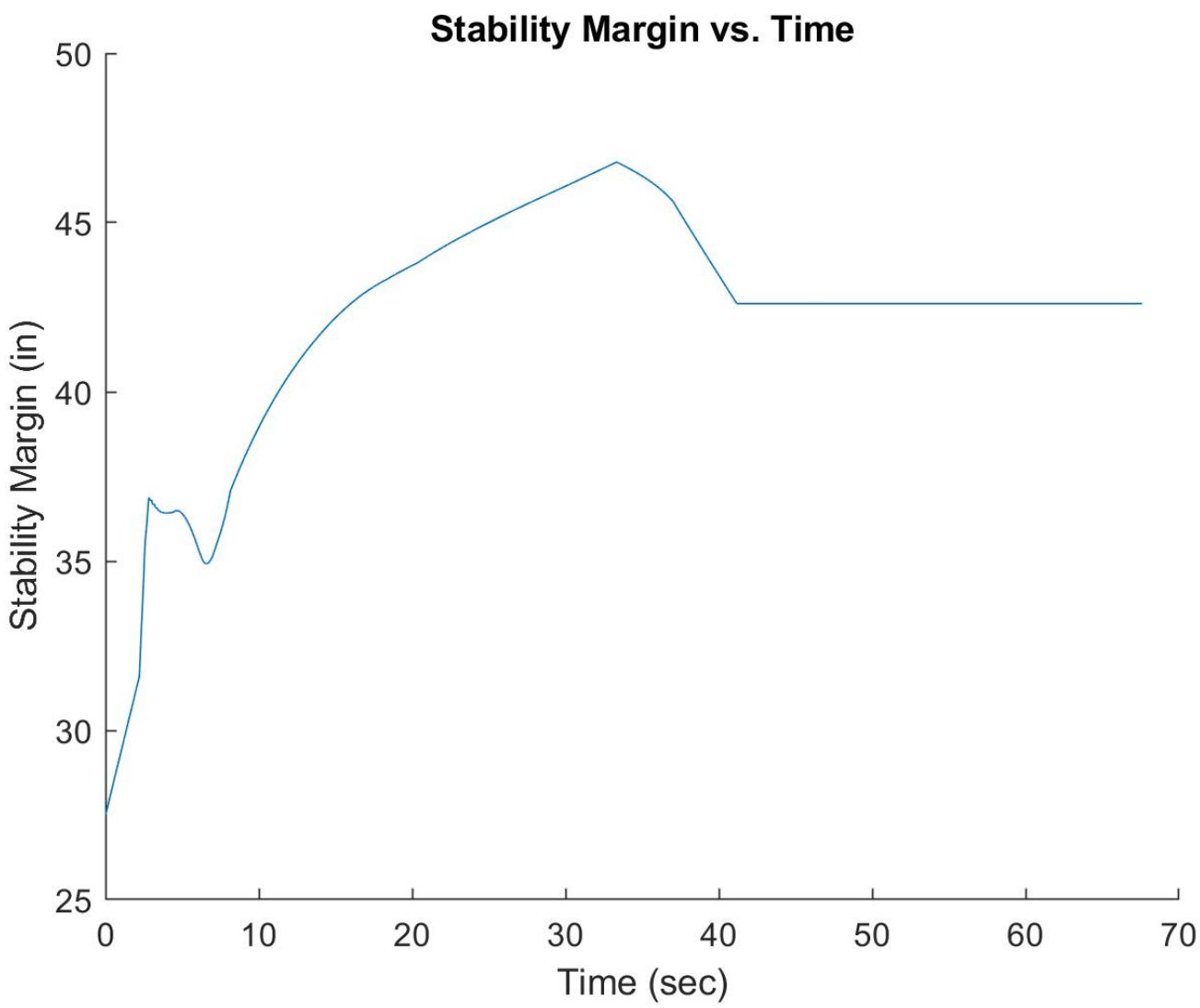
Dynamic Stability Characteristics

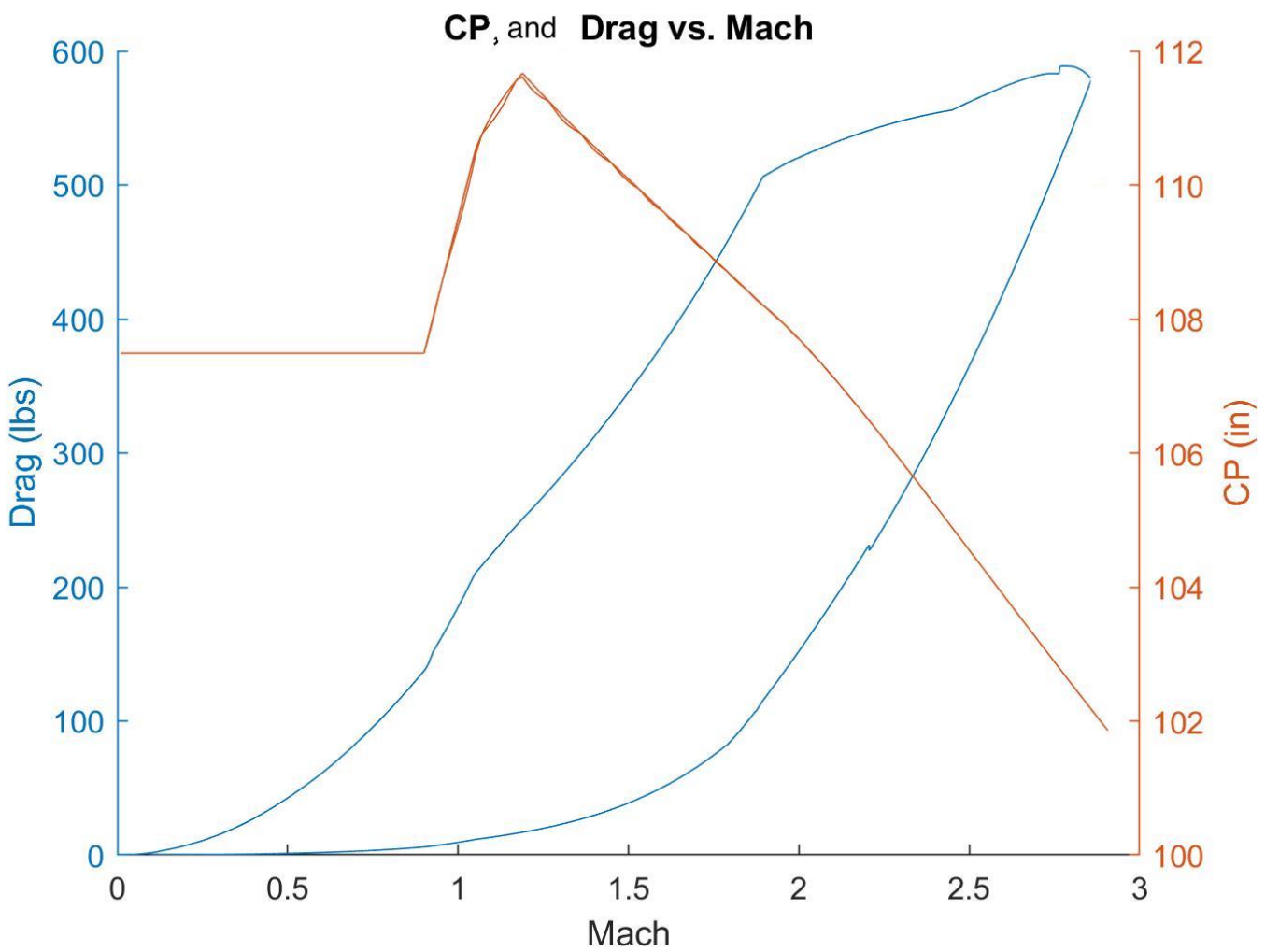
The charts below demonstrate the vehicle mass, propulsion, and stability properties. They were made using the boost and ascent phases of the flight, where these values change in a relevant way.

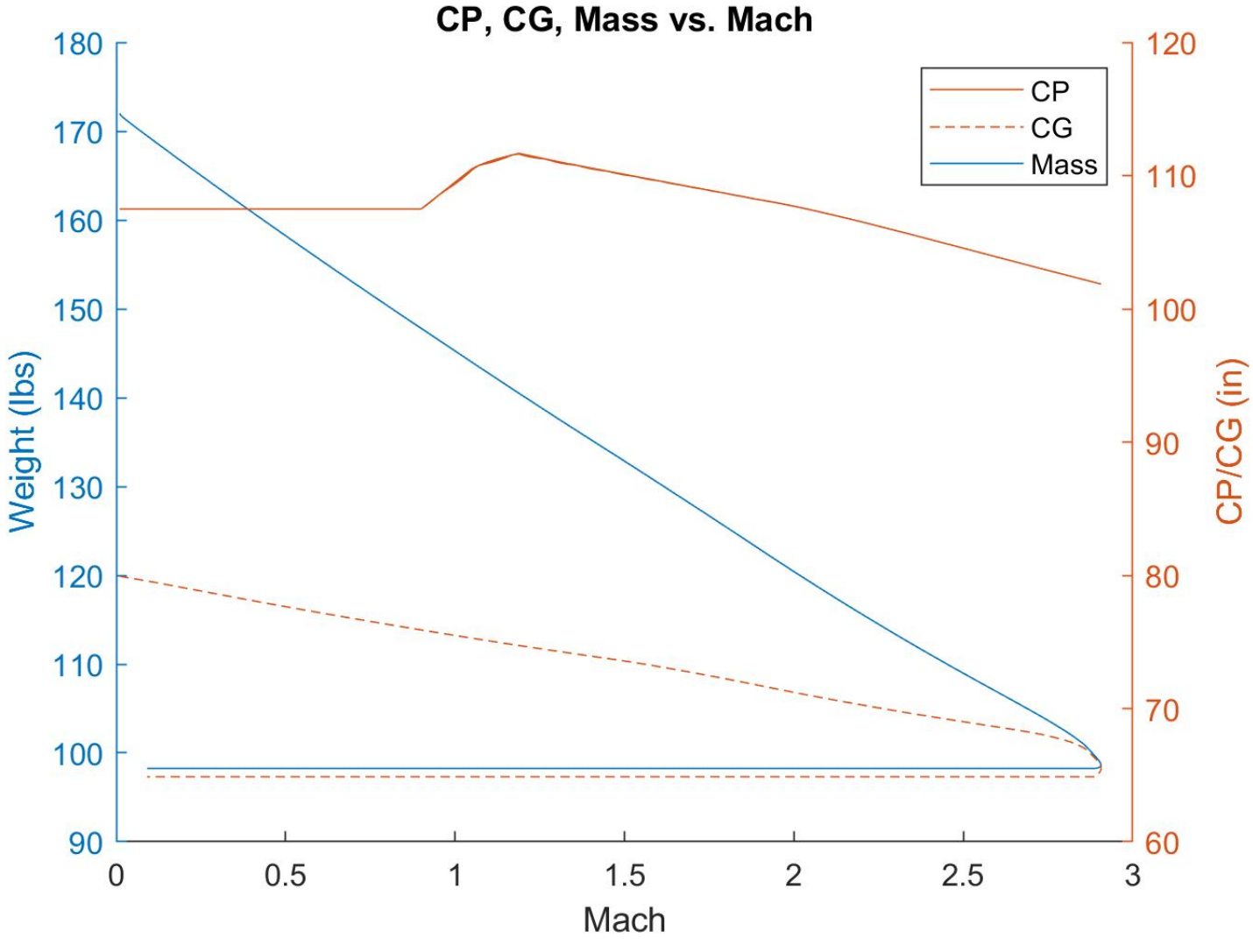



CG, Mass vs. Time
Weight (lbs)
CG (in)
Time (s)
180
170
160
150
140
130
120
110
100
90
80
78
76
74
72
70
68
66
64
0
1
2
3
4
5
6
7
8
9
10

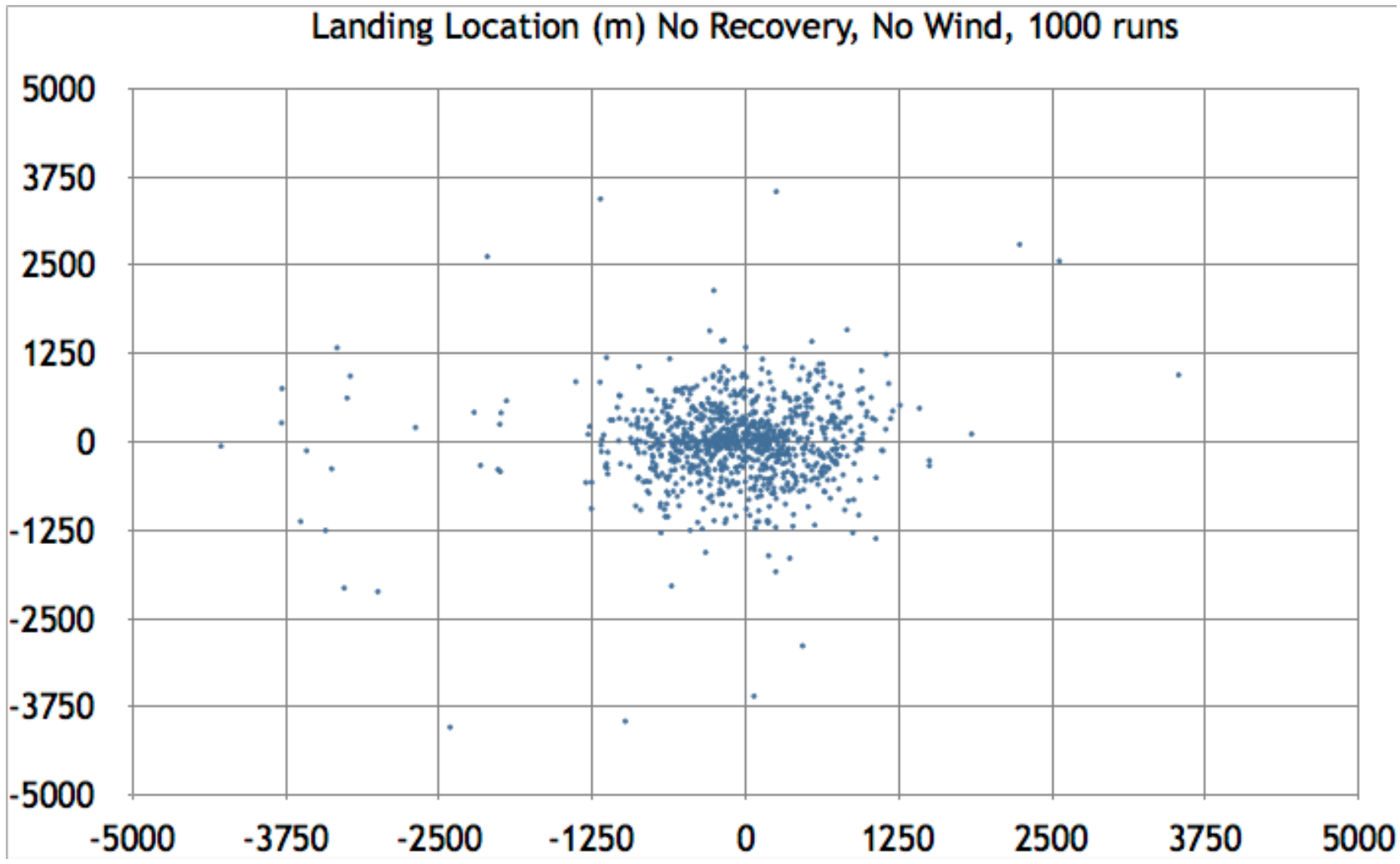

CP vs. Time
CP (in)
Time (s)
112
110
108
106
104
102
100
0
1
2
3
4
5
6
7
8
9
10

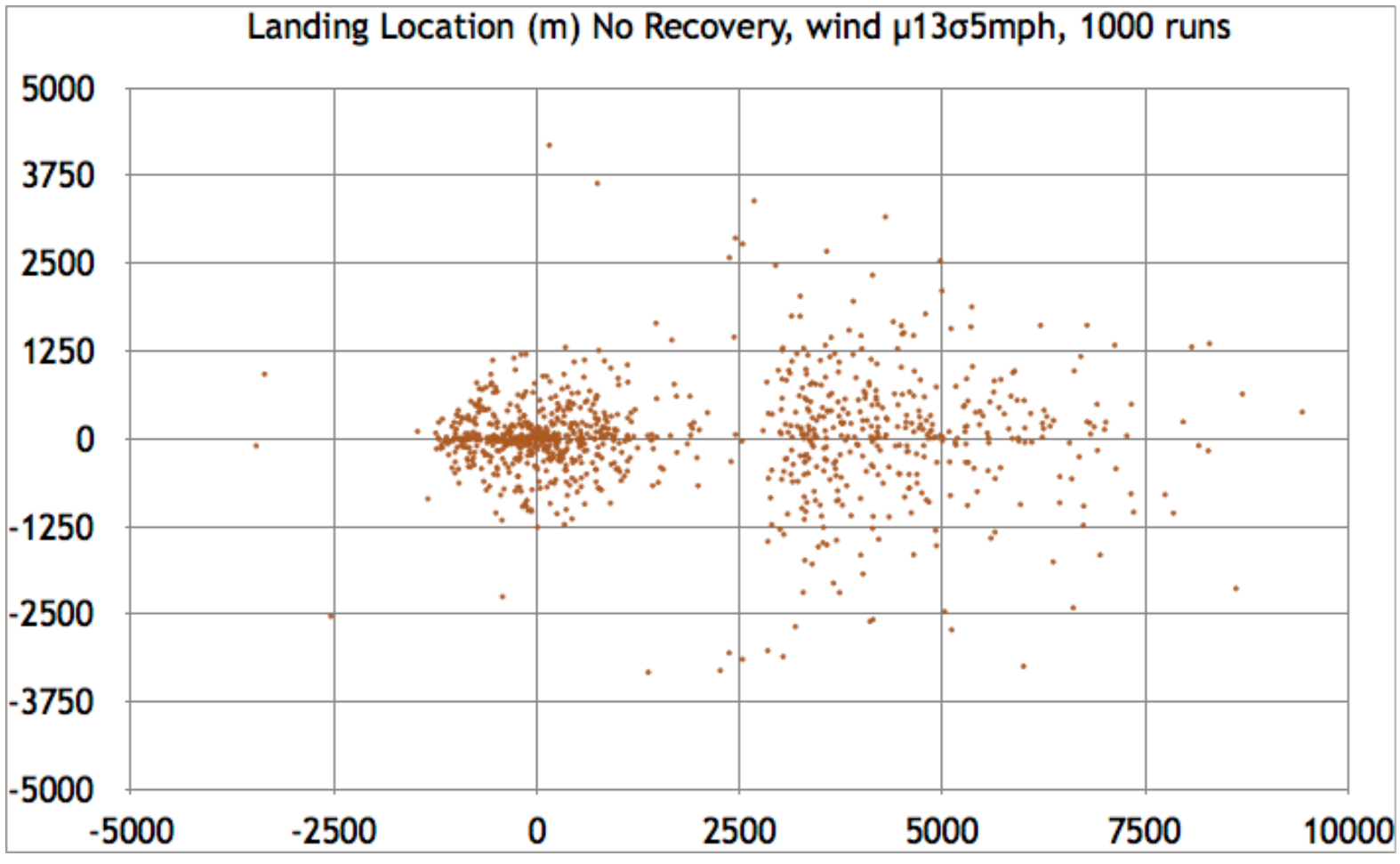

Stability Margin vs. Time
Stability Margin (in)
Time (sec)
50
45
40
35
30
25
0
10
20
30
40
50
60
70

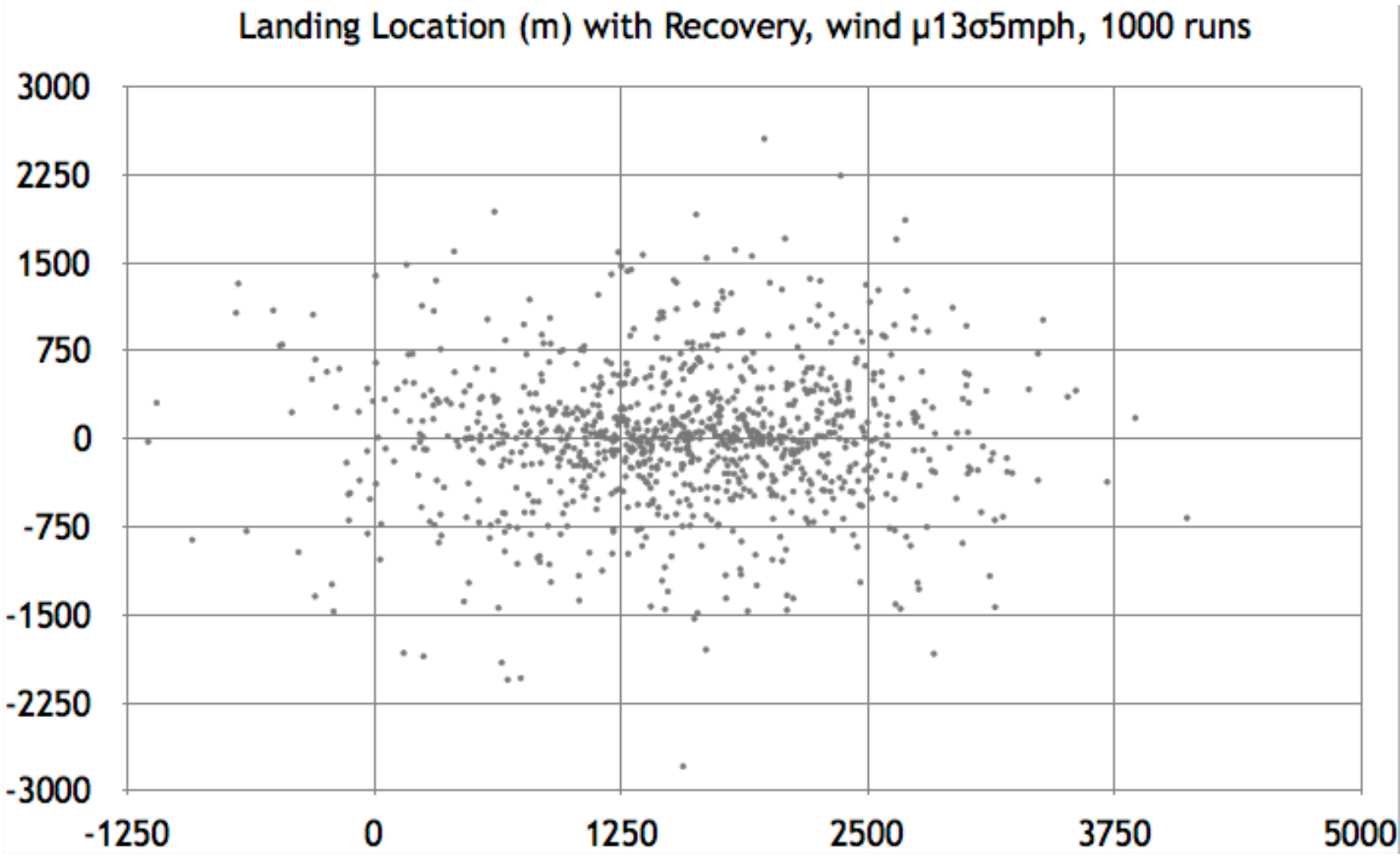

CP, and Drag vs. Mach
Drag (lbs)
CP (in)
Mach
0
100
200
300
400
500
600
100
102
104
106
108
110
112
0
0.5
1
1.5
2
2.5
3

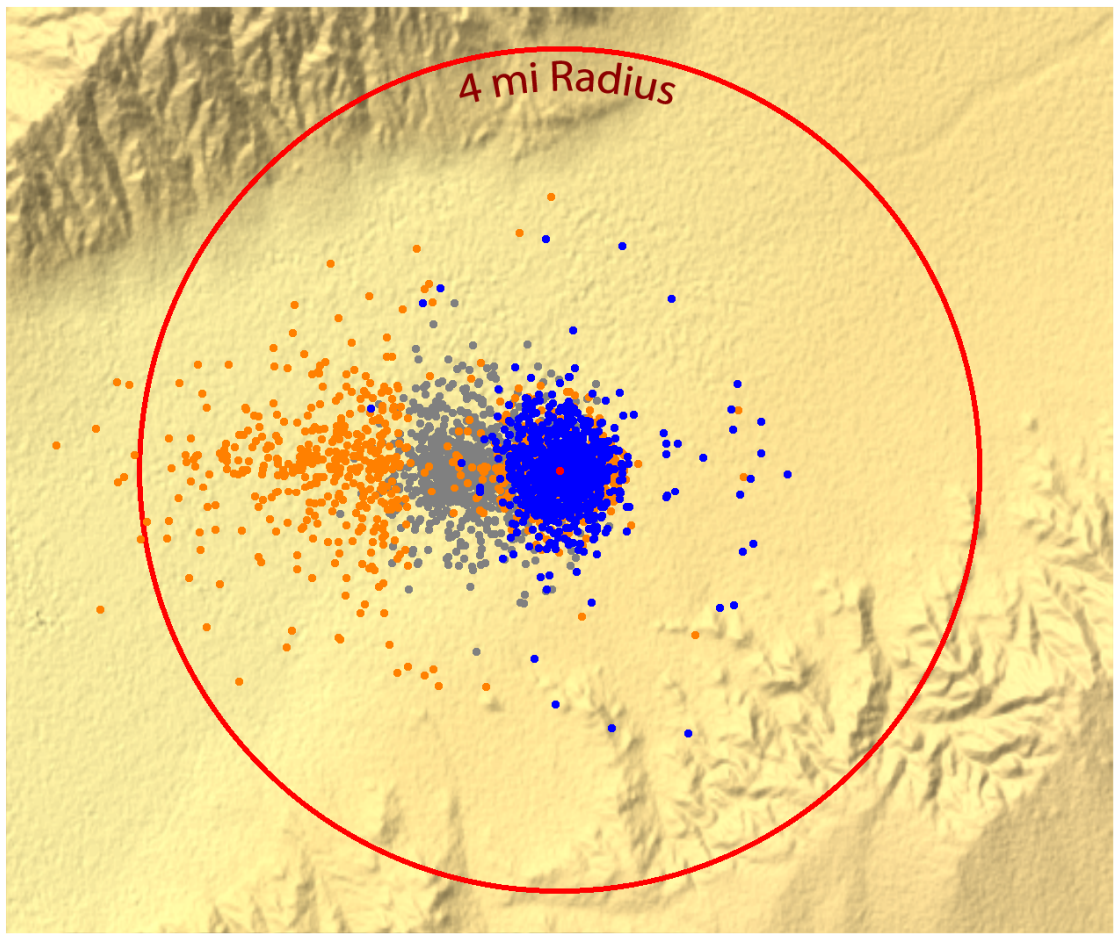

CP, CG, Mass vs. Mach
CP
CG
Mass
Weight (lbs)
CP/CG (in)
Mach
90
100
110
120
130
140
150
160
170
180
60
70
80
90
100
110
120
0
0.5
1
1.5
2
2.5
3

Dispersion Analysis

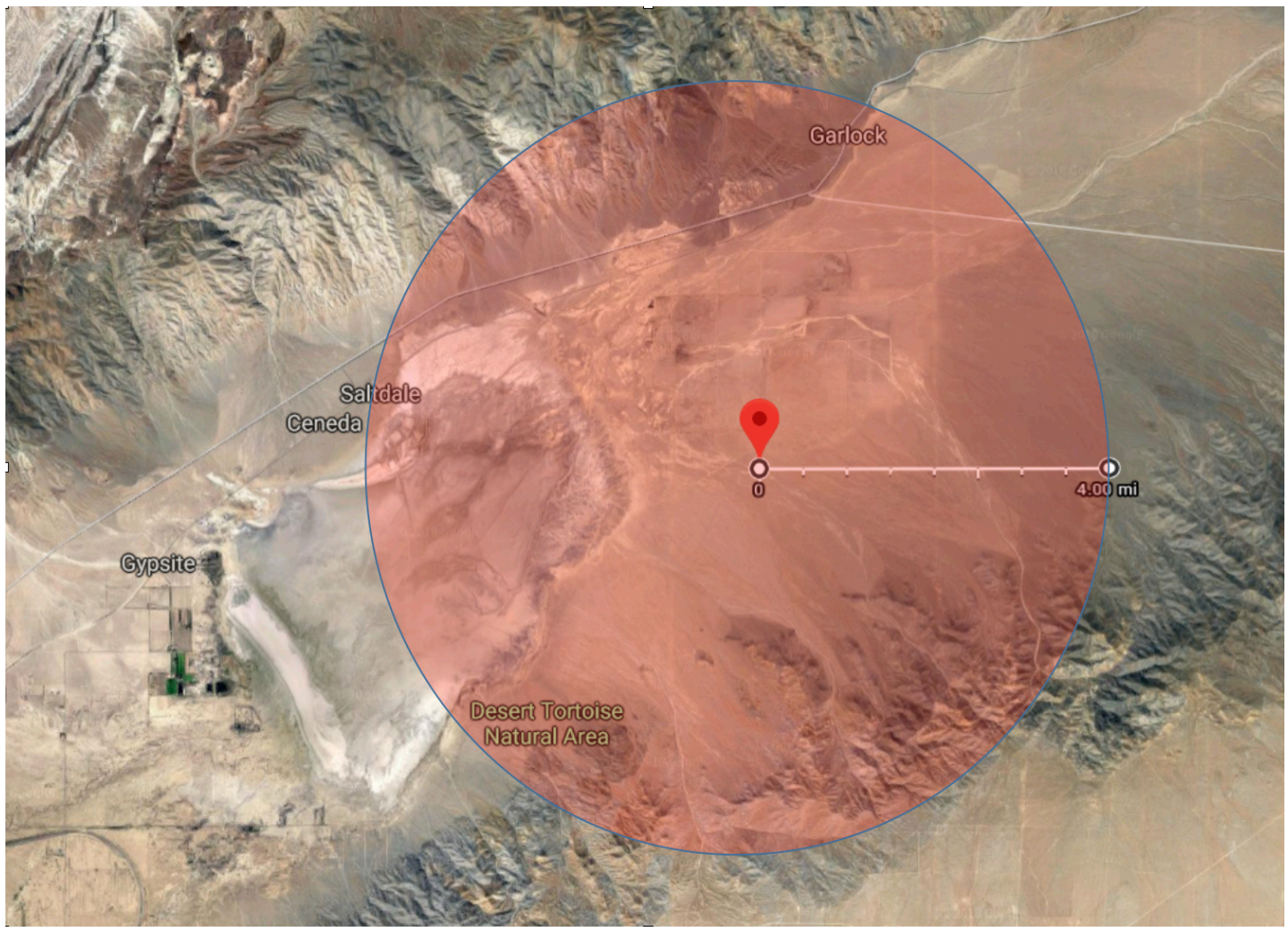








The above map shows: the location of launch (FAR, red dot in center), landing locations from previous plots (1000 runs of OpenRocket) overlaid to represent wind direction, and a 4 mile radius (¼ of the expected altitude).



Satellite view of launch site, with 4 mile radius marked (4 miles is ¼ of the projected altitude). There are no habited areas within this radius. The town seen in the range, Garlock, has no residents.

Safety Procedures

a. Checklists will be used for prelaunch, launch, and recovery operations. These identify and mitigate common hazards to the team and others in the area. Specific team members are assigned to ensure the checklists are followed correctly on-site, and launch can only occur upon completion of the pre-launch and launch checklists.
b. Handheld radios will be used to communicate launch prep and launch status.
c. Launch sequence will be announced on the PA system.
d. Launch control has 3 interlocks to ensure the rocket does not fire accidentally (detailed above in Support Equipment Section).

Launch Commit Criteria

The launch can be executed if and only if the following criteria are met:

Criteria Name	Description
Rocket complete	All assembly and pre-launch checklists have been completed, and any day-of issues signed off by the Chief Engineer and President.
Ground winds	Winds at the launch pad do not exceed 15 mph in any direction.
Sky clear	No visible aircraft in the sky, less than 50% sky coverage by clouds.

Communication	All electronics are communicating with the launch line ground station and ground station operators ready for launch.
Personnel safe	All personnel are adequately sheltered from the imminent rocket flight, utilizing shelters

Countdown Procedure

1. After the prelaunch checklist is complete, the FAA is notified that the launch will commence soon.
2. The rocket is brought to the launch tower and a prelaunch warning is announced over the PA system.
3. A 10 minute warning is announced when most personnel leave for the insertion of the igniter.
4. A final warning is given once the igniter is inserted and all pad cameras are rolling.
5. The launch controller verifies the launch commit criteria with team members.
6. “Ready for Launch” is announced over the PA system, followed by a countdown from 10 seconds.
7. The launch control box is armed 3 seconds before the end of the countdown.
8. At 0 seconds, the “Fire” button is pressed to send current through the igniter and ignite the motor.

Mishap Procedures

The team implements the following structure for contingency situations:

1. Ensure all personnel are safe. The Rocket Team President will have operational control over all contingency situations. Inform MIT contacts in AeroAstro -- Paulo Lozano: (617)258-0742 -- and the Edgerton Center -- Sandra Lipnoski: (617)253-4629.
2. Activate appropriate emergency services for injuries or imminent hazards. The nearest emergency medical facilities are in Ridgecrest, CA -- Ridgecrest Regional Hospital, 1041 N China Lake Blvd, Ridgecrest, CA 93555.
3. Establish and document the state of the vehicle. Personal Protective Equipment should be worn.
4. Disarm any remaining energetics (unburnt propellant, pyrotechnic charges, damaged batteries).
5. Return the site to its original condition.

b. Custom data acquisition PCB stores data.
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