Altitude Prediction

Theory

From our rocket motor theory, we have a basic method for predicting the altitude achieved by a model rocket. The method assumes the total impulse of the rocket motor is instantaneously applied to the momentum of the rocket. This gives us an initial upward velocity of the rocket. The method then assumes only gravity slows the rocket (it ignores the drag of air resistance) and calculates the time of flight to apogee (the highest point of the rocket's trajectory). Finally, the method calculates the distance traveled under the constant deceleration of gravity during the time of flight to apogee.

Let's apply this theory to an example:

- Quest PayloaderONE rocket
- payload: Perfectflite A15K altimeter
- motor: Estes B6-4
- total impulse: 4.33 nt-sec
- burn time: 0.86 sec
- delay time: 3.68 sec
- time to ejection: 4.54 sec
- launch mass: 0.0724 kg

Launch velocity:

$P_{exhaust}$ = 4.33 newton-second, m_r = 0.0724 kilograms

$v_r = P_{exhaust} / m_r$

v_r = 4.33 newton-second / 0.0724 kilograms

v_r = 59.8 meters/second

Time to apogee:

t = v / g = 59.8 meters/second / 9.8 meters/second^2

t = 6.10 seconds

Apogee altitude:

$y = {}^1/_2\ a\ t^2$

$y = {}^1/_2 * 9.8 * (6.10)^2$

y = 182.3 meters

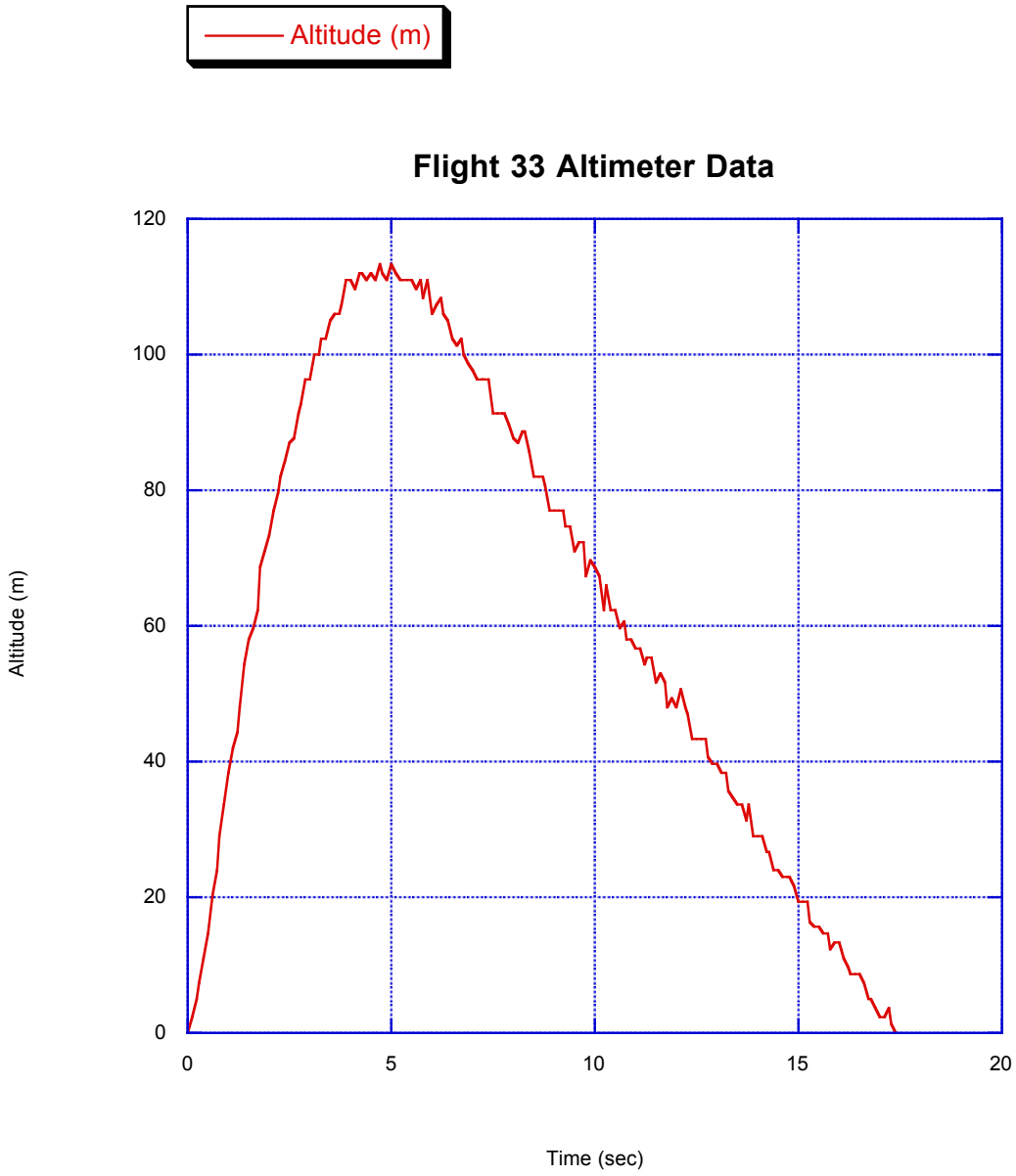
Experiment

Parker Model Rocket Flight #33

- Quest PayloaderONE rocket
- payload: Perfectflite A15K altimeter
- motor: Estes B6-4
- launch mass: 0.0724 kg

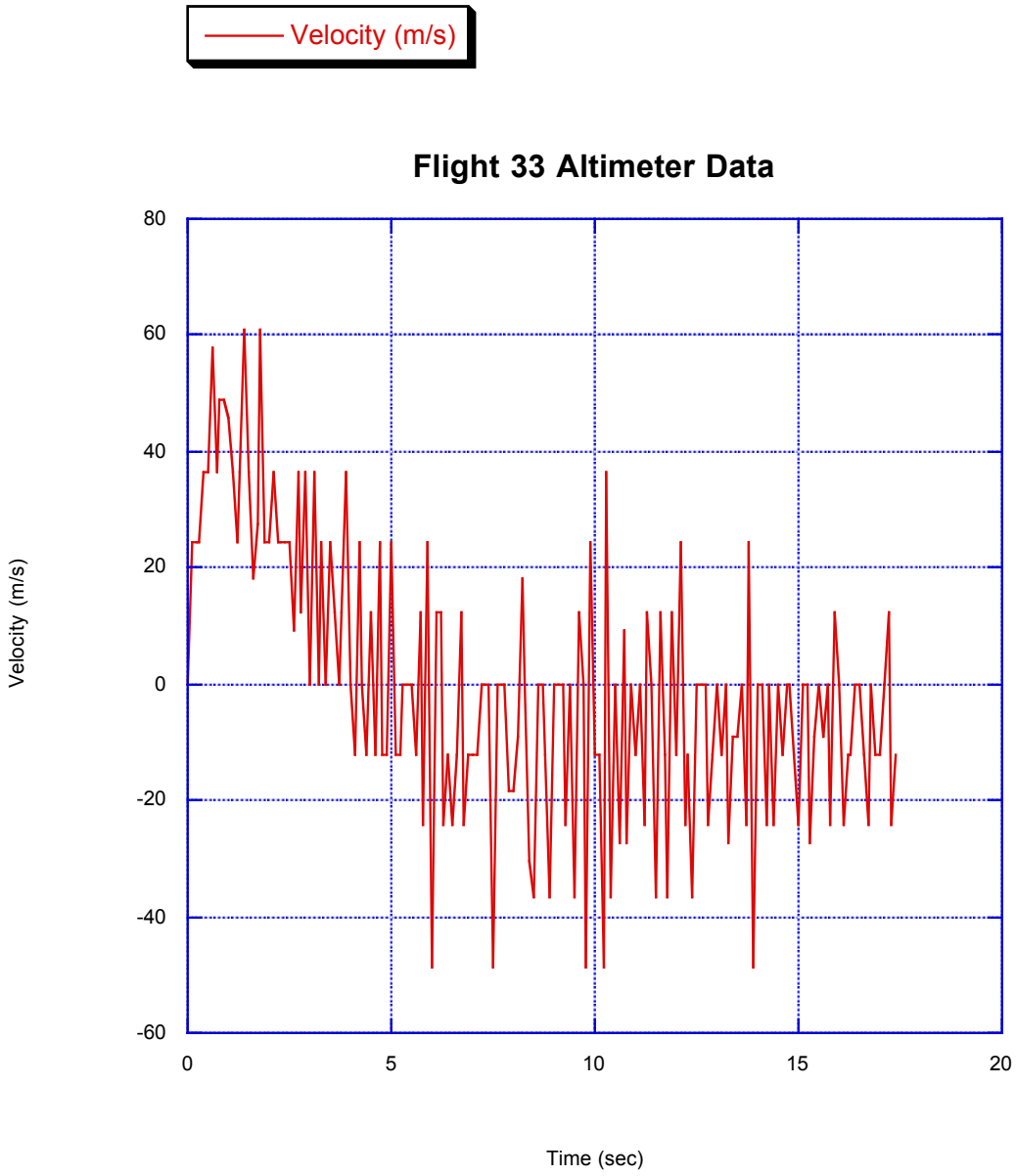
PerfectFlite Alt15K/WD
Ground: -303
Apogee: 372
NumSamps: 216
Comments:

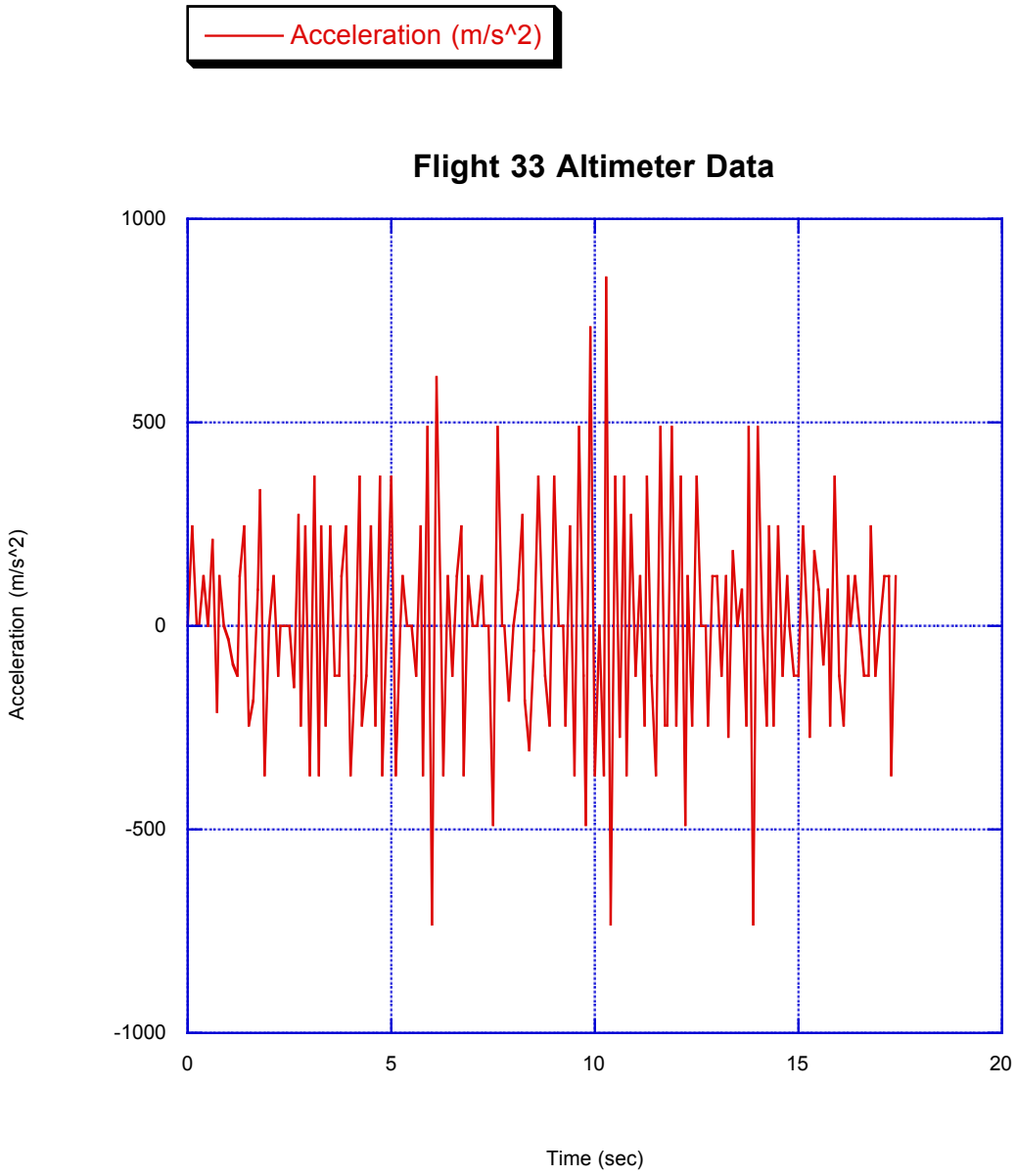
**!!Data:
00008
00016
00024
00036
00048
00067
00079
00095
00111
00126
00138
00146
00158
00178
00190
00196
00205
00225
00233
00241
00253
00261
00269
00277
00285
00288
00300
00304
00316
00316
00328
00328
00336
...

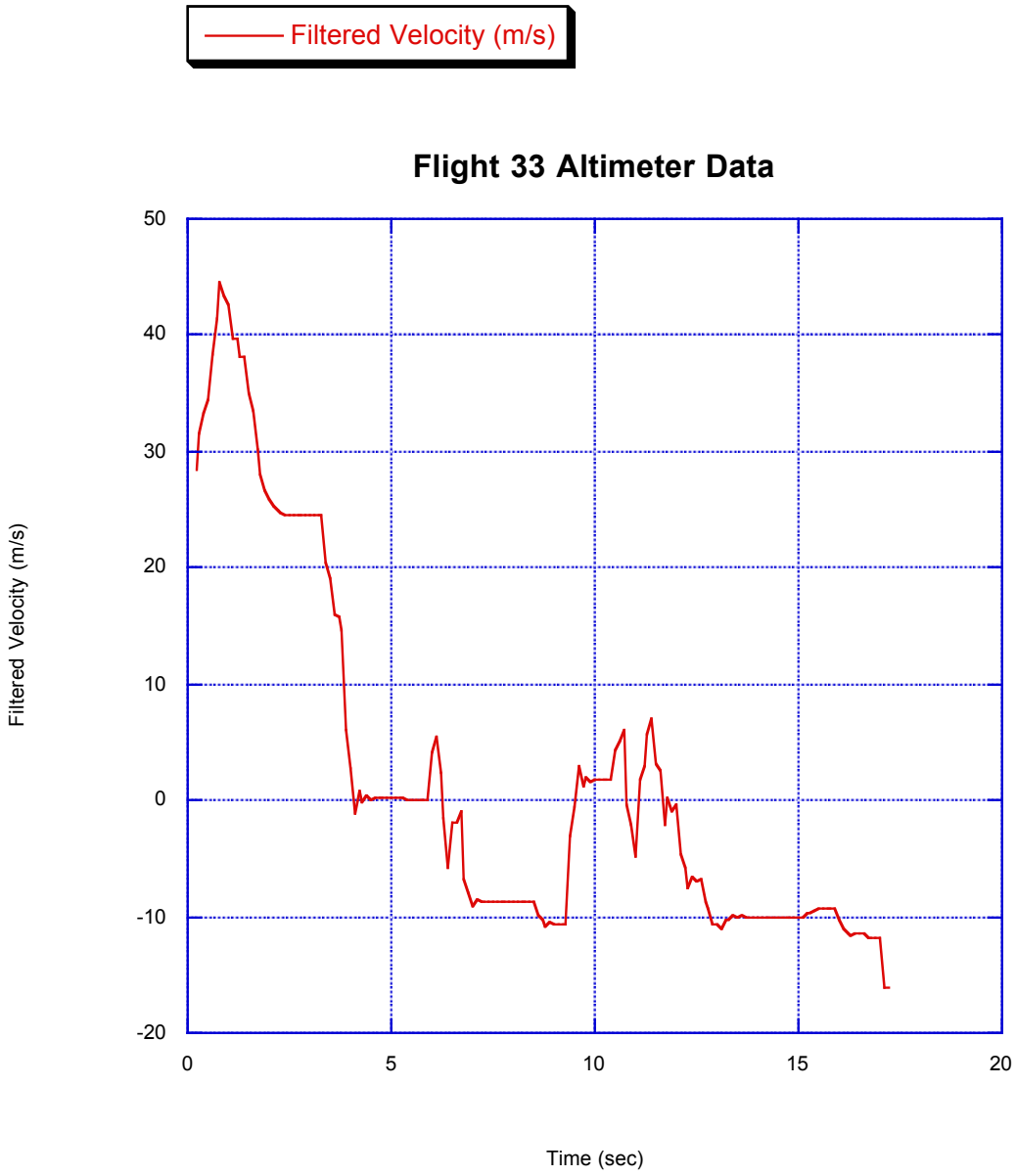


Apogee of 113.4 meters at time 4.85 seconds.

Theory predicted 182.3 meters at time 6.10 seconds.


Velocity (m/s)
Flight 33 Altimeter Data
80
60
40
20
0
-20
-40
-60
0
5
10
15
20
Velocity (m/s)
Time (sec)


Acceleration (m/s^2)
Flight 33 Altimeter Data
1000
500
0
-500
-1000
Acceleration (m/s^2)
0
5
10
15
20
Time (sec)



Motor burnout at 0.85 seconds. Velocity starts decreasing after burnout. Velocity is about zero at apogee. Negative velocity is descent after deploying parachute.

Velocity at burnout is 44.6 meters/second^2.

Theory predicted 59.8 meters/second^2.

TARC Design Problem

A minimum-mass TARC model rocket will mass about 350 grams (0.350 kg). If it is powered by a combination of motors delivering 33.68 nt-s of total impulse, what is its predicted burnout velocity, predicted time to apogee, and predicted apogee altitude?

If the measured burnout velocity, time to apogee, and apogee altitude for a PayloaderONE rocket is observed to be about 66% of the theoretical prediction, what value would you estimate for the burnout velocity, time to apogee, and apogee altitude for the TARC model above?

The TARC target altitude of 850 feet is 259.08 meters.

Two Estes D12 motors deliver 33.68 nt-s of total impulse.

What total impulse do you estimate you need for your TARC model rocket?