

Considerations for High-Altitude Rocket Flights

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NARCON
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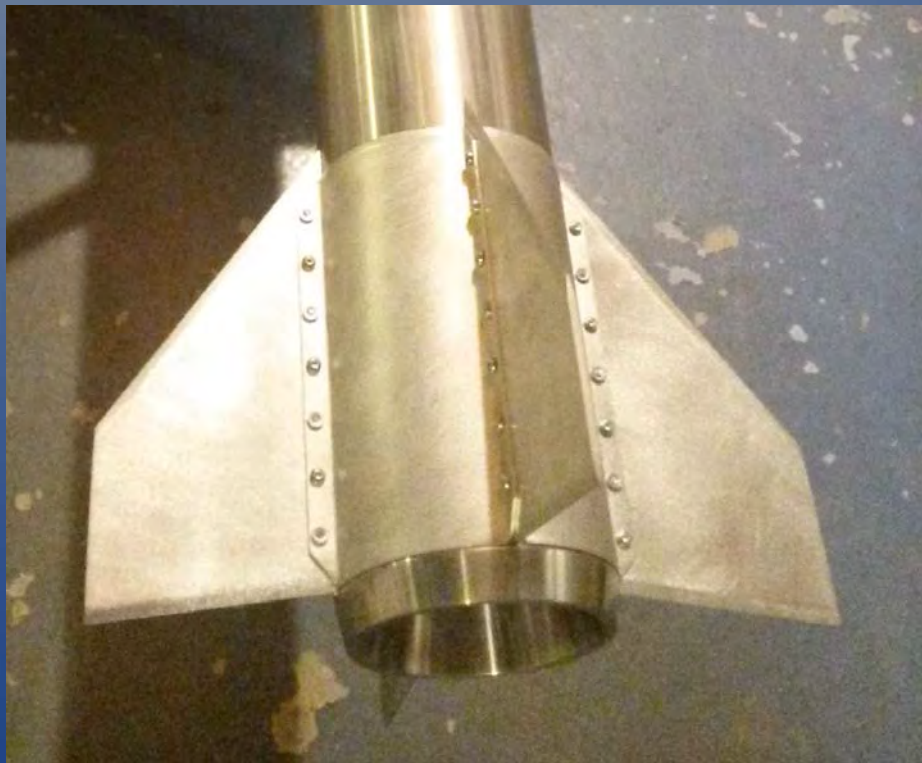
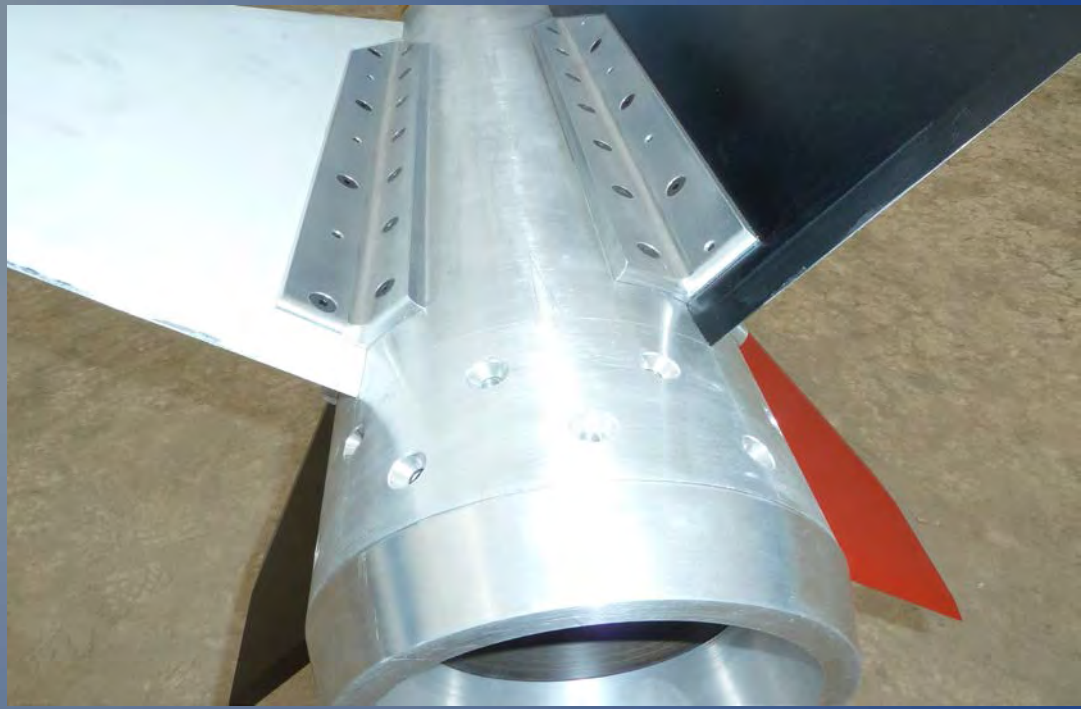
Challenges

- Design considerations
- Waiver/Field Suitability
- Stability
- Structural integrity
- Electronics selection
- Recovery system initiation
- Finding it after the flight!!

Design Considerations

- **Diameter** - minimum or near-minimum
- **Fin attachment** – surface, fin can
- **Single tube**, not usually broken
- **Motor retention** – forward , Slimline
- **Deployment** – small drogue or DD
- **Nose Cone** – Haack Series, VK ogive
- **Optimize** for altitude?





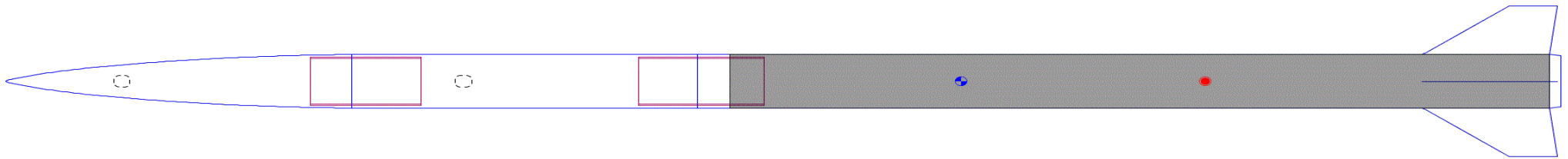
Design Considerations

Relative Efficiency

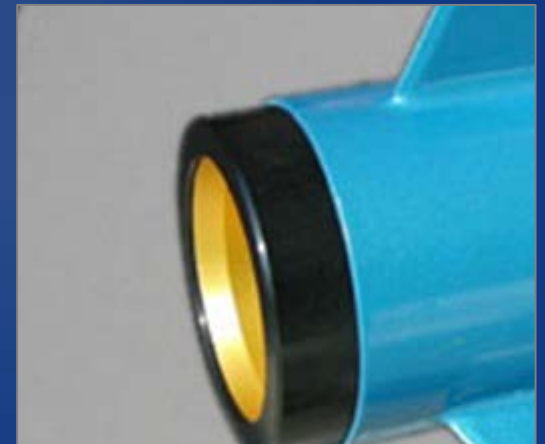
Project	Altitude (M)	Total Impulse	Ratio
ARCAS	60960	40000	1.5
GoFast	116000	480000	0.2
FourCarbYen	32004	34150	0.9
Qu8k	36880	143000	0.3

Design Considerations

- One piece air frame, not usually broken
- Single use or re-usable?



Motor Retention - forward, Aeropak, Slimline

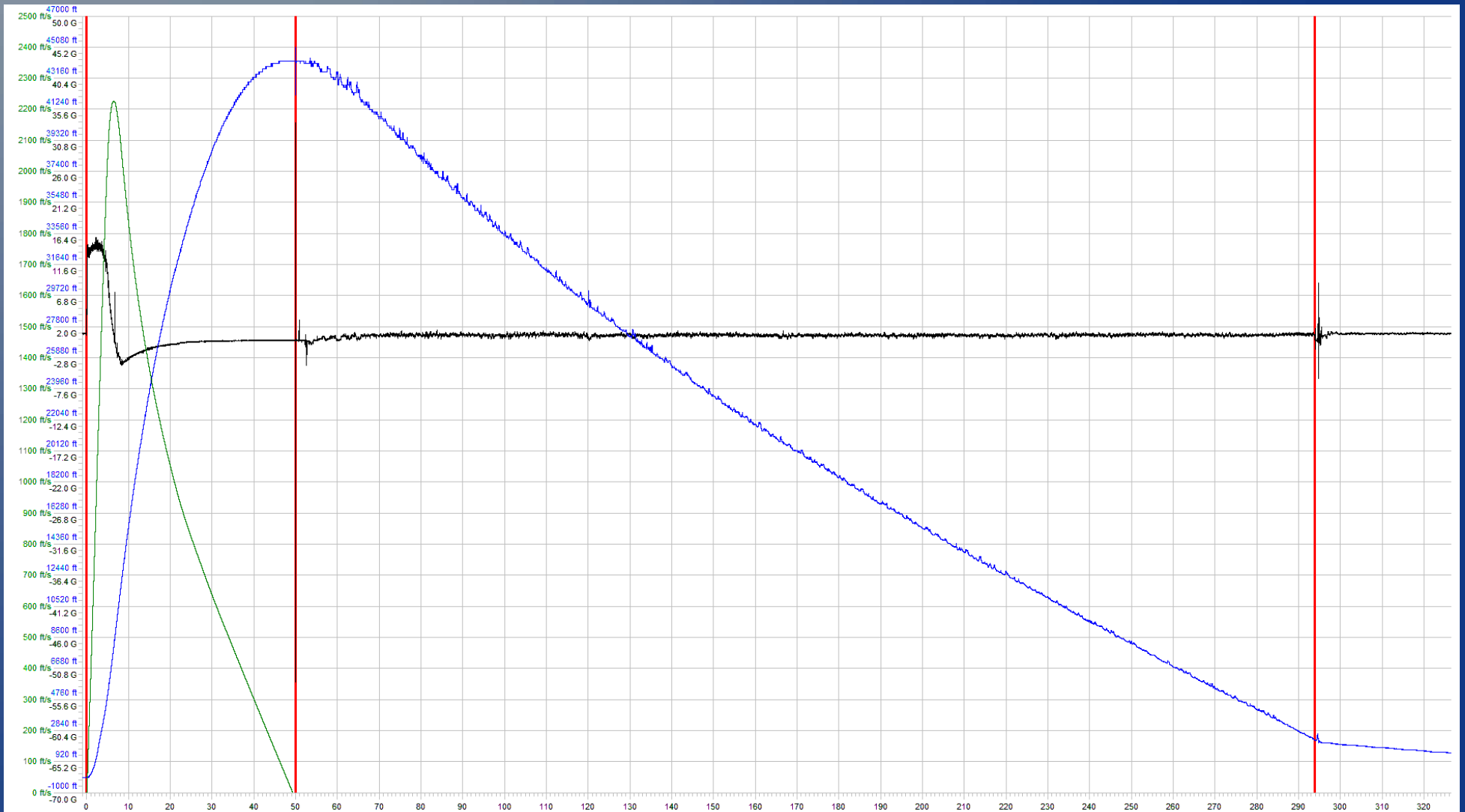


Design Considerations

Deployment – drogue/main-only, DD

Altitude, wind dependent

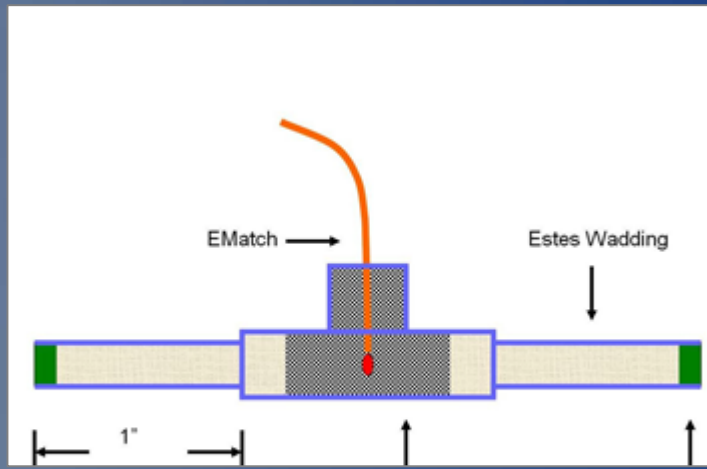
Flight below was 170 fps descent rate



Design Considerations

BP efficacy at altitude

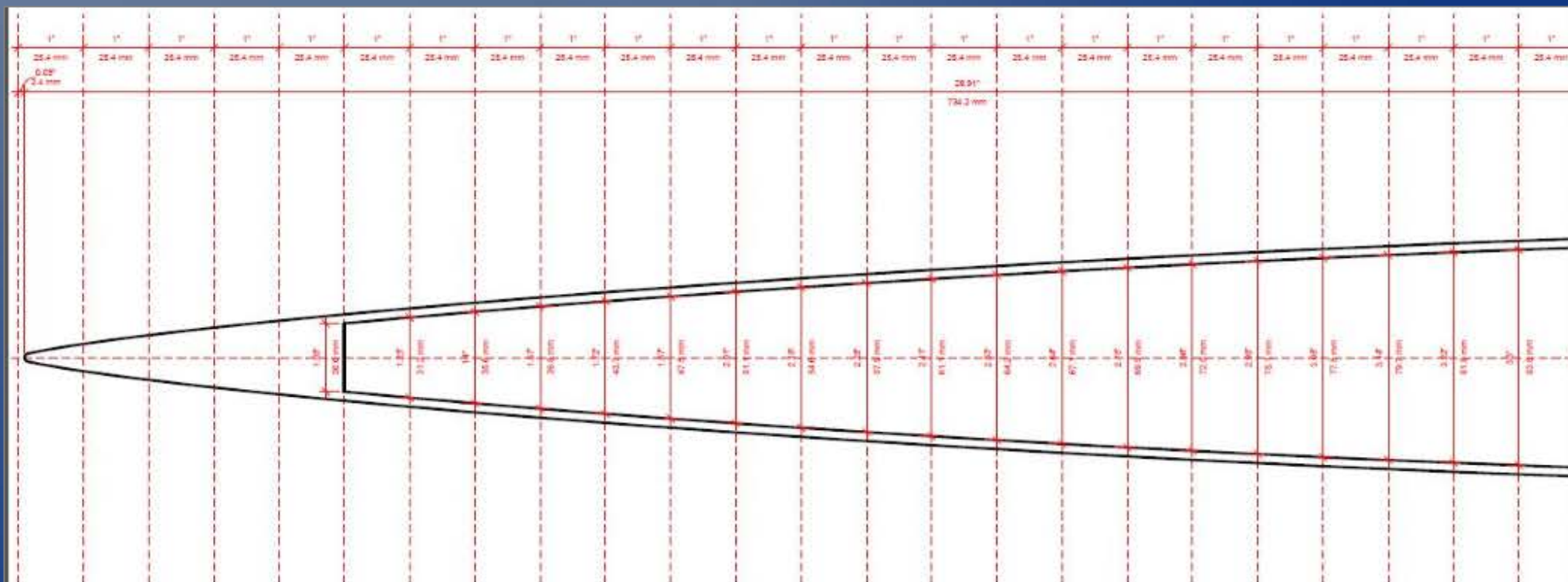
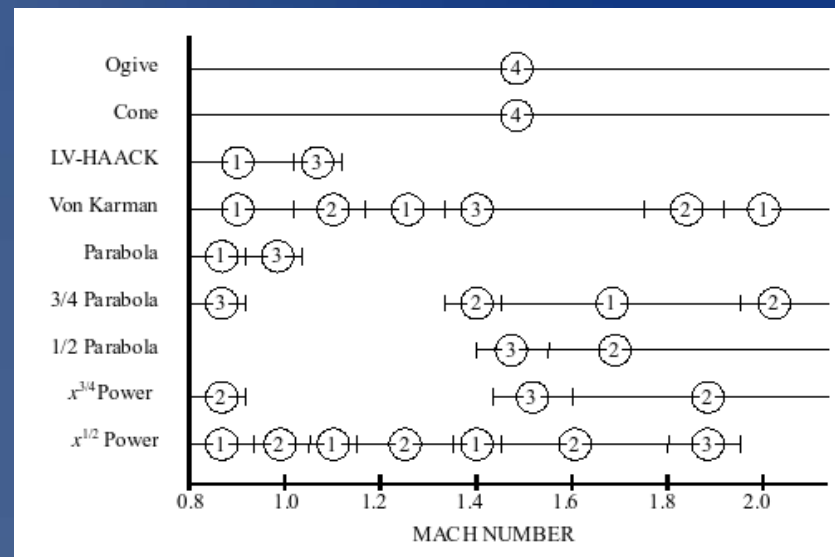
- above 20,000', incomplete combustion
- sealed charge
- “tee” or “cannon”
- “head-end” e-match placement
- CO-2



Design Considerations

Nose Cone

- Haack Series
- Mathematically derived
- Minimizes drag
- Von Karmen min drag for given L:D



Design Considerations

To Optimize or Not?

- Maximize mass fraction
- Minimize length, drag



Sim Tools

Open Rocket

RasAero

RockSim

FinSim

Open Rocket

- Good drag, sim estimates
- Nice design tool

The screenshot displays the Open Rocket software interface. At the top, the menu bar includes File, Edit, Tools, and Help. Below the menu bar, there are tabs for "Rocket design", "Motors & Configuration", and "Flight simulations".

The main workspace is divided into several sections:

- Left Panel (Rocket Hierarchy):** A tree view showing the components of the rocket. The "Rocket" is composed of a "Sustainer" and a "Booster stage". The "Sustainer" includes a "Nose cone", "Bulkhead", "Body tube", "Sustainer Motor bg", "Tube coupler", and another "Bulkhead". The "Booster stage" includes a "Transition", "Body tube", "Booster Motor", "Tube coupler", and another "Trapezoidal fin set".
- Right Panel (Add new component):** A grid of icons for adding components. It is divided into three categories: "Body components and fin sets" (Nose cone, Body tube, Transition, Trapezoidal, Blotter, Bevel, Tube fin, Launch lug), "Inner component" (Inner tube, Coupler, Centering ring, Bulkhead, Engine block), and "Mass objects" (Concrete, Streamer, Shock cord, Mass component).
- Bottom Panel (View and Simulation):** A side view of the rocket with a coordinate system. The x-axis represents length in inches (0 to 150), and the y-axis represents height in inches (-30 to 25). The rocket is shown in a side view, with a red dot indicating the center of pressure (CP) and a blue dot indicating the center of gravity (CG). The simulation results are displayed on the right side of the view.

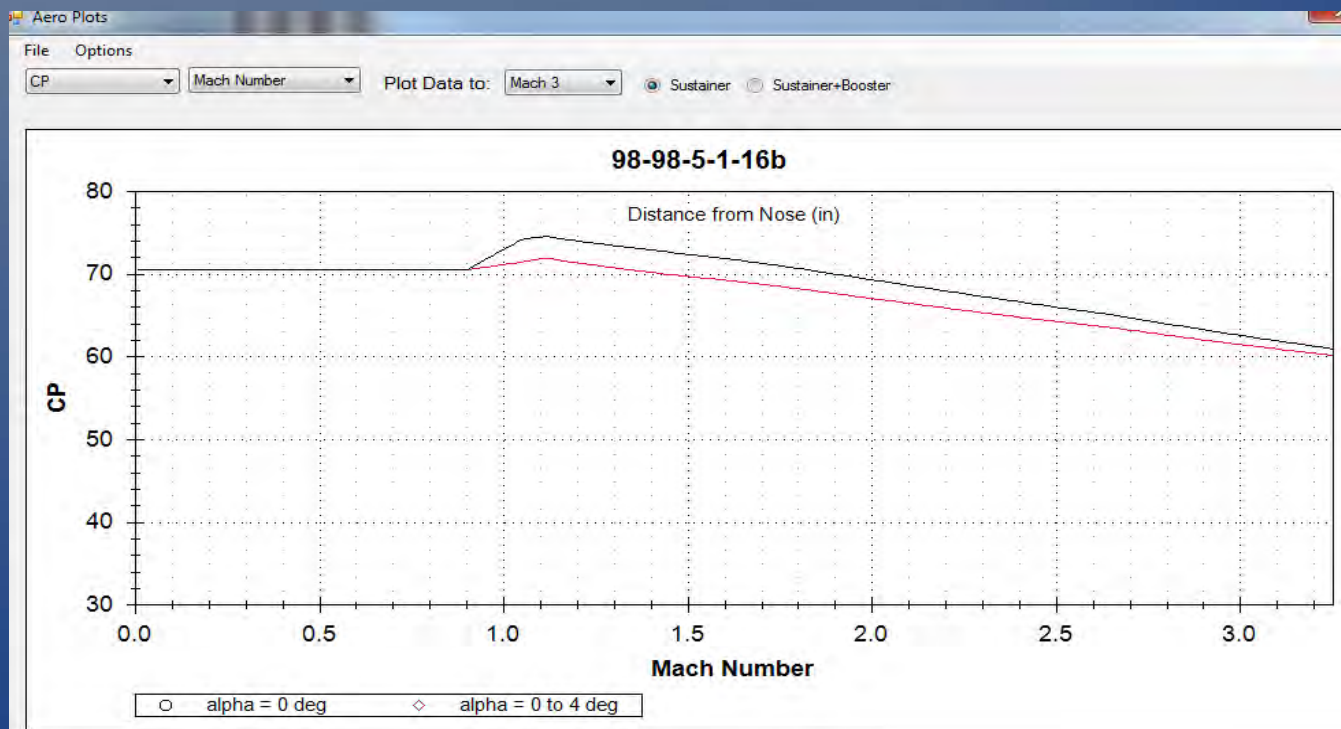
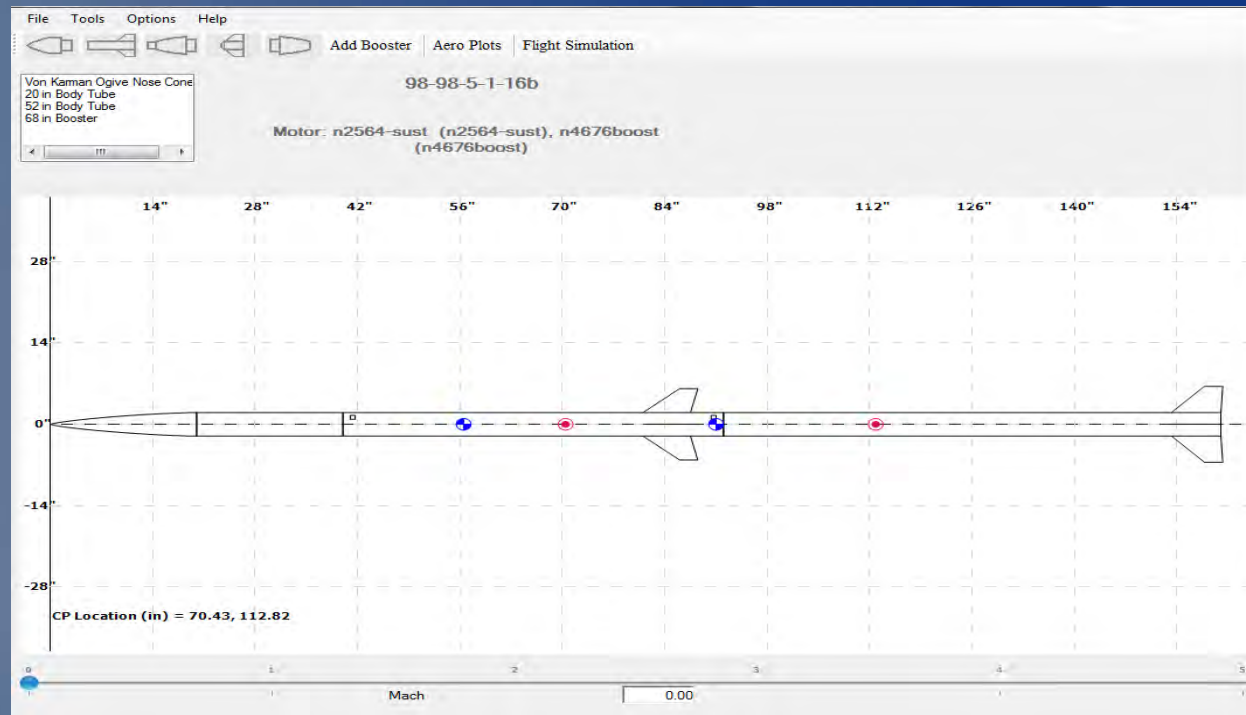
Simulation Results:

- Stability: 4.66 cal
- CG: 89.691 in
- CP: 111 in at $M=0.30$
- Apogee: 155690 ft
- Max. velocity: 3762 ft/s (Mach 3.76)
- Max. acceleration: 26.9 G

Additional information shown includes "View Type: Side view", "Fit (7.9%)", "Stage 1", "Stage 2", and "Flight configuration: [N313047-0; O3212-50]".

RasAero

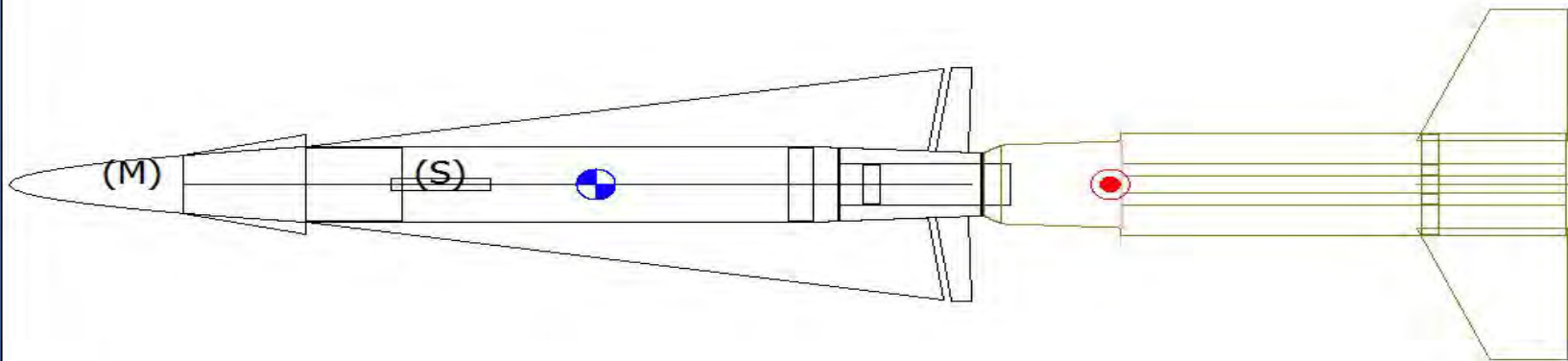
- Detailed aero plots
- 2-Stage Capable (RA II)
- Quirky interface
- Not a design tool
- Optimistic altitude sims



RockSim

- Underestimates altitude
- Overestimates drag
- Good sub-sonic
- Required by TRA for dispersion

Nike Hercules
Length: 15.8020 In. , Diameter: 1.5840 In. , Span diameter: 4.5400 In.
Mass 1.5292 Oz. , Selected stage mass 1.5292 Oz.
CG: 5.9494 In., CP: 11.1661 In., Margin: 6.96 Overstable
Shown without engines.



Fin Sim

Structural Analysis

- Computes max bending
- Computes lift, drag
- Displays highest speeds

Spin Stabilized

- Canted fins

Flutter & Divergence Velocity

- Up to 6 fin sets
- Pines or Theodorsen

AeroFinSim - Fin Aeroelastic Analysis Program By AeroRocket

File Additional Results Results Units CN-alpha Help

Pines' Method (Quasi-Steady Aerodynamics) for Torsion-Flexure Flutter
 Note: To avoid fin-separation the maximum flight velocity should not exceed the flutter velocity or the divergence velocity. If either critical velocity is exceeded the fins may be ripped off by the aerodynamic loads. For a more accurate flutter analysis use the Torsion-Flexure Unsteady Flutter command button (above).

Rocket flight altitude for aeroelastic analysis: 13K FT
 Velocity UNITS for aeroelastic analysis: FT/SEC
 Results dimensions - use "Results Units": INCH-POUND-SECOND

NEW AEROELASTIC ANALYSIS

Fin-Set Description	Fin Materials
ALUM	Aluminum
alum2	Aluminum

Critical (Not To Exceed) Velocity

Divergence FT/SEC	Flutter FT/SEC	Lift Slope CN-a
2343.69	3188.24	8.6777
2290.6	3116.01	9.0909

Additional Results

Set	E (psi)	G (psi)	Poissons Ratio	Density(lb/in^3)	f_bending (HZ)	f_torsion (HZ)
1	10000000.0	3759398.37	0.33	0.098	250.78	359.518
2	10000000.0	3759398.37	0.33	0.098	250.78	343.304

Fin Geometry For Aeroelastic Analysis

File

UNITS: INCHES

Fin Geometry (inches) - Up To Six Fin-Sets

Description	Fin#	Root Chord	Tip-Chord	Semi-Span	Mid-Chord	Sweep	Thickness
1 Slight sweep	4	8.0	3.0	4.0	5.0	5.5	0.1
2 90 deg	4	8.0	3.0	4.0	4.771	5.1	0.1
3 SSB	4	7.0	3.0	4.0	4.614	4.3	0.1
4							
5							
6							

NOTE: All fin dimensions must be inch UNITS
 NOTE: Mid-Chord length is not an input, these values are computed from the other fin dimensions

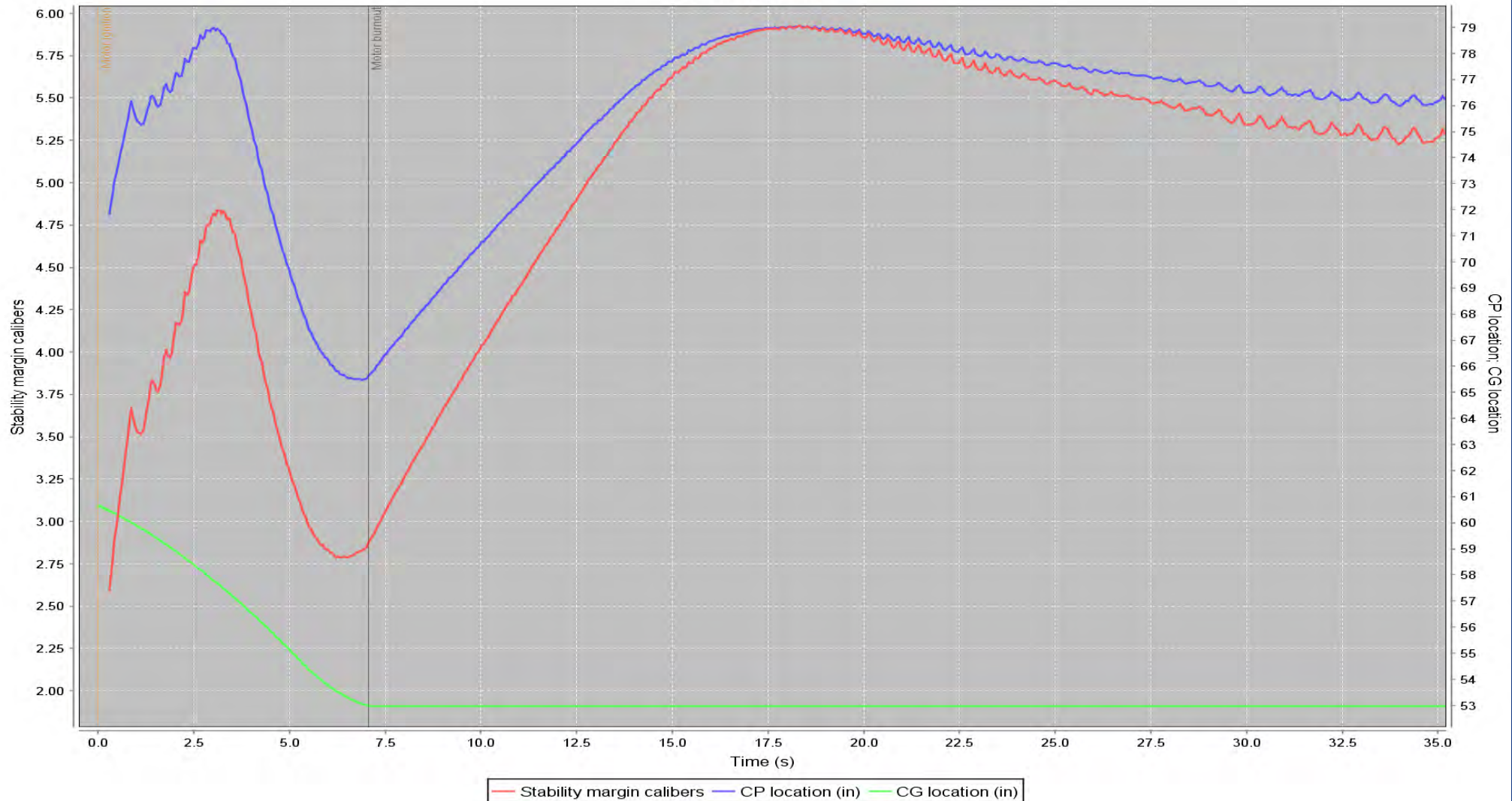
Stability



Stability vs Time

Simulation 10

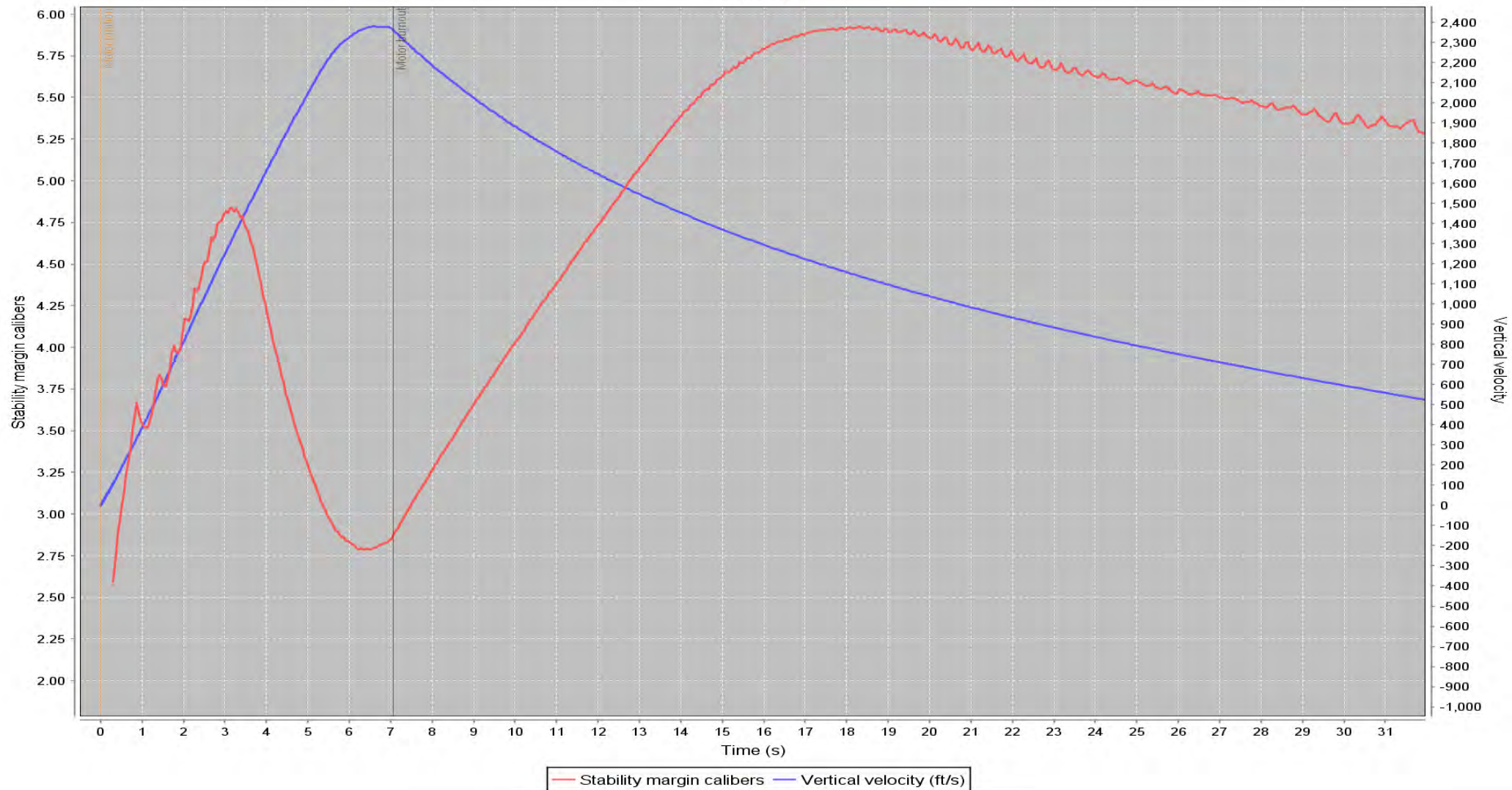
Stability vs. time



Stability vs Velocity

Simulation 10

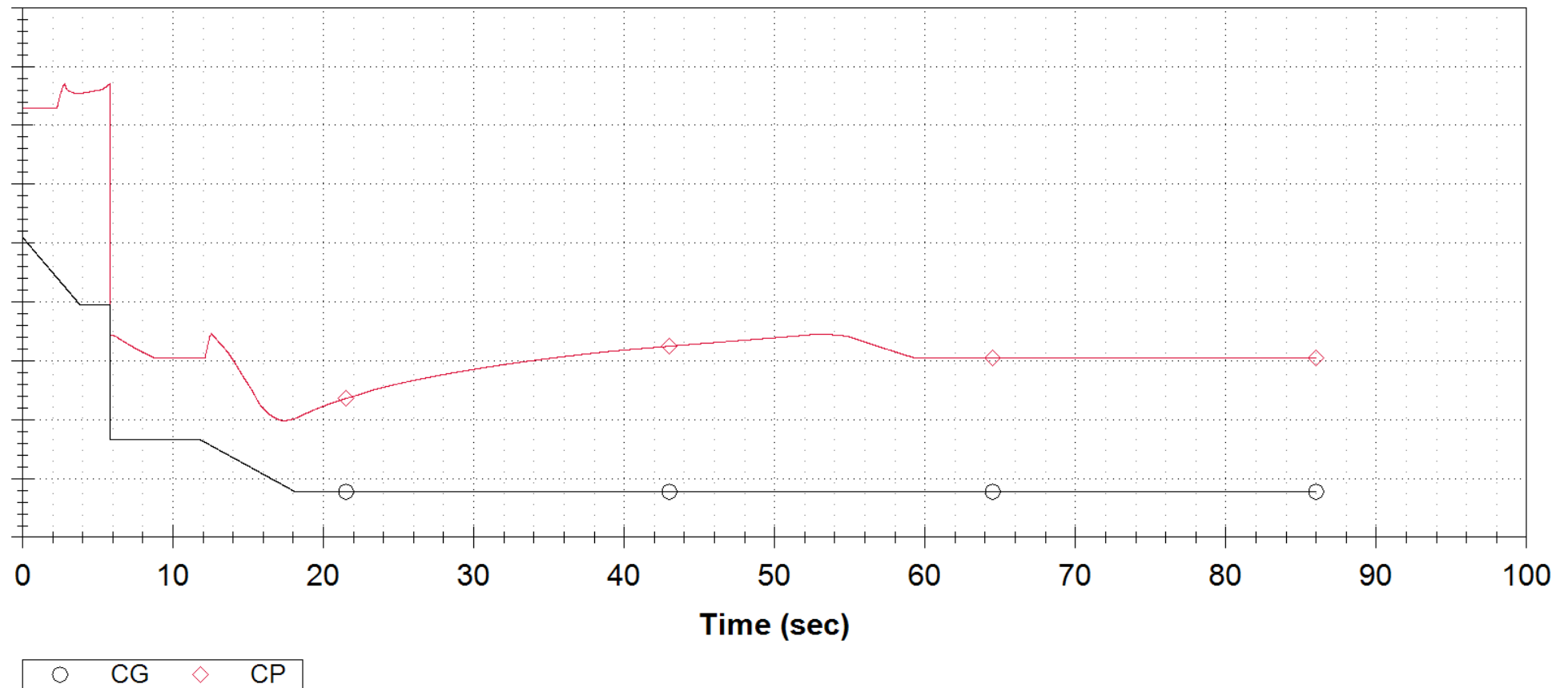
Custom



CP vs CG 2-Stage

CG and CP

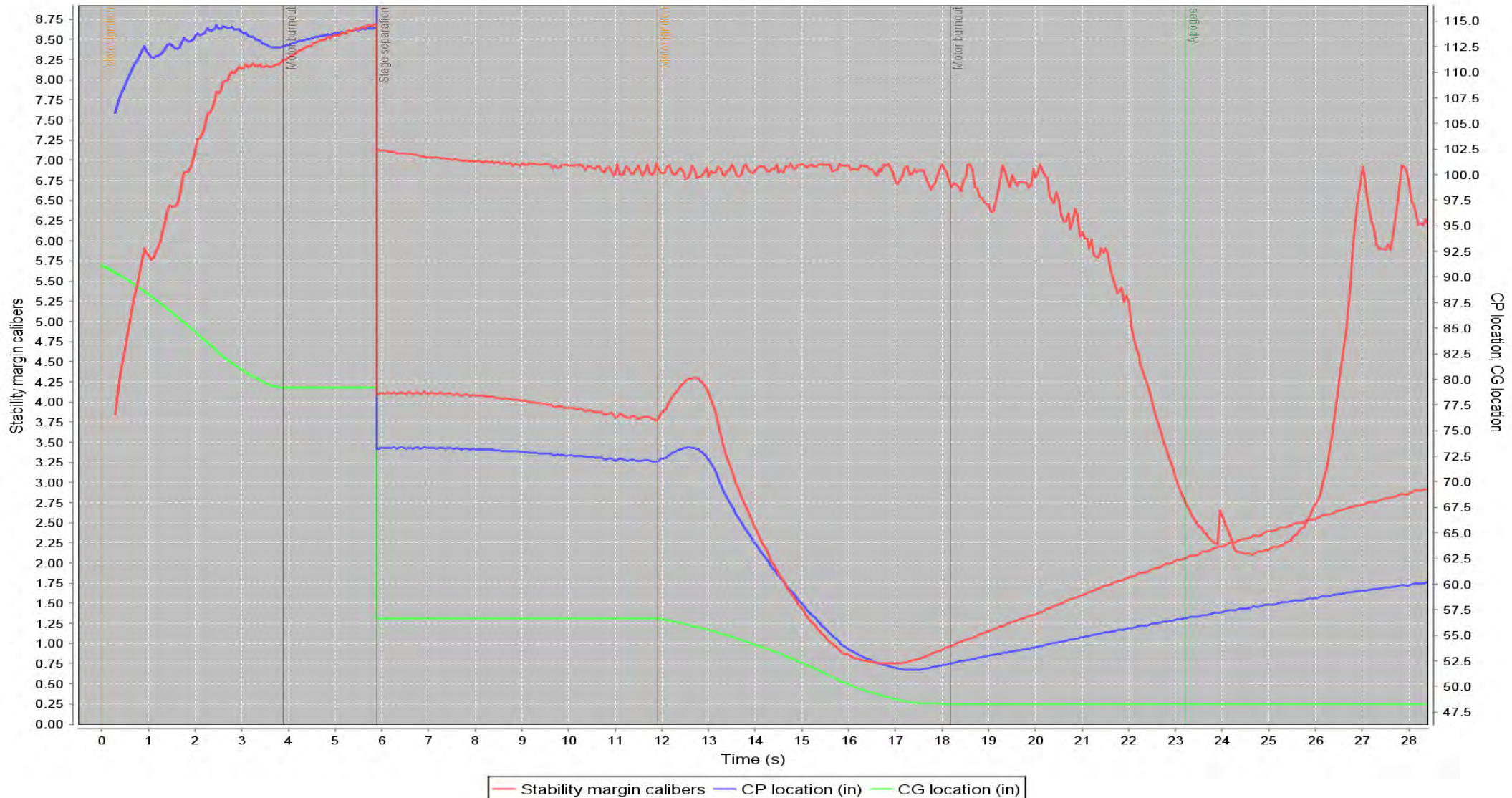
98-98-5-1-16b
Max Alt = 110,136 ft



Stability - 2-Stage

Simulation 5

Stability vs. time



Stability 2-Stage





Structure Materials

Airframe & Fins

- Composites
 - Carbon fiber vs fiberglass
 - Convolute vs filament wound
 - Cost & weight
- Aluminum

Nose Cone

- Usually fiberglass
- RF Transparent

Electronics

Accelerometers

- Apogee accuracy, integration errors

Barometric

- Mach lockout
- Some newer units Mach-immune

Timers

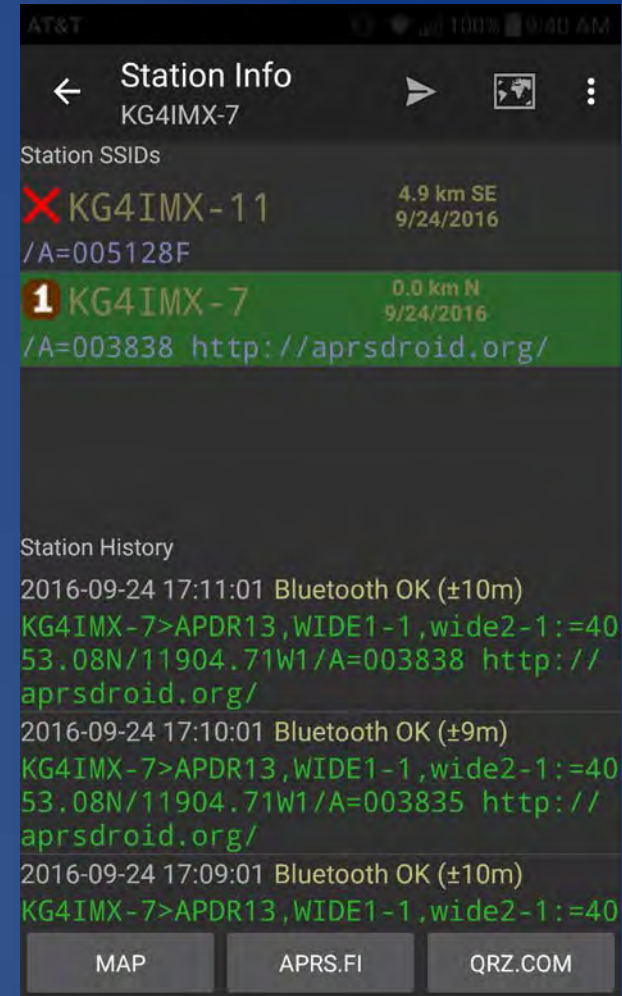
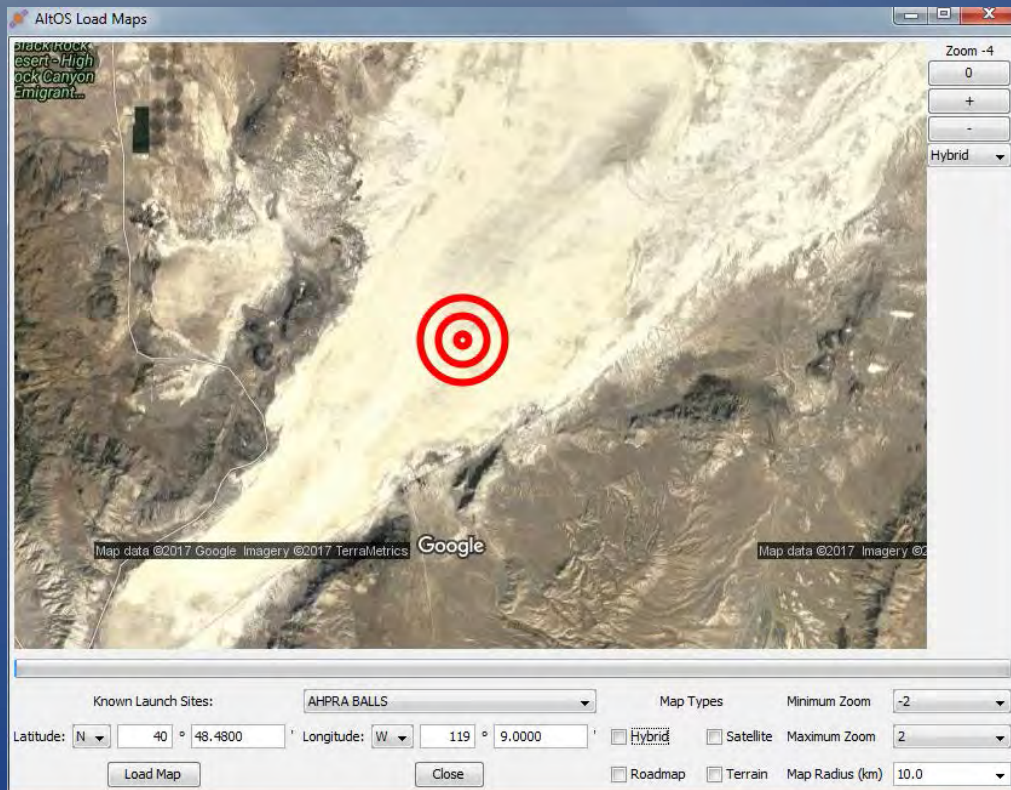
- Depend on accurate sims

GPS

- Licensed vs non-licensed
- Big Red Bee
- Aim Xtra
- Tele GPS
- TLA
- GPS-1
- KATE

Beacons

- Beeline
- Walston



Resources

- <http://www.aerorocket.com/finsim.html>
- <http://openrocket.sourceforge.net/>
- <http://www.rasaero.com/>
- <http://www.aeropac.org/>
- <http://forum.ausrocketry.com/>
- <http://www.rimworld.com/nassarocketry/fabrication/nosecones/spreadsheet.html>
- https://www.apogeerockets.com/Rocket_Software/RockSim
- <http://www.bigredbee.com/>
- <http://altusmetrum.org/>
- <https://fruitychutes.com/>
- <http://prolinerocketry.com/store/index.php>