Aerodynamics Assessment and Development of Smokey SAM Rocket Prototype

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OVERVIEW

- Research motivation
- Introduction
- Research methodology
- Results & discussions
- Conclusion

Research Significance

Smokey SAM Rocket

Significance

- small unguided rocket developed
- as a threat simulator for use during military exercises

- Save cost during military training
- Reduce risk
- Test the pilot sensitivity of detecting threat from the ground

GTR-18 Smokey SAM

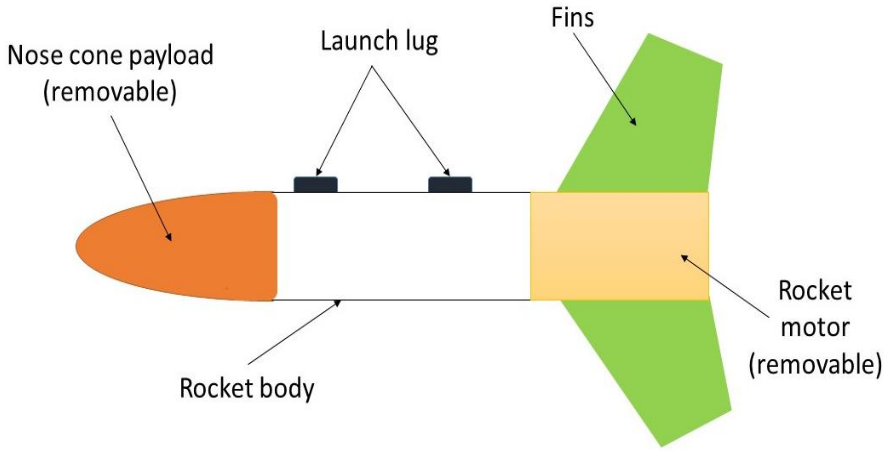
- The GTR-18 was invented in the late 1970s by Robert A. McLellan, a Weapons Range Scientist working with Exercise Red Flag at Nellis Air Force Base. He first sought a commercially available system that would function as he envisioned.

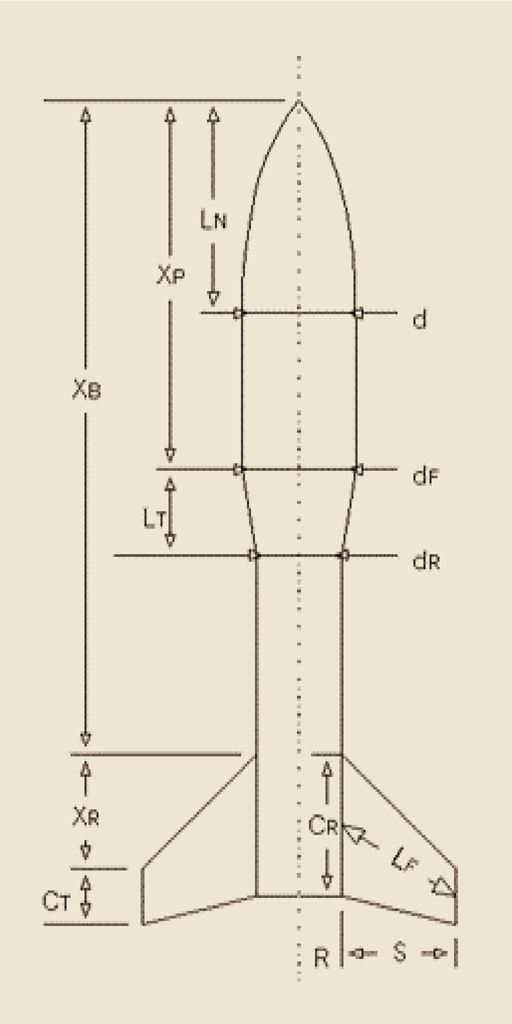
- It quickly became visible that no commercial product would perform satisfactorily, so the development of the GTR-18 was undertaken by the Naval Weapons Center (NWC) during the early 1980s to develop Mr McLellan's idea of a simple and inexpensive rocket for visually simulating the launch of surface-to-air missiles (SAMs) during training exercises.

Methodology

Design Requirements & Objectives (DRO)

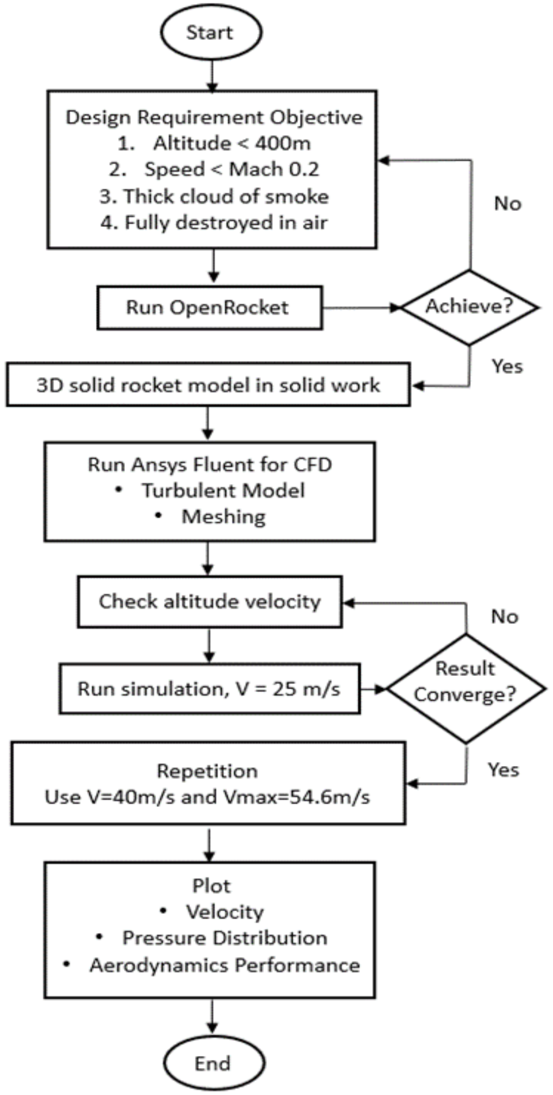
1. Altitude < 400m
2. Speed < Mach 0.2
3. Thick cloud of smoke
4. Fully destroyed in air





L_N = length of nose,
d = diameter at base of nose,
d_F = diameter at front of transition,
d_R= diameter at rear of transition,
L_T = length of transition,
X_P = distance from tip of nose to front of transition,
C_R = fin root chord,
C_T = fin tip chord,
S = fin semispan,
L_F= length of fin mid-chord line,
R = radius of body at aft end,
X_R= distance between fin root leading edge and fin tip leading edge parallel to body,
X_B = distance from nose tip to fin root chord leading edge, and
N = number of fins.

Modelling Scheme Flowchart

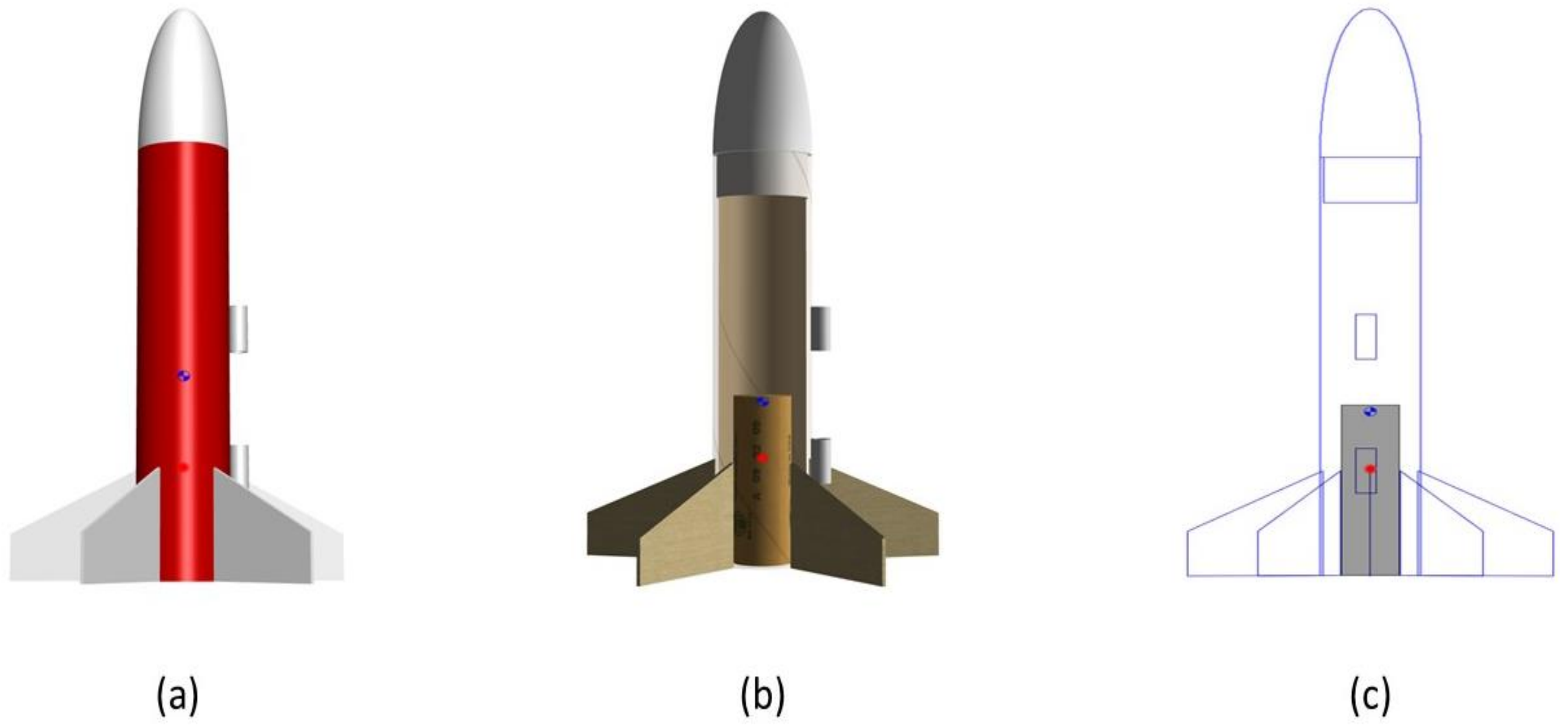


Geometric parameters of the design through OpenRocket modelling

Parameter	Components				
	Nose cone	Body tube	Fins	Launch Lug 1	Launch Lug 2
Shape	Ellipsoid	n/a	Trapezoidal	n/a	n/a
Length (cm)	10.00	28.00	n/a	3.00	3.00
Base diameter (cm)	5.00	n/a	n/a	n/a	n/a
Thickness (cm)	0.20	0.30	0.20	0.10	0.10
Shoulder diameter (cm)	4.60	n/a	n/a	n/a	n/a
Shoulder length (cm)	3.00	n/a	n/a	n/a	n/a
Outer diameter (cm)	n/a	5.00	n/a	1.00	1.00
Inner diameter (cm)	n/a	4.40	n/a	0.80	0.80
Cross section	n/a	n/a	Square	n/a	n/a
Number of fins	n/a	n/a	5.00	n/a	n/a
Root chord (cm)	n/a	n/a	7.00	n/a	n/a
Tip chord (cm)	n/a	n/a	3.00	n/a	n/a
Height (cm)	n/a	n/a	7.00	n/a	n/a
Sweep length (cm)	n/a	n/a	4.04	n/a	n/a
Sweep angle (°)	n/a	n/a	30.00	n/a	n/a
Radial position (°)	n/a	n/a	n/a	40.00	40.00
Position relative to top of parent component (cm)	n/a	n/a	n/a	10.50	10.50

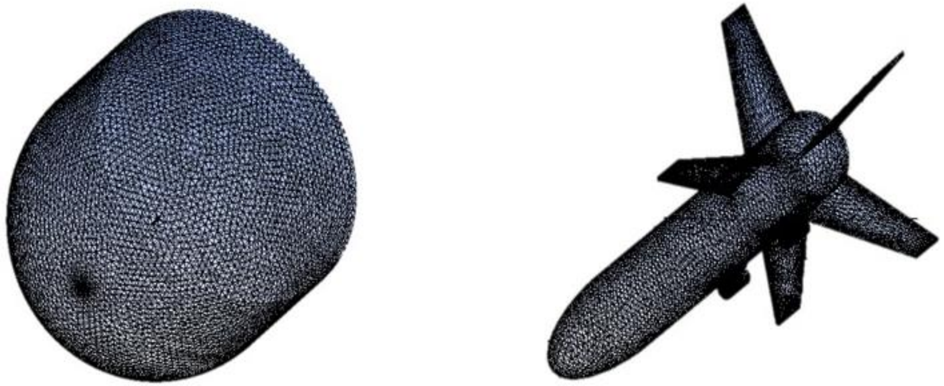
Methodology

Design - Modelling



Developed Smokey SAM model for CFD analysis

CFD - Modelling



(a) (b)

Meshing element on presented Smokey SAM model

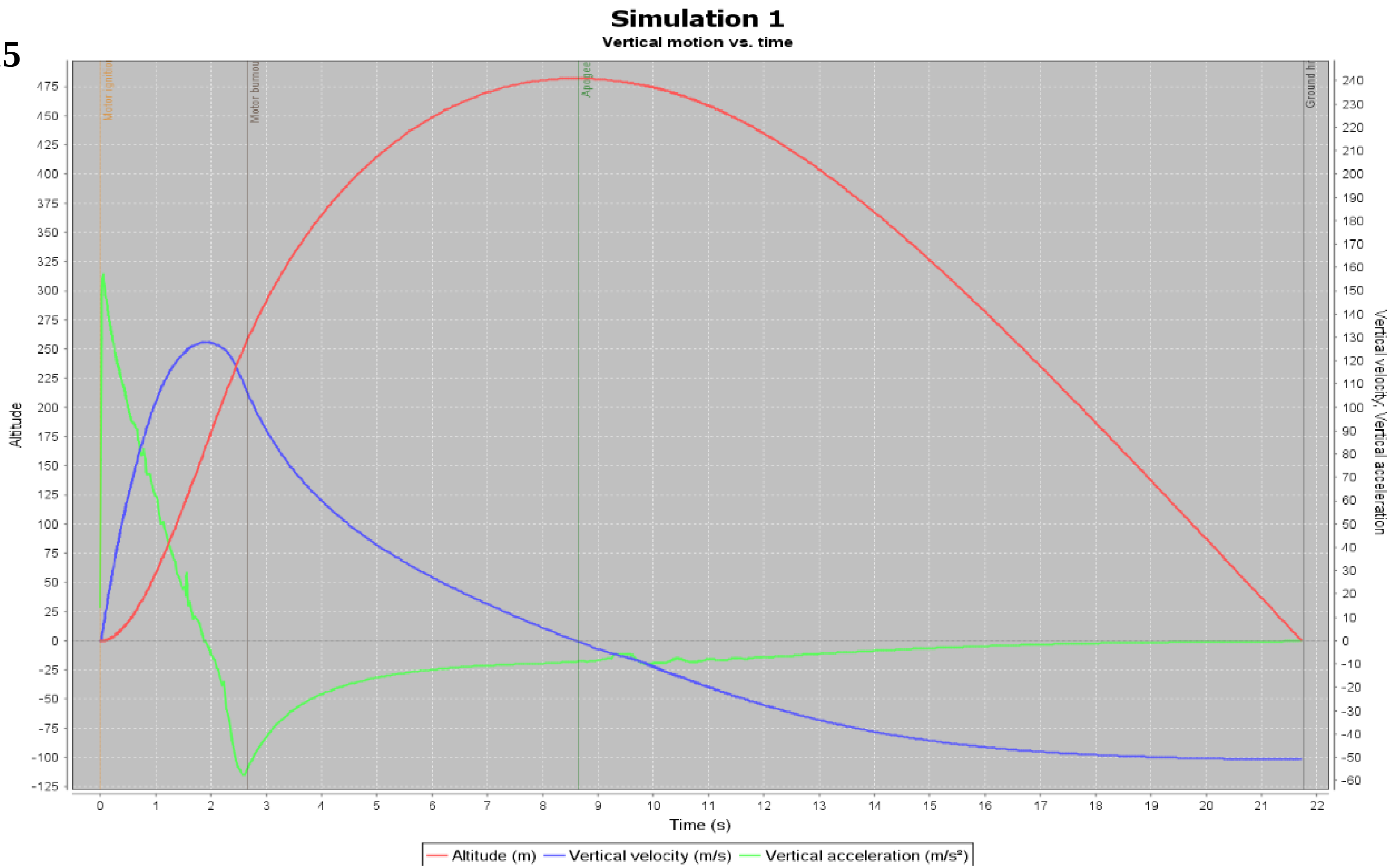
Present model element meshing parameters

Kinematic viscosity, μ	Density, ρ (kg/m³)	Velocity, V (m/s)	y+, (m)	Re
Fin: Length = 0.07 m, Area = 0.003403 m²				
$1.508x10^{-5}$	1.178	54.60	$5.059x10^{-6}$	$2.986x10^{5}$
		40.00	$6.754x10^{-6}$	$2.188x10^{5}$
		25.00	$1.045x10^{-6}$	$1.367x10^{5}$
Body: Length = 0.37 m, Area = 0.005346 m²				
Kinematic viscosity, μ	Density, ρ (kg/m³)	Velocity, V (m/s)	y+, (m)	Re
$1.508x10^{-5}$	1.178	54.60	$5.698x10^{-6}$	$1.578x10^{6}$
		40.00	$7.607x10^{-6}$	$1.156x10^{6}$
		25.00	1.17710^{-6}	$7.227x10^{5}$

Results

Design – Rocket Motor Testing

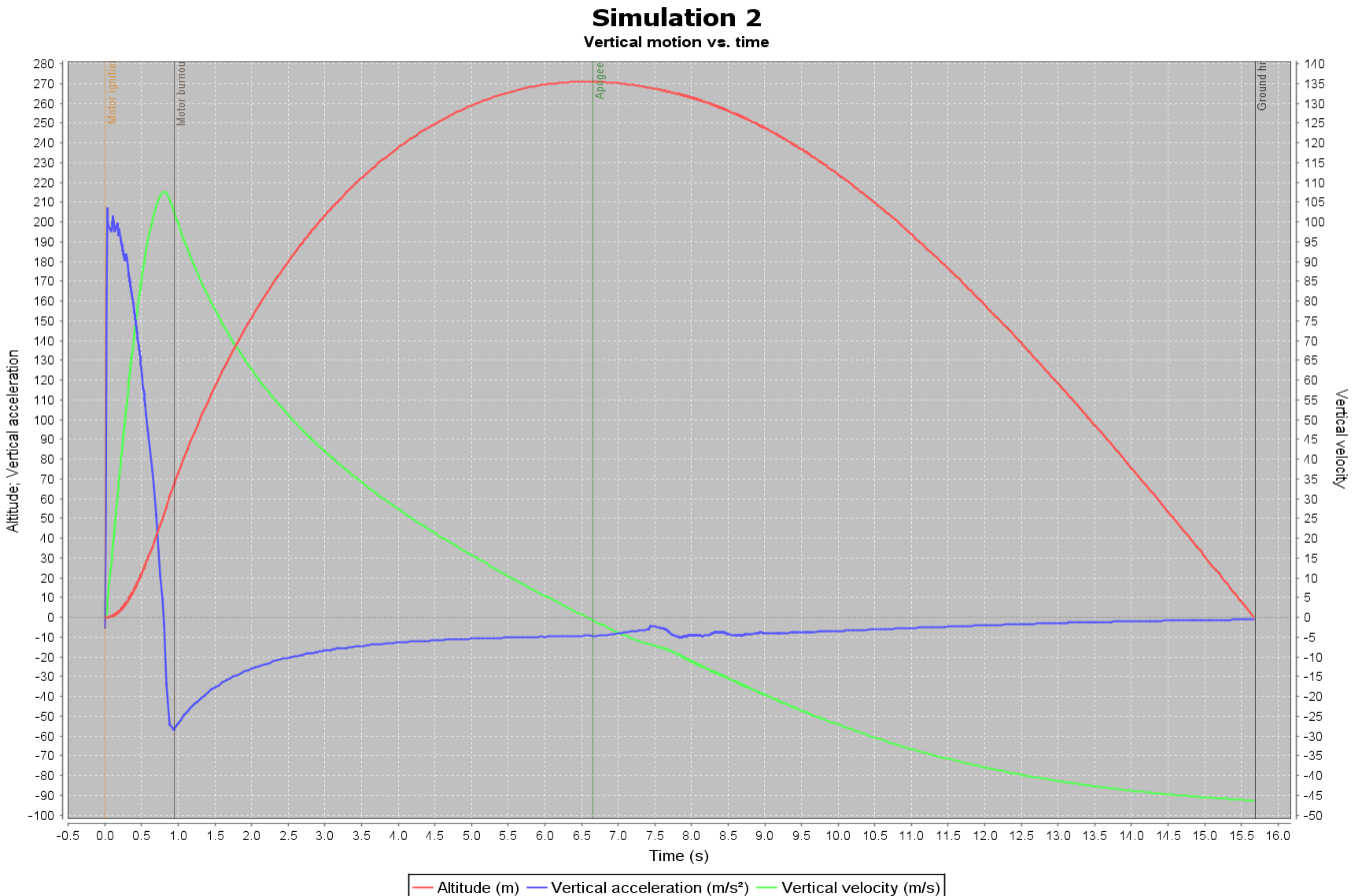
AeroTech E15



Results

Design – Rocket Motor Testing

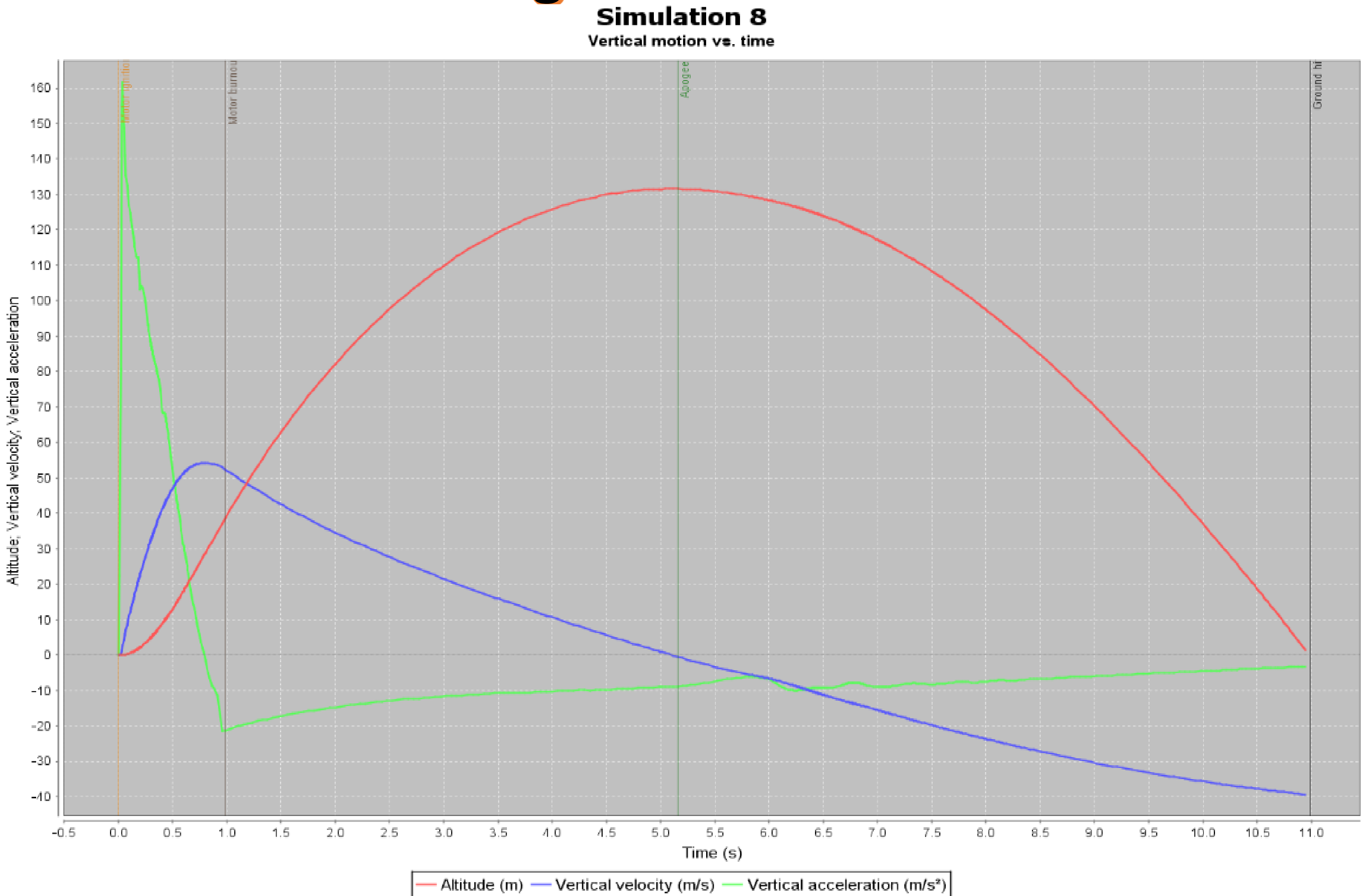
AeroTech D21



Results

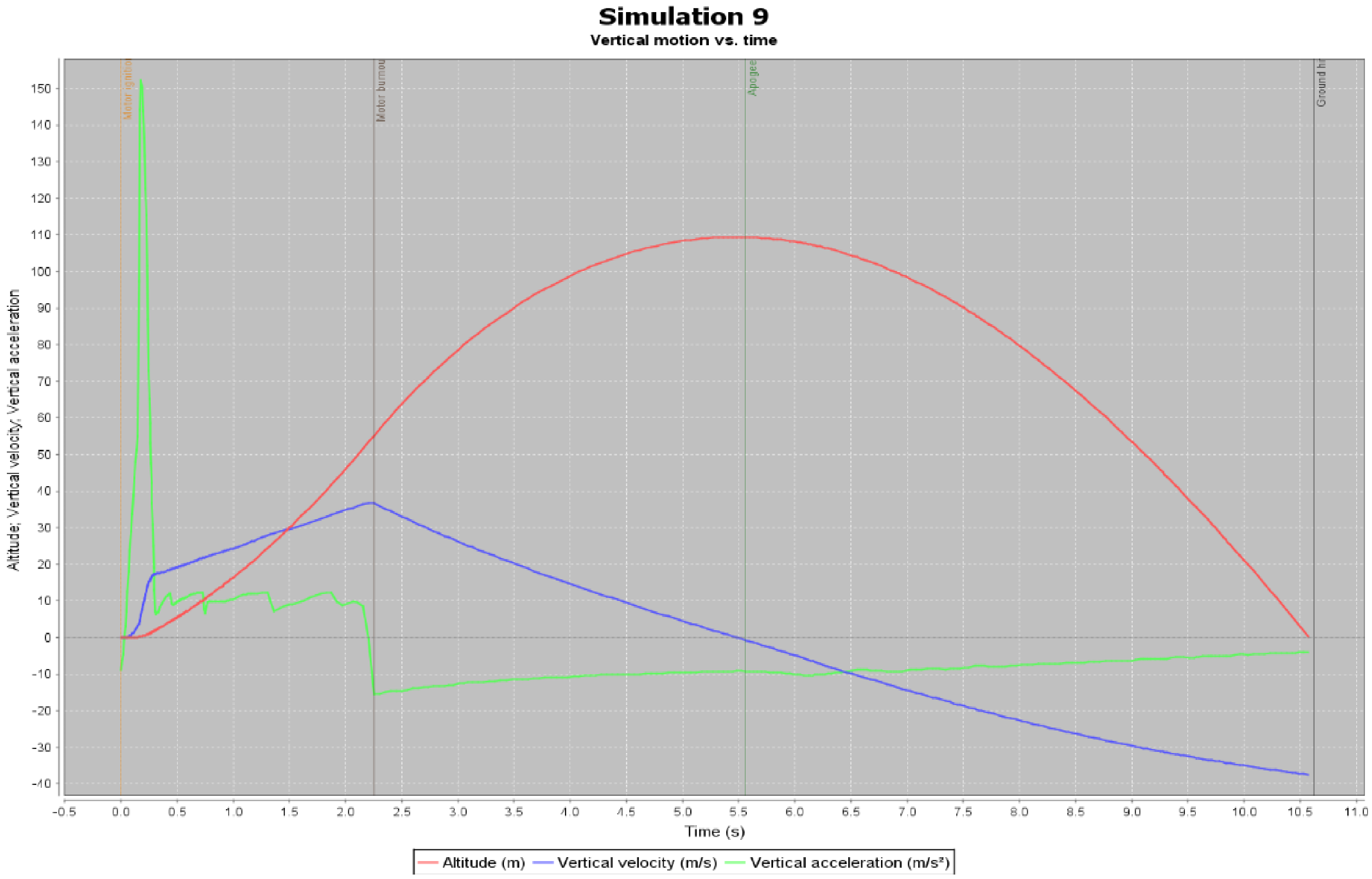
Design – Rocket Motor Testing

Apogee C10



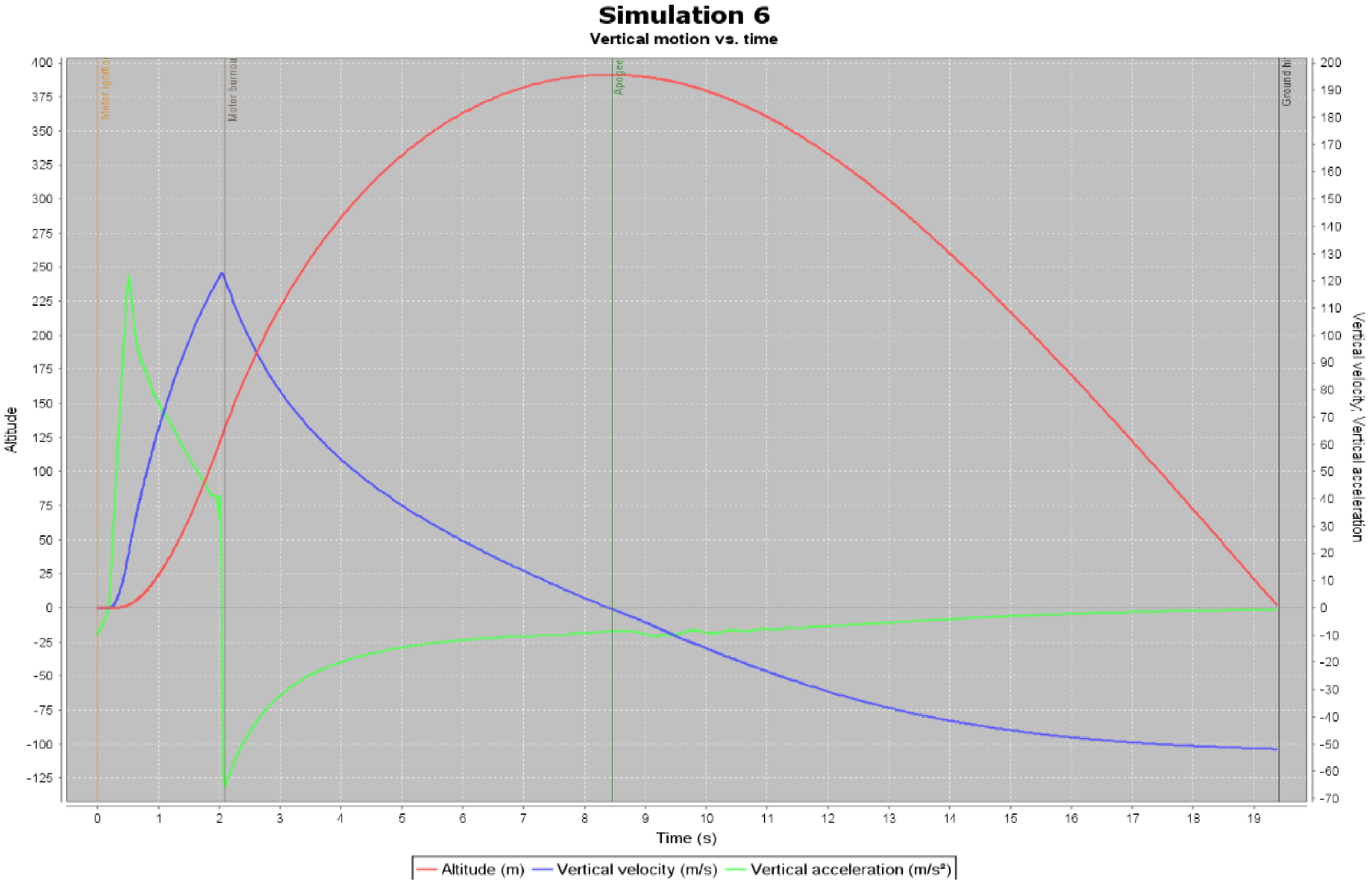
Design – Rocket Motor Testing

Quest C6



Design – Rocket Motor Testing

Estes E16



Methodology

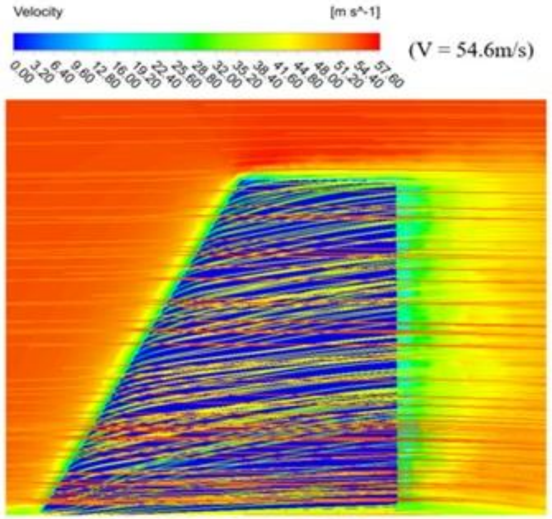
Design - Modelling

Tested Rocket Motor for Designed Smokey SAM
(Open-source software: OpenRocket)

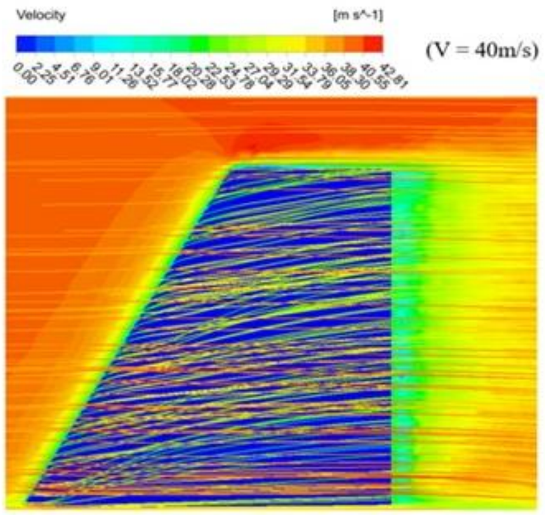
Parameter	Single-use motor				
	AeroTech E15	AeroTech D21	Apogee C10	Quest C6	Estes E16
Manufacturer	AeroTech	AeroTech	Apogee	Quest	Estes
Designation	E15W-4	D21-7	C10-4	C6-5	E16-4
Total Impulse (Ns)	40	20.00	10.00	9.00	34.00
Diameter (cm)	2.40	1.80	1.80	1.80	2.90
Length (cm)	7.00	7.00	5.00	7.00	11.40

Results & discussions

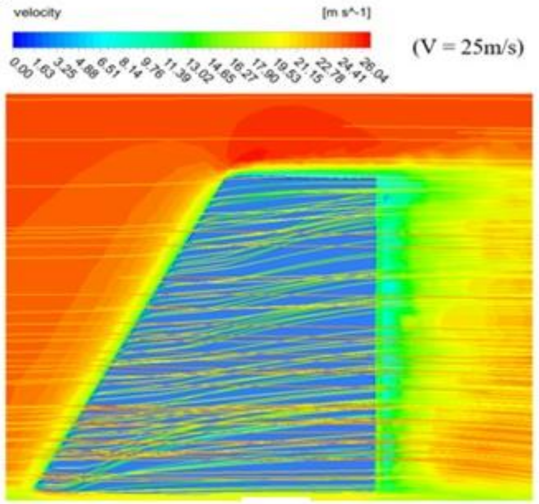
Velocity & Flow Distributions



(a)

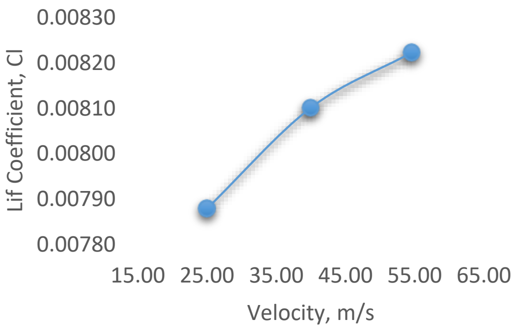


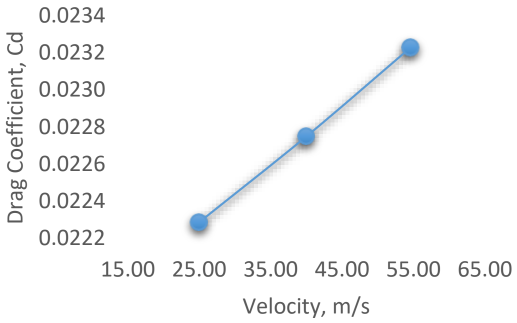
(b)

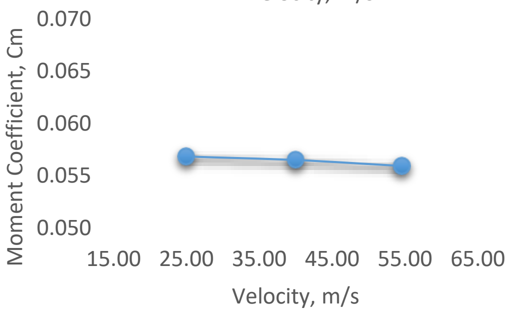


(c)

Velocity contour at fin for (a) V = 54.6 m/s, (b) V = 40m/s, and (c) V = 25m/s



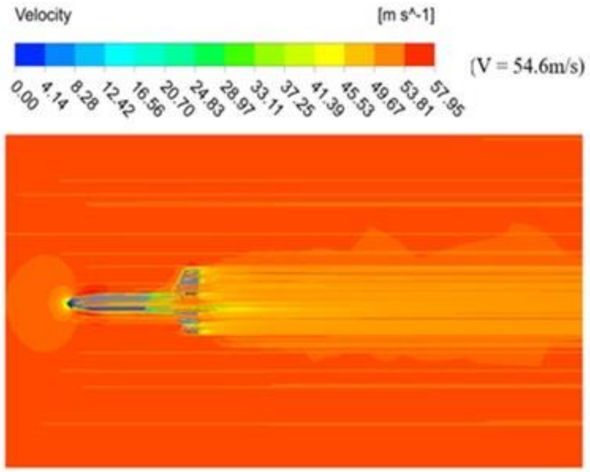




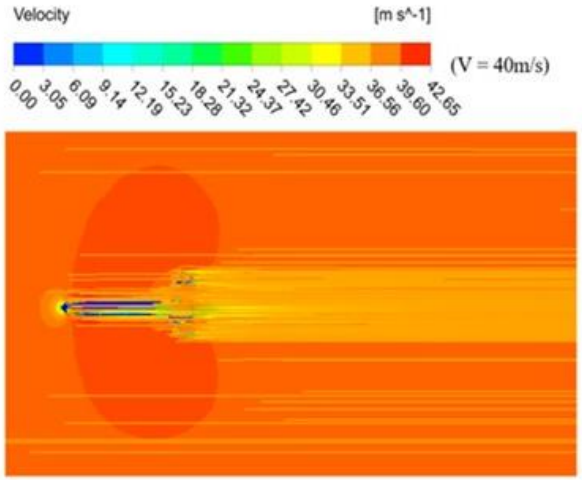
Fin						
V, m/s	Lift, N	Lift Coefficient, C_l	Drag, N	Drag Coefficient, C_d	Moment, N.m	Moment Coefficient
54.60	0.049	0.00822	0.274	0.0232	0.023	0.056
40.00	0.026	0.00810	0.153	0.0227	0.013	0.057
25.00	0.010	0.00788	0.062	0.0223	0.005	0.057

Results & discussions

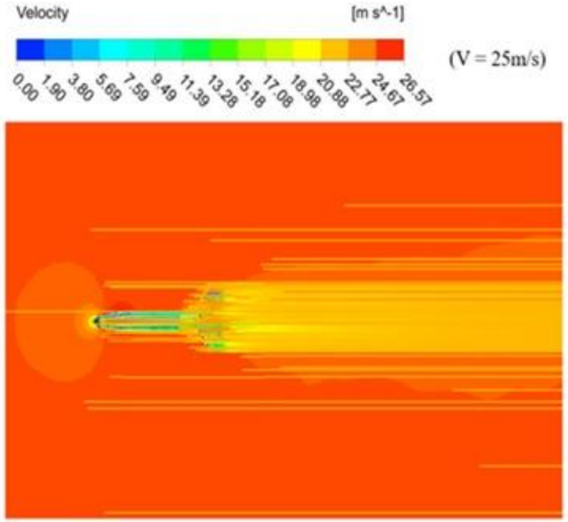
Velocity & Flow Distributions



(a)

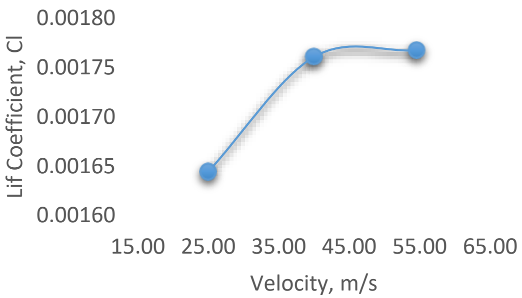


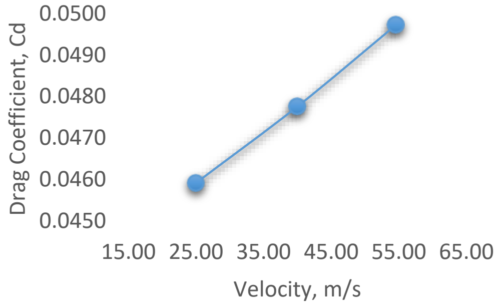
(b)

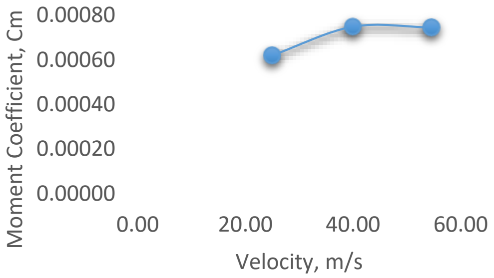


(c)

Velocity contour of whole rocket body for (a) V = 54.6 m/s, (b) V = 40m/s, and (c) V = 25m/s

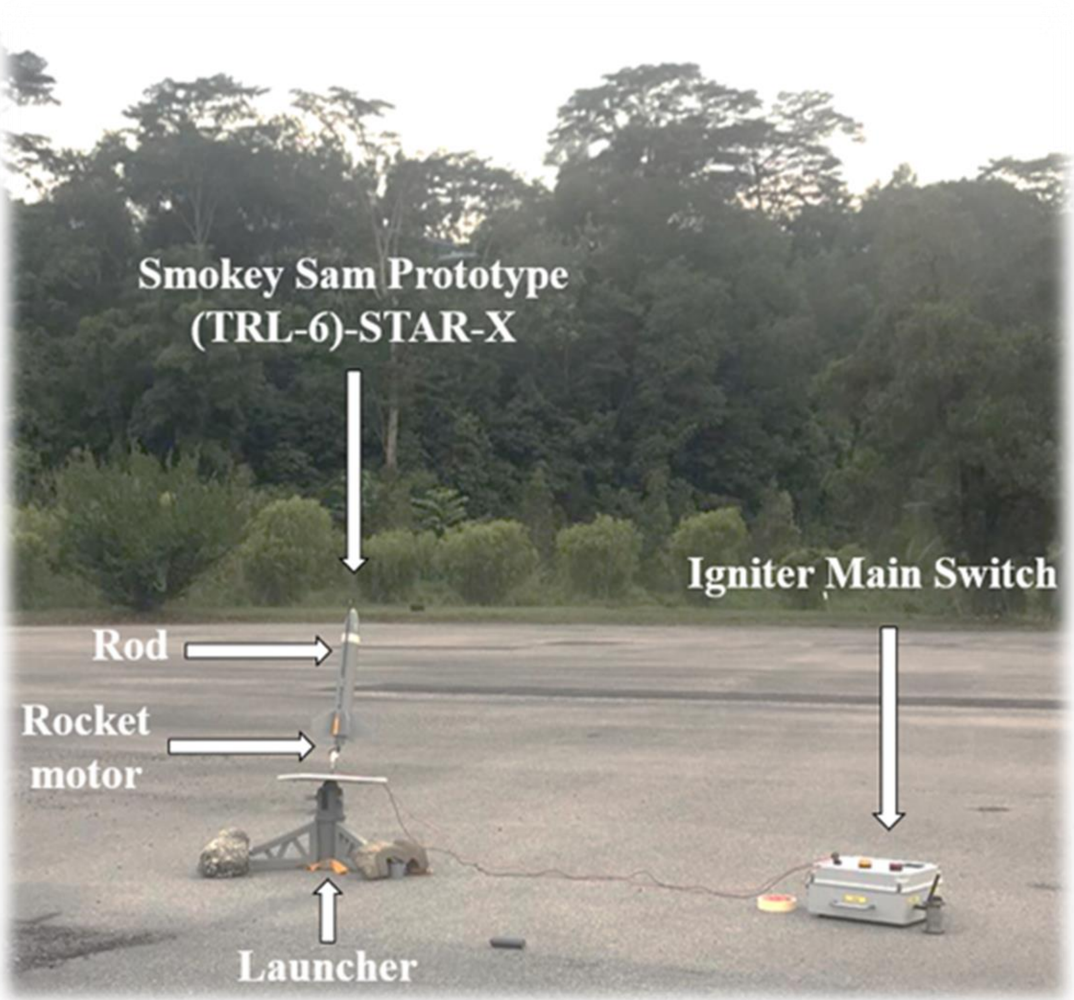




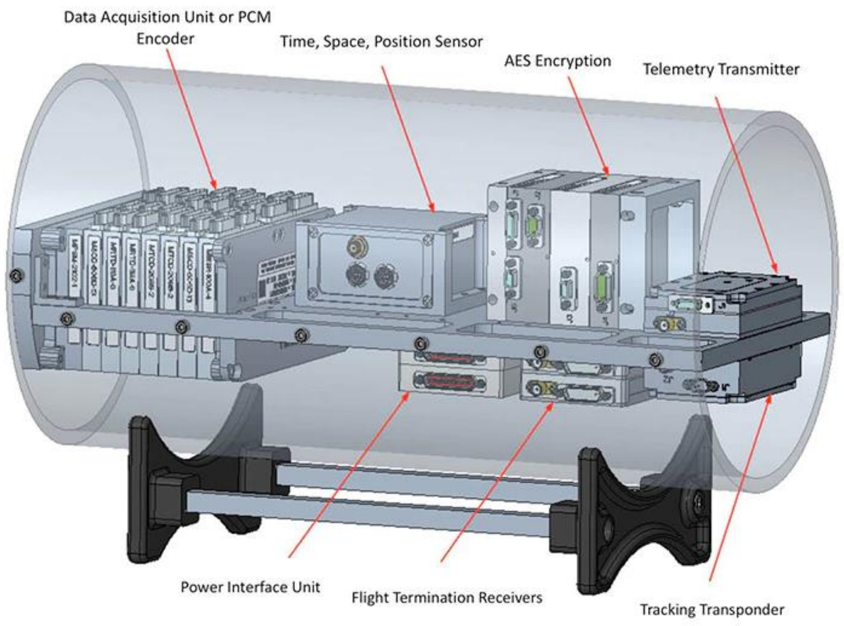


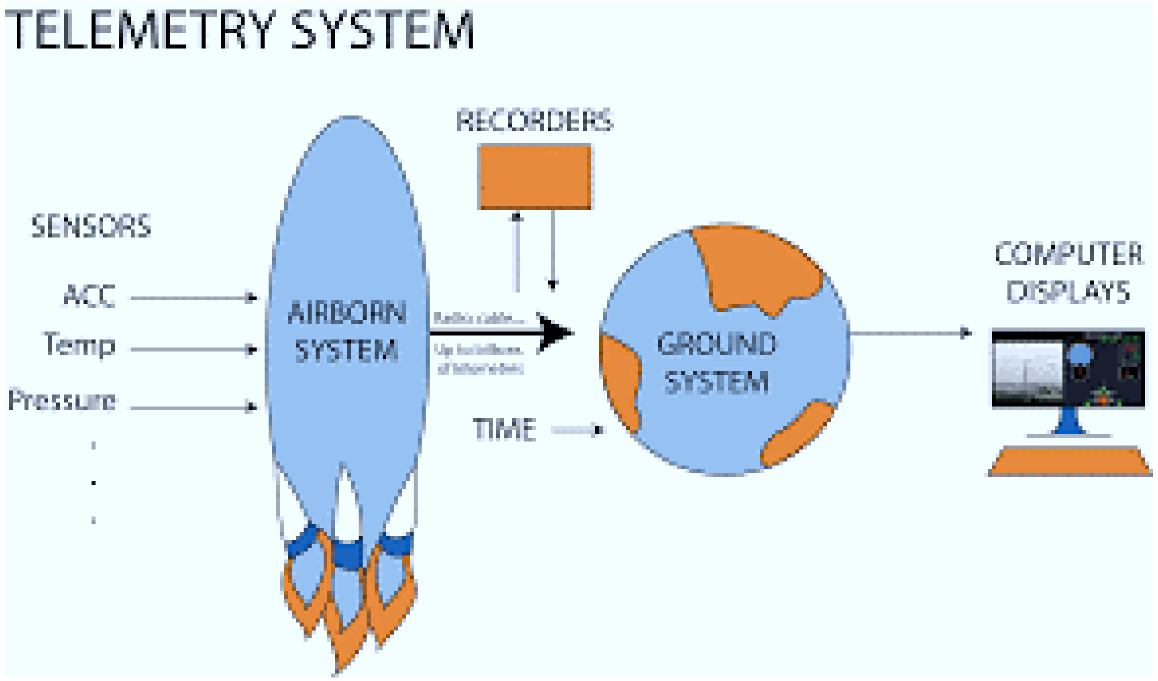
Body						
V, m/s	Lift, N	Lift Coefficient, C_l	Drag, N	Drag Coefficient, C_d	Moment, N.m	Moment Coefficient
54.60	0.166	0.00177	2.092	0.0497	0.026	0.00074
40.00	0.089	0.00176	1.146	0.0478	0.014	0.00075
25.00	0.032	0.00164	0.457	0.0459	0.005	0.00062

Launching Set-Up

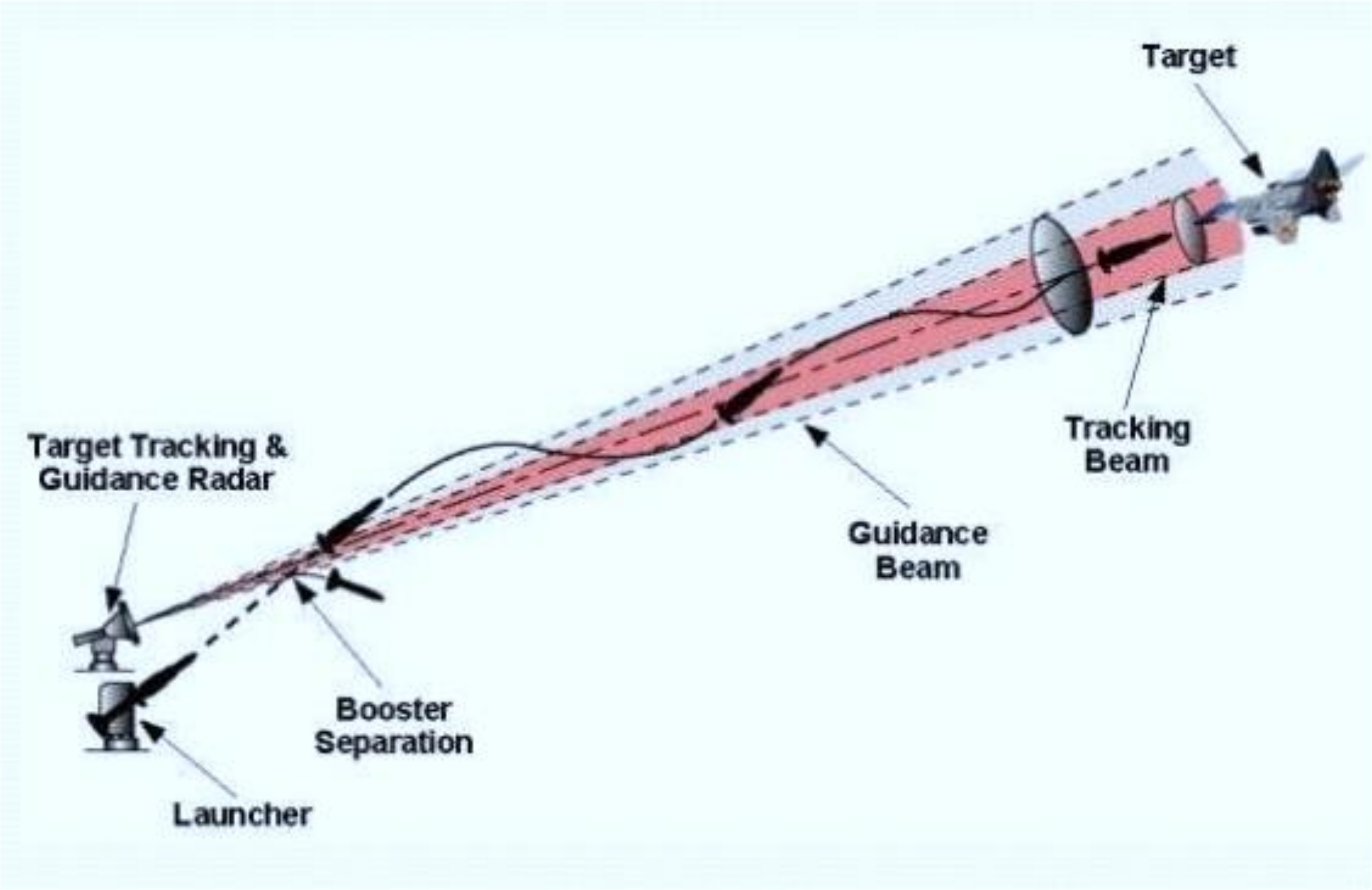


Telemetry System





Guidance System



Conclusion

- This paper intends to study the rocket's aerodynamics performance when flying; the aerodynamics analysis on the Smokey SAM prototype rocket has not been widely studied yet. The aerodynamics loads acting on the rocket body must ensure the steady flight condition can be achieved.

- Observation can be made from the real time flight test validation. The flight test was successful since the rocket managed to stabilise itself despite the instability while leaving the rod. Thus, this validate the CFD simulation where the aerodynamics loads acting on the rocket is low thus that ensure the rocket to have a good and stable flight path.

- In terms of body contribution, the trend is just the same as fin where the simulation recorded that as the speed increases, the pressure also increases.

Acknowledgment

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