Design and Flight Testing of the ARLISS Rocket and CFD Modeling of the Nosecone Region

Deeptanshu Arnold*
Patricia Nerio
Austin Epps
Dr. P. Papadopoulos

Special Thanks to
Tom Rouse,
Rocketeer

What is Arliss?

- A Rocket Launch for International Students Satellites.
- Organization started in 1999 by Professor Bob Twiggs and AeroPac members.
- Two options: CanSat or ComeBack.

Why Arliss?

- Provides learning experience for all students
- Stimulates interests in Rocketry
- Gain hands on experience with rockets

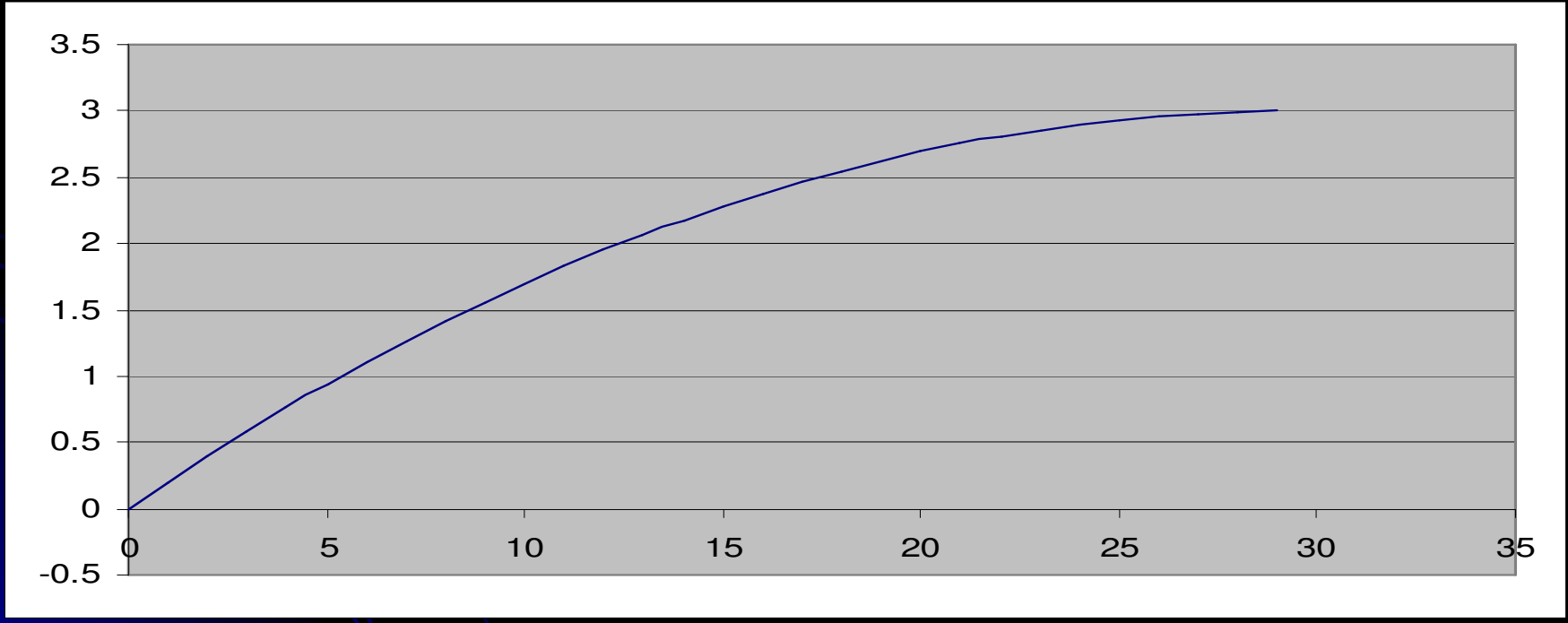
Approach

- Various nose cone profiles were studied and analyzed using CFD.
- Detailed CFD modeling and analysis was done for tangent ogive nose cone.
- Rocket was designed using Rocksim.
- Rocket was built and tested. Flight data was recorded and compared with CFD and Rocksim simulations.

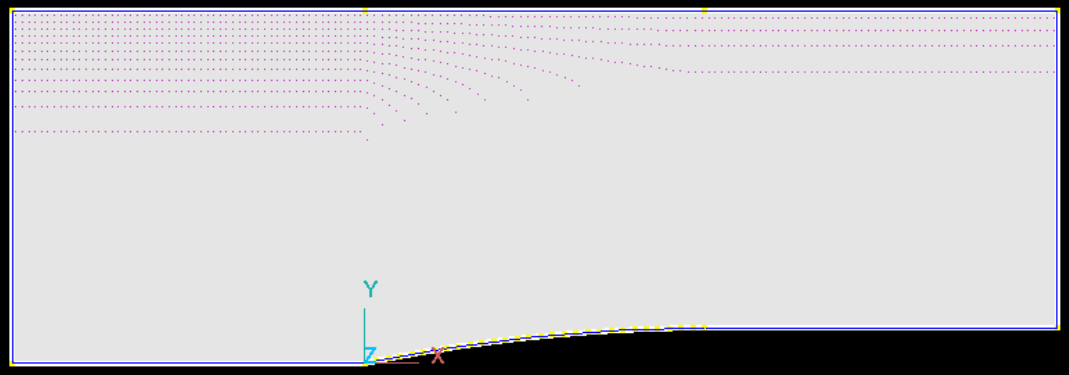
CFD Analysis

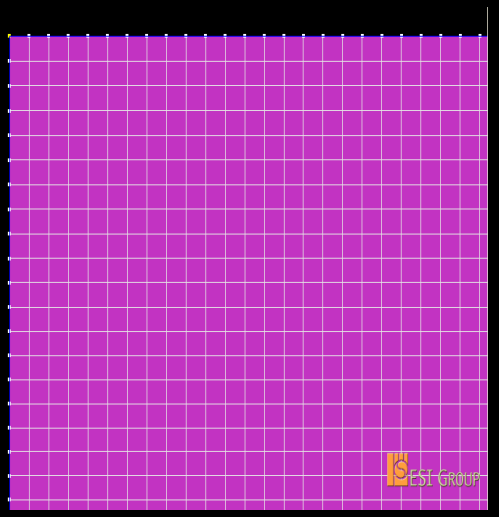
- 2-D Axisymmetry model

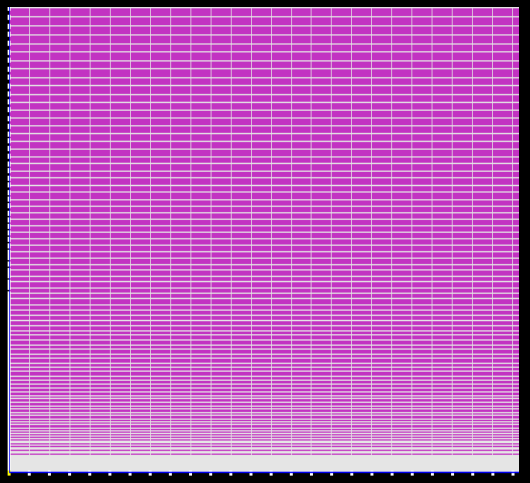
Tangent ogive nose cone profile



Grid Modeling

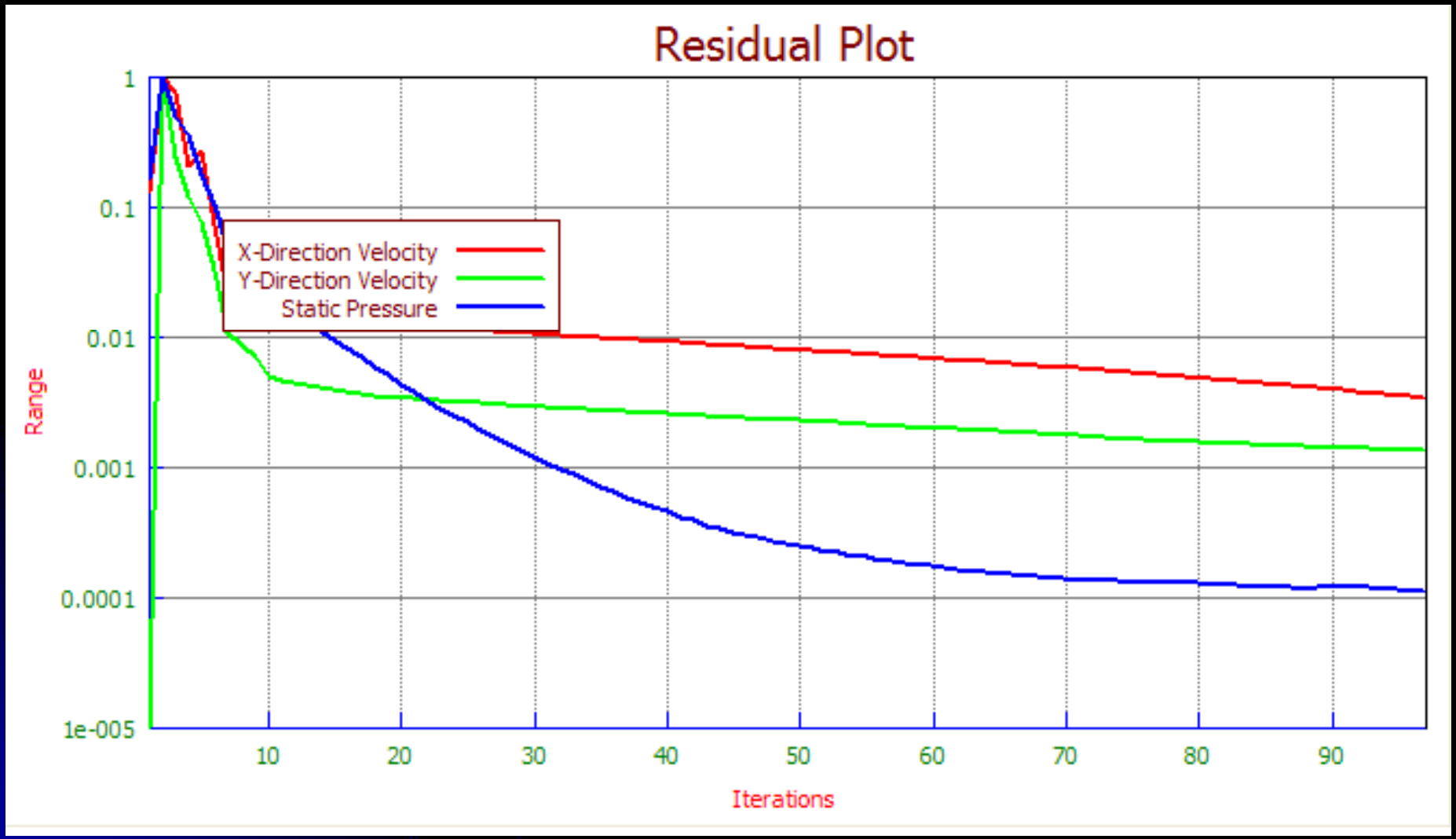






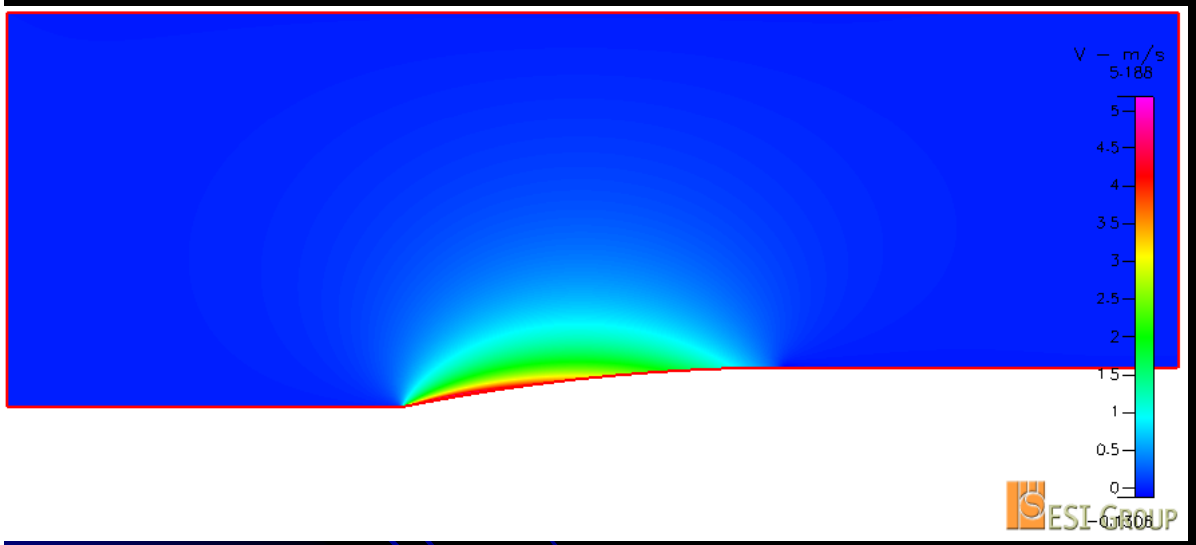
- No of cells: 238203
- Smallest Volume: 4.386218E-14
- Largest Volume: 1.110289E-05
- Smallest Angle : 32.20°

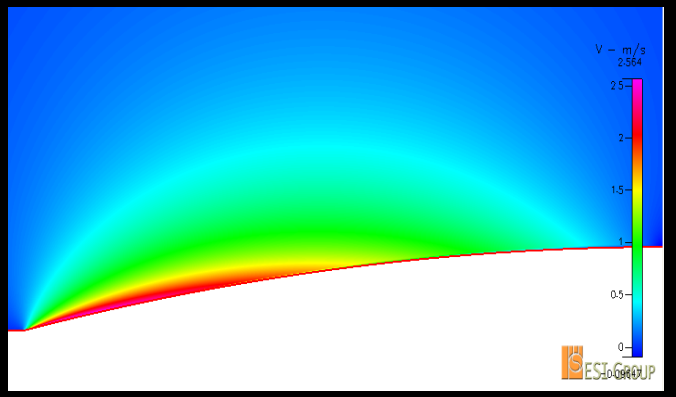
Results

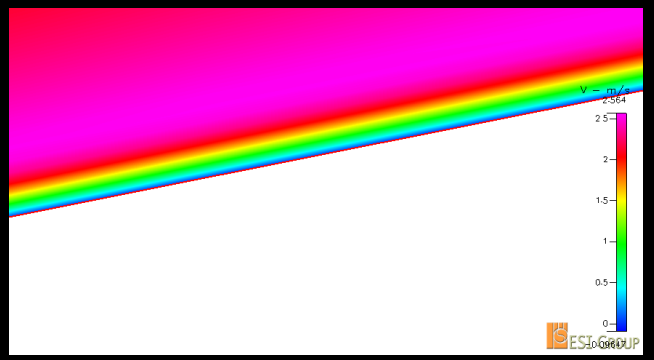

Residual Plot
1
0.1
0.01
0.001
0.0001
1e-005
Range
X-Direction Velocity
Y-Direction Velocity
Static Pressure
10
20
30
40
50
60
70
80
90
Iterations

Screen Shots

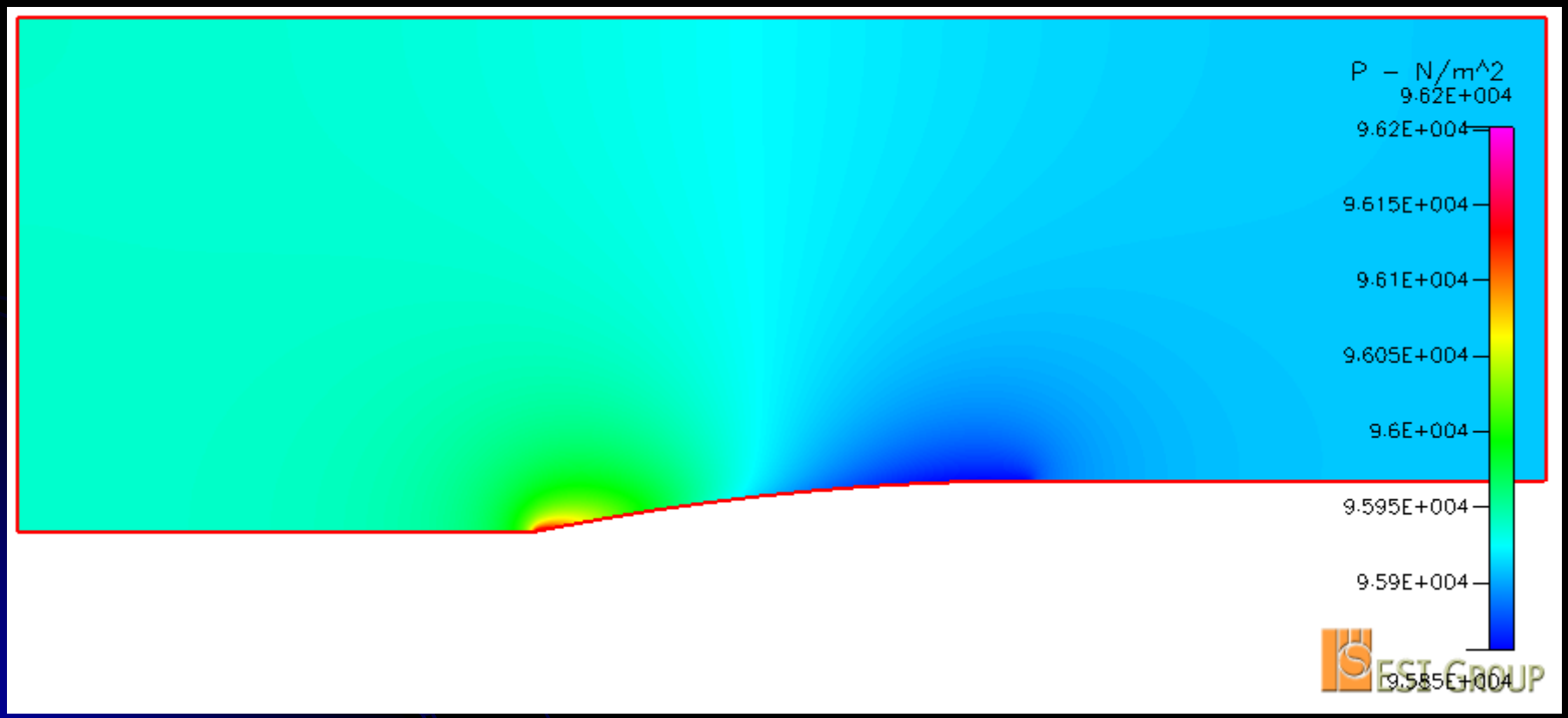
Velocity Distribution







Pressure Distribution



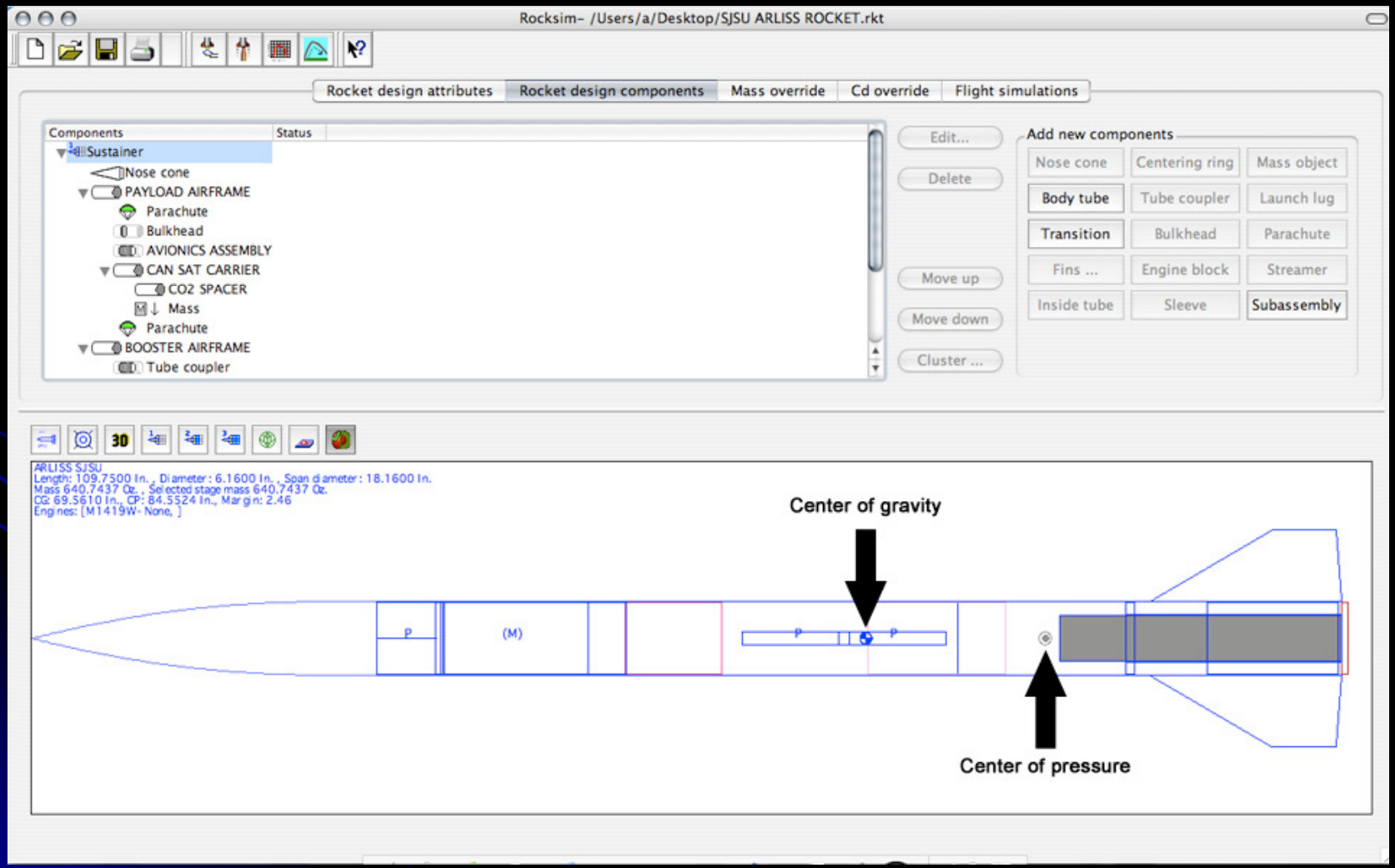
Results cont.

ALTITUDE (Feets)	VELOCITY (m/s)	PRESSURE (Pa)	DRAG (N)	DENSITY (Kg/m^3)	Cd
500	134.1	768.01	13.9418	1.207171805	*0.070757*
1000	**152.4**	**756.79**	**13.73812**	**1.18954585**	***0.054784***
1500	184.4	749.76	13.6105	1.172126046	*0.037623*
2000	195	744.4	13.5132	1.154912393	*0.033901*
2500	182.9	722.96	13.124	1.137904892	*0.037985*
3000	176.8	709.36	12.87711	1.121052005	*0.040486*
3500	155.4	692.71	12.57486	1.104405269	*0.051946*
4000	134.1	676.6	12.28242	1.087964685	*0.069166*
4500	115.8	661.99	12.0172	1.071678714	*0.09213*
5000	91.44	647.12	11.74726	1.055598895	*0.146637*

RockSim

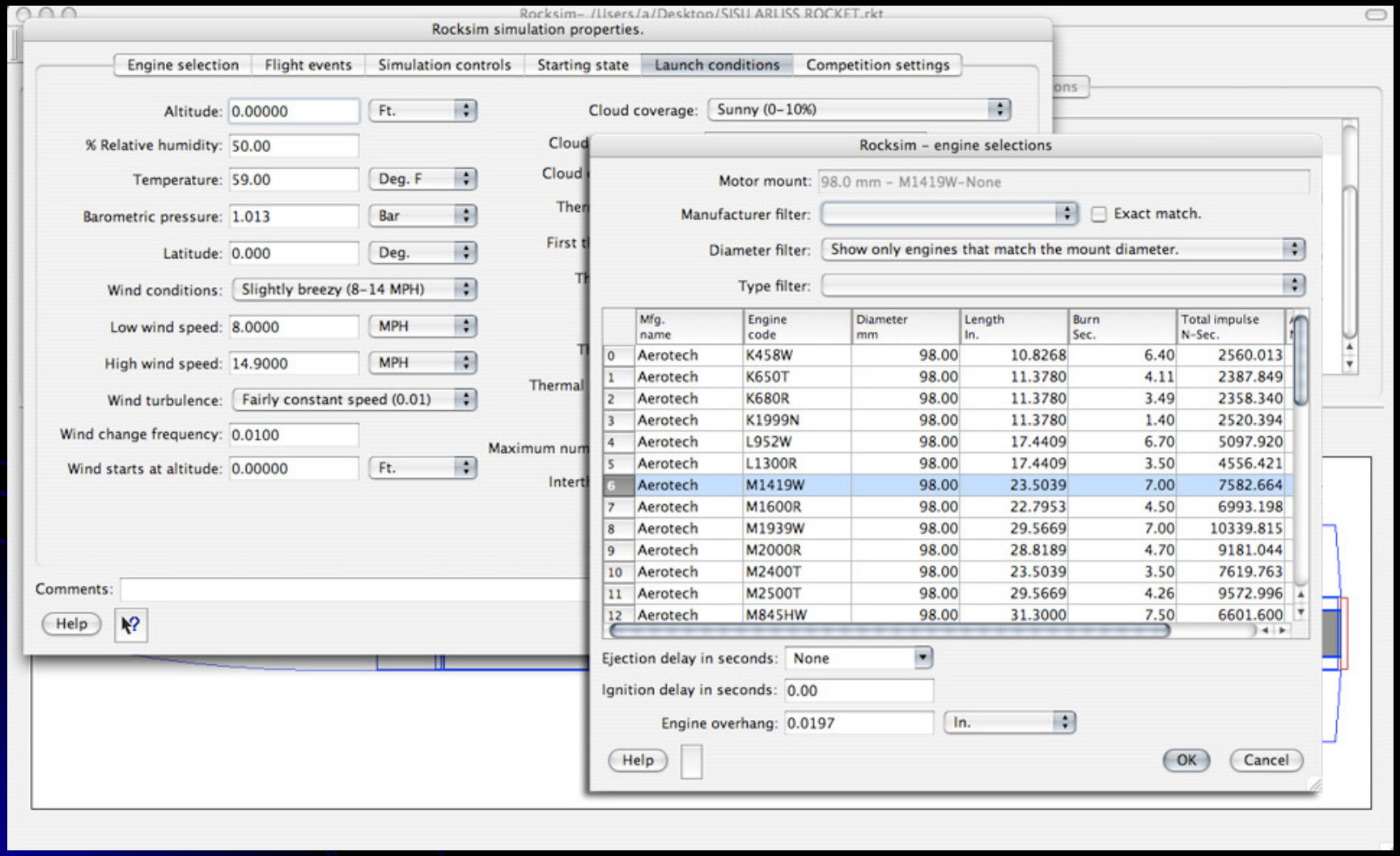
- Software to design model rockets and simulate their flights.

Step 1: Choose or design components, then assemble them to create the rocket.



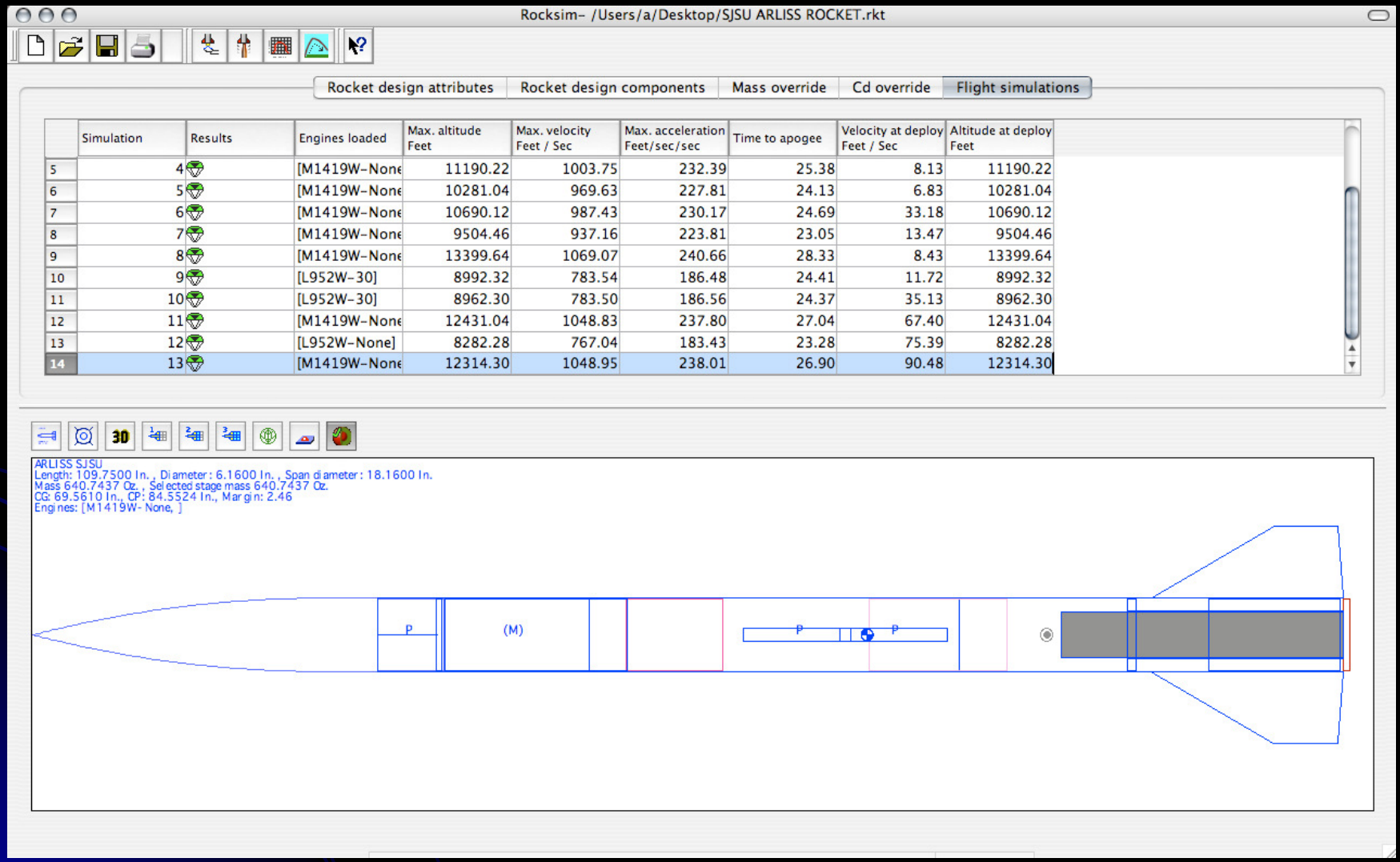
RockSim

Step 2: Choose an engine and set launch conditions.



RockSim

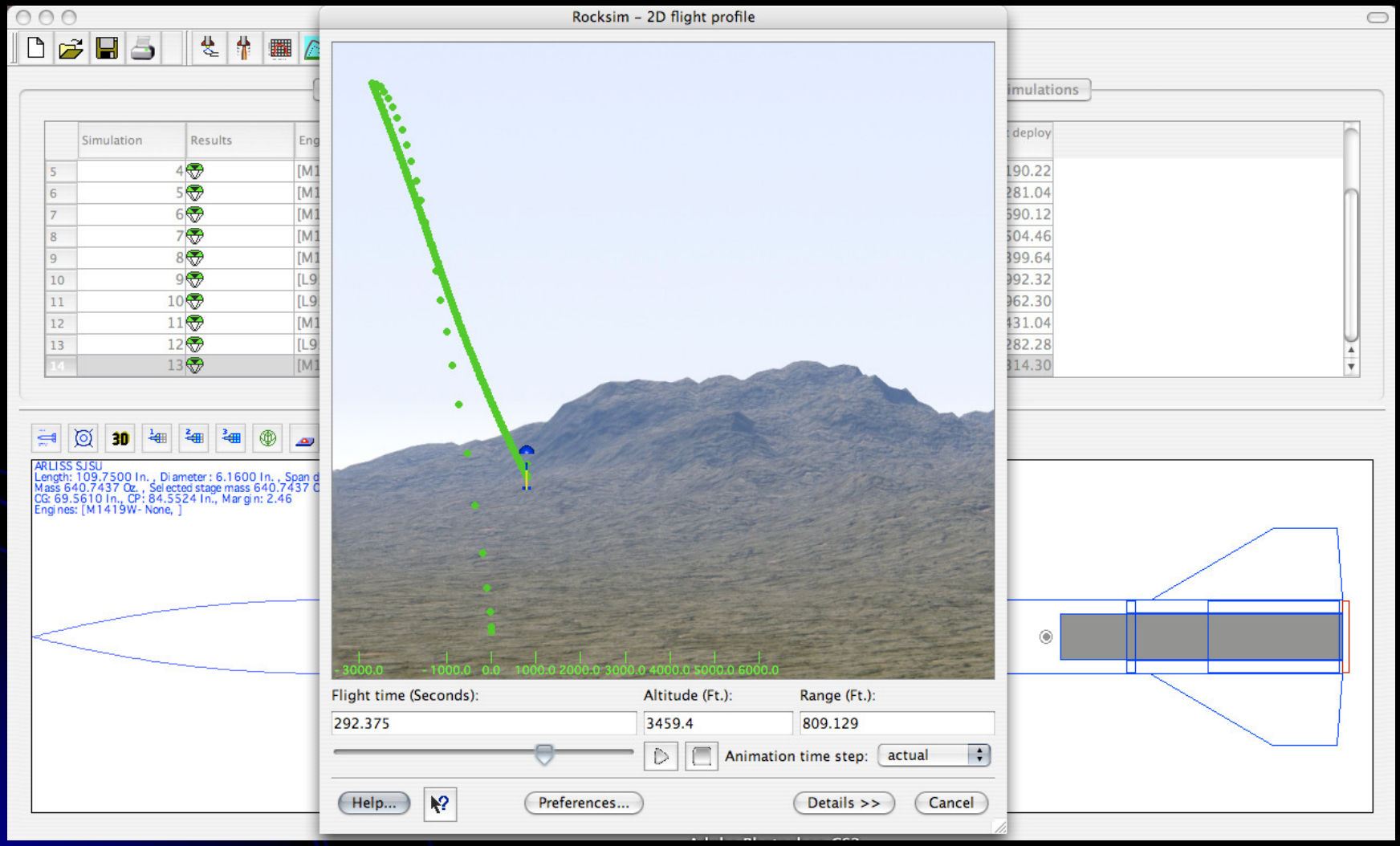
Step 3: Run simulation.



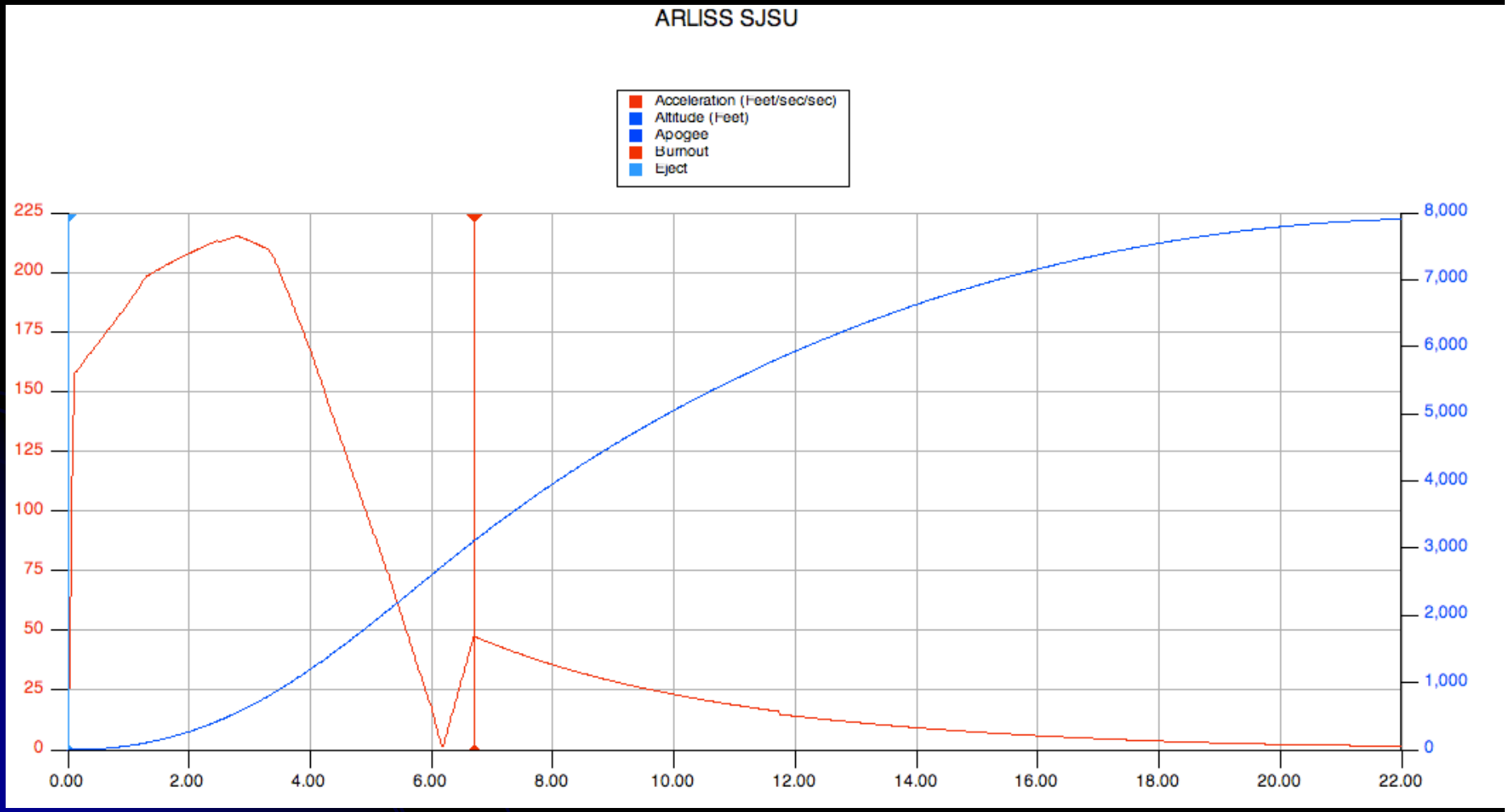
	Simulation	Results	Engines loaded	Max. altitude Feet	Max. velocity Feet / Sec	Max. acceleration Feet/sec/sec	Time to apogee	Velocity at deploy Feet / Sec	Altitude at deploy Feet
5	4		[M1419W-None	11190.22	1003.75	232.39	25.38	8.13	11190.22
6	5		[M1419W-None	10281.04	969.63	227.81	24.13	6.83	10281.04
7	6		[M1419W-None	10690.12	987.43	230.17	24.69	33.18	10690.12
8	7		[M1419W-None	9504.46	937.16	223.81	23.05	13.47	9504.46
9	8		[M1419W-None	13399.64	1069.07	240.66	28.33	8.43	13399.64
10	9		[L952W-30]	8992.32	783.54	186.48	24.41	11.72	8992.32
11	10		[L952W-30]	8962.30	783.50	186.56	24.37	35.13	8962.30
12	11		[M1419W-None	12431.04	1048.83	237.80	27.04	67.40	12431.04
13	12		[L952W-None]	8282.28	767.04	183.43	23.28	75.39	8282.28
14	13		[M1419W-None	12314.30	1048.95	238.01	26.90	90.48	12314.30

RockSim

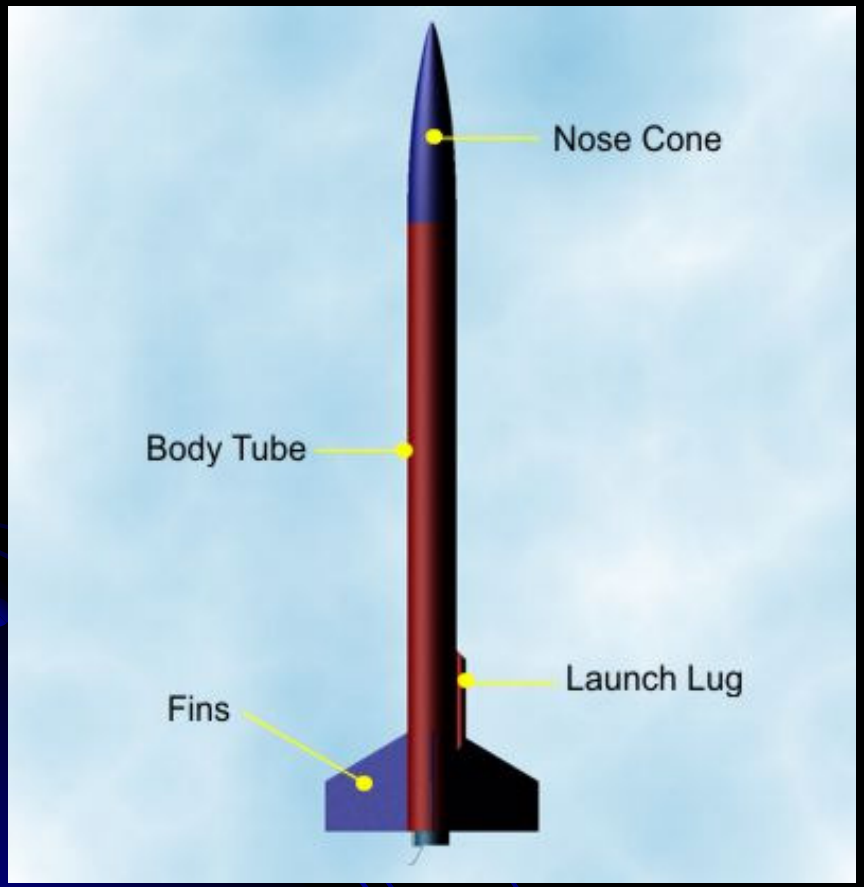
Step 3: Run simulation.



Rocksim estimated graph of altitude and acceleration



Main Parts of Rocket

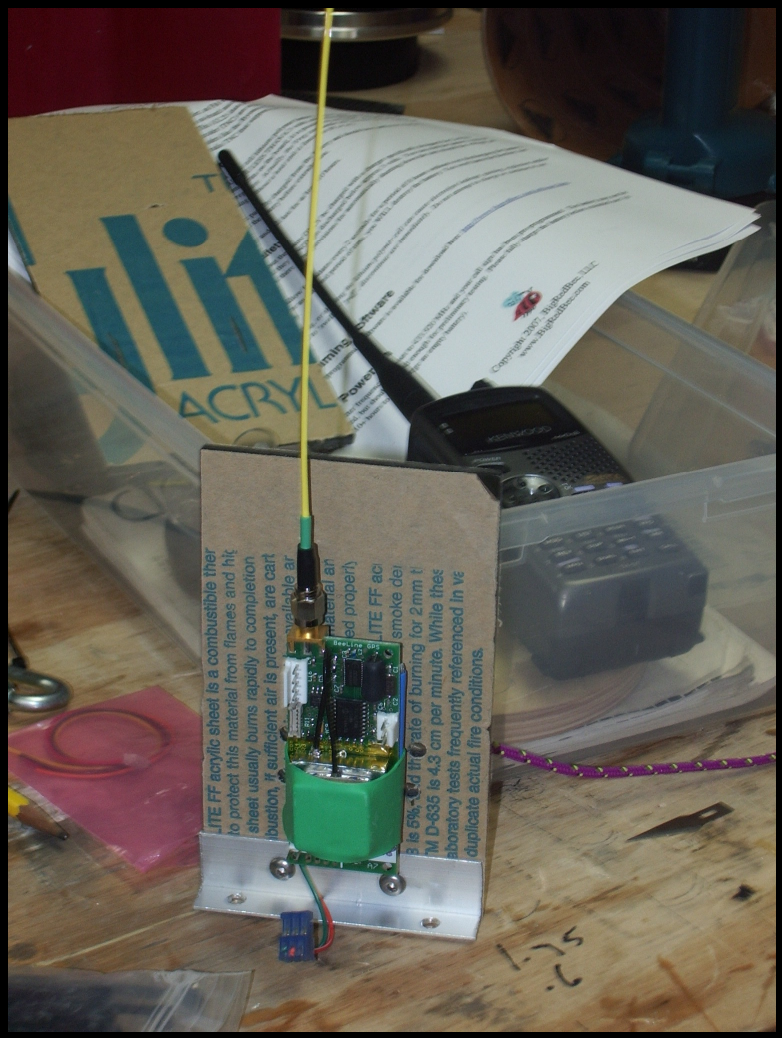


- Nose Cone
  - Parachute
  - GPS
- Body Tube
  - Cansat carrier
  - Electronics Bay
  - Coupler tube
- Booster Frame/Fins
  - Coupler tube
  - Motor


SAN
JOSE STA

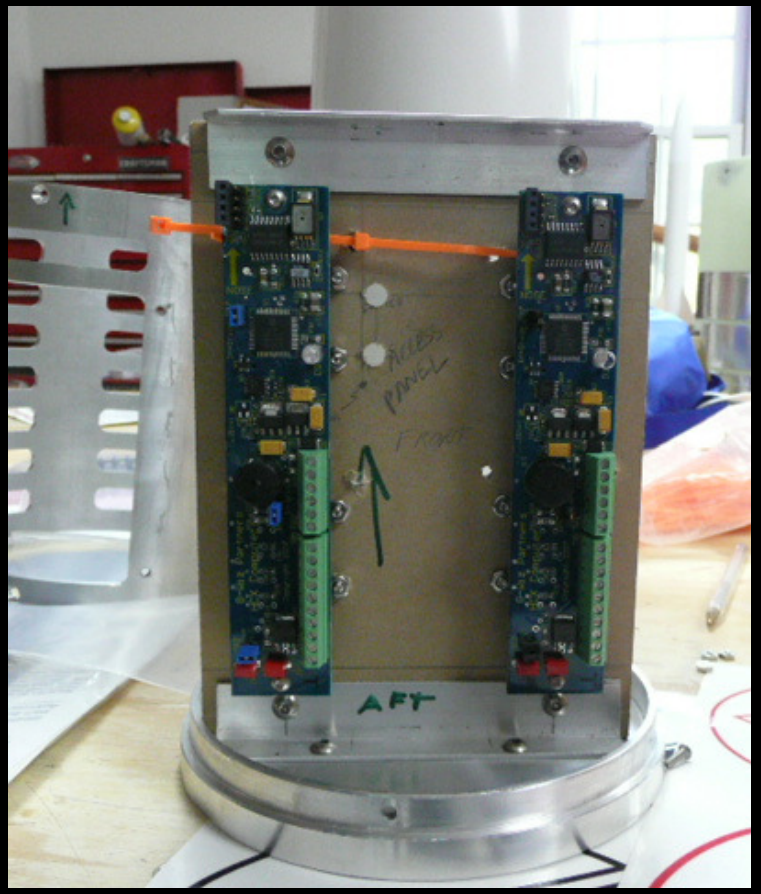
Rocket Electronics

- 1x BeeLine GPS Transmitter
  - Mounted inside the plastic RF-transparent nosecone
  - Transmits data on 70cm HAM radio band
  - Uses the Automated Packet Reporting System (APRS) protocol to communicate with a Kenwood TH-D7A receiver
  - Transmits altitude, latitude, longitude, heading, and speed
  - Range of up to 20 miles line-of-sight
  - On-board memory to store in-flight data

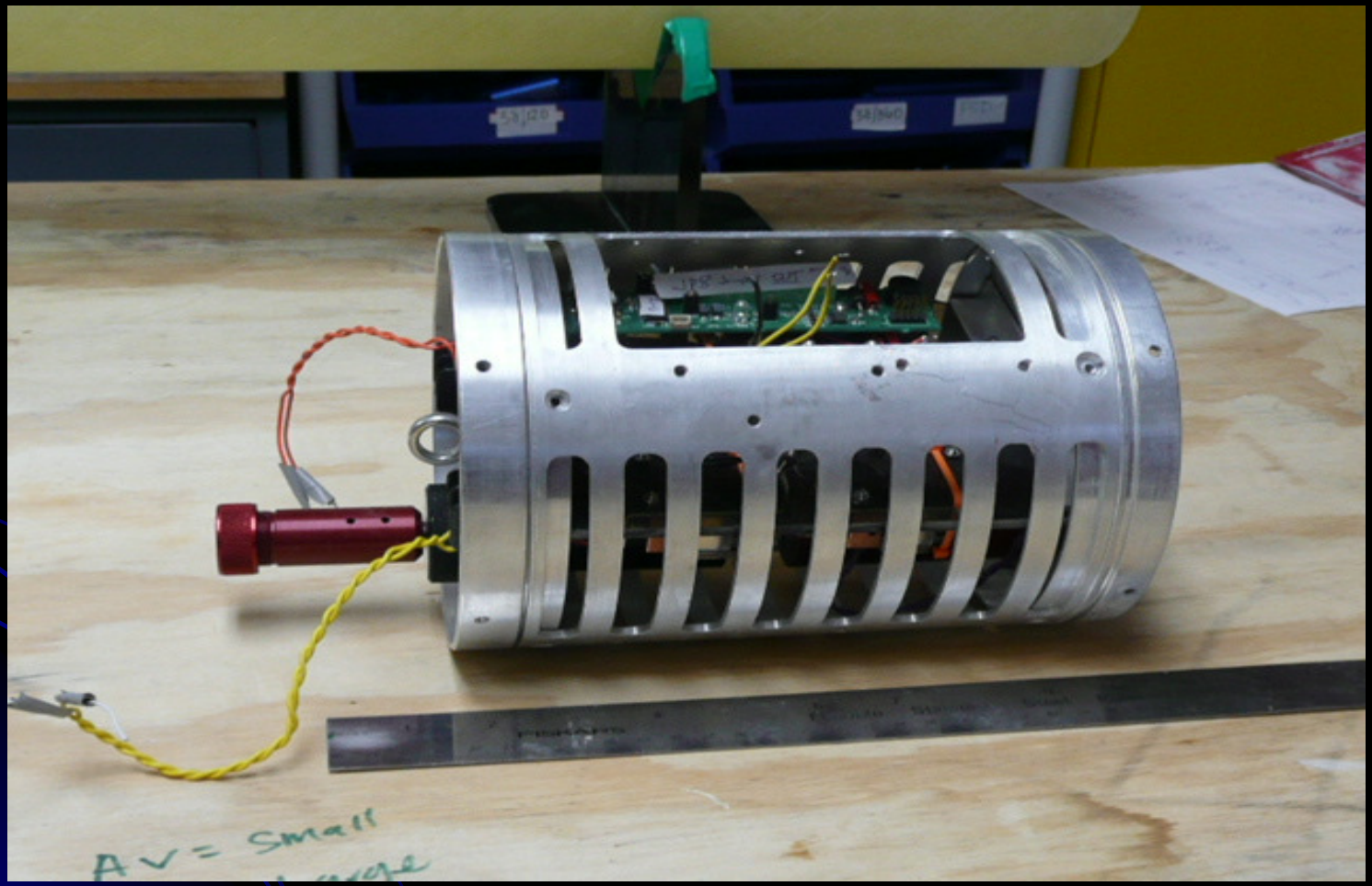


Rocket Electronics

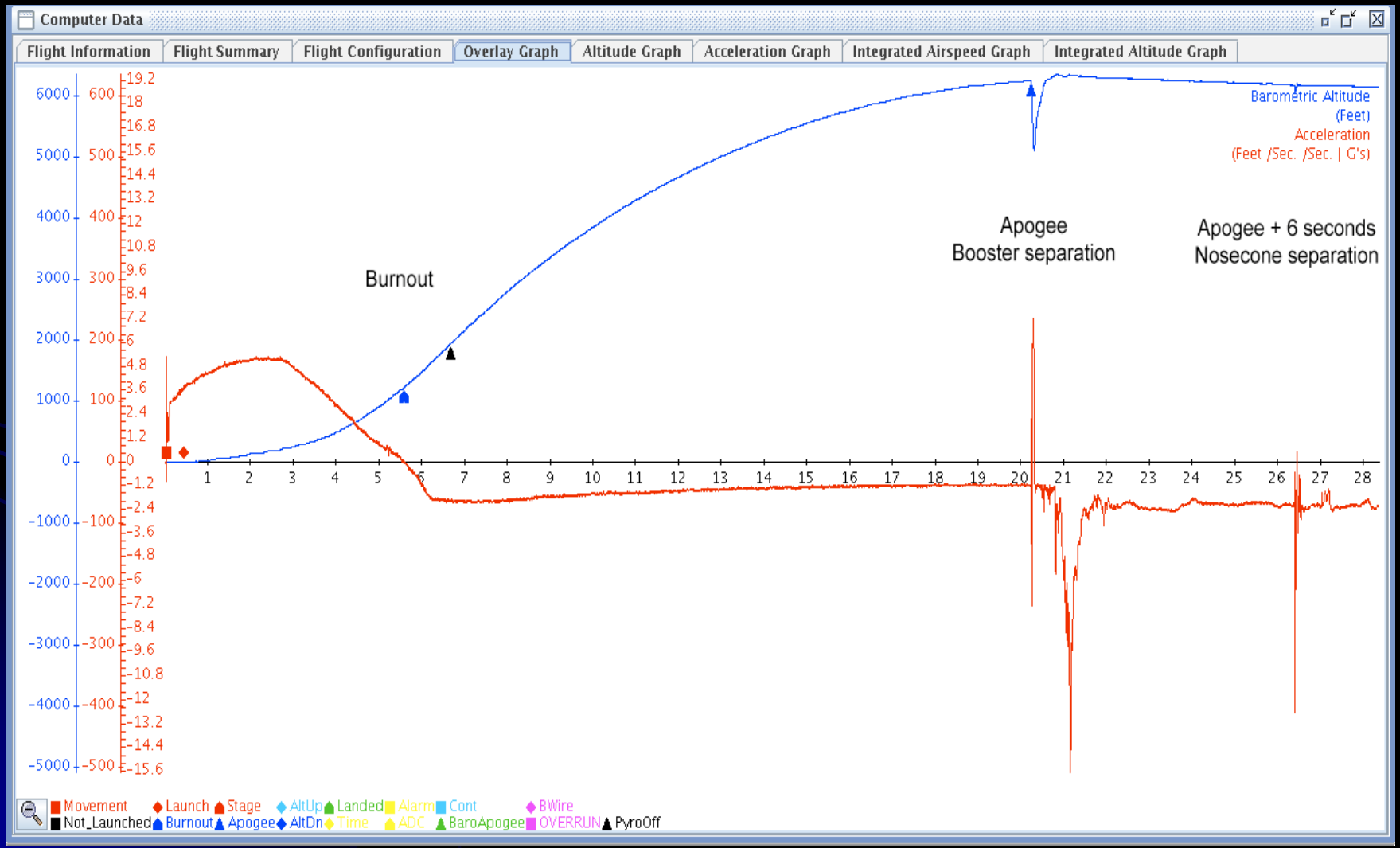
- **2x G-Wiz HCX/50 Flight Computers**
  - **Operate simultaneously to provide redundancy**
  - **Records acceleration and barometric data**
  - **Apogee is detected via accelerometer**
  - **Fires main CO_2 ejection system at apogee to separate booster**
  - **Fires secondary CO_2 charge 6 seconds after apogee to separate nosecone and CanSat carrier.**
  - **Computers and ejection system are powered by four 9V Duracell batteries**



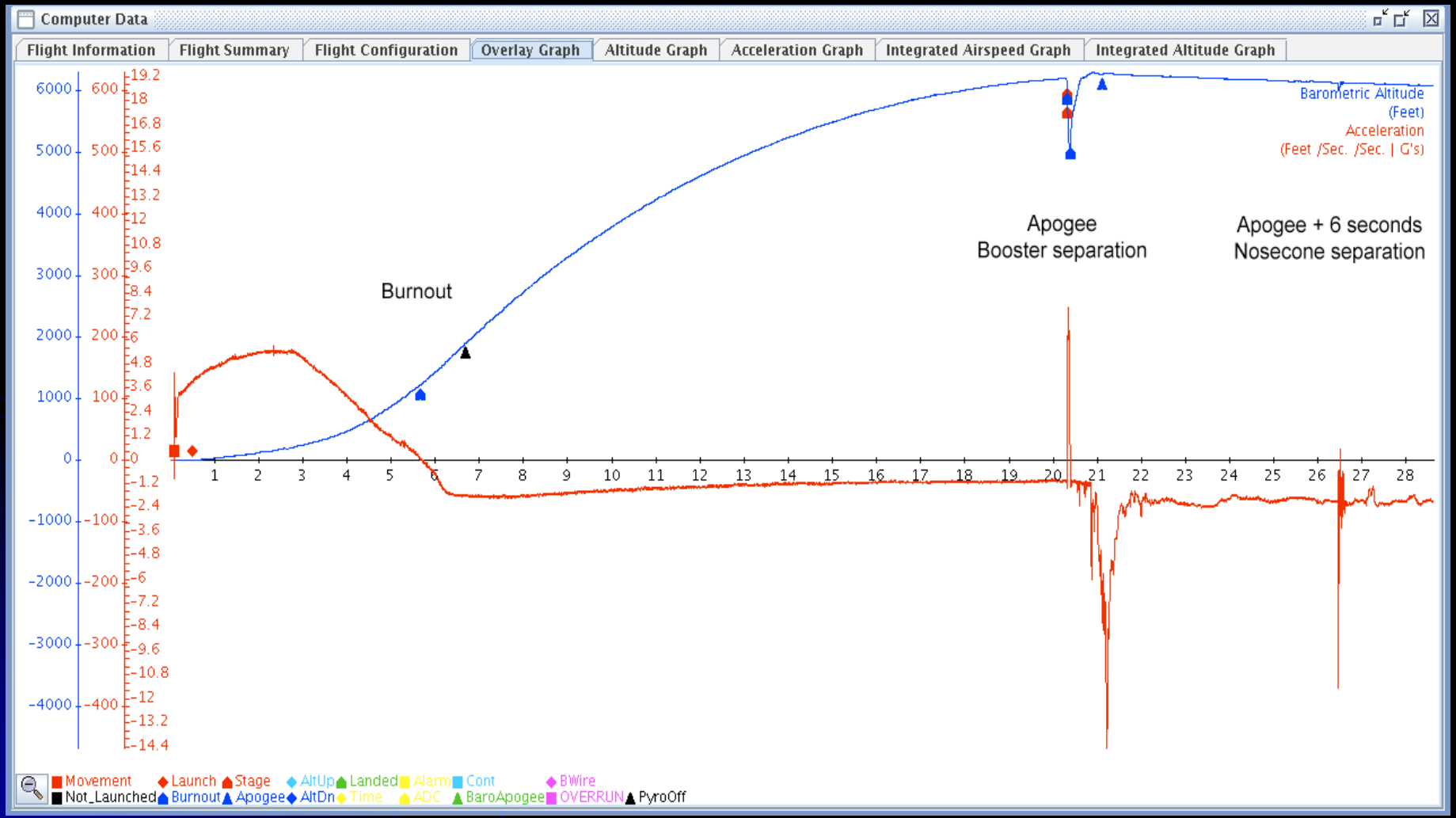
Electronics Bay



Acceleration and altitude versus time from flight computer 1



Acceleration and altitude versus time from flight computer 2



	Computer 1	Computer 2	Discrepancy
Max altitude	6302.0	6269.0	0.5%
Max airspeed	636.0	675.4	6.1%
Max Mach	0.57	0.61	7.0%
Alt. of max. airspeed	2081.7	2233.0	7.3%
Time to apogee	20.2	21.1	4.5%
Time to burnout	5.6	5.7	1.8%

Conclusions

	Simulation 1	Simulation 2	Simulation 3	Actual	CFD
Weight (lbs)	35 lbs	35 lbs	35 lbs	35lbs	-
Cd @ 500ft	-	-	-	0.092	0.071
Max altitude (ft)	7913	7711	6318	6302	-
Max velocity (ft/s)	767	723	671	636	-
Max acceleration (ft/s2)	183	172	164	170	-
Time to apogee	23.3	22.8	20.3	20.3	`

Dimensions of the Arliss Rocket

Total Thrust	952 N
Propellant Weight	2650 gm
Burn Time	6.2 s