Team Orbit Rocket Design Report
Wisconsin Space Grant Competition 2013

1. **Objective**: LCCC's Team Orbit will research & build a rocket capable of SAFELY reaching 3,000 ft altitude when launched from the competition site near Milwaukee, Wisconsin. The team will share their experiences and knowledge with other students in the Northeast Ohio area encouraging them to look at rocketry as a science. On April 26th and 27, 2013, the team will launch their rocket to the exact height of 3,000 feet and recover the rocket intact and capable of another flight using a 38mm diameter I540 CTI solid rocket propellant motor. The team will collect data during the flight, analyze the performance of the rocket against computer models and test results, and report the results to the competition committee.

2. Team Members and Roles

2.1. The team has 7 members and an advisor. The travel team that will be in Wisconsin consists of two team members: Pete Buca and Marlin Linger.

2.2. Members are:

a) Pete Buca - Captain TRA #14213 Level 1 Certification
b) Marlin Linger - Advisor / Safety Officer
c) Dan Bihary - Student
d) Mike Torres - Student
e) Scott Fraser - Student
f) Doreen Summersbee - Student
g) Dan Augustin - Student
h) Bob Hill - Student

2.3. Team Orbit Photograph

3. Addressing the Engineering Challenge

High Power rockets are capable of flying to great heights. Recently, one launch reached over 100,000 feet. A launch to 3,000 feet would seem a simple thing to do. As we learned in this project, there was a lot more to think about to reach the exact height of 3,000 feet than we expected. This report details the learning we gained but we think it is important to explain the crux of the challenge and why is was such a fun engineering problem.

To fly over 3,000 feet on an I540 motor is relatively simple. If that were the requirement, the team would have quickly been able to construct any number of rockets capable of such a flight. In order to fly EXACTLY 3,000 feet, however, the team had to know much more about the rocket than we imagined. We first had to understand the flight profile of the rocket that we would choose. We needed to know what the exact static Cd was for our rocket. We had to understand the velocity profile during the proposed flight to be certain the rocket was stable and not too susceptible to the effects of wind or weather. We could not pick a rocket that need so much weight added that it would be unstable in a wind gust. We needed to know if the rocket would be exceeding the speed of sound in flight because if that were the case it needed to be far more sturdily built. When the rocket reached apogee, how would we recover it before it landed in a tree or a pond or a road? How could we safely bring the rocket down as close a possible to the launch site?

We learned that designing a rocket for any mission requires the balancing of many, many, factors. Thrust, weight, drag, Center of Pressure, Center of Gravity, force generated by Pyrodex propellant – how the grind size of the propellant affected ignition delay and discharge force. These things and many more were studied and partially mastered by the team. We learned from books. We learned by asking questions of experts in our rocketry club, Skybusters. We learned from YouTube. We learned from trial and error during testing. We understood that of all the factors we could manipulate, weight was perhaps the simplest. All the learning we achieved is wrapped inside a six foot tall paper tube painted in the colors of our school. It is our sincere belief that we will demonstrate the degree and success of our learning experience on April 27th in Wisconsin.

How did we solve the problem? We studied many different rocket designs and simulated flights with RockSim. We built 4 Mark IV rockets, a HyperLOC 300 rocket, and an Excel 38mm rocket. These rockets represented the most durable, reliable, and suitable designs we could find. We then launched them and studied the results. The Mark IV was a great rocket but simulations said the Cd was too high to reach 3,000 at normal build weight. The HyperLOC 300 was a marvelous flyer with a low Cd – too low. It would get close to Mach 1 if we weren't careful. If we only used weight to bring it down to 3,000 feet, we would have almost double its normal flight weight. The Excel was our Goldilocks rocket. It has wonderful flight characteristics and would only have to carry an extra pound or two to trim it to exactly 3,000 feet. It's nosecone and upper body are great locations to stow heavy modeling clay. It's test flight – normally loaded – flew within a few feet of prediction 3,552 ft vs 3,500.

4. Analytical Tools

4.1. The team's primary tool for simulating rocket flight and determining rocket Cp was RockSim 9.0 by Apogee Rocketry. RockSim 9.0 has also been used to analyze flight results and estimate true static Cd of various rocket designs examined in this competition.

4.2. Featherweight Interface Program (FIP) from Featherweight Altimeters, the maker of the Raven 3, was also used to extract data from the Raven 3 computer.

4.3. Excel, Word, and OpenOffice were used to prepare graphs and reports in the course of this project.

5. Safety Requirements

5.1. Average Thrust to Weight Ratio

a) The Team Orbit rocket will maintain an average thrust to weight ratio exceeding 5.0 with I540 installed and weighted to accomplish the 3,000 foot altitude objective.

b) All rockets considered in the design phase of this project exceed a ratio of 10.0 with the I540 motor.

5.2. Stability

a) Static

- All designs considered for use by Team Orbit maintain Cg positions forward of the Cp position by one or more body diameters. Only statically stable kit designs were considered as candidates for rocket selection

b) Dynamic

- The team has set the minimum launch velocity at end of rail to be in excess of 75 feet/sec. For all kits considered, this minimum velocity assures that the fins will be in full aerodynamic control of the rocket's flight BEFORE the rocket leaves its rail.

5.3. Safety Officer

a) Marlin Linger will act as Safety Officer for all test flights, live testing, and competition flights. In this capacity, the following activities MUST receive Marlin's approval prior to execution. This protocol will be assured through use of a checklist with critical safety steps requiring the Safety Officer's initials.

- Critical Safety Steps requiring approval of Safety Officer PRIOR to progressing to the next step in the Safety Checklist.
  - Pre-flight Rocket Check Completion
  - Pre-flight Motor Check Completion
  - Rail Mount
  - Electronics Arming
  - Ignitor Placement and firing system attachments
  - Launch
  - Post-Launch preparation for examination
  - Lessons Learned Review

b) Safety is considered the responsibility of everyone on the team. All team members are expected to contribute to a safe design, build, and launch process for the team, volunteers, competitors, and spectators at the event.

5.4. Safety Checklist

a) The team will use the attached **Safety Checklist (see Appendix A:)** as a mandatory part of the flight regime
b) Any knowledge gained that will positively affect Safety directly through launch experiences of the team or observations made of other team's launch experiences will be documented and incorporated into the Safety Check List prior to the next launch.

5.5. Rocket Arming and Error Prevention Protocols

a) Team Orbit adopts the use of a red streamer attached to the surface of the avionics bay of the rocket to indicate that the avionics of the rocket are prepped for launch AND the electronics are in the "OFF" position.
b) Once the rocket is installed on the rail and prepped for launch, the avionics will be turned on and the team will establish audio and visual queues to confirm they are on and ready for launch. At that point and not before, the red streamer will be removed from the rocket indicating that is ready for launch with fully functional avionics.

6. Rocket Selection Criteria

6.1. The team determined that commercially available kits were likely to meet the competition criteria. Rather than design its own rocket, the team decided that its strategy would be to analyze kits available for suitability and select from among them to get the competition rocket.

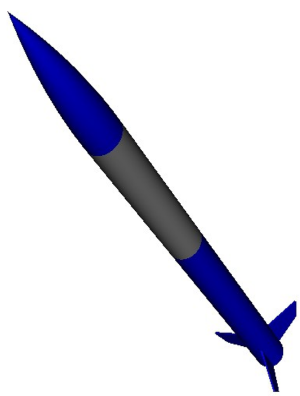
6.2. Lorain County Community College's rocket program has been using the LOC/ Precision Mark IV rocket design in its construction and flight program for approximately one year. The program has built and flown 4 of these rockets and has extensive data on their performance.

6.3. Criteria for selection of the competition rocket kit

a) 72 inches or less in total length from base to rocket nozzle tip
b) 38 mm or 54 mm motor mount (with adapter)
c) 4 inch diameter body or less
d) Capable of reaching 3,250 or more with an I540 motor
e) Capable of trimming altitude to 3,000 by addition of weight to rocket that would increase total rocket weight by 33% or less
    - This criteria was established to avoid excessive weighting of rockets thereby reducing overstability that could lead to weathercocking difficulties
f) Robust, durable, and aerodynamically efficient design
g) Subsonic operation
h) Proven design
i) Off the rail velocity of 75 feet/sec or more

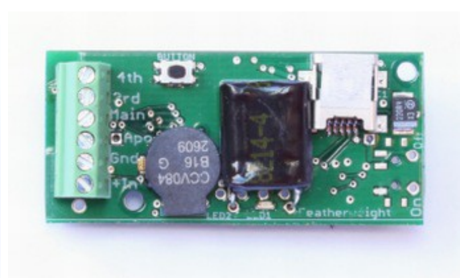
6.4. Rocket Selection

a) The reader is invited to examine Appendix B: Comparative Rocket Analysis to follow the team's process for rocket selection.
b) Based on the process illustrated in Appendix B, the team selected the Binder Designs Excel 38mm Rocket Kit with avionics bay as their competition platform.
c) **Excel 38mm Rocket**:
Key Features: Length 72”, 4”dia, Motor 38mm, Weight w/o Motor ~5.5 lbs.



7. Electronics

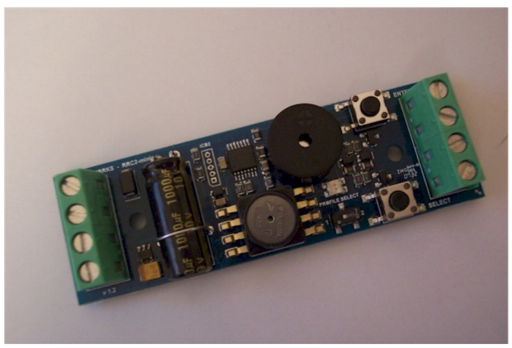
7.1. Raven 3 Flight Computer



a) The Raven 3 Flight Computer is the standard control and data acquisition system selected for the Wisconsin competition. Prior to this event, Team Orbit has had no experience with the Raven 3 so the team procured a system and incorporated the use of the Raven 3 into its test and flight program.
b) The Raven 3 is designed and manufactured by Featherweight Altimeters, Inc. and is available from multiple online sources including Aerocon Systems. Web links to both Featherweight Altimeters and Aerocon are provided below for reference
    - www.featherweightaltimeters.com
    - www.aeroconsystems.com

c) Raven 3 Specifications
- •400 Hz axial accelerometer, +/- 70 Gs
- •200 Hz lateral accelerometer, +/- 35 Gs
- •250 G single-axis accelerometer available as an option
- •20 Hz Baro data, +/- 0.3% accuracy!
- •20 Hz voltage on each of 4 deployment outputs
- •40 Hz output current
- •20 Hz high-precision temperature sensor
- •20 Hz for All flight events used for deployment logic.
- •Flight counter
- •All output program settings
- •Accelerometer calibrations used during the flight
- •Pad altitude ASL
- •8 minutes of high-rate data+ 45 minutes for each flight. The newest 5 flights are stored.

7.2. MW RRC2 Backup Altimeter



a) Prior to the 2013 Wisconsin competition, Team Orbit has used the Missile Works RRC2 altimeter for both data collection and dual deployment control. The team has had good experience with the RRC2 and has developed a good understanding of its behaviors and proper use. All test flights made so far by the team have used the RRC2 as the main control and we have incorporated the Raven 3 as a backup/data collection device to improve our understanding of the Raven 3 characteristics.

b) For the Wisconsin competition, the team will use the Raven 3 as the main control/data collection system but will also fly the RRC2 concurrently as a data backup.

c) Missle Works RRC2 Specifications
- Operational range 0-40K MSL Dimensions 1" W x 3.15" L
- Arming mode barometric Nominal Battery load 6-14ma
- Minimum altitude for arming 250 ft. AGL Output current (sinking) 5A @ 0.5 sec
- Battery/Power range 9V / 7-10V Continuity current 9µa
- Weight 17 grams

7.3. Avionics Switch Selection & Operation

a) During testing for the competition, the team investigated multiple switch systems including externally mounted rocker switches, externally mounted push button switches, and externally mounted rotary switches.

b) While our best results were achieved with the rocker switches, the team prefers the action and lighted response it gets from the push button switch. For the competition, Team Orbit will use an internally mounted lighted push button switch to achieve the benefits of the push button while eliminating the potential for an inadvertent switch off event to which externally mounted push buttons can be prone.

8. Testing

8.1. Rocket Tests

a) Three different rockets were actually launched during the process of rocket selection. Appendix C: Flight Test Results LOC/Precision Mark IV Rocket has data on the second place candidate rocket, the Mark IV.

b) The Team Orbit Excel 38mm Rocket was flight tested on April 6th, 2013 at the Skybusters rocket launch in Amherst, Ohio. The rocket was flown with an I540 motor using a 13 second delay on the motor ejection charge as a backup to the drogue chute deployment charge under the control of the MW RRC2 altimeter. The Raven 3 was on board and powered during the flight. Data from the flight and pre-flight simulations are presented in Section 8 of this report, The Team Orbit 38mm Rocket.

c) One additional day of testing is scheduled for April 20, 2013 also at the Amherst field with Skybusters. The plan is to launch the completed, painted, competition-ready rocket on an I540 motor with full competition weight. The team will use the complete procedure including Safety Checklist and may modify the Checklist if improvements are identified.

8.2. Motor Tests

a) No ground motor tests were performed in preparation for this competition. During flight testing, Mark IV rockets were flown with CTI H125 and H120 motors to calibrate the static Cd of that design. The excel design was flown on an I540 engine and performed exactly according to the prediction of the RockSim 9.0 simulation.

b) Motor data was taken from RockSim 9.0 data tables and agreed well with observed performance.

8.3. Avionics Tests

a) The Raven 3 computer was calibrated and tested prior to use.

b) As noted, the Raven 3 was flown multiple times in test as a secondary computer.

8.4. Safety during testing

a) All testing above was conducted in accord with the NRA/TRA safety practices and guidelines.

b) The Safety Checklist included in this report was developed during the conduct of the tests described above.

8.5. Excel Test Video Link:

http://www.youtube.com/watch?v=A_jBqipB4u0&feature=youtube_gdata

9. The Team Orbit Excel 38mm Rocket

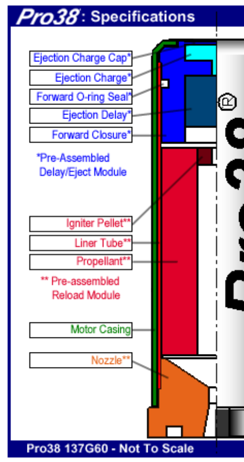
9.1. RockSim 9.0 Summary Report

a) Orbit Excel 38mm Competition Rocket - Simulation results

- Engine selection
  - [I540WT-13]
- Simulation control parameters
  - Flight resolution: 800.000000 samples/second Descent resolution: 1.000000 samples/second Method: Explicit Euler End the simulation when the rocket reaches the ground., Weight 7.27 pounds.
- Launch conditions
  - Altitude: 650.00000 Ft. Relative humidity: 50.000 % Temperature: 59.000 Deg. F Pressure: 29.5891 In.
  - Wind speed model: Light (3-7 MPH)
  - Low wind speed: 3.0000 MPH High wind speed: 7.9000 MPH
  - Wind turbulence: Fairly constant speed (0.01)
  - Frequency: 0.010000 rad/second Wind starts at altitude: 0.00000 Ft. Launch guide angle: 0.000 Deg. Latitude: 43.039 Degrees
- Launch guide data:
  - Launch guide length: 72.0000 In. Velocity at launch guide departure: 76.1284 ft/s The launch guide was cleared at : 0.173 Seconds User specified minimum velocity for stable flight: 43.9993 ft/s Minimum velocity for stable flight reached at: 24.8968 In.
- Max data values:
  - Maximum acceleration:Vertical (y): 506.672 Ft./s/sHorizontal (x): 0.904 Ft./s/sMagnitude: 506.923 Ft./s/s Maximum velocity:Vertical (y): 504.7033 ft/s, Horizontal (x): 6.6965 ft/s, Magnitude: 504.8532 ft/s Maximum range from launch site: 279.19011 Ft. Maximum altitude: 3000.54630 Ft.
- Engine ejection charge data:
  - Using a delay time of : 13.000 Seconds Velocity: 26.2653 ft/s Altitude: 2988.90890 Ft.
- Recovery system data
  - P: Parachute Deployed at : 13.318 Seconds Velocity at deployment: 8.5424 ft/s Altitude at deployment: 3000.54630 Ft. Range at deployment: -110.21302 Ft.
- Time data
  - Time to burnout: 1.181 Sec. Time to apogee: 13.318 Sec. Optimal ejection delay: 12.136 Sec.
- Landing data
  - Successful landing Time to landing: 81.715 Sec.

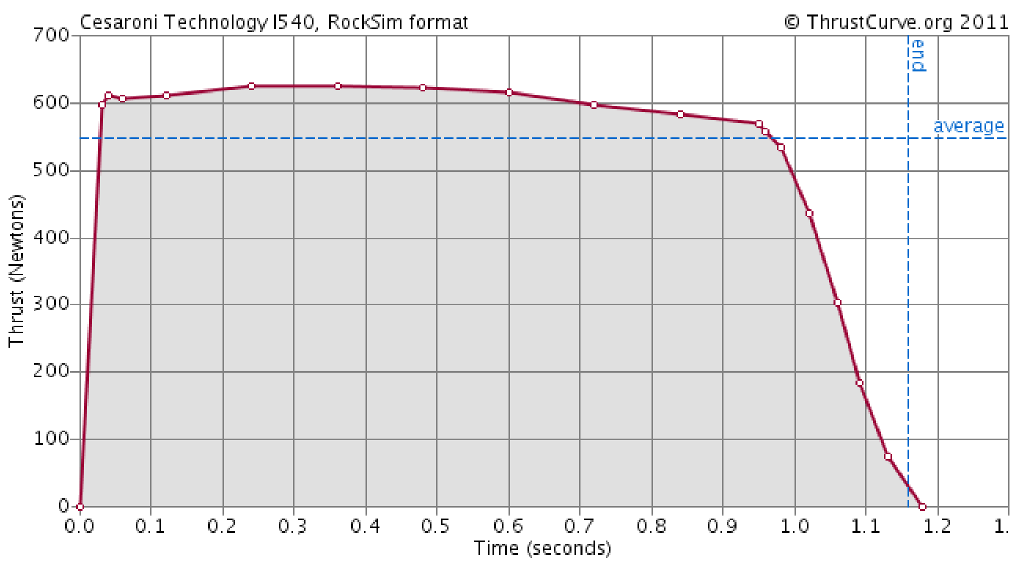
9.2. Design Details

a) CTI Pro38 Motor Tubes will be used with dual bolt, washer retainer system.



b) Cesaroni Technologies 634I540-16A Motor Data

ThrustCurve Motor Performance Graph



Statistics	Declared	Calculated	Official
Diameter (mm):	38.0		38.0
Length (cm):	36.7		36.7
Prop. Weight (g):	328.8		—
Total Weight (g):	598.2		—
Avg. Thrust (N):	537.8	548.3	540.0
Max. Thrust (N):	626.0	626.0	—
Tot. Impulse (Ns):	634.6	634.6	634.6
Burn Time (s):	1.2	1.2	1.2

c) Shock Cord and Attachments
- Shock cords used in the Team Orbit Rocket are ade from 1/2" wide tubular Kevlar. This gives it tensile strength similar or better than the metal connection points used and provides a fireproof solution with enough stretch to cushion ejection forces and prevent rocket body damage.
- All metal attachments are open loop metal eyelets reinforced at their open point with epoxy glue. We have never had a failure in an open loop attachment point.
- All parachutes are attached to 800 lb swivels to prevent winding and tangling of the chutes after ejection.
- Shock cords are 12 feet in length and two (2) are used in the rocket, one in the lower body and one in the upper body.

9.3. Parachute Selection

a) Staging considerations
- The droque chute will be staged in the lower body with the main in the upper body.
- Separate charges are set for each chamber while the main motor charge is retained as a backup for the drogue deployment.

b) E-match & ejection charges
- Commercial ignitors are being used for both applications.
- In the case of the ignitor, we are using the CTI supplied units, for the e-matches on the avionics bay, we are using units supplied by LOC/Precision.

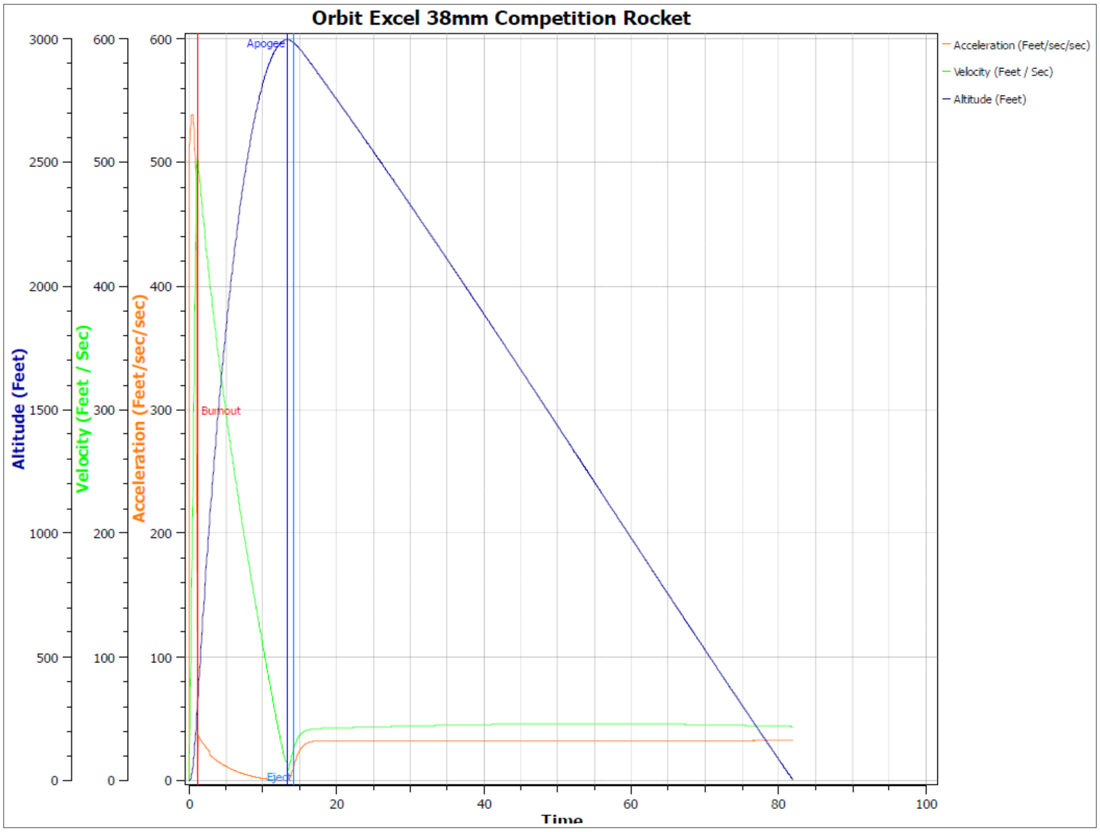
c) Redundancy Provisions
- The rocket will be mounted with a Raven 3 flight computer and a MWRRC2 Mini altimeter to provide redundant data sources.
- We may mount an additional Raven 3 subject to review with the competition committee.

9.4. Safety

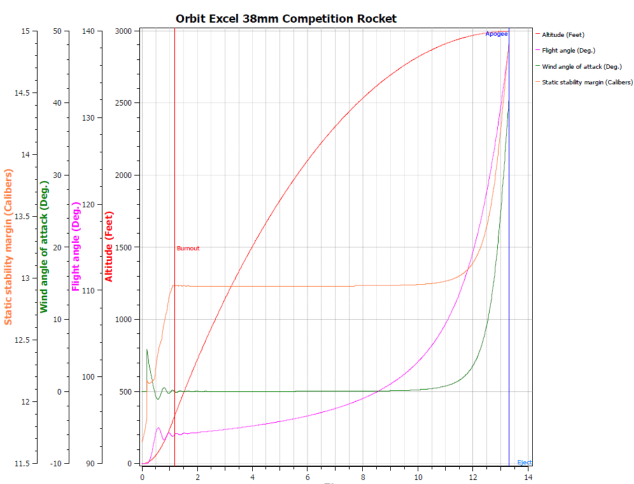
a) Average Thrust to Weight Ratio
- At 540N average thrust and a flight weight predicted to be 7.2 lbs. The average thrust to weight ration will be:

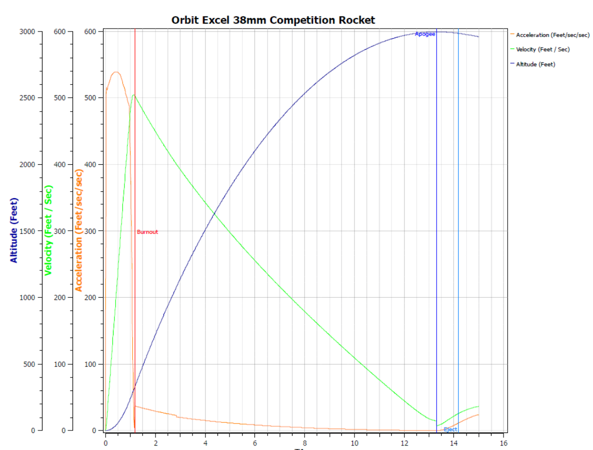
(540 N/ 4.45 N/lb) / 7.27 lbs = **16.69** vs. 5 minimum required

From RockSim 9.0, velocity at end of guide rail will be: **76.13 fps**
Conclusion: Stable liftoff and a safe flight.



Altitude/Acceleration/Velocity Graph 2





Wind Tip Off Analysis Graph 3

Expanded Altitude/Accel/Vel Graph 4

9.5. Color Scheme and Paint

a) LCCC School Colors are Gold and Blue. Team Orbit colors will take these and add a red asymmetric ribbon to separate them. The color pattern on the rocket will be predominantly gold with a blue drape over the nose cone and body. The blue and gold regions will be separated by an asymmetric red ribbon for contrast. Fins will alternate between gold on one sde and dark blue on the other with a Team Orbit logo on each dark blue face.

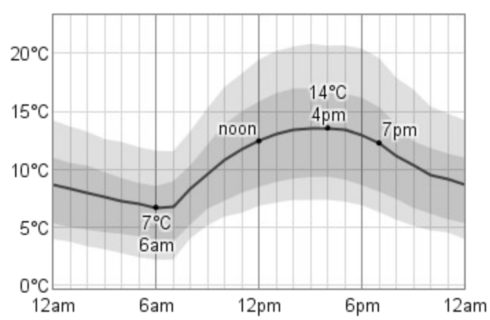
b) Asymmetric patterns have been selected both for style and to assist in the visual tracking of the rocket's rotation.
c) Bright Gold coloration should be helpful with rocket recovery as well.

10. Launch Day Assumptions

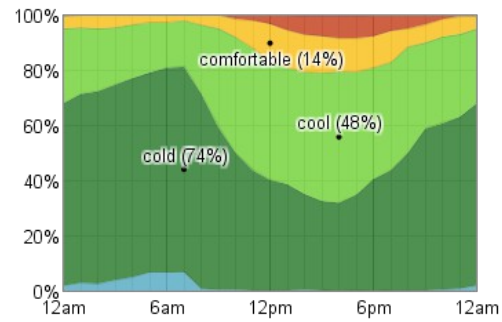
10.1. Conditions: weather data taken from www.weatherspark.com/averages for 4/26

a) Average and Peak Wind Speeds	7-12 miles per hour, +/- 3mph
b) Temperature	59 degrees F
c) Altitude:	650 feet above sea level
d) Barometric Pressure	29.60 inches of mercury

Temperature

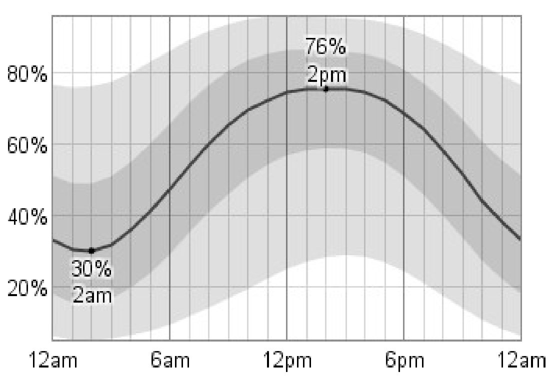


Temperature Bands

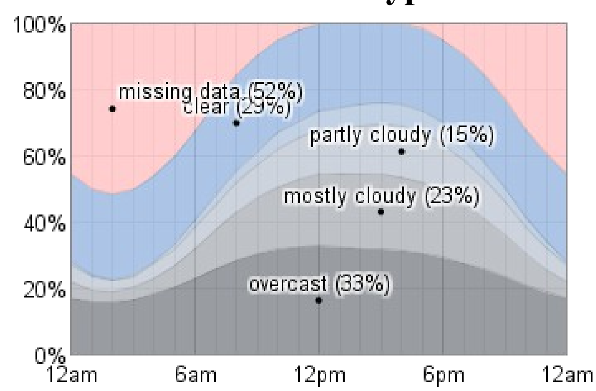


On April 26 the Sun rises at 5:52am and sets at 7:48pm. Solar noon is at 12:49pm.

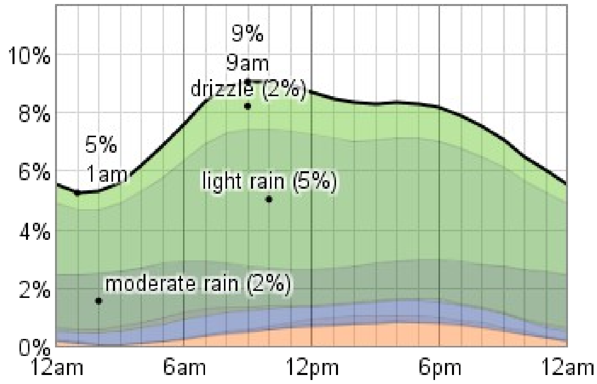
Median Cloud Cover



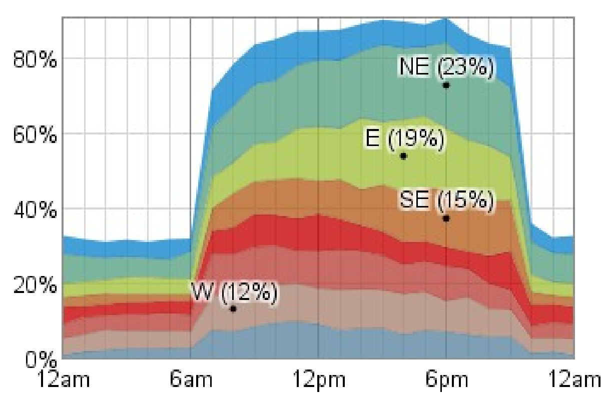
Cloud Cover Types



Average Precipitation



Wind Directions



10.2. Flight Considerations

a) FAA Clearance Confirmation	Obtained by Competition
b) Launch Siting Precautions	Assumed moderately hard landing
c) Topology	Flat, water within 1,500 feet of launch

10.3. Recovery Process & Team — Two person recovery team. Both at launch.

11. Post Launch Report and Analysis

11.1. Goal is to complete report and submit within two weeks after day of launch.

Appendix A: Team Orbit Safety Checklist

S.O. Initials

☐ Pre-Flight Rocket Inspection Completed ________

- ☐ Weights are securely placed and attachments are sound. NO MOVEMENT IS OBSERVED IN WEIGHTS. Shaking the rocket vigorously does not dislodge weights.
- ☐ Avionics Bay prepped and ready with power off. Install red "off" streamer to rocket
- ☐ Fill forward black powder charge tube with 2.5 grams FFFFG Pyrodex propellant
- ☐ Fill aft black powder charge tube with 1.5 grams of FFFFG Pyrodex propellant
- ☐ E-Matches attached to Raven 3 wiring block in correct positions
- ☐ E-matches inserted into black powder charge tubes, wadding stuffed into tubes to hold e-match and black powder in place, tape applied to seal end of tubes
- ☐ 18" Drogue Chute packed and installed properly into lower compartment. Shock cord is attached to eyebolts and flameproof blanket is in place over parachute.
- ☐ 36" Main Chute packed and installed properly into upper compartment. Shock cord is attached to eyebolts and flameproof blanket is in place over parachute.
- ☐ Nosecone is attached to upper body tube with steel screws.
- ☐ Nylon shear pins are installed (2) securing upper body tube to avionics bay with heads of the pins flush with the outer surface of the rocket body
- ☐ Motor tube is EMPTY.
- ☐ Rocket is completely assembled
- ☐ Record rocket pre-flight weight without motor installed (6.6lbs) ____________
- ☐ Record rocket pre-flight length (<=72") ____________
- ☐ Check that Cp is marked on body tube.

☐ Pre-flight Motor Check Completed __________

- ☐ Motor tube has no defects or damage
- ☐ Motor grains are assembled correctly into motor reload
- ☐ Seals appear to be defect free with no damage, soft and pliable
- ☐ Insert motor spacer into motor tube with smaller diameter away from nozzle

- ☐ Motor reload assembled correctly into motor tube
- ☐ Nozzle hand tight in motor tube with 1/16" max gap at shoulder

☐ Two nylon shear pins installed in upper body to nose cone, heads flush ________

☐ Install Motor & tighten both retention bolts behind neck of motor nozzle. ________

☐ Record weight in flight ready condition with motor installed (7.27 lbs) ______________

☐ Determine Cg of rocket loaded for flight with motor installed and mark on body tube

☐ Record Cg to Cp distance measured from Rocket Nose End ______________

☐ Confirm Static Stability (Cg forward of Cp by 4" or more)

☐ **Range Safety Officer Inspection Passed RSO Signature ______________**

☐ Received instructions to mount rocket on rail and prep for launch ________

☐ Record launch rail designated for use ______________

☐ Confirm authorization to mount rocket and prep for launch

☐ Launch team wearing safety glasses and gloves?

☐ Launch team has ignitor with them?

☐ Launch team has long screwdriver to push internal on switch?

☐ Launch area clear for transport

☐ Transport rocket to designated launch area

☐ Ignition switch on launch system is in "**OFF"** position

☐ Confirm that rocket avionics are "**OFF"**

☐ Clear to mount rocket on rail ________

☐ Disengage rail locks and drop rail to horizontal position

- ☐ Mount rocket on rail engaging both rail buttons in rail channel
- ☐ Slip rocket to lowest position on rail while horizontal
- ☐ Raise rail to vertical with mounted rocket at lowest position
- ☐ Lock rail into vertical position
- ☐ Remove yellow plastic cap from motor and slip over the flammable end of the ignitor
- ☐ Insert ignitor into rocket motor until ignitor tip contacts the end of the motor (full insertion)
- ☐ Form tension loop in the ignitor wire forward of the yellow ignitor cap. Push yellow cap over tension loop and onto base of motor. Yellow cap should be firmly in place on release from hand.
- ☐ Separate electrical leads from launch system and attached one at a time to the leads of the ignitor. Clip alligator clips onto the ignitor leads one per lead and wrap ignitor bare copper around alligator clip.
- ☐ Secure launch system leads to the rail below the rocket relieving the strain of the wire weight from the ignitor inserted into the motor.
- ☐ Turn Rocket Avionics and flight control "**ON**"
- ☐ Confirm avionics "**ON**" status by sound and visually, pull streamer __________
- ☐ Turn launch ignition system to "**ON**" position
- ☐ **Clear launch area – ALL TEAM MEMBERS, HELPERS, VISITORS, AND SPECTATORS ARE BEHIND FIRE CONTROL POSITION.**
- ☐ Notify recovery team of flight readiness
- ☐ Check surrounding skies for aircraft, notify Fire Control if aircraft spotted
- ☐ Check photography readiness
- ☐ IF everything is still good, signal Fire Control that team is ready for launch __________

☐ LAUNCH

- ☐ Post-Launch Recovery ________
  - ☐ Photograph location and condition of rocket at place of landing
  - ☐ Record auditory signals from rocket avionics
  - ☐ Note condition of rocket, position of components, interactions with touchdown area,
  - ☐ Retrieve rocket and return to launch area
  - ☐ Submit rocket for inspection by competition committee representative(s)
  - ☐ Reassemble rocket and record rocket weight
  - ☐ Retrieve data from the flight computer(s)
  - ☐ Note repairs necessary to return to flight condition

- ☐ **Lessons Learned Review – safety, performance, teamwork, knowledge**
  - ☐ **What do we keep doing?**
  - ☐ **What do we stop doing?**
  - ☐ **What do we start doing?**

Appendix B: Comparative Rocket Analysis

Kit	Ht.	Motor	Dia.	Alt.	33.00%	Robust	SubSon	Proven	Rail
Mark IV	70”	38mm	4”	N	Y	Y	Y	Y	Y
HyperLOC 300	60”	54mm	3”	Y	N	N	Y	Y	Y
Excel 38mm	72”	38mm	4”	Y	Y	Y	Y	Y	Y
Endeavor 38KS	71”	54/38mm	4”	Y	Y	N	Y	N	Y
MoonRaker	69”	54mm	4”	Y	Y	Y	Y	N	Y
SuperDX3	66.5”	38mm	4”	Y	N	Y	Y	N	Y

Team Orbit Rocket Design Report
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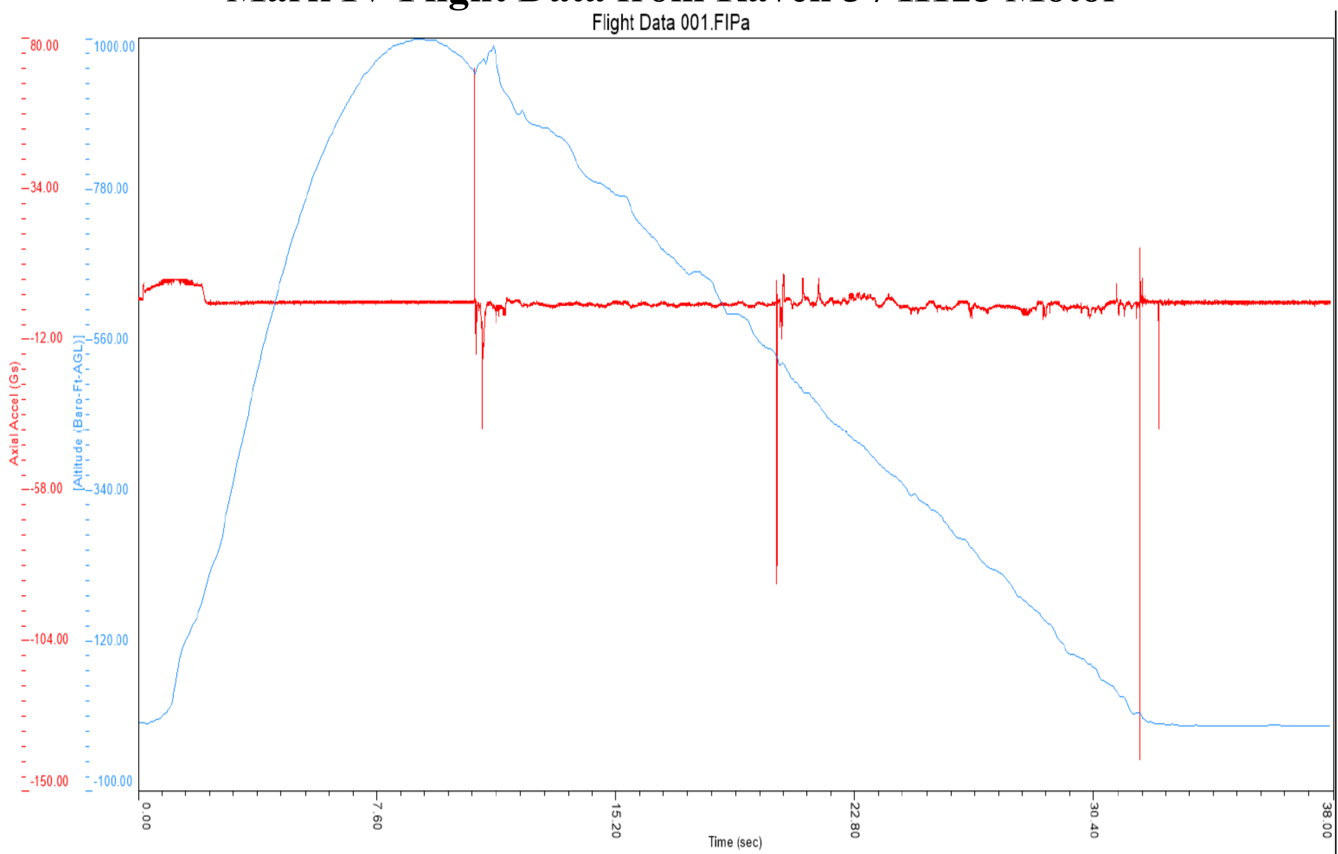
Appendix C: Flight Test Results
LOC/Precision Mark IV Rocket

Mark IV Flight Data from Raven 3 / H125 Motor



Summary Results Mark IV Flight with Raven 3 / H125 Motor

Data	Min/Nominal	Max
Average PreLaunch Altitude (ft)	546	-
Average PreLaunch Axial (Gs)	0.8	-
Average PreLaunch Axial Offset	0.8	-
Axial Accel (Gs)	6.28	-
Baro (Atm)	0.95	0.98
Current Draw (A)	0	0.06
Motor Ignition Time (sec)	0.15	-
Temperature (F)	74.88	74.92
Time (sec)	0	9.78
Velocity (Accel-Ft/Sec)	0	285
Volts Battery (V)	8.28	8.32
[Altitude (Accel-Ft)]	0	930
[Altitude (Baro-Ft-AGL)]	0	999
[Altitude (Baro-Ft-ASL)]	546	1545
[Velocity (Accel-Ft/Sec)]	-111	264
[Velocity (Accel-MPH)]	-76	180