David Antaki
Project RP1
Technical Report

NAR Level 1 & Level 2
Certification Rocket



June 28th, 2019

David Antaki

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APPENDICES

Suffix Key:

D: Appendices that I wrote.
M: Manuals, datasheets, and guides.
R: Rules, regulations, and laws.

Appendix D1 – Budget

Appendix D2 – Receipts

Appendix D3 – Gantt Chart & Schedule

Appendix D4 - Filled Certification Application

Appendix D5 - Altimeter Launch Settings

Appendix D7 – Photos

Appendix M1 - StratoLoggerCF Manual

Appendix M3 - Geox Powder Potassium Nitrate MSDS 2

Appendix M4 - Rocketmaterials.org Sheer Pin Strengths

Appendix M5 - Calculating Shock Cord Length (Apogee)

Appendix M6 - Cesaroni Pro38 Reload Instructions

Appendix M7 - Level 2 Certification Test Question Pool

Appendix M8 - Motor Classes

Appendix R1 - NFPA 1122 2002 Edition

Appendix R2 - NFPA 1127 2002 & 2008 Edition

Appendix R3 - NAR High Power Rocket Safety Code

Appendix R4 - FAA Regulations Part 101

1. EXECUTIVE SUMMARY

High power rocketry requires that individuals obtain certifications from either the National Association of Rocketry or the Tripoli Rocketry Association to launch a rocket with a high-power class motor in it. There are three certifications levels: Level 1 which allows you to launch H and I class motors, Level 2 which allows you to launch J, K, and L class motors, and Level 3 which allows you to launch M, N, and O class motors. Each motor letter specifies a range of impulses (see Appendix M8).

The goal of this project was to safely plan, build, fly, and recover a high-power rocket with a Level 1 class motor in hopes of receiving a Level 1 certification from NAR. If this was successful, I planned to fly this rocket again with a Level 2 class motor in hopes of receiving a Level 2 certification from NAR on the same day.

To maximize my probability for success, I diligently organized, planned, and practiced for this launch. This technical report sought to help in my organization by compiling the materials used, the decisions made, and the steps taken to accomplish this project.

2. TERMS AND ABBREVIATIONS

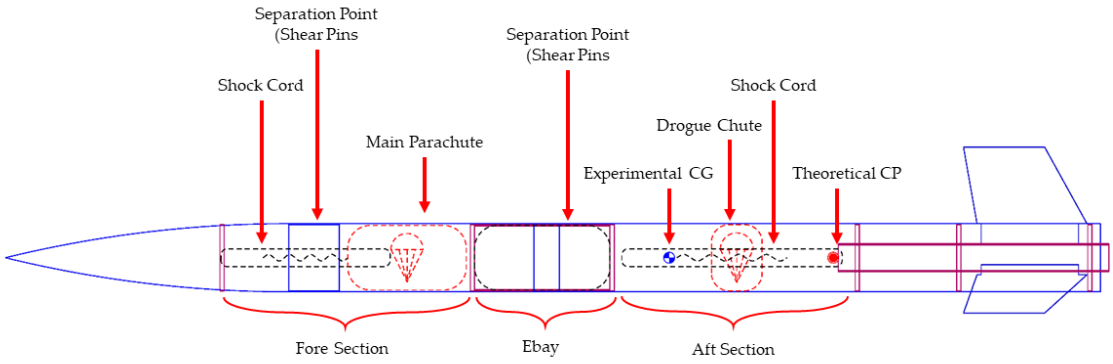
- RP1: For me to know, for only a select few others to know, and for everyone else to never find out.
- NAR: The National Association of Rocketry is one of two governing bodies of sport high power rocketry in the United States. The other being Tripoli Rocketry Association. These organizations oversee sport and hobby rocketry launch sites and certification of its members for flying high power class rockets. There are three certification levels, Level 1, 2, and 3.
- TRA: Tripoli Rocketry Association
- Level 1 (L1): Refers to a Level 1 High Power Rocketry Certification issued by NAR upon successful completion of the certification requirements. Level 1 allows the purchase and use of H and I impulse class motors; solid and hybrid. Certain F and G motors may also require Level 1 certification for purchase and use. These are motors with 160.01 to 640.00 Newton-seconds of impulse.
- Level 2 (L2): Refers to a Level 2 High Power Rocketry Certification issued by NAR upon successful completion of the certification requirements. Level 2 allows the purchase and use of J, K, and L impulse class motors; solid and hybrid. These are motors with 640.01 to 5,120 Newton-seconds of impulse.
- Level 3 (L3): Refers to a Level 3 High Power Rocketry Certification issued by NAR upon successful completion of the certification requirements. Level 3 certification allows the purchase and use of M, N, and O impulse class rocket motors; solid and hybrid. These are motors with 5,120.01 to 40,960 Newton-seconds of impulse.
- High Power Rocketry (HPR): Rocket motors which exceed model rocketry motor definitions and the models that use these motors are collectively referred to as High Power Rocketry.
- National Fire Protection Association (NFPA): The National Fire Protection Association is a United States trade association, albeit with some international members, that creates and maintains private, copyrighted standards and codes for usage and adoption by local governments.
- NFPA 1127: The code in which High Power Rocketry is governed under assuming the state in which you are launching has adopted NFPA Code 1 (“Code for High Power Rocketry”).
- NFPA1122: The code in which Model Power Rocketry is governed under assuming the state in which you are launching has adopted NFPA Code 1 (“Code for Model Rocketry”).

- Ebay: Stands for electronics bay or avionics bay and is where the flight controllers/altimeters are housed to control when to fire the ejection charges. Known as "firing circuits" in NFPA 1127.
- Animal Motor Works (AMW): A sport rocketry retailer whom AeroNU has had a relationship with for a few years.
- AeroNU: The name of the rocketry and drone club at Northeastern. A chapter of AIAA and formally known as "AIAA" at Northeastern.
- American Institute of Aeronautics and Astronautics (AIAA): The American Institute of Aeronautics and Astronautics is a professional society for the field of aerospace engineering.
- Federal Aviation Regulations (FAR): The FAA's regulations for aviation. High Power Model rocketry is governed under the FAR Part 101 ("Amateur Rockets") section.
- NAR Safety Code: The safety code all members of NAR must abide by.
- Dog Barf: A cellulose, insulation type stuffing treated with fire retardant. It is stuffed into the charge blast caps over the black powder to prevent the black powder from leaking out.
- CG: Center of Gravity
- CP: Center of Pressure

3. ROCKET DESIGN

3.1 OpenRocket Design

Length: 65.25 in



3.2 CAD Model & Renders

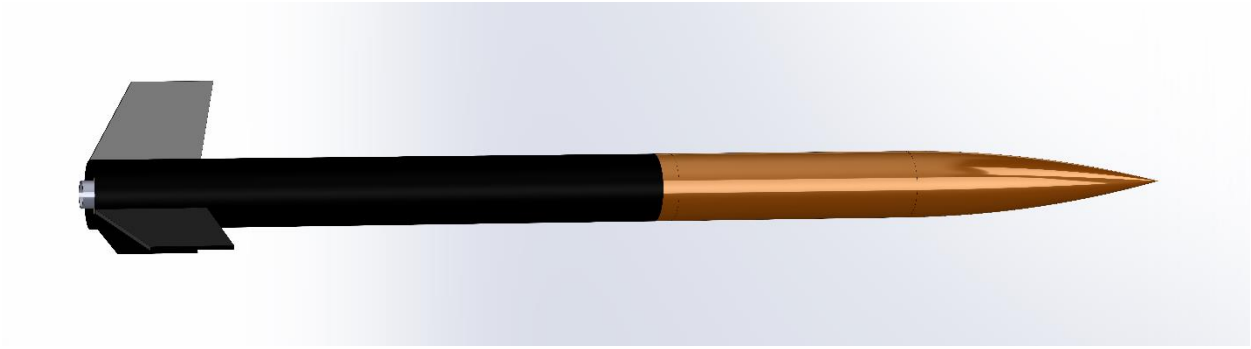


Figure 1 - Render of the RP1 CAD model in its fully assembled form.

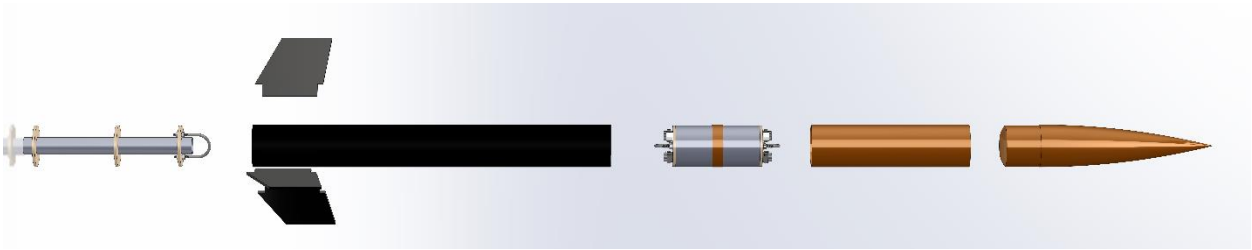


Figure 2 - Exploded view of the rocket assembly and its main components.

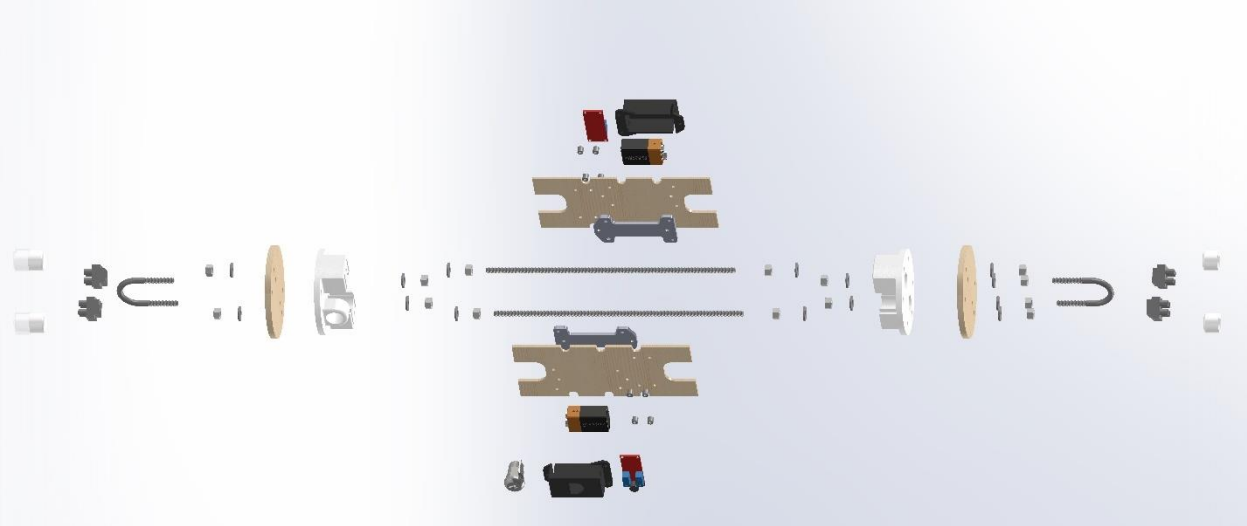


Figure 3 - Exploded view of the Ebay assembly.

Of worthy not in the Ebay assembly above, the white pieces sandwiched between the two bulkheads are the 3D printed Ebay enclosure pieces printed in white PLA. PLA was used since they are not load baring. The white blast caps are actually black polycarbonate (as can be seen in the final photos). The battery covers are secured to the Ebay wood mounting plates with screws that screw into a 3D printed back plate (the grey pieces) that has heat set inserts.

3.3 Component Selection

See also Appendix D1 for the Budget which lays out all components bought for this rocket.

- Main Parachute + Shock Cord:
  - 48 *in* Fruity Chutes main parachute with 27 *ft* of 1500 *lb* test strength braided Kevlar shock cord.
- Drogue Chute + Shock Cord:
  - 18 *in* Fruity Chutes drogue with 15 *ft* of 1500 *lb* test strength braided Kevlar shock cord.
- Shear Pins:

  Whenever/wherever sheer pins are used, three sheer pins were used as this was how many were used during ejection testing of both main and drogue parachutes.
  - #2-56 nylon sheer pins.
- Set Screws:
  - #4-40 screws.
- Altimeters:
  - Two PerfectFlite StratoLoggerCF altimeters were used.

    - Altimeter 1 (Serial #4154) is the main altimeter that fires first.
    - Altimeter 2 (Serial #4374) is the backup altimeter that fires second.
- Airframe:
    - 4 *in* Blue Tube.
- Nosecone:
    - 16.5 *in* Ogive PNC.
- Motor Mount:
    - 38 *mm* Blue Tube.
- Hardware:
    - 1/4-20 Black-Oxide Steel U-Bolt for shock cord attachments.
    - 1/4-20 Aluminum Threaded Rod for Ebay structure.
- Blast Caps:
    - 3D Printed Polycarbonate.
- Fins:
    - 1/4 *in* Laser Cut Pine.
    - Designed in OpenRocket & SolidWorks.
- Bulkheads & Centering Rings:
    - 1/4 *in* Laser Cut Pine.
    - Designed in OpenRocket & SolidWorks.
- Ebay:
    - 1/8 *in* Pine for the mounting plates.
    - 3D Printed PLA for the top and bottom enclosure pieces.
- Chute Protectors:
    - Nomex chute protectors

3.4 Motor Thrust Curves

All thrust curves and motor data are taken from OpenRocket's database and were double checked with ThrustCruve.org and the motor's manufacturers.

- Motor Casing: Cesaroni Pro 38mm.

- L1 Primary Motor: Cesaroni H152BS 2 grain from AMW.

    - Total Impulse: 279 Ns
    - Avg. Thrust: 153 N
    - Max Thrust: 213 N
    - Burn Time: 1.82 s
    - Launch Mass: 298 g
    - Empty Mass: 160 g

- Delay Charge: 16 *s*
- Thrust Profile:

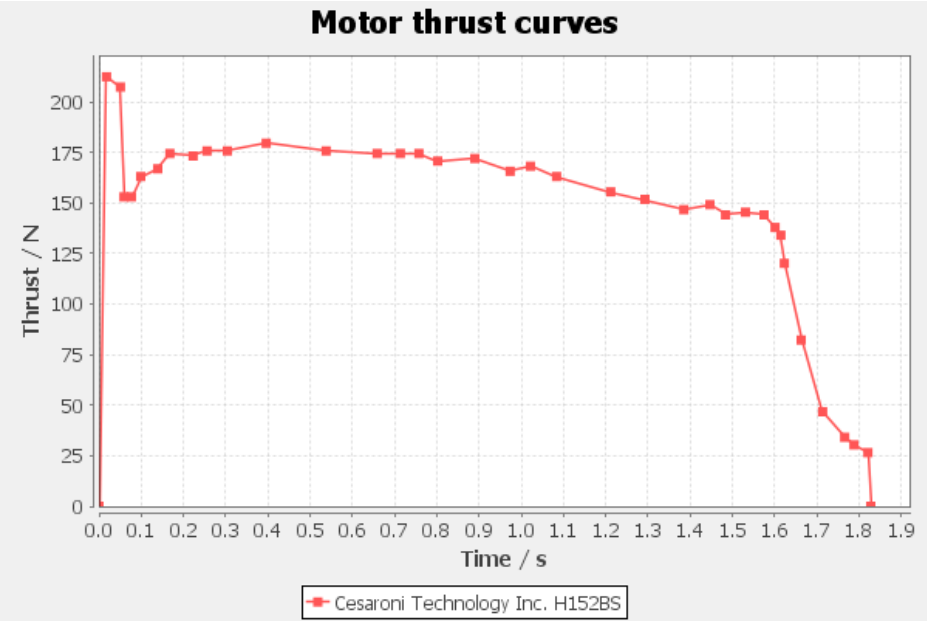


Figure 4 - Thrust curve for H152BS motor.

- L1 Secondary Motor: Cesaroni H125 Classic 2 grain from AMW.
    - Total Impulse: 268 Ns
    - Avg. Thrust: 131 N
    - Max Thrust: 154 N
    - Burn Time: 2.05 s
    - Launch Mass: 293 g
    - Empty Mass: 155 g
    - Thrust Profile:

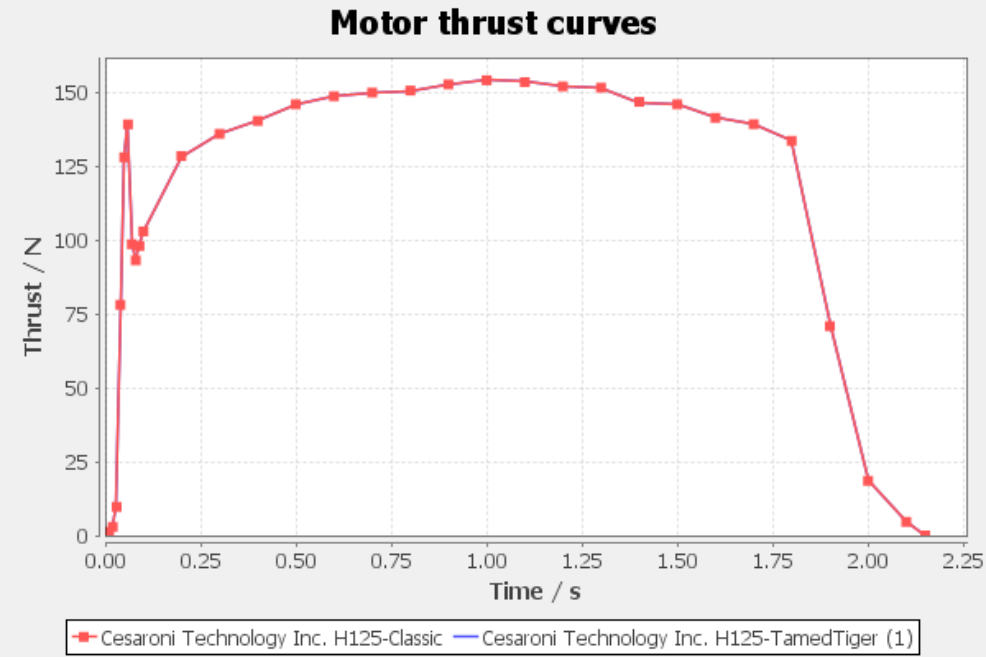


Figure 5 - Thrust curve for H125CL motor.

- L1 Tertiary Motor: Cesaroni I195 Red Lighting 3 grain
    - Total Impulse: 395 N
    - Avg. Thrust: 196 N
    - Max Thrust: 235 N
    - Burn Time: 2.01 s
    - Launch Mass: 417 g
    - Empty Mass: 191 g
    - Delay Charge: 16 *s*
    - Thrust Profile:

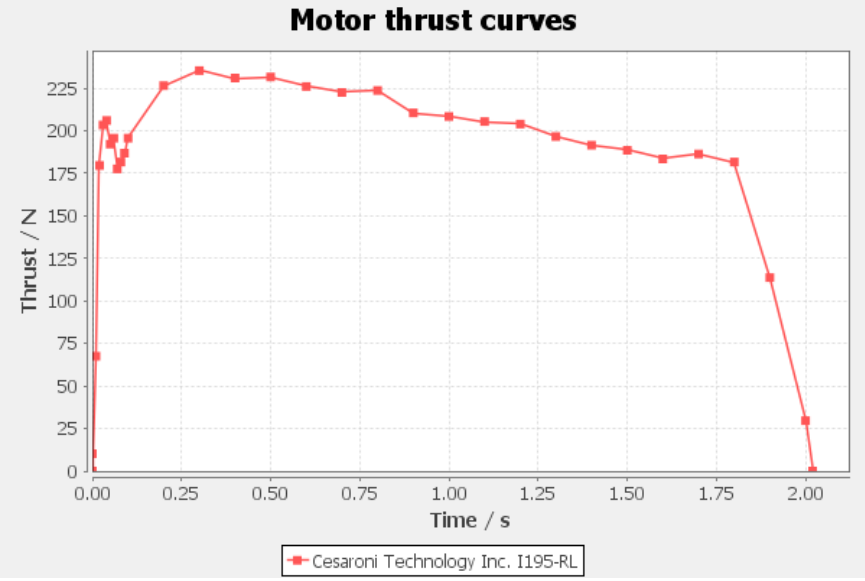


Figure 6 - Thrust curve for H195RL motor.

- L2 Motor: Cesaroni J357 Blue Streak 5 grain from AMW [4]
    - Total Impulse: 657 Ns
    - Avg. Thrust: 373 N
    - Max Thrust: 514 N
    - Burn Time: 1.76 s
    - Launch Mass: 601 g
    - Empty Mass: 264 g
    - Delay Charge: 17 *s*
    - Thrust Profile:

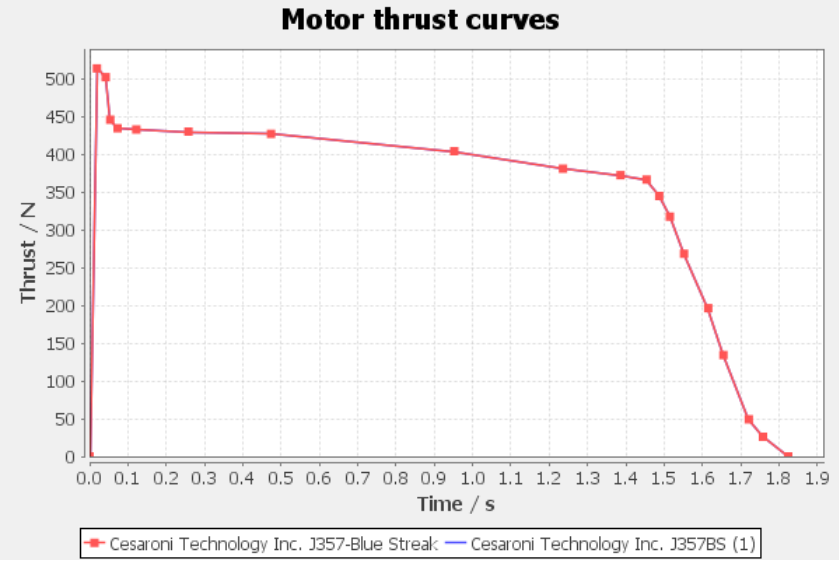


Figure 7 - Thrust curve for J357BS motor.

3.5 Selected Motors

- L1 Motor: I195RL-16A
- L2 Motor: J357BS-17A

An H152BS was ordered from Animal Motor Works, however, they were out of H152BS's and so sent me an H125CL instead. The plan was to use the H125CL as it gave me a greater than 5 thrust to weight ratio using my theoretical rocket weight, however, after experimentally weighing my rocket in its dual deploy flight configuration, I found it to be much heavier than I expected/calculated. This meant my actual thrust to weight (and therefore exit rail velocity) was reduced to an unsafe ratio of 3.390. This was with a dual deploy configuration. I considered going back to my single deploy configuration for L1 and dual deploy configuration for L2 in order to reduce my L1 wet weight by 365 *g* (by removing the drogue and its shock cord), however, this would only have increased my thrust to weight ratio to 3.754, still too low and unsafe. Therefore, I stuck with the dual deploy configuration for both L1 and L2 launches and instead sourced an I195RL from a fellow club member. *(This is also explained in Flight Recovery Configurations)*

3.6 Rocket Construction

3.6.1 Construction Summary:

- 4 in blue tube airframe
- ¼ in laser cut, pine, through-wall, trapezoidal fins
- ¼ in laser cut, pine, bulkheads and centering rings
- RocketPoxy on bulkheads and centering rings
- Blue Tube MMT
- JB Welded 1/4 in rail buttons
- JB Welded motor retainer
- J-B Weld on motor retainer
- PLA 3D printed Ebay inner bulkheads
- 1/4 in-20 threaded rod through Ebay
- 2 Strataloggers for dual deploy
- 4 black powder charges

3.6.2 Airframe

The airframe is made of 4 in diameter Blue Tube. 3.9 in Blue Tube coupler was used to construct the Ebay. Blue Tube was chosen because it is strong and able to withstand the forces exerted on the rocket during flight.

3.6.3 Motor Assembly

The motor mount was constructed of 38mm Blue Tube with three ¼in centering rings equally spaced apart. RocketPoxy was used to secure the centering rings to the motor tube. A U-Bolt was put on the fore centering ring for shock cord attachment. RocketPoxy was used to secure the motor assembly to the aft airframe section.

U-Bolts were preferred over eyebolts because U-Bolts are attached symmetrically on either side of the centering ring exerting symmetrical force on the centering ring as opposed to an eyebolt that would be attached on one side of the centering ring, therefore exerting force only on one side of the centering ring during ejection. Though unlikely, this creates a greater chance of the centering ring being ripped out.

The aft centering ring was attached 1 in above the end of the motor tube. The motor assembly was glued into the airframe so that the aft centering ring was ½in into the airframe and the end of the motor tube was ½in stuck out from the end of the airframe.

3.6.4 Fins

The fins were designed in OpenRocket, transferred to SolidWorks and laser cut in ¼ in pine wood. They were designed to maximize stability and caliber. Three fins were used, have through-the-wall tabs, butt up against the motor mount tube. They were

attached using RocketPoxy and positioned with a club made, laser cut fin jig set at 120° apart.

3.6.5 Bulkheads and Centering Rings:

All bulkheads were modeled in SolidWorks and laser cut out of ¼ in pine wood. All bulkheads were secured using RocketPoxy. Three centering rings were used on the motor mount and were laser cut in 1/4 in pine wood.

3.7 Rocket Markings

3.7.1 External Markings

- L1 and L2 Center of Gravity's are marked with a line on tape along with the motor that was installed when the CG was found.
- L1 and L2 Center of Pressures are marked with a line on tape.
- On and Off positions for key switch.
- Aft to Ebay alignment marking.
- Fore to Ebay alignment marking.
- Fore to nosecone alignment marking.

3.7.2 Internal Markings

- Top and bottom marking of fore section.
- Top and bottom marking for Ebay airframe.

4. AVIONICS

4.1 L1 Avionics Configuration:

Two PerfectFlite StratoLoggerCF Altimeters were used to deploy the main parachute: one altimeter was set to be fired first. This altimeter was called "Alt. 1" as labeled on the avionics bay. The second altimeter was used for redundancy and was set to fire 5 seconds after the first altimeter was set to fire. This backup altimeter was called "Alt. 2" as labeled on the avionics bay.

4.2 Keylock Switch:

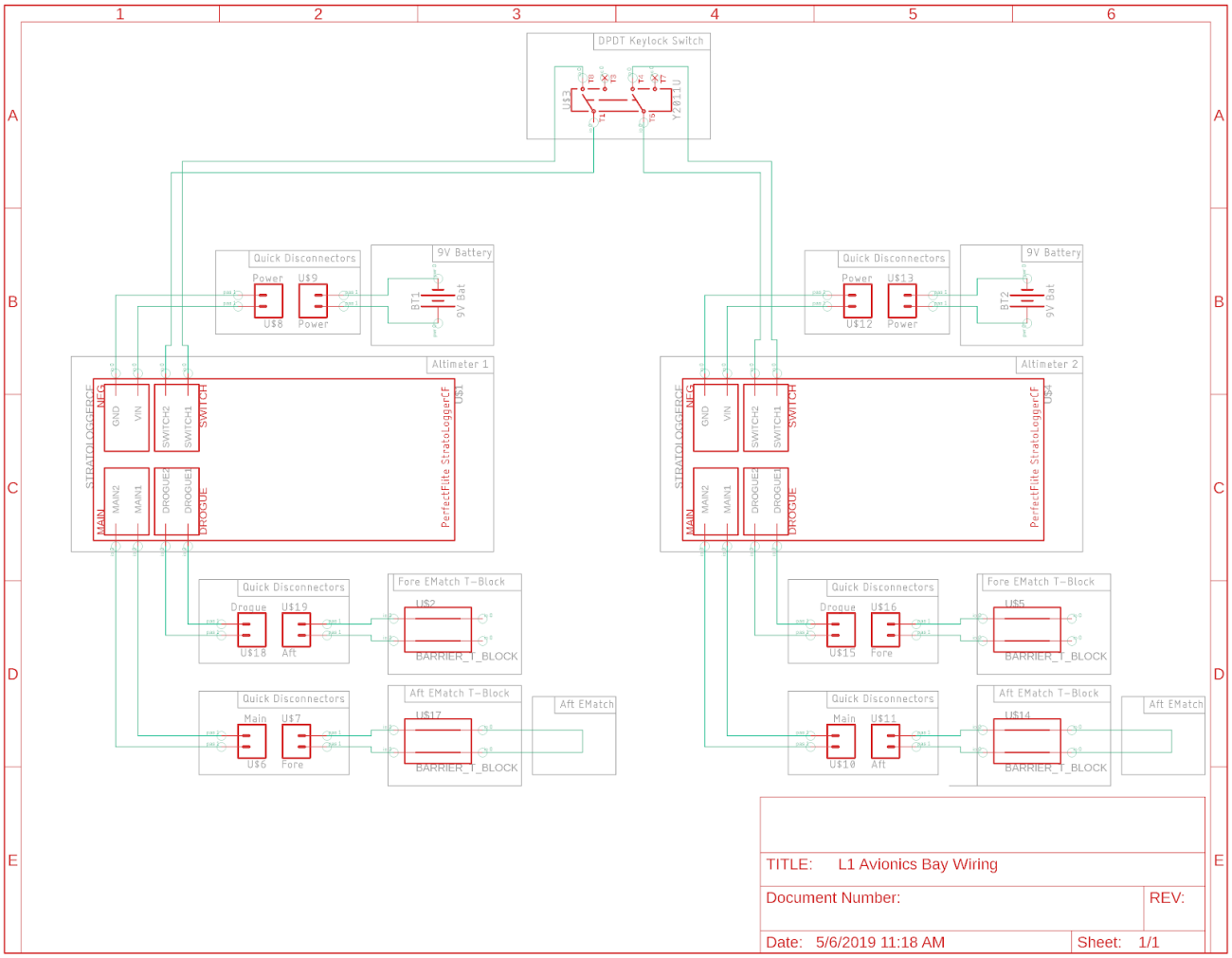
A 2 circuit keylock switch was used to turn on both altimeters. One keylock switch was preferred over two to reduce the number of solder points and the number of failure points. Further, one switch was used to reduce the number of holes in the airframe that would require alignment.

- Manufacturer: C&K
- Model: Y2011U
- Digi-Key: https://www.digikey.com/product-detail/en/c-k/Y101132C203NQ/CKN11517-ND/484276

4.3 L1 Avionics Bay Wiring:

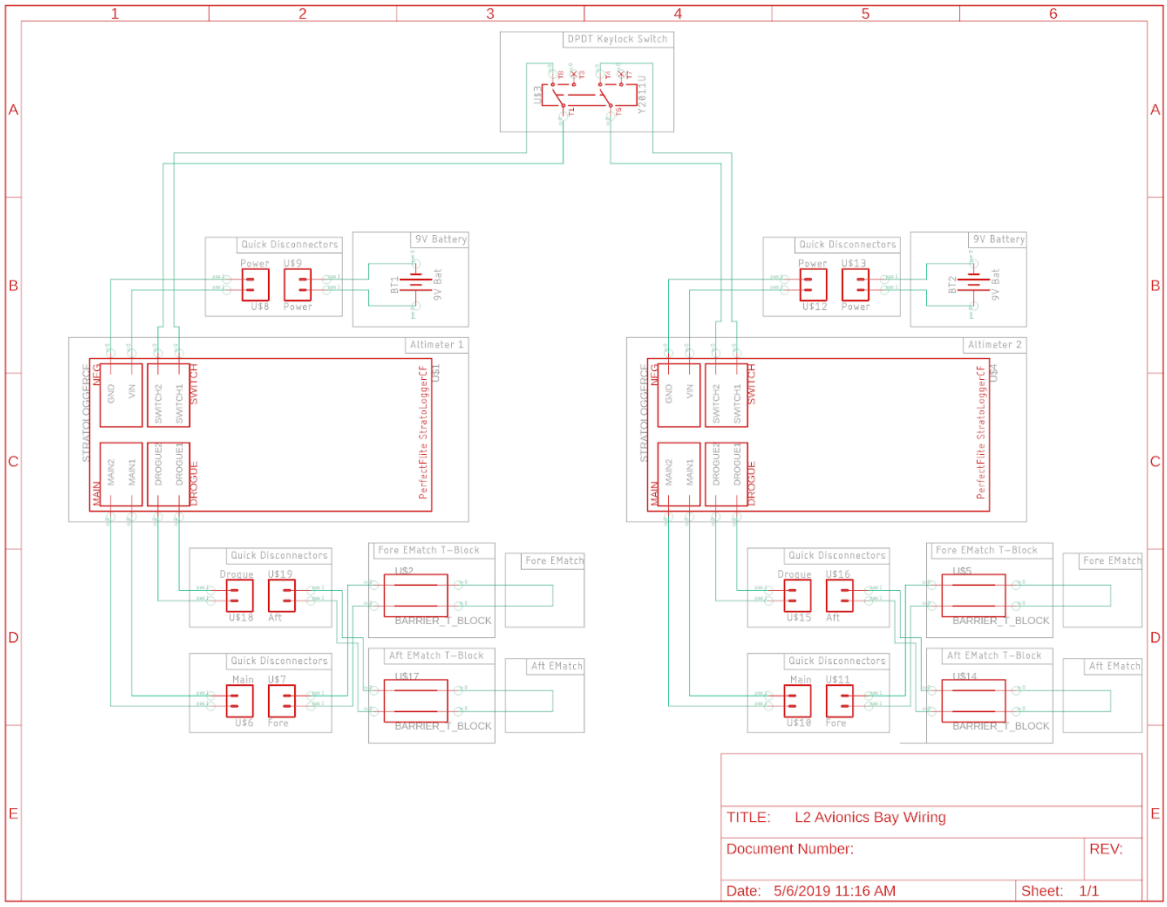
Two PerfectFlite StratoLoggerCF Altimeters were used for single deployment of the main parachute. One altimeter acts as the main altimeter that fires first (called "Altimeter 1"), the second altimeter is a backup for redundancy in case Altimeter 1 fails. This backup altimeter is called "Altimeter 2".

There is one E-match per altimeter and both are on the aft side of the avionics bay bulkhead as the main parachute is in the aft section for the L1 launch. Each E-match connects to a passthrough barrier terminal block for easy replacement of the matches. Each terminal block is wired through the respective bulkhead (fore and aft) and connected to their respective altimeters with quick disconnects so that the avionics bay bulkheads can be easy removed. Each altimeter is powered by their own 9V battery and connected using quick disconnects.



This schematic was created in Autodesk's Eagle EDA software and depicts the wiring of the avionics bay for the L1 launch configuration of the rocket.

L1 Avionics Bay Wiring:



This schematic was created in Autodesk's Eagle EDA software and depicts the wiring of the avionics bay for the L2 launch configuration of the rocket.

5. RECOVERY CONFIGURATIONS

Originally, RP1 was planned to be flown in two different configurations, one for the L1 attempt and another for the L2 attempt (assuming a successful launch and recovery of my L1 attempt). The L1 configuration was to have only the main parachute in the aft section with the nose cone set screwed and the L2 configuration was to have the drogue in the aft section and the main in the fore section with sheer pins in both fore and aft sections. However, doing this would have required rearranging the parachutes, the shock cords, and the Ebay wiring between both launches, increasing the chance of incorrect wiring and assembly. Therefore, it was decided to only use one configuration for both launches to minimize the chances of failure.

An H152BS was ordered from Animal Motor Works, however, they were out of H152BS's and so sent me an H125CL instead. The plan was to use the H125CL as it gave me a greater than 5 thrust to weight ratio using my theoretical rocket weight, however, after experimentally weighing my rocket in its dual deploy flight configuration, I found it to be much heavier than I expected/calculated. This meant my actual thrust to weight (and therefore exit rail velocity) was reduced to an unsafe ratio of 3.390. This was with a dual deploy configuration. I considered going back to my single deploy configuration for L1 and dual deploy configuration for L2 in order to reduce my L1 wet weight by 365 g (by removing the drogue and it's shock cord), however, this would only have increased my thrust to weight ratio to 3.754, still too low and unsafe. Therefore, I stuck with the dual deploy configuration for both L1 and L2 launches and instead sourced an I195RL from a fellow club member.

5.1 Configuration Option 1:

- <u>L1 Configuration:</u>
    - Nose cone sheer pinned to fore section
    - Fore section set screwed to Ebay
    - Aft section set screwed to Ebay
    - Separate into two pieces:
        1. Nose cone
        2. Fore section, Ebay, aft section
    - Main parachute in the fore section with 27 ft of 1500 lb test strength braided Kevlar shock cord
    - No drogue, no drogue shock cord
    - Two black powder charges in Ebay firing into fore section
        - Altimeter 1 firing first
        - Altimeter 2 firing shortly after

- <u>L2 Configuration:</u>

- 48 in Fruity Chutes main parachute in the fore section with 27 ft of 1500 lb test strength braided Kevlar shock cord.
- 18 in Fruity Chutes drogue in the aft section with 15 ft of 1500 lb test strength braided Kevlar shock cord.
- Three #2-56 nylon sheer pins holding the nose cone to the fore section.
- Three #2-56 nylon sheer pins holding the Ebay to the aft section.
- Four set screws holding the Ebay to the fore section.
- Four total black powder ejection charges in Ebay.
    - Altimeter 1 firing first for both drogue and main (one charge in fore section and one charge in aft section).
    - Altimeter 2 (backup) firing second for both drogue and main (one charge in fore section and one charge in aft section).
    - Secondary Backup charge from the motors for deploying the drogue in case both altimeters fail (which has happened multiple times in AeroNU club history).

5.2 L1 and L2 Chosen Flight Configuration Option:

- 1010 8ft launch rail.
- 48 in Fruity Chutes main parachute in the fore section with 27 ft of 1500 lb test strength braided Kevlar shock cord.
- 18 in Fruity Chutes drogue in the aft section with 15 ft of 1500 lb test strength braided Kevlar shock cord.
- Three #2-56 nylon sheer pins holding the nose cone to the fore section.
- Three #2-56 nylon sheer pins holding the Ebay to the aft section.
- Four set screws holding the Ebay to the fore section.
- Four total black powder ejection charges in Ebay.
    - Altimeter 1 firing first for both drogue and main (one charge in fore section and one charge in aft section).
    - Altimeter 2 (backup) firing second for both drogue and main (one charge in fore section and one charge in aft section).
    - Secondary Backup charge from the motors for deploying the drogue in case both altimeters fail (which has happened multiple times in AeroNU club history).

6. MEASUREMENTS AND CALCULATIONS

6.1 Stability

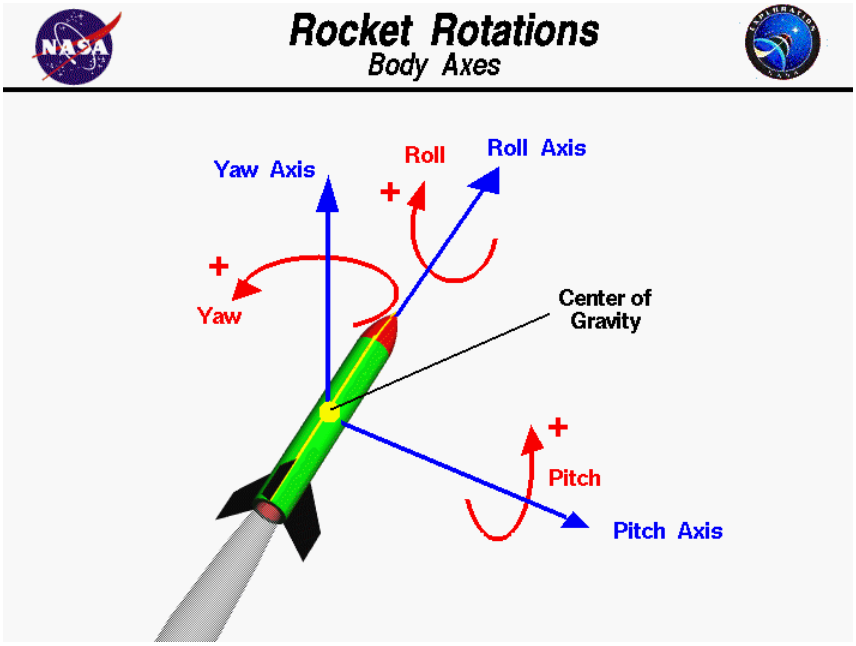


Figure 8 - Rocket rotations.
https://www.grc.nasa.gov/WWW/K-12/rocket/rotations.html

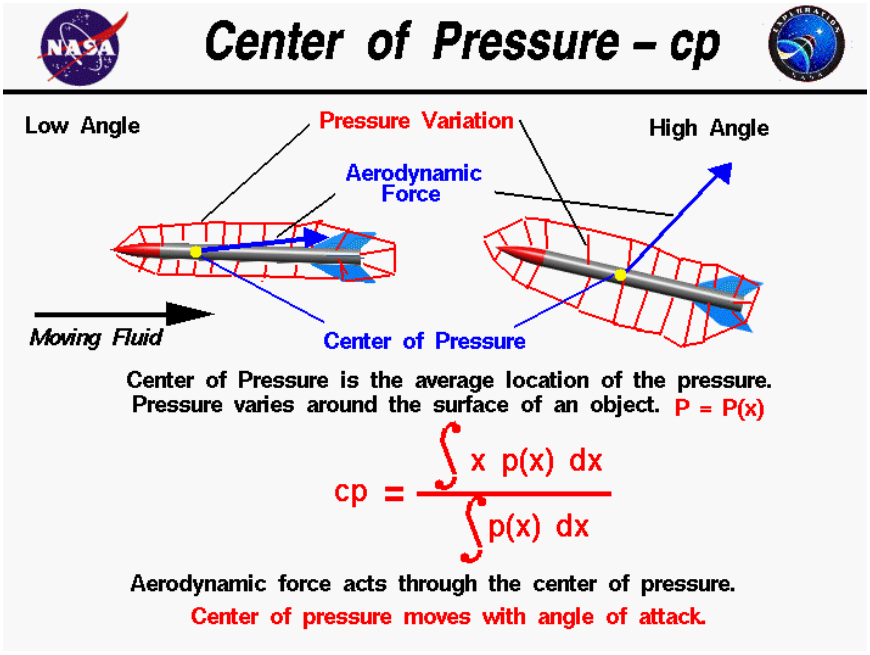


Figure 9 - Rocket Center of Pressure calculations
https://www.grc.nasa.gov/WWW/K-12/rocket/cp.html.

Stability of an HPR rocket is mainly determined by the locations of the center of gravity and the center of pressure. The center of gravity is where all the mass of the rocket can be thought to be concentrated; it is the point at which there is equal torque on either side of the CG. CG can be found by balancing the rocket until it does not sway to either side. The CP is the point where the total sum of a pressure field acts on a body, causing a force to act through that point. Basically, where all aerodynamic forces can be thought of as acting through. The CP is calculated by averaging the pressure at each location on the rocket. OpenRocket was used to calculate CP.

For a rocket to be stable, the CP should be behind or aft of the center of gravity. This is so that the CP, or the aerodynamic forces on the rocket act as a restoring force when the rocket begins to pitch or yaw. A measurement of the caliber (cal) can be used to determine the rough stability of a model. A caliber is the diameter of the airframe (4 in in my case). The measurement of cal in terms of a rocket's stability is how far away the CP and CG are. By rule of thumb, you want a cal of at least 1 *cal*, or in other words, you want the CP at least one airframe diameter aft of the CG.

6.1.1 Center of Gravity

- These were found experimentally by installing everything in the rocket in its launch configuration and then finding the balance point of the rocket.
- These are marked on the rocket.
    - *I195:*
        - 38.5 *in* from fore of rocket
        - 26.00 *in* from aft of rocket
    - *J357BS:*
        - 39.25 *in* from fore of rocket
        - 25.375 *in* from aft of rocket

6.1.2 Center of Pressure

- *I195:*
    - 15.75 *in* from aft of rocket
- *J357BS:*
    - 15.75 *in* from aft of rocket

6.1.3 Caliber

The difference in OpenRocket's cal calculation and my cal calculation is that OpenRocket uses the position of CG and CP measured from the fore of the rocket where as I did it from the aft of the rocket. OpenRocket's measurements start from ~6 in from the tip of the nose cone.

- *I195:*
  - OpenRocket: 2.74 cal
  - Hand Calc.:
    - 26.00 in – 15.75 in = 10.25 in
    - 10.25 in / 4 in = 2.56 cal
- *J357BS:*
  - OpenRocket: 2.42 cal
  - Hand Calc.:
    - 25.375 *in* – 15.75 in = 9.625 in
    - 9.625 in / 4 in = 2.41 cal

6.2 Rocket Mass

- **Dry Weight (everything but motor): 3.470 *kg***
- Wet Weights: The following are the wet rocket weights with the following motors installed in the rocket (Dry weight plus weight of motor).
  - *H125CL:* 3.763 *kg*
  - *H152BS:* 3.768 *kg*
  - *I195:* 3.887 kg
  - *J357BS:* 4.071 *kg*
- Misc. Measurements:
  - Drogue + Shock Cord Mass: 0.365 *kg*
  - Dry Weight (w/o drogue + shock cord): 3.105 *kg*

Rocket airframe, no Ebay, no motor, no parachutes, no shock cord, no motor retainer	1.74 kg
Ebay, no E-matches, no BP	0.57 kg
99 in (1/2in Kevlar) shock cord + 48in white red fruity chutes parachute	0.24 kg
15in white and red fruity chutes parachute	0.03 kg
Total	2.58 kg

Figure 10 - Miscellaneous mass measurements included for completeness but are now obsolete.

6.3 Rail Exit Velocity

Rail exit velocity is the velocity at which the rocket leaves the launch rail, or, the point at which there is only one rail button in the launch rail as this is the point at which the launch rail is no longer providing guidance to the rocket and the rocket is free to yaw and pitch.

The NAR HPR Safety Code states, "Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable

flight, and that is pointed to within 20 degrees of vertical [1]. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher."

"A speed that ensures a stable flight" means the speed at which the fins exert aerodynamic control of the vehicle."

Experience-based rule of thumb is to have an exit velocity of at least 4 times the velocity of the cross wind [2, pp. 31] since it is the cross wind and its angle of attack that will provide the force that tilts the rocket once it is free of the launch rail.

As can be seen in the SIMULATIONS section below, RP1 has an exit rail velocity of 32.2 ft/s with the I195RL motor, meaning the cross wind cannot exceed 8.05 ft/s or 5.49 MPH. With the J357BS motor, RP1 has an exit rail velocity of 47.5 ft/s, therefore the cross wind cannot exceed 11.88 ft/s or 8.10 MPH.

Thrust to weight is also used to determine a safe launch velocity.

6.4 Thrust to Weight

Thrust to weight is a ratio of the average thrust of the motor to the wet launch weight. Wet launch wet is the weight of the rocket with propellent.

Thrust to weight helps determine a safe rail exit velocity. By experience-based rule of thumb, a thrust to weight ratio of 4:1 is the minimum with no wind speeds with a preferred ratio of 6:1 to be safe. In-between these two ratios may be unsafe in windy conditions. My target was a minimum thrust to weight ratio of 5:1. [2, pp. 118].

6.4.1 H125CL

- Avg. Thrust: 125 N
- Wet Mass: 3.763 kg
- Wet Weight: 36.877 N

$$Thrust{:}\,Weight = \frac{125\ N}{36.877\ N} = 3.390$$

This is an unsafe Thrust to Weight

6.4.2 I195RL

- Avg. Thrust: 195 N
- Wet Mass: 3.887 kg
- Wet Weight: 38.093 N

$$Thrust{:}\,Weight = \frac{195\ N}{38.093\ N} = 5.119$$

This is a safe Thrust to Weight

6.4.3 J357BS

- Avg. Thrust: 357 N
- Wet Mass: 4.071 kg
- Wet Weight: 39.896 N

$$Thrust{:}\,Weight = \frac{357\ N}{39.896\ N} = 8.948$$

This is a safe Thrust to Weight

6.5 Black Powder

The amount of black powder needed per charge for each fore and aft sections was calculated starting with the ideal gas constant given by:

$$PV = nRT \tag{1}$$

where P is the chamber pressure in *psi*, V is the chamber volume in *cubic inches*, n is number of moles of gas in *mol*, R is the ideal gas constant, and T is the combustion gas temperature of the black powder in degrees Rankine *(°R)*.

This equation can be rearranged to give the weight W in pounds of black powder needed given by:

$$W = \frac{PV}{RT} \tag{2}$$

The combustion gas constant of FFFF black powder is given by:

$$R = 22.16\frac{ft-lbf}{lbm{\cdot}R} = 265.92\frac{in-lbf}{lbm{\cdot}R} \tag{3}$$

The chamber volume is given by:

$$V = \frac{1}{4}\pi D^2 L \tag{4}$$

where D is the airframe diameter in *inches* and L is the chamber length in *inches*.

The combustion gas temperature T of black powder is given by:

$$T = 3307°R \tag{5}$$

The weight W in pounds is converted to grams by multiplying the weight by 454 $\frac{g}{lb}$. Plugging Equations (3), (4), and (5) into Equation (2), we get:

$$N = \frac{P\frac{1}{4}\pi D^2 L}{265.92\frac{in-lbf}{lbm \cdot R} \cdot 3307°R} \cdot 454\ \frac{g}{lb} \tag{6}$$

where N is the mass of black powder needed in grams, P is the desired chamber pressure in psi, D is the chamber/airframe diameter, and L is the length of the chamber being pressurized.

From here, the required black powder was calculated for each section (fore and aft):

Fore Section:

- Desired Pressure: $P = 12\ psi$
- Chamber Diameter: $D = 3.9\ in$
- Chamber Length: $L = 14.75 in$

$$N = \frac{12\ psi\ \frac{1}{4}\pi(3.9\ in)^2 14.75\ in}{265.92\frac{in-lbf}{lbm \cdot R} \cdot 3307°R} \cdot 454\ \frac{gm}{lb} = 1.091\ g \tag{7}$$

Aft Section:

- Desired Pressure: $P = 12\ psi$
- Chamber Diameter: $D = 3.9\ in$
- Chamber Length: $L = 14.25\ in$

$$N = \frac{12\ psi\ \frac{1}{4}\pi(3.9\ in)^2 14.25\ in}{265.92\frac{in-lbf}{lbm \cdot R} \cdot 3307°R} \cdot 454\ \frac{gm}{lb} = 1.055\ g \tag{8}$$

The black powder charges were rounded down to $1\ g$ and tested (*See the TESTING section below).* These black powder quantities were further verified using online black powder charge calculators [11-13]. The quantities were also verified with experienced club members.

6.6 Delay Charges

The delay charge on each motor is to be used as a third back up to the drogue chute (as the drogue is in the aft section and the motor ejection charges would separate the at section only). The first Ebay drogue charge fires at apogee when the altimeter detects a peaking of altitude. The second drogue charge is set to fire 3 seconds after apogee is detected. It is desired to have the motor backup charge fire 5 seconds after the 2nd Ebay ejection charge. 5 seconds is desired (longer than the delay between first and second drogue charges) to reduce the chance of the backup charge firing too early in case the flight takes longer than what the simulations predicted (since the motor ejection charge is timed based and not altitude based).

6.6.1 I195RL-16A

- Motor Burn Time (OpenRocket): 2.01 s
- Time to Apogee (OpenRocket): 8.96 s
- Time to Alt 1 Drogue Charge Fire: 8.96 s
- Time to Alt 2 Drogue Charge Fire:

  8.96 s + 3 s = 11.96 s

- Desired Time to Motor Ejection Charge Fire (Time after liftoff I want the motor ejection charge to fire):

  11.96 s + 5 s = 16.96 s

- Motor Ejection Charge Delay Setting (What the motor ejection charge should actually be set at) (Time to Motor Ejection Charge – Motor Burn Time):

  16.96 s – 2.01 s = 14.95 s ≈ 15 s

  Rounded to 15 s because the Cesaroni delay drill tool can only be set to the whole seconds.

- Max Delay Charge Setting: 15.3 s

  This was calculated simply by finding the time between when the ejection charge delay begins (when the motor burn ends) and the time the rocket would free fall to the ground using $\Delta y = \frac{1}{2}at^2$. In the case that both altimeters fail and neither drogue nor main parachutes deploy, the rocket is in free fall and will fall to the ground quicker. Therefore, you want the motor ejection charge (3rd backup) to fire before the rocket free falls to the ground. This was calculated assuming worse case: No drag and no terminal velocity hit, just plain free fall to ground, therefore factoring in a margin of safety.
  - Delay Charge: 16 s

- Burn Time 2.01 s
- Time to Apogee: 8.96 s
- Apogee (Δy): 342 m
- Free Fall Acceleration *(a)*: 9.8 m/s
- Time between delay charge ignite and apogee (Time to apogee – burn time):

  8.96 s – 2.01 s = 6.95 s
- Time between apogee and ground hit (assuming free fall and no drag):

$$\Delta y = \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2\Delta y}{a}}$$

$$t = 8.35\ s$$

- Max Delay = Free fall time + Time between delay charge ignite and apogee:

  6.95 s + 8.35 s = 15.3 s

  Therefore, setting the motor ejection charge delay to 15 s will be safe; the rocket will not hit the ground before the motor ejection charge fires.

6.6.2 J357BS-17A

- Motor Burn Time (OpenRocket): 1.76 s
- Time to Apogee (OpenRocket): 11.6 s
- Time to Alt 1 Drogue Charge Fire: 11.6 s
- Time to Alt 2 Drogue Charge Fire:

  11.6 s + 3 s = 14.6 s

- Desired Time to Motor Ejection Charge Fire (Time after liftoff I want the motor ejection charge to fire):

  14.6 s + 5 s = 19.6 s

- Motor Ejection Charge Delay Setting (What the motor ejection charge should actually be set at) (Time to Motor Ejection Charge – Motor Burn Time):

  19.6 s – 1.76 s = 17.84 s

  The J357BS-17A has a max delay setting of 17 s, therefore, no adjustment was done to the delay charge and it was left at 17 s.

- Max Delay Charge Setting: 21.8 s

  This was calculated simply by finding the time between when the ejection charge delay begins (when the motor burn ends) and the time the rocket would free fall to the ground using $\Delta y = \frac{1}{2}at^2$. In the case that both altimeters fail and neither drogue nor main parachutes deploy, the rocket is in free fall and will fall to the ground quicker. Therefore, you want the motor ejection charge (3rd backup) to fire before the rocket free falls to the ground. This was calculated assuming worse case: No drag and no terminal velocity hit, just plain free fall to ground, therefore factoring in a margin of safety.

  - Delay Charge: 17 s
  - Burn Time 1.76 s
  - Time to Apogee: 11.6 s
  - Apogee (Δy): 701 m
  - Free Fall Acceleration *(a)*: 9.8 m/s
  - Time between delay charge ignite and apogee (Time to apogee – burn time):

    11.6 s – 1.76 s = 9.84 s
  - Time between apogee and ground hit (assuming free fall and no drag):

$$\Delta y = \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2\Delta y}{a}}$$

$$t = 11.96\ s$$

  - Max Delay = Free fall time + Time between delay charge ignite and apogee:

    9.84 s + 11.96 s = 21.8 s

    Therefore, if both altimeters fail, setting the delay charge to 17 s will be safe; the rocket will not hit the ground before the motor ejection charge fires.

6.7 Shock Cord

Refer to Appendix M5

There are two forces exerted on the shock cord during a flight. The first is a force as the nosecone or Ebay reaches the full length of the shock cord following ejection. The second is a force immediately after the ejection of the nosecone or the Ebay: the force of the parachute opening as the rocket falls.

The shock cord must be long enough to stretch and absorb these two forces without the cord breaking or ripping apart of the rocket out (i.e. an eye bolt or bulkhead). I am

using 1 in 1500 lb test strength Kevlar shock cord, meaning the cord has a tensile strength of 1500 lb and can be expected to break under 1500 lb of tension (if new). This 1500 lb test strength or roughly 680 kg can withstand a force on Earth of 6664 N (assuming a gravitational field strength of 9.8 N/kg on Earth). As can be seen by the calculations below, this far exceeds the amount of force RP1 exerts on the shock cord during its flight. I did not calculate the length of shock needed to be *stretched* to absorb the energy as the sections separate. I lay out how to calculate this, but I do not use this to determine a shock cord length because of past testing with other club rockets having been successful with the same shock cord and the same length. I only give one example of calculating the shock cord length and the amount of energy needed to be absorbed by it. Though I did not use this to determine my shock cord length (as the length was determined by club shock cord availability), I do give a "worse case scenario" example of the calculations to demonstrate that my shock cord is more than long enough.

Beyond this, another reason for having long enough shock cord is so that it does not zipper the rocket's airframe. Zippering occurs when the shock cord rips a slot in the side of the rocket as tension/an impulse is exerted by the ejected section, making the rocket unflyable until the airframe is replaced.

The desired ejection chamber pressure was 12 psi (the pressure at which the amount of black powder was calculated for above). This resulted in a little over 1 g of black powder to produce this chamber pressure (as calculated above), however, 1 g of black powder was used in ground testing and will be the amount used in flight, therefore this is the amount of black powder that will be used in the following calculations.

6.7.1 Fore Section Separation

1 g of black powder would produce a chamber pressure of 10.99 psi in the fore section using equation (6). Pressure is given by

$$P = \frac{F}{A}$$

Where P is the pressure, F is the force, and A is the area in which a force is exerted by the pressure. Therefore, the force exerted on the nosecone bulkhead is given by

$$\mathrm{F} = \mathrm{PA} = 10.99\ \mathrm{psi} \cdot \left(\pi \cdot \left(\frac{1}{2} \cdot\ 3.9\ in\right)^2\right) = 131.28\ \mathrm{lb}$$

Three #2 nylon shear pins will be used in the fore section. Three #2 nylon shear pins require a force of 64.24 lb to break in half (see Appendix M4). Subtracting the pounds of force needed to break the shear pins from the force exerted on the bulkhead we get $131.28\ lb - 64.24\ lb = 67.04\ lb$ of force that is exerted on the bulkhead over a distance equal to the length of the coupler shoulder that accelerates the nosecone outwards. 67.04 *lb* is equal to 298.01 *N*.

The nosecone shoulder is 3 *in* or 0.0762 *m*. Change in energy is equal to the work done and the work done is equal to the force applied over a distance (assume equal force exerted throughout the separation of the nosecone). Therefore, the nosecone has a change in energy (or gains kinetic energy) of $298.01\ N \cdot 0.0762\ m = 22.71\ J$. This is the amount of energy that the shock cord must absorb. Shock cord absorbs energy based on elastic potential energy. The amount of elastic potential energy shock cord has is given by

$$PE = \frac{1}{2}kx^2$$

Where PE is the potential energy stored, *k* is the spring constant, and *x* is the amount of stretch or

$$x = \sqrt{\frac{E}{0.5 \cdot k}}$$

If we say the spring constant is $k = 1$, then the shock cord would have to stretch 2.33 *m*.

7. SIMULATIONS

7.1 I195RL-16A

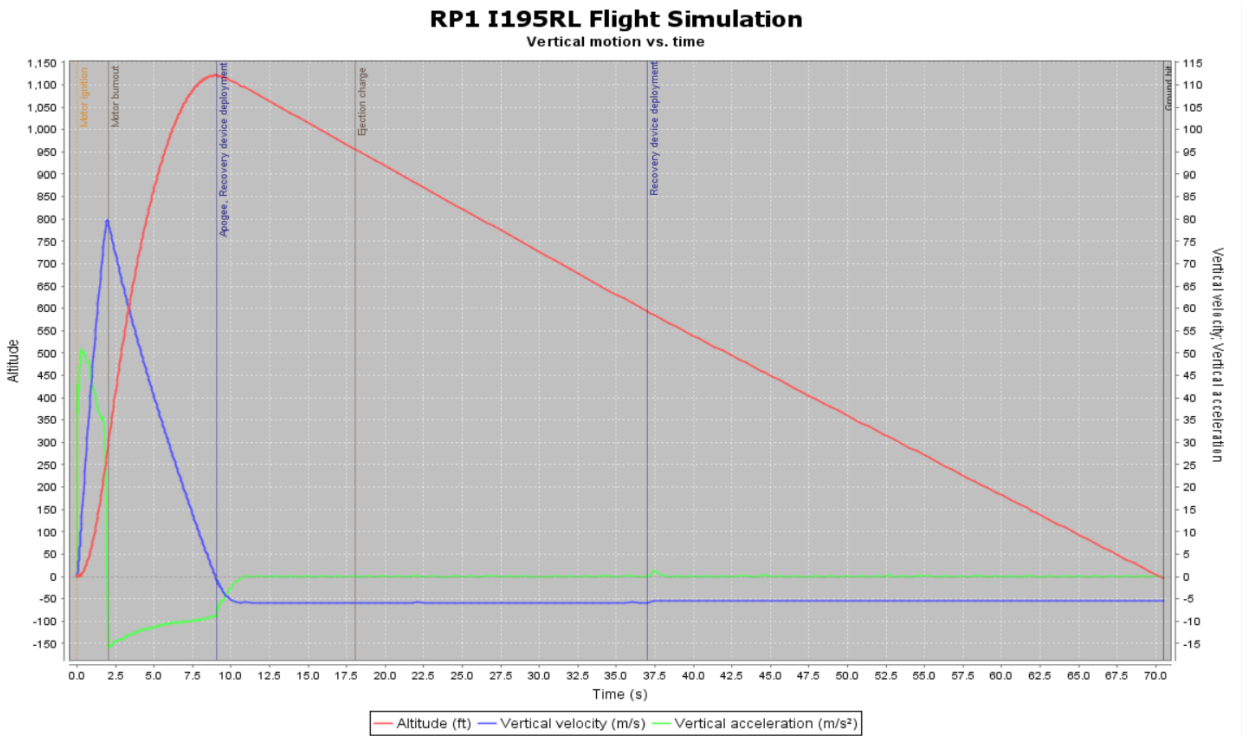


Figure 11 - OpenRocket flight simulation of RP1 with an I195RL-16A motor.

- Apogee: 342 m (1121 ft)
- Velocity off Rod: 9.82 m/s (32.2 ft/s)
- Velocity at Drogue Deploy: 5.85 m/s (19.2 ft/s)
- Optimum Delay: 7 s
- Max. Velocity: 80.1 m/s (263 ft/s)
- Max. Acceleration: 50.8 m/s^2 (167 ft/s^2)
- Time to Apogee: 8.96 s
- Flight Time: 70.5 s (Does not account for dual deploy)
- Ground Hit Velocity: 5.38 m/s (17.7 ft/s)

7.2 J357BS-17A

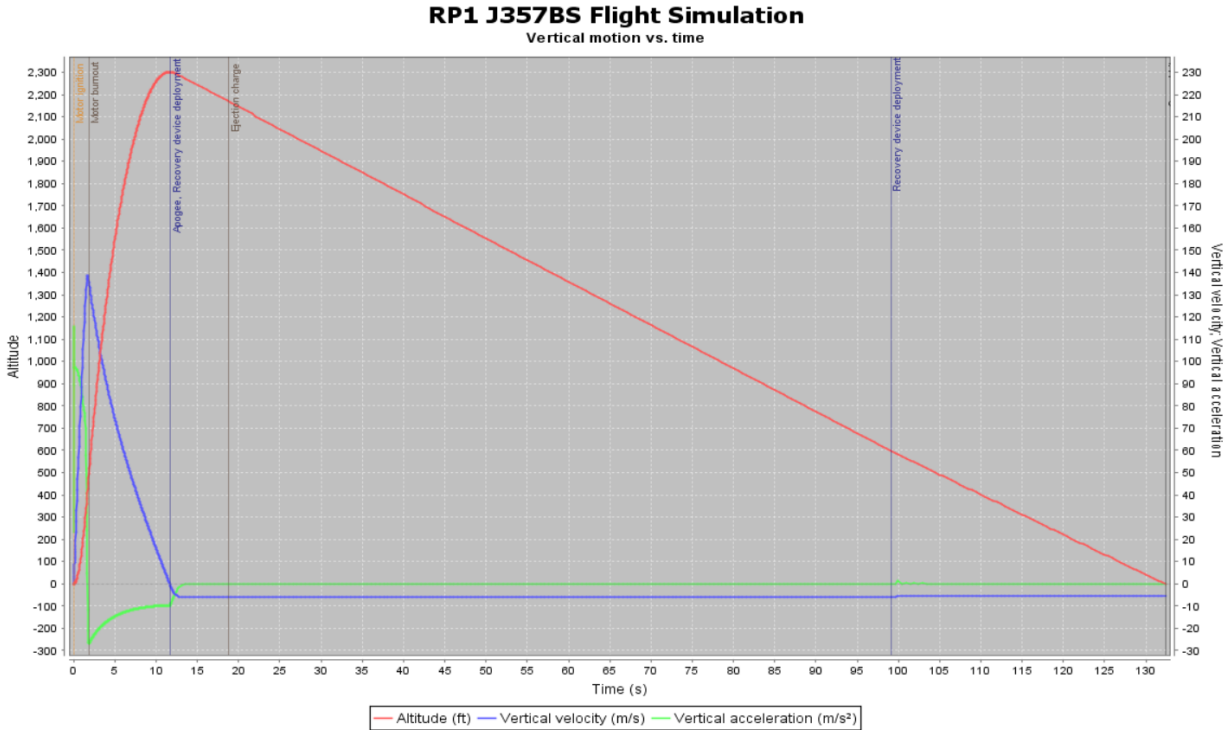


Figure 12 - OpenRocket flight simulation of RP1 with an J357BS-17A motor.

- Apogee: 701 m (2301 ft)
- Velocity off Rod: 14.5 m/s (47.5 ft/s)
- Velocity at Drogue Deploy: 5.89 m/s (19.3 ft/s)
- Optimum Delay: 9.85 s
- Max. Velocity: 139 m/s (455 ft/s)
- Max. Acceleration: 116 m/s^2 (380 ft/s^2)
- Time to Apogee: 11.6 s
- Flight Time: 133 s (Does not account for dual deploy)
- Ground Hit Velocity: 5.48 m/s (18 ft/s)

8. TESTING

8.1 Ground Ejection Testing

Ground ejection testing was conducted for both main and drogue deploy, not using the altimeters. E-matches were wired from the charge terminal blocks into the blast caps. 1 *g* of ffffg black powder was loaded into one fore section blast cap and one aft section blast cap. Dog Barf was loaded over the black powder to keep the black powder from leaking out and then the blast caps were taped over with masking tape. A long wire was then wired to the aft terminal block and run through the key hole. The Ebay was assembled, then the rocket was assembled in its flight configuration including shock cord, parachutes, and Nomex. The motor mount was stuffed with Nomex and then duct taped at the end as no motor was in the motor mount during testing. This kept the aft section volume about the same as what it would be in flight to best simulate the volume that would be pressured. The long wire was touched to a drill wire to fire the charge. This setup was done again for testing the fore section, requiring a rewiring of the long igniter wire.

8.1.1 Results

Both fore and aft ejection tests were successful with 1 *g* of black powder and used 3 shear pins for each section.

8.2 Ground Altimeter Testing

The procedure laid out by PerfectFlite in their StratoLoggerCF manual was followed to test the altimeters detecting apogee to fire the drogue parachute, and then the subsequent altitude to fire the main parachute. That procedure is as follows.

Set up your altimeter bay with the battery and Ematches you plan on using, but without any black powder ejection charges. If you are using commercial Ematches or any other ematch with flammable pyrogen, make sure the Ematches are located away from flammable objects or body parts. Turn the altimeter on and wait for the continuity beeps – ensure that they are as expected (three beeps repeated if you are using two event deployment).

Use a shop vac to apply a vacuum to the static pressure sampling hole on your altimeter bay (you will not be able to pull enough vacuum with your lungs due to the leaky nature of most altimeter bays). You can make a "head" for the shop vac hose out of a block of soft foam and carve it to conform to the curvature of your rocket body tube to protect your rocket's finish and to provide maximum vacuum. Shortly after the vacuum "peaks", the drogue ematch

should fire. After the drogue match fires, remove the vacuum and the main ematch should fire. Make 100% certain that the Ematches fired in the correct order – if you accidentally swap the main and drogue charge wires, your large main chute will deploy at apogee and you will be in for a long walk!

If you look at the "flight" curve from your shop vac tests you may notice that the apogee deployment appears to be delayed several seconds from where you might expect it. This is because the sudden application of a strong vacuum from the shop vac will activate the MachLock feature of the altimeter. Once MachLock is activated, the altimeter requires the speed to fall below a predetermined threshold for a period of time before looking for apogee conditions. In a normal rocket flight, this will happen gradually as the rocket approaches apogee. When you jerk the shop vac away, the apparent speed suddenly goes negative instead of slowing gradually, and apogee will not be detected until several seconds later. This will never occur in a normal rocket flight profile.

8.2.1 Altimeter 1 (#4154) Results:

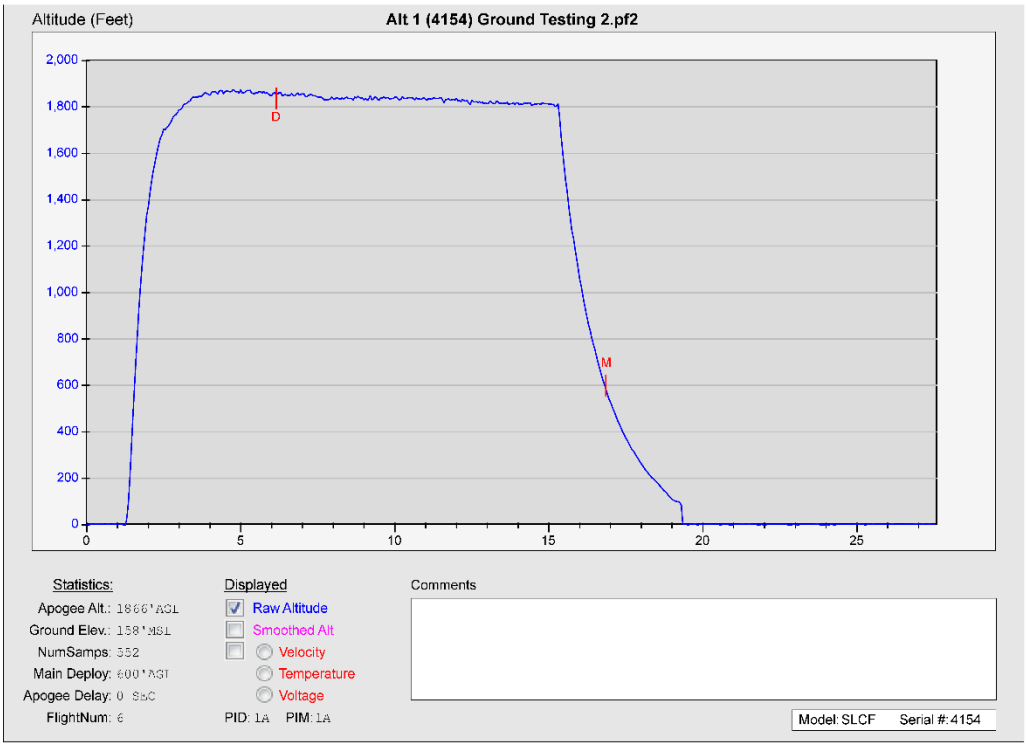


Figure 13 - Altimeter 1 ground testing deployment with shop vac method. Graph shows the flight curve of altitude (ft) vs time (s).

Altimeter 1 performed nominally. The initial increase in altitude is from the shop vac turning on, lowering the pressure inside the Ebay, therefore making the altimeter think the

rocket is going up into the atmosphere where pressure decreases as you get higher. The leveling out of the curve at around 2,500 ft is where the shop vac peaks. At ~6 s, the drogue charge fired. The shop vac was turned off, causing the decrease in altitude as the Ebay pressure rises again. The main parachute charge fired at 600 ft, where it was set to fire.

8.2.2 Altimeter 2 (#4374) Results:

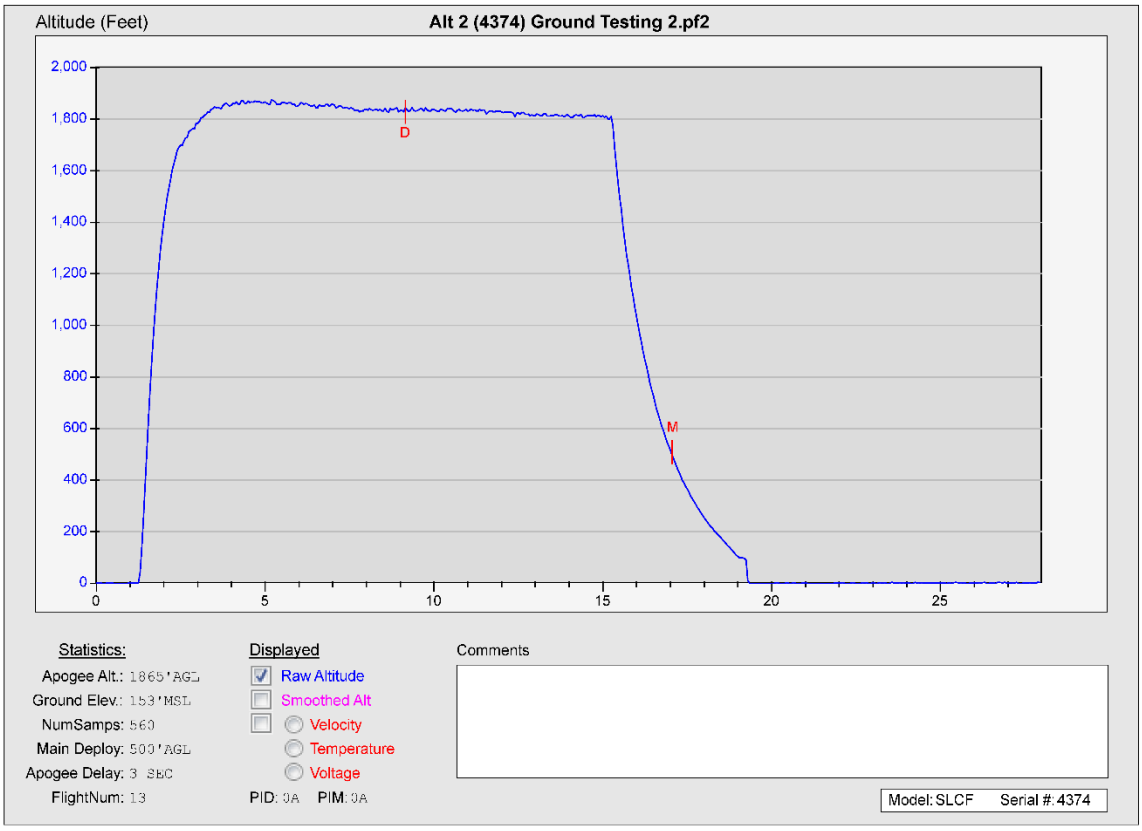


Figure 14 - Altimeter 2 ground testing deployment with shop vac method. Graph shows the flight curve of altitude (ft) vs time (s).

Altimeter 2 performed nominally. The initial increase in altitude is from the shop vac turning on, lowering the pressure inside the Ebay, therefore making the altimeter think the rocket is going up into the atmosphere where pressure decreases as you get higher. The leveling out of the curve at around 2,500 ft is where the shop vac peaks. At ~9 s, the drogue charge is fired. This is 3 seconds after altimeter 1 fired its drogue charge (as was programmed). The shop vac was turned off, causing the decrease in altitude as the Ebay pressure rises again. The main parachute charge fired at 500 ft, where it was set to fire.

9. LAUNCH LIST

- Tools:
    - Duct tape
    - Masking tape
    - Painters tape
    - Dremel
    - Drill
    - Drill batteries
    - Soldering iron
    - Solder
    - Small screw driver set
    - Large screw drivers
    - Pliers
    - Clamps
    - Safety goggles
    - Wrenches
    - Clamps
    - Scissors
    - Kwik weld
    - E6000
    - Headlamp
    - Hammer
    - Mallet
    - Saw
    - Masks
    - Eye protection
    - Ear protection
    - Multimeter
    - Hot glue
    - Measuring tape
    - Electrical tape
    - Shrink wrap
    - Hand gloves
    - Surgical gloves
    - Extension cord
    - Ratchet set
    - Sand paper

    - Drill bits
    - Lighter
    - Wire stripper
    - Wire

- Rocket Equipment:
    - PVC stand for rocket
    - Black powder
    - Ematches
    - Sheer pins
    - Set screws
    - New 9V Batteries
    - H125, I195, and J357 motors
    - Main drogue parachutes
    - Shock cord
    - Sheer pins
    - Set screws

- Other:
    - Tent cover (in case of rain)
    - Folding chairs
    - Folding table(s)
    - License
    - NAR Membership card
    - Camera gear
    - Rain coat
    - Boots

10. NIGHT BEFORE LAUNCH TO-DOS

10.1 Altimeter Checks (If have data cord)

10.1.1 Altimeter 1 Check

1. Read the Alt 1 9V battery voltage with multimeter at both the battery terminals **as well** as the quick connector terminals and record below.
    - Alt 1 Battery Voltage: _____ *V*
1. Plug Alt 1 into laptop and ensure Setup settings match Alt 1 Launch Setting in **Error! R eference source not found.**.
2. In the PerfectFlite software, test the altimeter under Altimeter → Test
    2.1. Perform Self-Test.
        2.1.1. Should read **"Self test passed!"**
    2.2. Perform Get Data.
        2.2.1. Ensure Temp reading is within the Low and High temp readings taken in **Error! Reference source not found.** Section 8.2.
        2.2.2. Ensure Pressure reading is reasonably close to the pressure reading taken in **Error! Reference source not found.** Section 8.1.
        2.2.3. Ensure the Voltage reading is reasonably close to the voltage reading taken in Pre-Launch Procedures Section 1.2.2.
3. Disconnect Altimeter from laptop.

10.1.2 Altimeter 2 Check

1. Read the Altimeter 2 9V battery voltage with multimeter at both the battery terminals **as well** as the quick connector terminals and record below.
    - Altimeter 2 Battery Voltage: _____ *V*
2. Plug Altimeter 2 into laptop and ensure Setup settings match Altimeter 2 Launch Setting in **Error! Reference source not found.**.
3. In the PerfectFlite software, test the altimeter under Altimeter → Test
    3.1. Perform Self-Test.
        3.1.1. Should read **"Self test passed!"**
    3.2. Perform Get Data.
        3.2.1. Ensure Temp reading is within the Low and High temp readings taken in **Error! Reference source not found.** Section 8.2.
        3.2.2. Ensure Pressure reading is reasonably close to the pressure reading taken in **Error! Reference source not found.** Section 8.1.
        3.2.3. Ensure the Voltage reading is reasonably close to the voltage reading taken in Pre-Launch Procedures Section 1.2.2.
4. Disconnect Altimeter from laptop.

11. MORNING OF LAUNCH TO DOS

11.1 Pressure Check

Check pressure level in St. Albans VT using the Weather Channel and record it below in *inches mercury* (*" Hg* or *in Hg*). This reading will be used later to verify the altimeters pressure readings.

- Pressure: _____ *in Hg*

11.2 Temperature Check

Check the high and low temperature in St. Albans VT using the Weather Channel and record it. This reading will be used later to verify the altimeters temperature readings.

- High Temp: _____ *°F*
- Low Temp: _____ *°F*

12. LAUNCH PROCEDURES

Purpose: These pre-launch procedures are meant to provide a step-by-step process for each L1 and L2 launch for the preparation and launch of the rocket before each flight. These procedures are to be followed and performed completely.

Good Resource: http://www.gorgerocketclub.com/pre-flight-procedures/

12.1 L1 Pre-Launch Procedure

1. Altimeter 1 Pre-Check Procedure:
    1.1. Ensure NO CHARGES are loaded.
    1.2. Install Alt 1 battery.
    1.3. Read the Alt 1 battery voltage at the quick connector terminals and record below.
        - Alt 1 Battery Voltage: _____ *V*
    1.4. Plug 9V battery into Alt 1.
    1.5. Turn Alt 1 on and ensure proper settings are reported based on Alt 1 Launch Setting in Appendix D5.
        1.5.1. Short siren, one or more digits representing error code (if there is one), another short siren.
        1.5.2. Short tone, one digit for current program preset.
            1.5.2.1. **Preset #:** _____
            1.5.2.2. **Should be preset 1.**
        1.5.3. Short tone, three or four digit (100 ft to 9,999 ft) for main deploy altitude.
            1.5.3.1. **Main Deploy:** _____
            1.5.3.2. Should be 600 ft
        1.5.4. **Should be NO** five second continuous tone warning that an apogee delay is set.
        1.5.5. Short tone, then a three to six digit number (160 ft to 103,500 ft) for apogee altitude of last flight.
            1.5.5.1. **Apogee:** _____
        1.5.6. Short tone, then a two or three digit number for battery voltage.
            1.5.6.1. **Voltage:** _____
        1.5.7. Short tone, then one of the following continuity beep sequences repeated every 0.8 sec:
            1.5.7.1. Single beep = drogue continuity OK.
            1.5.7.2. Two beeps = main ematch continuity OK.

1.5.7.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING

1.5.7.4. Silence = Neither drogue nor main have continuity.

1.5.8. Alt 1 Pre-check good, turn key off, disconnect 9V battery.

2. Altimeter 2 Pre-Check Procedure:
   - 2.1. Ensure NO CHARGES are loaded.
   - 2.2. Read the Alt 2 battery voltage at the quick connector terminals and record below.
     - Alt 2 Battery Voltage: _____ *V*
   - 2.3. Plug 9V battery into Alt 2.
   - 2.4. Turn Alt 2 on and ensure proper settings are reported based on Alt 2 Launch Setting in **Error! Reference source not found.**
     - 2.4.1. Short siren, one or more digits representing error code (if there is one), another short siren.
     - 2.4.2. Short tone, one digit for current program preset.
       - 2.4.2.1. **Preset #:** _____
       - 2.4.2.2. **Should be preset 1.**
     - 2.4.3. Short tone, three or four digit (100 ft to 9,999 ft) for main deploy altitude.
       - 2.4.3.1. **Main Deploy:** _____
       - **2.4.3.2. Should be 600 ft**
     - 2.4.4. **Should be NO** five second continuous tone warning that an apogee delay is set.
     - 2.4.5. Short tone, then a three to six digit number (160 ft to 103,500 ft) for apogee altitude of last flight.
       - 2.4.5.1. **Apogee:** _____
     - 2.4.6. Short tone, then a two or three digit number for battery voltage.
       - 2.4.6.1. **Voltage:** _____
     - 2.4.7. Short tone, then one of the following continuity beep sequences repeated every 0.8 sec:
       - 2.4.7.1. Single beep = drogue continuity OK.
       - 2.4.7.2. Two beeps = main ematch continuity OK.
       - **2.4.7.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING**
       - 2.4.7.4. Silence = Neither drogue nor main have continuity.
     - 2.4.8. Alt 2 Pre-check good, turn key off, disconnect 9V battery.

3. Ebay Pre-Launch Procedure:
    3.1. *Pre-Checks:*
        3.1.1. Check continuity between each altimeter and each terminal on the outside of the Ebay.
        3.1.2. Check resistance.
            3.1.2.1. Should be zero resistance.
    3.2. *Charges:*
        3.2.1. Make sure all the batteries are disconnected.
        3.2.2. Load black powder charges into all four blast caps based on the black powder mass calculations in the "Calculations" section.
        3.2.3. Stuff blast caps with Dog Barf over BP.
        3.2.4. Install E-matches into blast caps and tape ejection charges.

    3.3. *Batteries*
        3.3.1. Install 9V batteries.
        3.3.2. Ensure key switch is off and connect batteries to altimeters.
    3.4. *Assembly Ebay*
        3.4.1. Install and connect bottom bulkhead.
        3.4.2. Install Ebay into coupler from the bottom up.
        3.4.3. Install and connect top bulkhead.

4. Assemble Rocket:
    4.1. Using a bowline knot, attach shock cord to aft section U-bolt.
    4.2. Put a Nomex chute protector on the shock cord near the ejection charge and loop it back through twice so that it is "locked" in one place.
    4.3. Tie the other end of the chock cord to the aft end of the Ebay using a slip knot.
    4.4. Attach the **main** parachute 1/3 of the away down the shock cord from the Ebay. It should be farther from the ejection charge than the chute protector.
        4.4.1. Tie a loop at the 1/3 point and attach the parachute to that loop.
    4.5. Using a bowline knot, tie shock cord to the nose cone bulkhead.
    4.6. Put a Nomex chute protector on the shock cord near the ejection charge and loop it back through twice so that it is "locked" in one place.
    4.7. Run the other end of the shock through the fore section and attach to fore Ebay bulkhead.
    4.8. Tie shock cord to Ebay.
    4.9. Install Ebay into fore section and install 4 set screws.
    4.10. Pack and install drogue chute.

4.11. Pack and install main chute. Put 3 set screws each in the nosecone-fore section and Ebay to aft section.

4.12. Install motor.

12.2 L1 Launch Procedure:

1. Have your rocket inspected by RSO if applicable, install engine igniter, and place rocket on launch pad.
2. Turn altimeter power switch ON. If you hear a repeating error siren, turn altimeter OFF and do not launch until problem is corrected. The altimeter's settings will be reported as follows:
    2.1. Short tone.
    2.2. One or more digits for error code (if there is one).
    2.3. Short tone.
    2.4. One digit for current program preset (**Should be preset 1).**
    2.5. Short tone.
    2.6. Three or four digits for main deploy altitude (**Should be 600 ft).**
    2.7. Short tone.
    2.8. Five second continuous tone warning that an apogee delay is set.
    2.9. Short tone.
    2.10. Three to six digit number for apogee altitude of last flight.
    2.11. Short tone.
    2.12. Two or three digit number for battery voltage.
    2.13. Short tone.
    2.14. Continuity beeps:
        2.14.1. Single beep = drogue continuity OK.
        2.14.2. Two beeps = main ematch continuity OK.
        2.14.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING
        2.14.4. Silence = Neither drogue nor main have continuity.
3. If continuity is being reported as expected, attach launch system leads to engine igniter and launch!

12.3 L1 Launch Events

1. Rocket launch
2. +2s Engine cutoff
3. +7s apogee, alt 1 drogue fire
4. +3s, alt 2 drogue fire

5. +5s motor ejection charge fire
6. @600ft alt 1 main fire
7. @500ft alt 2 drogue fire
8. Ground hit

12.4 L1 Post Launch Procedure:

1. Altimeter will report in this sequence after launch:
   1.1. Extra-long tone indicate start of reporting
   1.2. 3-6 digits for peak altitude in feet
   1.3. Long tone.
   1.4. 2-5 digits for max velocity during flight in MPH
   1.5. Wait 5 seconds (see Altimeter Flight Settings for "Siren Delay")
   1.6. 10 second warbling siren tone to aid in locating
   1.7. 10 second of silence
   1.8. Sequence repeats
2. Bring rocket to Howard for inspection
3. If rocket is all good, complete L1 paper work.

12.5 L2 Pre-Launch Procedure

1. Take L2 Exam
2. Altimeter 1 Pre-Check Procedure:
   2.1. Ensure NO CHARGES are loaded.
   2.2. Install Alt 1 battery.
   2.3. Read the Alt 1 battery voltage at the quick connector terminals and record below.
      - Alt 1 Battery Voltage: _____ *V*
   2.4. Plug 9V battery into Alt 1.
   2.5. Turn Alt 1 on and ensure proper settings are reported based on Alt 1 Launch Setting in Appendix D5.
      2.5.1. Short siren, one or more digits representing error code (if there is one), another short siren.
      2.5.2. Short tone, one digit for current program preset.
         2.5.2.1. **Preset #:** _____
         2.5.2.2. **Should be preset 1.**
      2.5.3. Short tone, three or four digit (100 ft to 9,999 ft) for main deploy altitude.
         2.5.3.1. **Main Deploy:** _____

2.5.3.2. Should be 600 ft

2.5.4. **Should be NO** five second continuous tone warning that an apogee delay is set.

2.5.5. Short tone, then a three to six digit number (160 ft to 103,500 ft) for apogee altitude of last flight.

2.5.5.1. **Apogee:** _____

2.5.6. Short tone, then a two or three digit number for battery voltage.

2.5.6.1. **Voltage:** _____

2.5.7. Short tone, then one of the following continuity beep sequences repeated every 0.8 sec:

2.5.7.1. Single beep = drogue continuity OK.

2.5.7.2. Two beeps = main ematch continuity OK.

2.5.7.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING

2.5.7.4. Silence = Neither drogue nor main have continuity.

2.5.8. Alt 1 Pre-check good, turn key off, disconnect 9V battery.

3. Altimeter 2 Pre-Check Procedure:

3.1. Ensure NO CHARGES are loaded.

3.2. Read the Alt 2 battery voltage at the quick connector terminals and record below.

- Alt 2 Battery Voltage: _____ *V*

3.3. Plug 9V battery into Alt 2.

3.4. Turn Alt 2 on and ensure proper settings are reported based on Alt 2 Launch Setting in **Error! Reference source not found.**

3.4.1. Short siren, one or more digits representing error code (if there is one), another short siren.

3.4.2. Short tone, one digit for current program preset.

3.4.2.1. **Preset #:** _____

3.4.2.2. **Should be preset 1.**

3.4.3. Short tone, three or four digit (100 ft to 9,999 ft) for main deploy altitude.

3.4.3.1. **Main Deploy:** _____

3.4.3.2. Should be 600 ft

3.4.4. **Should be NO** five second continuous tone warning that an apogee delay is set.

3.4.5. Short tone, then a three to six digit number (160 ft to 103,500 ft) for apogee altitude of last flight.

3.4.5.1. **Apogee:** _____

3.4.6. Short tone, then a two or three digit number for battery voltage.

3.4.6.1. **Voltage:** _____

3.4.7. Short tone, then one of the following continuity beep sequences repeated every 0.8 sec:

3.4.7.1. Single beep = drogue continuity OK.

3.4.7.2. Two beeps = main ematch continuity OK.

3.4.7.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING

3.4.7.4. Silence = Neither drogue nor main have continuity.

3.4.8. Alt 2 Pre-check good, turn key off, disconnect 9V battery.

4. Ebay Pre-Launch Procedure:

4.1. *Pre-Checks:*

4.1.1. Check continuity between each altimeter and each terminal on the outside of the Ebay.

4.1.2. Check resistance.

4.1.2.1. Should be zero resistance.

4.2. *Charges:*

4.2.1. Make sure all the batteries are disconnected.

4.2.2. Load black powder charges into all four blast caps based on the black powder mass calculations in the "Calculations" section.

4.2.3. Stuff blast caps with Dog Barf over BP.

4.2.4. Install E-matches into blast caps and tape ejection charges.

4.3. *Batteries*

4.3.1. Install 9V batteries.

4.3.2. Ensure key switch is off and connect batteries to altimeters.

4.4. *Assembly Ebay*

4.4.1. Install and connect bottom bulkhead.

4.4.2. Install Ebay into coupler from the bottom up.

4.4.3. Install and connect top bulkhead.

5. Assemble Rocket:

5.1. Using a bowline knot, attach shock cord to aft section U-bolt.

5.2. Put a Nomex chute protector on the shock cord near the ejection charge and loop it back through twice so that it is "locked" in one place.

5.3. Tie the other end of the chock cord to the aft end of the Ebay using a slip knot.

5.4. Attach the **main** parachute 1/3 of the away down the shock cord from the Ebay. It should be farther from the ejection charge than the chute protector.
    5.4.1. Tie a loop at the 1/3 point and attach the parachute to that loop.
5.5. Using a bowline knot, tie shock cord to the nose cone bulkhead.
5.6. Put a Nomex chute protector on the shock cord near the ejection charge and loop it back through twice so that it is "locked" in one place.
5.7. Run the other end of the shock through the fore section and attach to fore Ebay bulkhead.
5.8. Tie shock cord to Ebay.
5.9. Install Ebay into fore section and install 4 set screws.
5.10. Pack and install drogue chute.
5.11. Pack and install main chute. Put 3 set screws each in the nosecone-fore section and Ebay to aft section.
5.12. Install motor.

12.6 L2 Launch Procedure:

1. Have your rocket inspected by RSO if applicable, install engine igniter, and place rocket on launch pad.
2. Turn altimeter power switch ON. If you hear a repeating error siren, turn altimeter OFF and do not launch until problem is corrected. The altimeter's settings will be reported as follows:
    2.1. Short tone.
    2.2. One or more digits for error code (if there is one).
    2.3. Short tone.
    2.4. One digit for current program preset (**Should be preset 1).**
    2.5. Short tone.
    2.6. Three or four digits for main deploy altitude (**Should be 600 ft).**
    2.7. Short tone.
    2.8. Five second continuous tone warning that an apogee delay is set.
    2.9. Short tone.
    2.10. Three to six digit number for apogee altitude of last flight.
    2.11. Short tone.
    2.12. Two or three digit number for battery voltage.
    2.13. Short tone.
    2.14. Continuity beeps:
        2.14.1. Single beep = drogue continuity OK.
        2.14.2. Two beeps = main ematch continuity OK.

2.14.3. Three beeps = both drogue and main ematch continuity OK. SHOULD BE THIS SETTING

2.14.4. Silence = Neither drogue nor main have continuity.

3. If continuity is being reported as expected, attach launch system leads to engine igniter and launch!

12.7 L2 Launch Events

1. Rocket launch
2. +1.76s Engine cutoff
3. +9.84s apogee, alt 1 drogue fire
4. +3s alt 2 drogue fire
5. +2.4s motor ejection charge fire
6. @600ft alt 1 main fire
7. @500ft alt 2 drogue fire
8. Ground hit

12.8 L2 Post Launch Procedure:

1. Altimeter will report in this sequence after launch:
   1.1. Extra-long tone indicate start of reporting
   1.2. 3-6 digits for peak altitude in feet
   1.3. Long tone.
   1.4. 2-5 digits for max velocity during flight in MPH
   1.5. Wait 5 seconds (see Altimeter Flight Settings for "Siren Delay")
   1.6. 10 second warbling siren tone to aid in locating
   1.7. 10 second of silence
   1.8. Sequence repeats
2. Bring rocket to Howard for inspection
3. If rocket is all good, complete L2 paper work.

13. RULES AND REGULATIONS

13.1 High Power Motor Classifications

Reference [17].

A rocket exceeds the definition of a Model Rocket under NFPA 1122 and becomes a High Power Rocket under NFPA 1127 if it:

- Uses a motor with more than 160 Newton-seconds of total impulse (an "H" motor or larger) or multiple motors that all together exceed 320 Newton-seconds; or
- Uses a motor with more than 80 Newtons average thrust (see rocket motor coding); or
- Exceeds 125 grams (4.4 ounces) of propellant; or
- Weighs more than 1,500 grams (53 ounces) including motor(s); or
- Uses a hybrid motor or a motor designed to emit sparks; or
- Includes any airframe parts of ductile metal.

In addition, under FAA rules (FAR 101.22), a rocket exceeds the definition of a Class 1 Model Rocket and becomes a Class 2 High Power Rocket if it weighs more than 1500 grams (53 ounces). See **FAA Regulations** for more information.

High Power Rockets fall under a code of regulations known as National Fire Protection Association (NFPA) Code 1127. The NFPA's current rocketry codes were first written in 1995. Many states have adopted these codes by reference through their adoption of NFPA 1. Please check your state's laws before attempting to launch High Power Rockets.

In addition, you must apply for and receive a Certificate of Waiver or Authorization (COA), commonly called a "Waiver", from the FAA before launching High Power Rockets. The purpose of a COA is to ensure compatibility of launching Class 2 rockets at a particular site with other uses within a designated airspace. To learn more about a Certificate of Waiver or Authorization and help applying for one, please see the Filing For FAA Launch Authorization page.

13.2 FAA Regulations

High Power Rocketry is governed under multiple codes and regulations. These include the FAA Regulation Part 101, the NFPA 1127, the NAR Safety Code (as a member of NAR), and state and local law.

In general, the FAA Regulations govern the airspace in which model rockets, high power rockets, and advanced high power rockets are launched into. NFPA 1127 governs the launch conditions at the launch to ensure safe handling and launching of high power rockets and their

equipment. NFPA code is only in affect if a state adopts it. If a state adopted a law implementing all NFPA codes, either by adoption of NFPA Code 1 or the International Fire Code (IFC), then the NFPA Codes 1122 and 1127 on rocketry are specifically in effect state-wide unless overridden by a specific state or local law. State and local law overrides NFPA or IFC codes.

NAR lists the states in which NFPA 1122 and 1127 are in effect on their website: https://www.nar.org/find-a-local-club/section-guidebook/laws-regulations/

There are two foundations for the hobby's regulatory coverage: the Codes of the National Fire Protection Association (NFPA) and the Code of Federal Regulations (CFR). The NFPA is a non-governmental public-safety organization dedicated to writing safety codes and model laws for fire prevention. These Codes are recognized nationwide as the single authoritative public safety source for fire marshals; most (but not all) states and local jurisdictions adopt them unchanged–check with your local fire marshal about your area. Both the NAR and the Tripoli Rocketry Association (TRA) belong to the NFPA and participate in writing its codes governing sport rocketry safety. The Code of Federal Regulations is the multi-volume set of regulatory details produced by the various enforcement agencies of the Executive Branch that "flesh out" the implementation of laws passed by Congress. The CFR's have the force of law.

In the latest rules, the FAA has defined three classes of amateur rockets in regard to our hobby. The Class 1 and Class 2 categories are the most relevant to NAR members and will be the focus of this article. You can read the complete regulations for additional information, including details on the Class 3 rocket category.

Class 1 Model Rockets

Class 1 rockets include what used to be known as model and large model rockets. They are defined at 14 CFR 101.22 (a) of the regulations and are listed as:

Class 1- Model Rocket means an amateur rocket that:

(1) Uses no more than 125 grams (4.4 ounces) of propellant;

(2) Uses a slow-burning propellant;

(3) Is made of paper, wood, or breakable plastic;

(4) Contains no substantial metal parts; and

(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

Launching large model rockets used to require providing prior notification to the FAA. Now, no such notification is required. So long as the general operating limitations at 14 CFR 101.23 as listed below are followed, they can be launched freely.

(a) You must operate an amateur rocket in such a manner that it:

(1) Is launched on a suborbital trajectory;

(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;

(3) Is unmanned; and

(4) Does not create a hazard to persons, property, or other aircraft.

(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

Class 2 High Power Rockets

The Class 2 rocket category covers high power rockets and is defined at 14 CFR 101.22 (b) and is listed as:

Class 2 – High-Power Rocket means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

While the older rules prohibited flying unmanned rockets into controlled airspace, the latest rules do not. The newer rules do however, require prior authorization before launching. This is part of the operating limitations for Class 2 High Power Rockets found at 14 CFR 101.25 and stating:

When operating Class 2-High Power Rockets or Class 3-Advanced High Power Rockets, you must comply with the General Operating Limitations of §101.23. In addition, you must not operate Class 2-High Power Rockets or Class 3-Advanced High Power Rockets—

(a) At any altitude where clouds or obscuring phenomena of more than five tenths coverage prevails;

(b) At any altitude where the horizontal visibility is less than five miles;

(c) Into any cloud;

(d) Between sunset and sunrise without prior authorization from the FAA;

(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;

(f) In controlled airspace without prior authorization from the FAA;

(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations applies:

(1) Not less than one quarter the maximum expected altitude;

(2) 457 meters (1,500 ft.);

(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the

operation, and has final approval authority for initiating high-power rocket flight; and

(i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

Prior authorization from the FAA, as mentioned in 14 CFR 101.25, items (d), (e), and (f), pertain to having an approved Certificate of Waiver or Authorization (COA) issued by the FAA. To get approval to make Class 2 rocket flights at a certain location, you must first apply for the COA using FAA Form 7711-2. You can find help with filling out this form at the link located at the end of this article. Once the application and other required information has been received, the FAA will conduct an airspace review to determine the compatibility of launching Class 2 rockets with other uses within the designated airspace.

14. NAR CERTIFICATION PROCESSES

14.1 Level 1 Certification Process and Requirements

https://www.nar.org/high-power-rocketry-info/level-1-hpr-certification/

Revision of November 20, 2011

- Level 1 high power certification (160.01 to 640.00 Newton-seconds impulse)

The procedures for Level 1 certification are documented below. Level 2 certification requires that you hold a valid Level 1 certification before applying. You can examine the HPR Level 2 Certification Procedures for more information, as well as review the HPR Level 2 Study guide. Level 3 certification requires in-process reviews of the certification model's design and construction prior to flight. Level 3 certification is covered in an application separate from the Level 1 and Level 2 paperwork. Please note that the NAR high power certification is only one consideration when purchasing and using high power rocket motors. Compliance with local and state laws as well as federal regulations (e.g., FAA FAR Part 101) is also required. High Power certification is intended to provide a measure of the modeler's competence to avoid gross violations of good modeling practice and safe model operation. The program is not foolproof. A single demonstration of a modeler's skills does not guarantee consistent safe performance. The certification program does not replace competent range personnel (note that high power range safety officers will require high power certification per NFPA 1127) to provide assurance of safe models and operating practices.

1. Who Needs HPR Certification? A person needs High Power certification if they:
    1. Launch models containing multiple motors with a total installed impulse of 320.01 Newton-seconds or more, or
    2. Launches models containing a single motor with a total installed impulse of 160.01 Newton-seconds or more, or
    3. Launches rockets that weigh more than 53 ounces (1500 grams), or
    4. Launches models powered by rocket motors not classified as model rocket motors per NFPA 1122, e.g.:
        a. Average thrust in excess of 80.0 Newtons
        b. Contains in excess of 125 grams of propellant
        c. Hybrid rocket motors

2. Minimum Requirements:

    The individual seeking Level 1 High Power certification must be a minimum of 18 years old at the time of certification .A birth certificate or drivers license is an acceptable

proof of age. Note: Other requirements may be imposed by state, or non-USA authorities. This document does not supersede any requirements imposed by the authorities having jurisdiction.. This document does not supersede any requirements imposed by the authorities having jurisdiction. The individual must be a member in good standing of the National Association of Rocketry (NAR) at the time of certification. Evidence of NAR membership will be requested prior to the certification attempt. Acceptable evidence of membership includes the NAR membership card, a canceled check indicating payment of membership fees, or participation in a NAR event where membership status is verified and indicated on the event materials. Motors used for certification attempts must be currently certified by the NAR, or by another organization (e.g., Tripoli) with a recognized certification program. Manufacturer's designations, not certification test data, will be used to identify suitability for the certification level being attempted (e.g., an H128 is an H, a G75 is a G).

3. Certification Teams
    1. The certification team consists of two individuals who are a minimum of 18 years old and are members in good standing of the NAR. The certification team members must be unrelated to the applicant. Members of Tripoli, unless they are also members of the NAR, cannot participate on a certification team.
    2. At least one of the team members must be already certified to a level equal to the certification level being attempted, e.g., a team member must be certified at Level 1 to judge another individual's Level 1 certification attempt.
    3. Level 1 certifications may be administered by a single NAR Level 2 certified individual; the two certified individuals requirement is waived in this case.
    4. Certification attempts must be witnessed in person by the certification team. Video recordings of a certification flight are not acceptable.

4. Certification Process and Documentation
    1. Certification may be accomplished at any launch where sufficient individuals meeting the requirements of paragraph 2 are available.
    2. FAA regulations requiring notification or waivers must be complied with and the launch site must have a FAA waiver for high power models (greater than 3.3 pounds launch weight and/or 4.4 ounces of propellant) in effect at the time of launch. All conditions and restrictions imposed by the FAA must be satisfied and followed.
    3. The member attempting certification must build the rocket that they wish to use for their certification attempt. The model may be either scratch built or a kit and the rocket must be contructed in such a manner that it will perform safely under

the additional stress of an HPR motor. Teams attempting to certify cannot use the same rocket, but rather are required to each build their own model. In addition, the member must use an active recovery system for their certification attempt, which usually includes parachute recovery; details of these recovery methods are described in the Definition of Active Recovery.

4. The modeler must demonstrate his ability to build and fly a rocket containing at least one H or I impulse class motor. Cluster or staged models used for certification may not contain over 640.00 Newton seconds total impulse. In the case of a cluster or staged model, at least one of the individual motors must be an H or I impulse motor. Combinations of D, E, F or G motors that meet the impulse requirements do not qualify as the model does not contain at least one H or I impulse motor. Single use, reloadable, or hybrid technology motors are permitted. The modeler must assemble the reloadable motor, if used, in the presence of a certification team member.
5. The individual attempting certification must also complete a **NAR High Power Certification Application** prior to his certification attempt.
6. The model will be subjected to a safety inspection prior to flight. The safety inspection form is on the back of the NAR High Power Certification Application. During the safety inspection the modeler will be expected to provide oral answers to technical questions related to the safety and construction of his model. The questions may include (but not limited to) identification of the model's center of gravity and center of pressure, methods used to determine model stability, and interpretation of the rocket motor's designation. The certification team will initial (or check) the blocks indicating that model safety, motor certification, and the existence of a FAA waiver (if required) in effect were verified prior to flight.
7. The individual will fly his model. The flight must be witnessed by the certification team members. Stability, deployment of the recovery system, and safe recovery should be considered when evaluating safety of the flight. Models experiencing a catastrophic failure of the airframe, rocket motor, and/or recovery system (e.g., shock cord separation) will not be considered as having a safe flight.
8. The model must be returned to the certification team after flight. and be inspected to verify engine retention and for evidence of flight-induced damage. The certification team will initial the blocks indicating that a safe flight was made and that the post-flight inspection was satisfactory. In general, the guideline for acceptable flight damage is that the model could be flown again without repair. It is left to the judgement of the certification team to differentiate between flight damage and "normal" maintenance to assure reliability (e.g., shock cord

replacement to prevent future flight problems). "Zippering" of the body tube is another area of flight damage left to certification team judgement for acceptability.

9. The certification team will sign the certification sheet to indicate that the certification attempt was successfully completed. Both the certification sheet and the certification card must be signed. The certification card and the certification sheet are normally returned to the certifying individual after the flight. At club launches or NAR sponsored activities (e.g., NARAM, NSL) the certification sheets may be retained by the event sponsors to be sent to NAR Headquarters as a group. In that event, only the certification card is returned to the certifying individual.
10. The certification sheets are returned to NAR Headquarters. No fees are required. The certification sheet must be returned by the certified individual or the event sponsors to NAR Headquarters to allow updating the NAR database. A new NAR membership card will be issued showing the certification level upon receipt of the certification paperwork.
11. The certification card is valid for one year after the certification date or until the end of the NAR member's membership, whichever comes first. The card is recognized as proof of the certification level. The certification card should be destroyed upon receipt of a new NAR membership card which shows the certification level.
12. Falsification of data or statements by the certifying individual will result in revocation of the high power certification. Falsification of data or statements by the certification team, e.g., failure to secure a FAA waiver, can result in revocation of the team members' NAR memberships.

5. <u>Level 1 high power certification (160.01 to 640.00 Newton-seconds impulse)</u>
    1. Certification at this level permits single or multiple motor rocket flights with motors having a maximum total impulse of 640.00 Newton seconds.

6. <u>Administrative items</u>
    1. NAR members who are currently Tripoli Level 1 certified may grandfather at the NAR Level 1 by completing the identification portion of a NAR high power application and attaching proof of current Tripoli certification (e.g., photocopy of Tripoli consumer confirmation card) to NAR headquarters with a request that their certification level be updated.
    2. Tripoli certifications will be honored at NAR launches. A current Tripoli Membership Card is required as evidence of Tripoli high power certification at launches.

3. NAR HPR certifications, once earned, are valid whenever NAR membership is current, and are reinstated upon request after membership lapses.

14.2 Level 2 Certification Process and Requirements

https://www.nar.org/high-power-rocketry-info/level-2-hpr-certification/

Revision of November 20, 2011

The procedures for Level 2 certification are documented below.

Level 2 certification requires that you hold a valid HPR Level 1 certification before applying. You can examine the HPR Level 2 Certification Procedures covered in this page for more information, as well as review the HPR Level 2 Study Guide. Please note that the NAR high power certification is only one consideration when purchasing and using high power rocket motors. Compliance with local and state laws as well as federal regulations (e.g., FAA FAR Part 101) is also required.

High Power certification is intended to provide a measure of the modeler's competence to avoid gross violations of good modeling practice and safe model operation. The program is not foolproof. A single demonstration of a modeler's skills does not guarantee consistent safe performance. The certification program does not replace competent range personnel (note that high power range safety officers will require high power certification per NFPA 1127) to provide assurance of safe models and operating practices.

1. Minimum Requirements:
    1. The individual seeking Level 2 High Power certification must be a minimum of 18 years old at the time of certification.
    2. A copy of their drivers license or birth certificate can be used for proof of age.
    3. Note: Other requirements may be imposed by state, or non-USA authorities. This document does not supersede any requirements imposed by the authorities having jurisdiction..
    4. The individual must be a member in good standing of the National Association of Rocketry (NAR) at the time of certification. Evidence of NAR membership will be requested prior to the certification attempt. Acceptable evidence of membership includes the NAR membership card, a canceled check indicating payment of membership fees, or participation in a NAR event where membership status is verified and indicated on the event materials.
    5. The individual must currently hold a HPR Level 1 certification, as identified on their Membership Card.
    6. Motors used for certification attempts must be currently certified by the NAR, or by another organization (e.g., Tripoli) with a recognized certification program.

2. Certification Teams
    1. The certification team consists of two individuals who are a minimum of 18 years old and are members in good standing of the NAR. The certification team members must be unrelated to the applicant. Members of Tripoli, unless they are also members of the NAR, cannot participate on a certification team.
    2. At least one of the team members must be already certified to a level equal to the certification level being attempted, e.g., a team member must be certified at Level 2 to judge another individual's Level 2 certification attempt.
    3. Level 2 certifications may be administered by a single NAR Level 3 certified individual; the two certified individuals requirement is waived in this case.
    4. Certification attempts must be witnessed in person by the certification team. Video recordings of a certification flight are not acceptable.

3. Certification Process and Documentation
    1. Certification may be accomplished at any launch where sufficient individuals meeting the requirements of paragraph 2 are available.
    2. FAA regulations requiring notification or waivers must be complied with and the launch site must have a FAA waiver for high power models (greater than 3.3 pounds launch weight and/or 4.4 ounces of propellant) in effect at the time of launch. All conditions and restrictions imposed by the FAA must be satisfied and followed.
    3. The individual must provide proof of previous Level 1 certification. Proof of previous certification includes the high power certification card or a NAR membership card showing the Level 1 certification level.
    4. The flyer is required to take and pass a HPR Level 2 Written Exam prior to their Level 2 certification flight attempt. The individual must demonstrate their knowledge of regulations and laws pertaining to high power rocketry. Questions concerning basic rocket technical knowledge, e.g., center of pressure and center of gravity relationships, will also be included.
        1. The examination will contain 37 questions in the multiple choice format.
        2. The questions will come from a 97 question pool of questions, which should be used as a HPR Level 2 Written Exam Study Guide.
        3. The passing grade is 88% ; this means you must have at least 32 or more correct answers out of the 37 questions in the exam.
        4. The test may be taken only once in a 30-day period.
        5. The test must be completed prior to the flight attempt. The flight attempt should be made as soon as reasonably and safely possible after successful test completion. The written test will not have to be repeated if the initial flight attempt(s) fail, or if

a successful flight is completed within one year of taking the written test. Tests should be retained by the individual until the completion of their certification flight. Once completed, the exam is returned with the application form to NAR Headquarters.

6. NAR HPR Level 2 Written Exams are available from:

   NAR HQ
   PO Box 407
   Marion, IA 52302
   800-262-4872
   nar-hq@nar.org

7. Master Exams and Key Sheets are provided by NAR Headquarters to each section for distribution to their certification team members or to a section officer (e.g., advisor, president). It is the responsibility of the section to make copies of these exams on an as-needed basis for their members.A soft copy of the exams can be requested by Section Leaders/Certification Teams by contacting the Chairman of High Power Services at the NAR. This allows the Sections to print the exams and study guides on an as needed basis.Exams can also be provided by NAR Headquarters to the individual on a case by case basis to be evaluated when the test is requested. The tests are sealed to prevent accidental disclosure of the questions. The tests should remain sealed until taken. Send and email to NAR Headquarters when requesting individual tests and allow one week minimum prior to a certification attempt to receive the test in the mail.
8. The member attempting certification must build the rocket that they wish to use for their certification attempt. The model may be either scratch built or a kit and the rocket must be contructed in such a manner that it will perform safely under the additional stress of an HPR motor. Teams attempting to certify cannot use the same rocket, but rather are required to each build their own model. In addition, the member must use an active recovery system for their certification attempt, which usually includes parachute recovery; details of these recovery methods are described in the Definition of Active Recovery.
9. The modeler must demonstrate his ability to build and fly a rocket containing at least one J, K or L impulse class motor. Cluster or staged models used for certification may not contain over 5120.00 Newton seconds total impulse. In the case of a cluster or staged model, at least one of the individual motors must be an J, K or L impulse motor. Combinations of smaller impulse motors that add up to meet the impulse requirements do not qualify as the model does not contain at least one J, K or L impulse motor. Single use, reloadable, or hybrid technology

motors are permitted. The modeler must assemble the reloadable motor, if used, in the presence of a certification team member.

10. The individual attempting certification must also complete a **NAR High Power Certification Application** prior to his certification attempt.
11. The model will be subjected to a safety inspection prior to flight. The safety inspection form is on the back of the NAR High Power Certification Application. During the safety inspection the modeler will be expected to provide oral answers to technical questions related to the safety and construction of his model. The questions may include (but not limited to) identification of the model's center of gravity and center of pressure, methods used to determine model stability, and interpretation of the rocket motor's designation. The certification team will initial (or check) the blocks indicating that model safety, motor certification, and the existence of a FAA waiver (if required) in effect were verified prior to flight.
12. The individual will fly his model. The flight must be witnessed by the certification team members. Stability, deployment of the recovery system, and safe recovery should be considered when evaluating safety of the flight. Models experiencing a catastrophic failure of the airframe, rocket motor, and/or recovery system (e.g., shock cord separation) will not be considered as having a safe flight.
13. The model must be returned to the certification team after flight. and be inspected to verify engine retention and for evidence of flight-induced damage. The certification team will initial the blocks indicating that a safe flight was made and that the post-flight inspection was satisfactory. In general, the guideline for acceptable flight damage is that the model could be flown again without repair. It is left to the judgement of the certification team to differentiate between flight damage and "normal" maintenance to assure reliability (e.g., shock cord replacement to prevent future flight problems). "Zippering" of the body tube is another area of flight damage left to certification team judgement for acceptability.
14. The certification team will sign the certification sheet to indicate that the certification attempt was successfully completed. Both the certification sheet and the certification card must be signed. The certification card and the certification sheet, as well as the successfully passed written exam are normally returned to the certifying individual after the flight. At club launches or NAR sponsored activities (e.g., NARAM, NSL) the certification sheets may be retained by the event sponsors to be sent to NAR Headquarters as a group. In that event, only the certification card is returned to the certifying individual.
15. The certification sheet and written exam are returned to NAR Headquarters. No fees are required. The certification sheet must be returned by the certified individual or the event sponsors to NAR Headquarters to allow updating the

NAR database. A new NAR membership card will be issued showing the certification level upon receipt of the certification paperwork.

16. The certification card is valid for one year after the certification date or until the end of the NAR member's membership, whichever comes first. The card is recognized as proof of the certification level. The certification card should be destroyed upon receipt of a new NAR membership card which shows the certification level.
17. Falsification of data or statements by the certifying individual will result in revocation of the high power certification. Falsification of data or statements by the certification team, e.g., failure to secure a FAA waiver, can result in revocation of the team members' NAR memberships.

5. Administrative items
    1. NAR members who are currently Tripoli Level 2 certified may grandfather at the NAR Level 2 by completing the identification portion of a NAR high power application and attaching proof of current Tripoli certification (e.g., photocopy of Tripoli consumer confirmation card) to NAR headquarters with a request that their certification level be updated.
    2. Tripoli certifications will be honored at NAR launches. A current Tripoli Membership Card is required as evidence of Tripoli high power certification at launches.
    3. NAR HPR certifications, once earned, are valid whenever NAR membership is current, and are reinstated upon request after membership lapses.

15. UPPERCLASSMAN ADVICE

15.1 From Arun Chundru

- Make sure the key hole for the Ebay is not in line with the rail buttons
- Make sure the set screws aren't in line with the rail buttons because then they rub on the launch rail
- Manually calculate the center of gravity/center of mass because OpenRocket won't have the density of things correct
    - OpenRocket should have the center of pressure accurate so don't have to calculate that
- Don't rely on the plastic loop on the nose cone to tie the shock cord to
    - Cut the plastic end off the shoulder and put a bulkhead in the nose cone with an eyebolt

15.2 From Tyler Kosakowski

- Mark which way is on and off for the key switch on the rocket airframe

16. FUTURE IMPROVEMENTS

1. Put the key hole in the section that is set screwed. When you are ground testing the ejection charges and need a long wire to come out of the key hole, the wire will strip when the section gets blasted off (i.e. the wire has to squeeze between the coupler shoulder and the airframe being blasted off).

17. REFERENCES

[1] NAR Safety Code: https://www.nar.org/safety-information/model-rocket-safety-code/
[2] NAR Launching Safely in the 21st Century: http://www.nar.org/pdf/launchsafe.pdf
[3] H125CL AMW Product Page:
http://cart.amwprox.com/index.php?option=com_virtuemart&view=productdetails&virtuemart_product_id=152&virtuemart_category_id=5
[4] J357BS AMW Product Page:
http://cart.amwprox.com/index.php?option=com_virtuemart&view=productdetails&virtuemart_product_id=180&virtuemart_category_id=5
[5] J357BS AMW NAR Motor Certification: http://nar.org/SandT/pdf/Animal/J357.pdf
[6] J357 Thrust Curve: http://www.thrustcurve.org/simfilesearch.jsp?id=1685
[7] H125 Thrust Curve: http://www.thrustcurve.org/motorsearch.jsp?id=566
[8] Tenney Lombard Davis, The Chemistry of Powder and Explosives, Angriff Press, 1972.
[9] http://hararocketry.org/hara/resources/how-to-size-ejection-charge/
[10] Black Powder charge calculations: http://www.arsabq.org/m.ejection.htm
[11] Black powder charge calculator: https://www.insanerocketry.com/blackpowder.html
[12] Black powder charge calculator:
http://www.rimworld.com/nassarocketry/tools/chargecalc/index.html
[13] Black powder charge calculator: http://www.rockethead.net/black_powder_calculator.htm
[14] Shock Cord Length:
https://www.apogeerockets.com/education/downloads/Newsletter348.pdf
[15] https://en.wikipedia.org/wiki/Model_rocket_motor_classification
[16] https://www.nar.org/high-power-rocketry-info/understanding-faa-regulations/
[17] https://www.nar.org/high-power-rocketry-info/

David Antaki
Project RP1

Appendix D1
Budget

NAR L1 & L2 Technical Report

June 28th, 2019

Appendix D1 - Budget

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Item	Description	Seller	Purchase Date	Cost
Airframe	4.014in, 48in Blue Tube Airframe Tube	Always Ready Rocketetry	2/2/2019	$ 38.95
Coupler	3.9in, 8in Blue Tube Coupler	Always Ready Rocketetry	2/2/2019	$ 10.95
Nose Cone	Ogive PNC-4.00" X 16.5" (98MM)	Always Ready Rocketetry	2/2/2019	$ 21.95
Motor Mount	38MM Blue Tube MMT	Always Ready Rocketetry	2/2/2019	$ 16.49
Motor Retainer	Aero Pack 38mm Retainer	Always Ready Rocketetry	2/2/2019	$ 29.00
ARR Shipping	N/A	Always Ready Rocketetry	2/2/2019	$ 18.95
Level 1 Motor	H152BS 38-2G Reload	Animal Motor Works	2/9/2019	$ 61.60
Level 2 Motor	J357BS 38-5G Reload	Animal Motor Works	2/9/2019	$ 70.40
Hazmat	N/A	Animal Motor Works	2/9/2019	$ 65.00
1x 2" U-Bolt	Black-Oxide Steel U-Bolt, 1/4"-20 Thread Size, 2"	McMaster-Carr	2/8/2019	$ 0.93
4x 1-1/4" U-Bolt	Black-Oxide Steel U-Bolt, 1/4"-20 Thread Size, 1-1/4"	McMaster-Carr	2/8/2019	$ 3.36
Threaded Rod	Aluminum , 1/4"-20 Thread Size, 2 Feet Long	McMaster-Carr	2/8/2019	$ 7.76
Sales Tax	N/A	McMaster-Carr	2/8/2019	$ 0.51
Shipping	N/A	McMaster-Carr	2/8/2019	$ 5.13
Rail Buttons	Standard Rail Button (fits 1" Rail - 1010)	Apogee Components	2/6/2019	$ 3.35
Paint	Spray Paint	Lowes	5/18/2019	$ 8.96
			Grand Total	**$ 363.29**

David Antaki
Project RP1

Appendix D2
Receipts

NAR L1 & L2 Technical Report

June 28th, 2019

Fwd: Order Confirmation No: 109964

1 message

Ben Helfrich <bph719@gmail.com> Wed, Feb 6, 2019 at 8:39 PM
To: davidantaki@gmail.com

---------- Forwarded message ---------
From: **Apogee Components** <orders@apogeerockets.com>
Date: Wed, Feb 6, 2019 at 8:33 PM
Subject: Order Confirmation No: 109964
To: Bennett Helfrich <bph719@gmail.com>



Apogee Order Confirmation

Order Number: 109964

Hello Bennett,

Thanks for shopping with us today!
The following are the details of your order.

Order Number: **109964**
Date Ordered: **02/06/2019**
Click here to check the status of your order

Products

Model	Qty	Name	Price
10504	x 1	75mm Blue Tube - *1 Per Pack*	$32.05
13060	x 2	Standard Rail Button (fits 1" Rail - 1010) - *2 Per Pack*	$6.70
		---	---
		Sub-Total:	$38.75
		USPS (Priority Mail, Est. 02/09):	$15.55
		Total:	$54.30

Address Information

Delivery Address	Billing Address
Bennett Helfrich 10 Forsyth St. #1114 Boston, MA 02115 United States	Bennett Helfrich 34 Eli Lane E. Falmouth, MA 02536 United States
Shipping Method	**Payment Method**
USPS (Priority Mail, Est. 02/09)	Credit Card MasterCard XX9643



If you want to keep your skills and rockets at the peak of performance, subscribe to weekly Apogee newsletter! Every alternating week, we send out a PDF with rocketry tips and a YouTube video with technique and product demonstrations.

This email address was given to us by you or by one of our customers. If you feel that you have received this email in error, please send an email to customerservice@apogeerockets.com

This email is sent in accordance with the US CAN-SPAM Law in effect 01/01/2004. Removal requests can be sent to this address and will be honored and respected.

Apogee Components - 4960 Northpark Drive, Colorado Springs, Colorado, USA

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Receipt for Your Payment to Always Ready Rocketry,LLC

1 message

service@paypal.com <service@paypal.com> Sat, Feb 2, 2019 at 9:47 PM
To: David Antaki <antakidavid@gmail.com>

PayPal

Feb 2, 2019 21:47:30 EST
Transaction ID: 61C543448N207494M

Hello David Antaki,

You sent a payment of $136.29 USD to Always Ready Rocketry,LLC (sales@alwaysreadyrocketry.com)

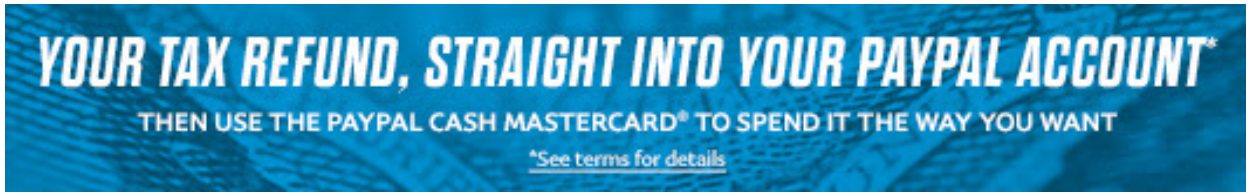
It may take a few moments for this transaction to appear in your account.

Merchant
Always Ready Rocketry,LLC
sales@alwaysreadyrocketry.com
360-445-2277

Instructions to merchant
You haven't entered any instructions.

Shipping address - confirmed
David Antaki
10 Forsyth St
#0934
Boston, MA 02115
United States

Shipping details
The seller hasn't provided any shipping details yet.



Description	Unit price	Qty	Amount
Airframes - 4"(3.9", 98mm) x .062 wall x 48" Airframe / MMT Item# BT20-9848	$38.95 USD	1	$38.95 USD
Standard Couplers - 4"(3.9", 98mm) x .062 wall x 8" Item# BT20-988C	$10.95 USD	1	$10.95 USD
Nosecones - 3.9 inch Ogive Nose Cone Item# NC-39	$21.95 USD	1	$21.95 USD
Aero Pack Motor Retainers - Retainer Assembly, 38mm, Blue Tube Item# RA38P	$29.00 USD	1	$29.00 USD
Airframes - 1.52" (38mm) x .062 wall x 48" MMT ONLY Item# BT20-3848M	$16.49 USD	1	$16.49 USD

Subtotal	$117.34 USD
Shipping and handling	$18.95 USD
Total	$136.29 USD
Payment	$136.29 USD

Charge will appear on your credit card statement as "PAYPAL *ALWAYSREADY"

Payment sent to sales@alwaysreadyrocketry.com

Payment sent from antakidavid@gmail.com

Funding Sources Used (Total)

Visa x-1385	$136.29 USD

Invoice ID: WC-4207

Issues with this transaction?

You have 180 days from the date of the transaction to open a dispute in the Resolution Center.

Questions? Go to the Help Center at www.paypal.com/help.

ADDITIONAL INFORMATION

Massachusetts Division of Banks, (617) 956-1501, http://www.mass.gov/dob , PayPal holds a Foreign Transmittal Agency license with the State of Massachusetts - License Number FT3345. NMLS Number: 910457.

Please do not reply to this email. This mailbox is not monitored and you will not receive a response. For assistance, log in to your PayPal account and click **Help** in the top right corner of any PayPal page or please contact us toll free at 1-888-221-1161. You can receive plain text emails instead of HTML emails. To change your Notifications preferences, log in to your account, go to your Profile, and click **My settings**.

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PayPal PPX001066:1.1:35410e7f5a191

February 9, 2019

Animal Motor Works, LLC.

Payment

- $257.50

Paid with

MasterCard x-1176

You'll see "PAYPAL *AMW" on your card statement.

Ship to

David Antaki

360 Huntington Ave 434 Curry Student Center

Boston, MA 02115

United States

Category

Entertainment

Transaction ID

1PA604369N676422R

Seller info

Animal Motor Works, LLC.

http://www.amwprox.com

Invoice ID

29e602748

Purchase details

Order Number: 29e602748	$257.50
Total	**$257.50**

Need help?

If there's a problem, make sure to contact the seller through PayPal by **August 8, 2019**.

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Privacy Legal Policy updates



AMW/ProX
Robert DeHate
2 Melvin Ave
01915 Beverly
United States
Massachusetts
978-766-9271

Invoice 19020936002524

Invoice date	2019-02-09
Delivery Date	Same as invoice date
Order Number	**29e602748**
Order Date	2019-02-09
Order Status	Confirmed
Shipment	Hazmat(US) LowHazmat for motors
Payment Method	Credit card or Paypal
Shopper's note	I am part of AIAA Northeastern and recently emailed you regarding the inclusion of a P38-5G motor casing. These motors are for L1 and L2 certification rockets and we would be more than grateful if you included a free casing with our order. Thank you! David Antaki
Total	**$257.50**

Bill To		**Ship To**	
E-Mail	antaki.d@husky.neu.edu	Address Nickname	Northeastern Curry
First Name	David	Company Name	AIAA
Last Name	Antaki	First Name	David
Address 1	118 Pond St	Last Name	Antaki
Zip / Postal Code	01748	Address 1	360 Huntington Ave 434 Curry Student Center
City	Hopkinton		
Country	United States	Zip / Postal Code	02115
State / Province / Region	Massachusetts	City	Boston
Phone	5089587024	Country	United States
		State / Province / Region	Massachusetts
		Phone	5089587024

SKU	Product Name	Product status	Price	Qty	Discount	Total
P38-5G-CL	P38-5G-CL	Confirmed	$60.50	1	$0.00	$60.50
P38-2G-BS	P38-2G-BS	Confirmed	$35.20	2	$0.00	$70.40
P38-5G-BS	P38-5G-BS	Confirmed	$61.60	1	$0.00	$61.60

Product prices result	$0.00	$192.50
Hazmat(US) LowHazmat for motors		$65.00
Credit card or Paypal		$0.00
Total	$0.00	**$257.50**

McMASTER-CARR

Receipt

609-689-3000
609-259-3575 (fax)
nj.sales@mcmaster.com

Purchase Order	**0206BHELFRICH**
Paid	**$27.61**
Invoice	**85923648**
Invoice Date	**2/7/19**

Billed to

ATTENTION: BENNETT HELFRICH
BENNETT HELFRICH
10 FORSYTH ST. #1114
BOSTON MA 02115

Shipped to

Bennett Helfrich
10 Forsyth St. #1114
Boston MA 02115

Information About Your Payment

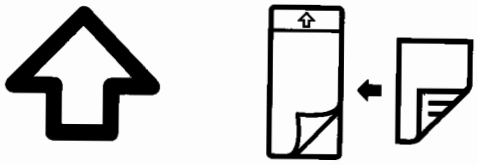
Credit Card	MasterCard Ending- 9643
Date	2/8/19
Name on Card	Bennett Helfrich
Your Account	99883100

Bennett Helfrich placed this order.

Line		Product	Ordered	Shipped	Balance	Price	Total
1	3201T16	Black-Oxide Steel U-Bolt, 1/4"-20 Thread Size, 2" ID	2 Each	2	0	0.93 Each	1.86
2	3201T29	Black-Oxide Steel U-Bolt, 1/4"-20 Thread Size, 1-1/4" ID	8 Each	8	0	0.84 Each	6.72
3	94435A515	Aluminum Threaded Rod, 1/4"-20 Thread Size, 2 Feet Long, Packs of 1	2 Packs	2	0	3.88 Per Pack	7.76

Merchandise	16.34
Sales Tax	1.02
Shipping	10.25
Total	$27.61
Payment Received 2/8/19	(27.61)
Balance Due	$0.00

Packing List	Shipped	Weight	Carrier	Tracking
7628019-01	2/7/19	4 lb	UPS	1Z0100830396667360



LOWE'S HOME CENTERS, LLC
40 FORTUNE BOULEVARD
MILFORD, MA 01757 (508) 282-4016

- SALE -

SALES#: S1889WC1 2651984 TRANS#: 7193256 05-18-19

1026747 12-OZ CX GLOSS PUMPKIN OR	3.98
1026718 12-OZ FUS GLOSS BLACK	4.98
355110 J-B KWIK EPOXY ADHESIVE	2.98
24088 3/4-IN SCH40 CROSS 420007	4.96
2 @ 2.48	

SUBTOTAL:	16.90
TAX:	1.06
INVOICE 07145 TOTAL:	17.96
DEBIT:	17.96

DEBIT:XXXXXXXXXXXX9936 AMOUNT:17.96 AUTHCD:192278
SWIPED REFID:188907123316 05/18/19 11:27:18
TRACE:00909928

PURCHASE	CASH BACK	TOTAL DEBIT
17.96	0.00	17.96

STORE: 1889 TERMINAL: 07 **05/18/19 11:27:53**

 # OF ITEMS PURCHASED: 5

EXCLUDES FEES, SERVICES AND SPECIAL ORDER ITEMS

THANK YOU FOR SHOPPING LOWE'S.
SEE REVERSE SIDE FOR RETURN POLICY.
STORE MANAGER: TARCISIO FERREIRA

LOWE'S PRICE MATCH GUARANTEE
FOR MORE DETAILS, VISIT LOWES.COM/PRICEMATCH

****
* YOUR OPINIONS COUNT! *
* **REGISTER FOR A CHANCE TO BE** *
* **ONE OF FIVE $300 WINNERS DRAWN MONTHLY!** *
* ¡REGISTRESE EN EL SORTEO MENSUAL *
* PARA SER UNO DE LOS CINCO GANADORES DE $300! *
*
* REGISTER BY COMPLETING A GUEST SATISFACTION SURVEY *
* **WITHIN ONE WEEK AT: www.lowes.com/survey** *
* Y O U R I D # 07145 1889 138 *
*
* NO PURCHASE NECESSARY TO ENTER OR WIN. *
* VOID WHERE PROHIBITED. MUST BE 18 OR OLDER TO ENTER. *

David Antaki

Project RP1

Appendix D3
Gantt Chart & Schedule

NAR L1 & L2 Technical Report

June 28th, 2019

| Task | Lab Needed? | Month | December | | |

| | | |

| | | | | | | **April** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | **May** | | | | | | | | | | | | | | | | | | |

| | June | | | | | | | | | | | | | | | | | | | | | | | | | | | | | July | | | | | | | | | | | | | | | | | | |

David Antaki
Project RP1

Appendix D4
Filled NAR L1 & L2
Certification Application

NAR L1 & L2 Technical Report

June 28th, 2019

NAR HIGH POWER CERTIFICATION APPLICATION

APPLICANT INFORMATION (Completed by applicant)

Name: David Antaki (First / Last) Birth Date 03 / 27 / 2000

Address: 118 Pond St (Street / Apt.) NAR No.: 106844

Hopkinton (City) MA (State) 01748 (Zip) Expiration Date: 02/29/2020 (Is membership current?)

Evening phone no.: (____) ____ Cell phone no.: (508) 9587024 (Optional)

I, David Antaki, certify that I am a member in good standing of the National Association of Rocketry. I am 18 years of age or older. I understand that I must comply with all applicable federal, state, and local laws or regulations during and after this certification attempt.

Signed: David Antaki, Date: 6/12/19, Location: Hopkinton, MA

HPR LEVEL 1 CERTIFICATION CHECKLIST (Certification Team - Use this section Only for HPR Level 1 Certification Attempts)

Preflight: Motor(s) used: ____ (At least one motor must be an H or I Impulse Motor)
☐ Motor is certified ☐ FAA Waiver available (if required) ☐ Safety checklist complete (see back)

Flight: ☐ Model is stable ☐ Recovery system deployed ☐ Safe recovery

Post Flight: ☐ Verify that no major damage is Present Minor impact damage or "zipper" is acceptable
☐ Verify motor(s) is (are) present **Successful flight?** ☐ Yes ☐ No

HPR LEVEL 2 CERTIFICATION CHECKLIST (Certification Team - Use this section Only for HPR Level 2 Certification Attempts)

Preflight: Motor(s) used: ____ (At least one motor must be an J, K or L Impulse Motor)
☐ Motor is certified ☐ FAA Waiver available (if required) ☐ Safety checklist complete (see back)
☐ Applicant is Level 1 certified ☐ Level 2 Written Exam passed within one year on __/__/__ (Month / Day / Year)

Flight: ☐ Model is stable ☐ Recovery system deployed ☐ Safety recovery

Post Flight: ☐ Verify that no major damage is Present Minor impact damage or "zipper" is acceptable
☐ Verify motor(s) is (are) present **Successful flight?** ☐ Yes ☐ No

CERTIFICATION AFFIDAVIT (Successful attempts only, completed by certification team)

We, the undersigned, being members of the National Association of Rocketry distinct from the applicant, have witnessed a demonstration by (Name) ____ (NAR#) ____, of skills relative to the building and safe operation of High Power Rockets. We attest that the applicant is 18 years of age or older and a member in good standing of the NAR. We believe this member is qualified to build and operate High Power rockets with a total installed impulse up to: ☐ 640 N-sec. (Level 1) ☐ 5120 N-sec. (Level 2)

Name (Printed): ____ Signature: ____ NAR No: ____

Birth Date: __/__/__ Membership Expiration Date: __/__/__ Certification Level: ____

Name (Printed): ____ Signature: ____ NAR No: ____

Birth Date: __/__/__ Membership Expiration Date: __/__/__ Certification Level: ____

NAR HIGH POWER CERTIFICATION

Name (Printed): ____

NAR No.: ____ Cert Level: ☐"1" ☐"2"

Certification Date: __/__/__

Witnessed By: ____

Witnessed By: ____

This card is void 60 days after Certification Date

Cut Along Dotted Line

1) Request individual Level 2 Written Exams from
NAR HQ
PO Box 407
Marion, IA 52302
Certification Teams or Section Leaders wishing to obtain multiple copies of the of the Level 2 Written Exams can send an email to the current NAR Chairman of Sport Services listed on the NAR Website for a soft copy of the files
2) Send completed forms (with exams, if applicable) to the NAR HQ address listed above

Revision 2-Oct-2010, File - hpappl

NAR HIGH POWER ROCKETRY CERTIFICATION CHECKLIST

Has the rocket model that is being used for the certification attempt been built by the applicant requesting certification?	
Is the nosecone or payload shoulder sufficiently light to prevent drag separation? The nosecone or payload should not wobble side to side or separate from its own weight. Is a vent hole needed to relieve pressure for high altitude flight? Do stage couplers fit snuggly to prevent bending or separation during flight? Is the body tube thickness adequate to withstand high power flight (typically .050 inch walls or thicker)? Is there pre-existing damage which may weaken the model structure (e.g. tube crimps)? Are screws and fasteners tight, if used?	
Are the launch lugs securely fastened to the model? Verify no cracking of adhesive joints. Is the launch lug(s) appropriately sized for the model, typically 1/4 inch or larger diameter? Will the launch lugs bind on the launch rod? Taped on launch lugs are not permitted.	
On cluster models are the spaces between the motor tubes filled to prevent ejection pressure leakage? If mixing black powder and composite motors does the modeler assure composite motor ignition before black powder motor ignition (composite motors ignite more slowly than black powder motors)? If the cluster model is not using all of its motors are the unused motor tubes plugged to prevent ejection blow-by?	
If a Level 1 Certification is being attempted, does the rocket model contain at least one single H or I impulse motor? If a Level 2 Certification is being attempted, does the rocket model contain at least one single J, K or L impulse motor?	
Is (are) the motor(s) sufficient to safely fly the model? Use motor manufacturer's recommendations or recommended motor lists for similarly sized models as a starting point (Also consider, model weight, configuration, and finish when evaluating motor capabilities). Is (are) the either NAR, Tripoli or CAR certified? Motors must be currently certified to be used. Low current igniter? ☐ Yes ☐ No	
Is (are) the rocket motor(s) firmly restrained in the model? Check for engine mount integrity to prevent a "fly through" (Is a thrust ring used?). Check for a motor hook or similar motor restraint. Carefully check taped or friction fit motors for tightness. Ask the modeler what adhesives were used during assembly. Are clusters wired in parallel?	
If electronics are used, is the battery secured against "g" loads? Will electrical connections fail or loosen from acceleration forces? Will igniters stay fully inserted in rocket motors during boost? Is the user protected against inadvertent operation, e.g. is the circuit remotely armed, are safety switches present, is an armed status indicator used (visual or audible)? Does the modeler have a checklist or reminder to arm or operate the system prior to flight?	
If radio control is used, is for flight functions (e.g. recovery) the operating frequency in the 27, 50, 53, or 72 megahertz bands? Use of 75 megahertz for flight functions is not permitted. Is the antenna protected from breakage (not flopping freely)? Did the operator range check his equipment?	
Are the fins fully secured to the model? Check for looseness or cracking at the fin to body tube junction. "Thru the wall" construction is recommended for high power models. Is the fin material compatible with the motor thrust range (1/8 inch minimum plywood is recommended for high power models)? Ask the modeler how his fins are mounted, what adhesives were used (epoxy is preferred), and what fin material was used. Are the fins mounted parallel to the roll axis of the model? Are any warps present which may cause erratic flight?	
Is the model stable? If stability is in doubt require proof of the CG and CP locations (remember CG should be forward of the CP by approximately 1.0 body tube diameters). Ask the modeler to show the CG and CP locations and how they were determined. Verify that the modeler shows the CG with the motor(s) intended for flight and not a smaller motor or fewer motors (clusters). Ask the modeler to show CG and CP for the complete model and less each stage for a staged model. Require evidence of CP calculations if further doubt exists.	
Will the model "bust" the FAA waiver? Verify compliance by comparing model weight and power with charts/tables (if available) or by calculation. Ask the modeler what the expected performance is and how he made his determination (e.g. computer simulation, similar models).	
Does the recovery system being used follow the requirements of an Active Recovery deployment system required for certifying? Inspect the recovery system. Verify that the shock cord is not cut or frayed and free of burns. Are the shock cord mounts securely mounted to the model? Are sharp edges present which may cut shock cords, parachute risers, and suspension lines? Is hardware, e.g. swivels, screw eyes, sufficiently strong to withstand recovery loads. If required, perform a pull test on the recovery system. Is parachute protection (e.g. wadding) adequate? Check for parachute damage, e.g. tears, burns, which may spread during recovery.	

David Antaki
Project RP1

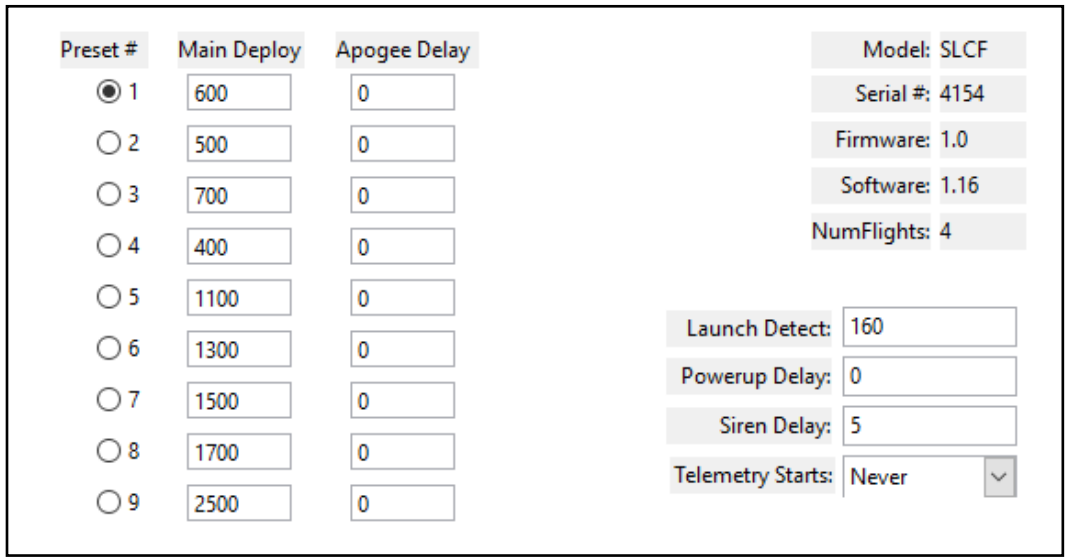
Appendix D5
Altimeter Launch Settings

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June 28th, 2019

Appendix D5

Altimeter 1 (Serial # 4154) Launch Settings



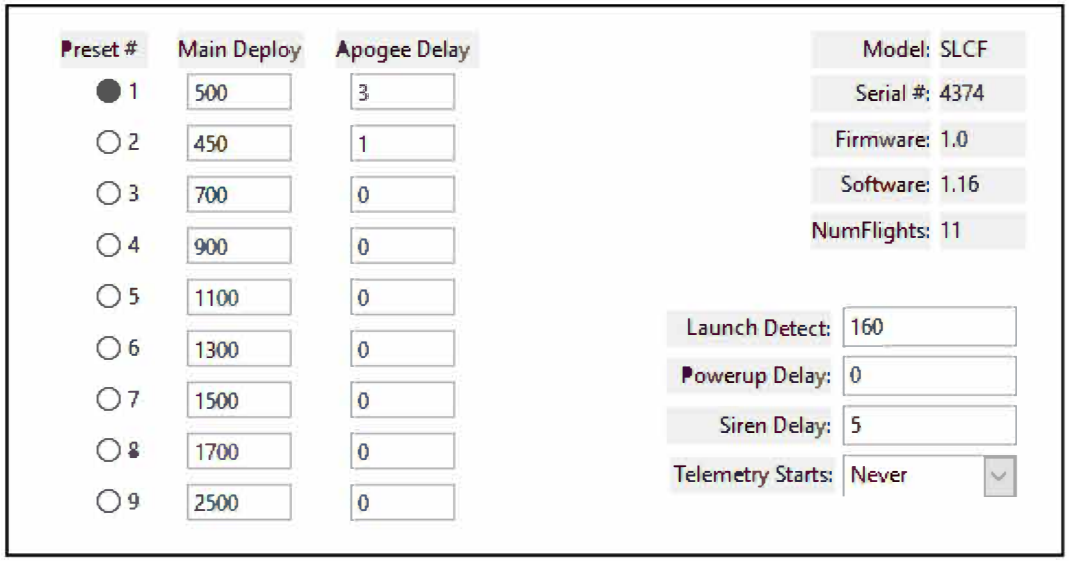
Preset #	Main Deploy	Apogee Delay
1	600	0
2	500	0
3	700	0
4	400	0
5	1100	0
6	1300	0
7	1500	0
8	1700	0
9	2500	0

Model:	SLCF
Serial #:	4154
Firmware:	1.0
Software:	1.16
NumFlights:	4

Launch Detect:	160
Powerup Delay:	0
Siren Delay:	5
Telemetry Starts:	Never

Appendix D5

Altimeter 2 (Serial # 4374) Launch Settings



Preset #	Main Deploy	Apogee Delay
1	500	3
2	450	1
3	700	0
4	900	0
5	1100	0
6	1300	0
7	1500	0
8	1700	0
9	2500	0

Model:	SLCF
Serial #:	4374
Firmware:	1.0
Software:	1.16
NumFlights:	11

Launch Detect:	160
Powerup Delay:	0
Siren Delay:	5
Telemetry Starts:	Never

David Antaki

Project RP1

Appendix D7

Photos

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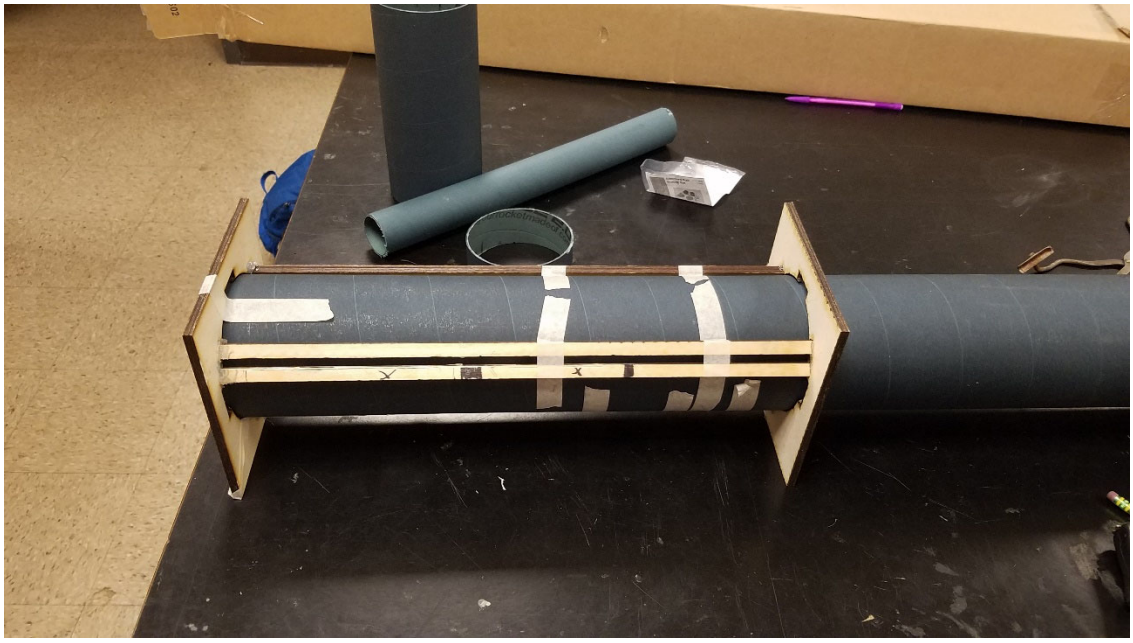


Figure 1 - Fin jig taped onto airframe for cutting fin slots.



Figure 2 - Fin jig taped onto airframe for cutting fin slots.

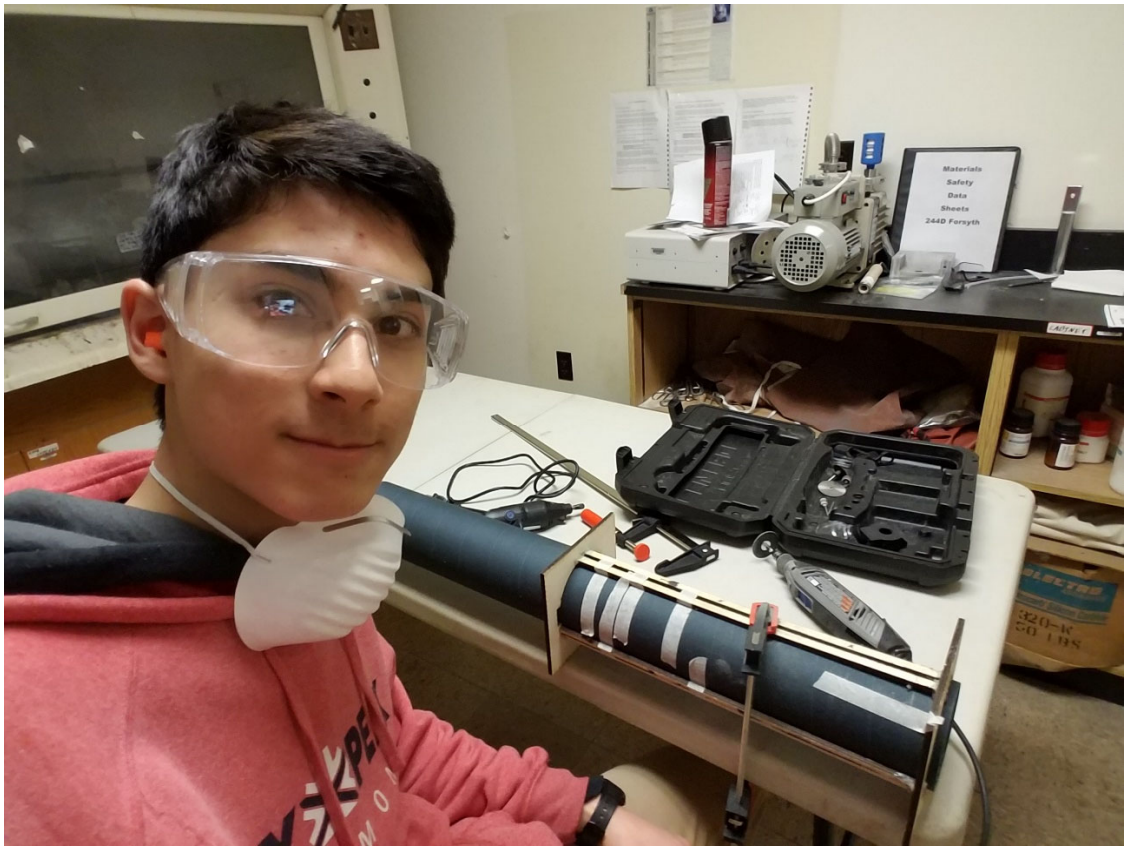


Figure 3 - Cutting fin slots.

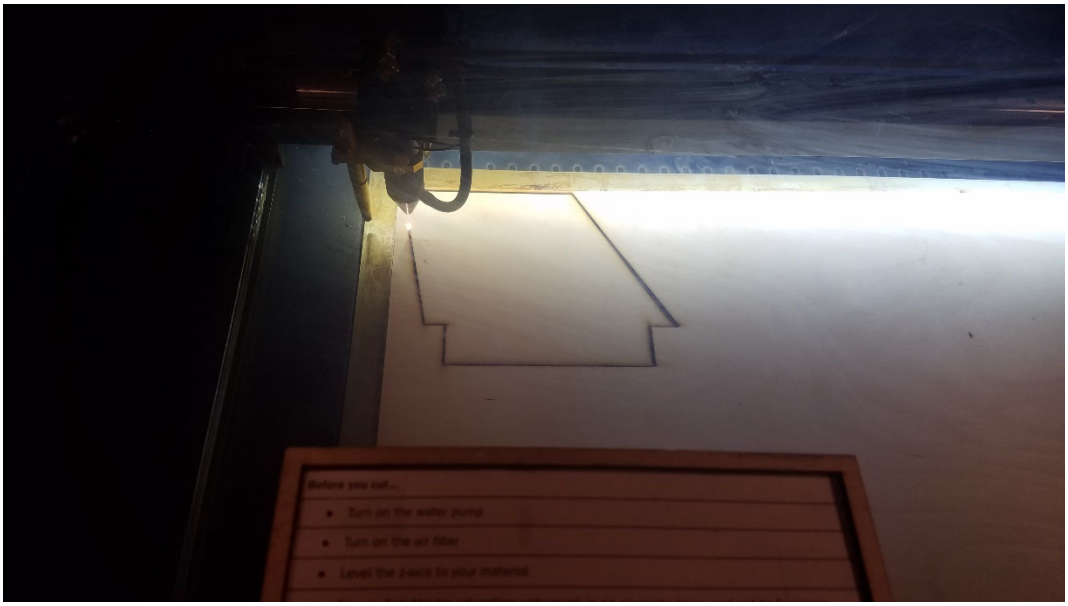


Figure 4 - Laser cutting fins with ¼ in pine.

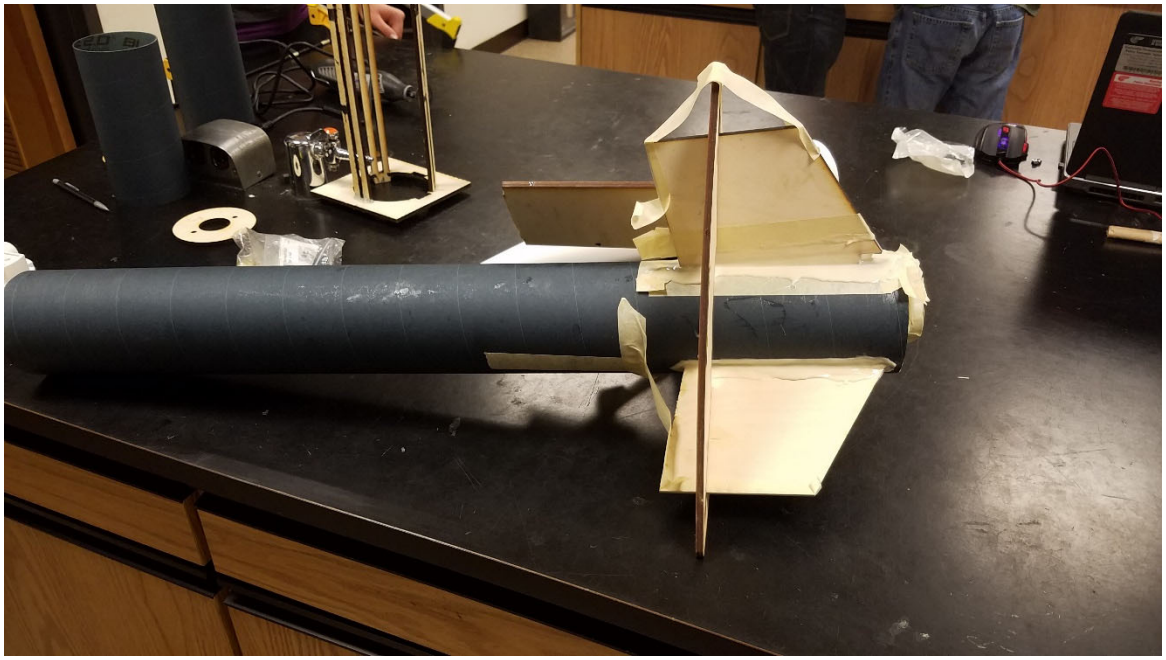


Figure 5 - Epoxying fins into fin slots using a club-made jig. Don't mind the fin tab gap…it'll be fine.

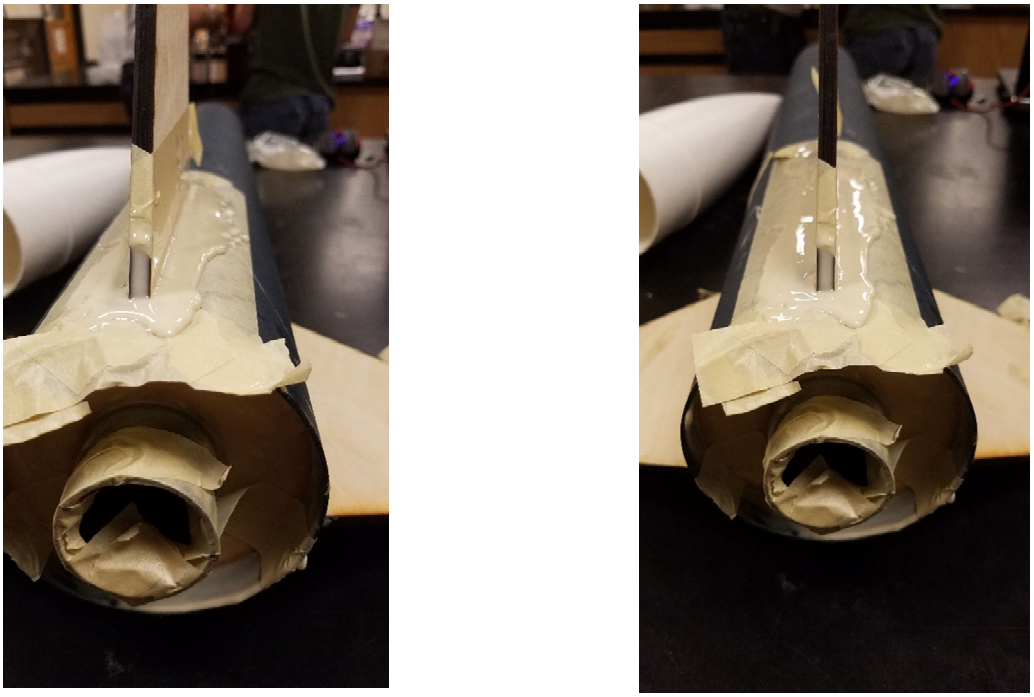


Figure 6 – Epoxying fins into fin slots with RocketPoxy.

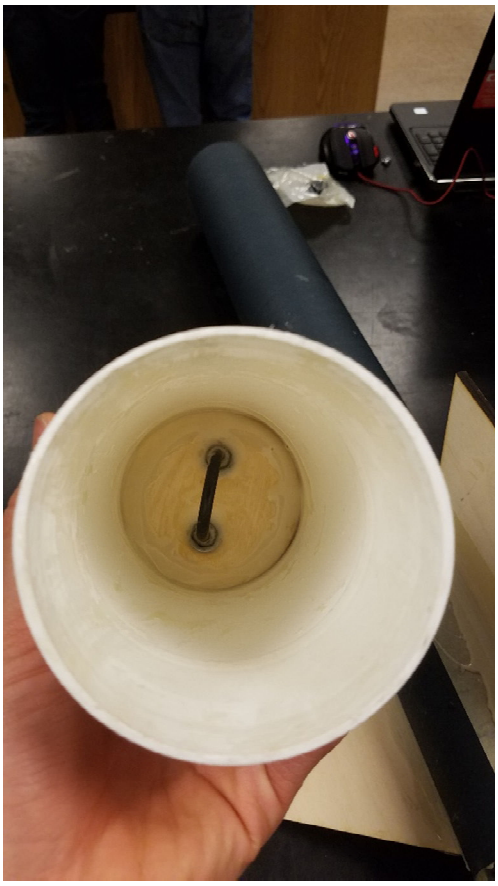


Figure 7 - Epoxied bulkhead in nosecone.

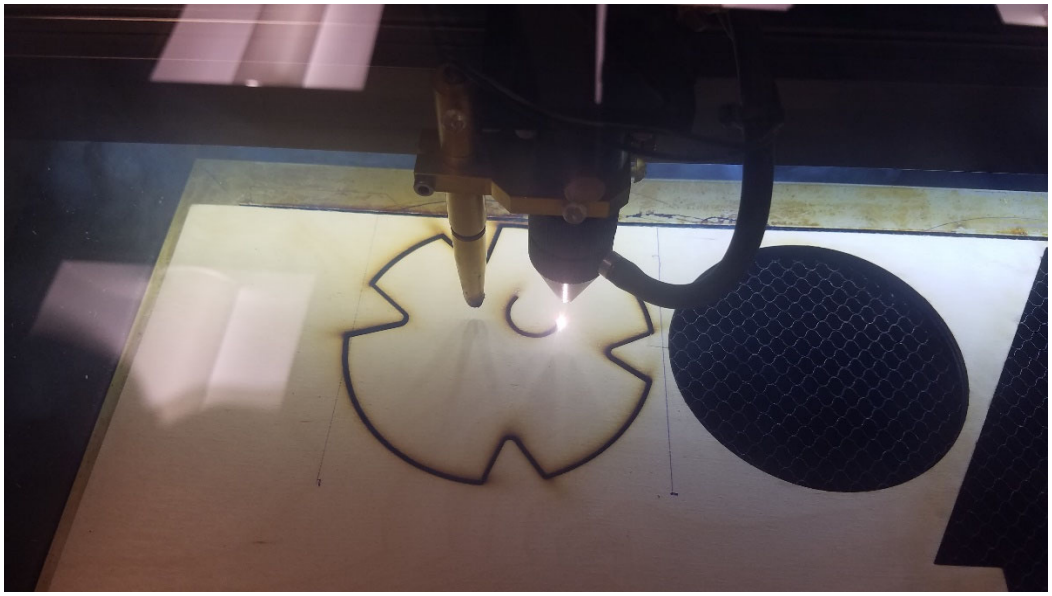


Figure 8 - Laser cutting Ebay bulkheads.



Figure 9 - Spray painting rocket.



Figure 10 - Final shots.



Figure 11 - Final shots. RP1 Logo.



Figure 12 - Final shots. Fin decal.



Figure 13 - Final shots.



Figure 14 - Final shots.



Figure 15 - Final shots.



Figure 16 - Final shots. Back markings.



Figure 17 - Final shots. Back markings.

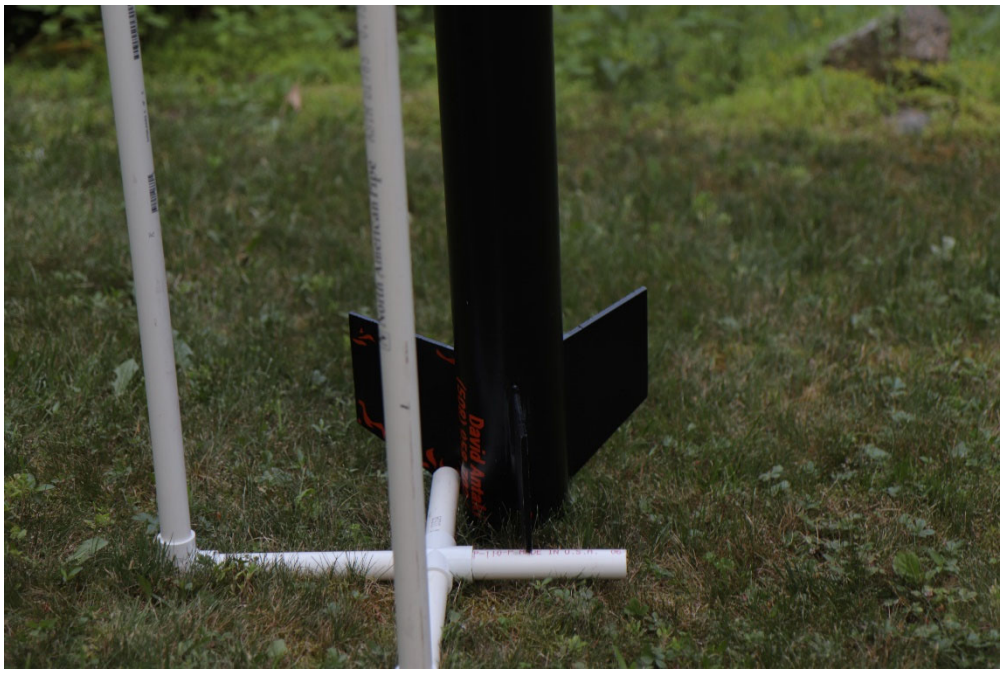


Figure 18 - Final shots. Back markings.



Figure 19 – Key switch markings.



Figure 20 - CG markings.



Figure 21 - In case of recovery system failing markings.

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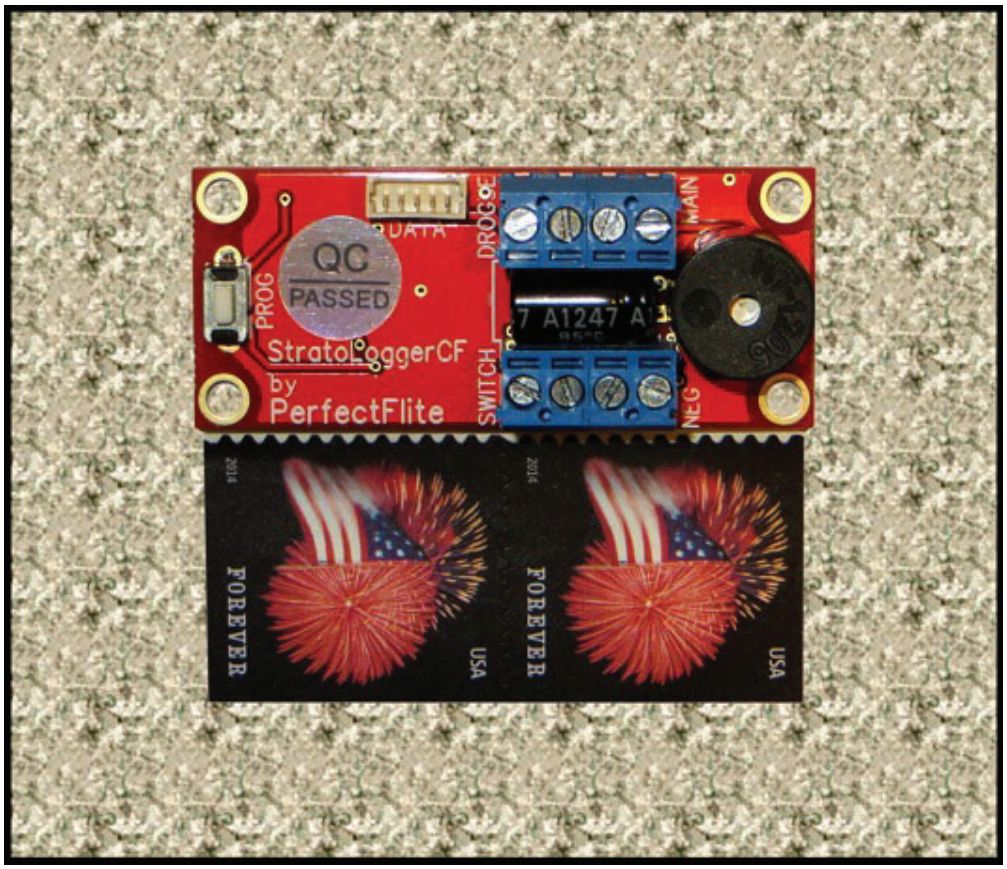
Project RP1

Appendix M1
StratoLoggerCF Manual

NAR L1 & L2 Technical Report

June 28th, 2019

StratoLoggerCF Users Manual



PerfectFlite

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Introduction

The *StratoLoggerCF* is one of the most accurate, versatile, and affordable rocketry altimeters available. It can be used to:

- Determine precisely how high your rocket went (up to 100,000 feet above sea level).
- Log and save full flight data (altitude, temperature, and battery voltage) from the last 16 flights for later download to a computer. The 17th and subsequent flights will replace the oldest flights, so you will always have a record of the most recent 16 flights.
- Provide control over firing a drogue and main parachute (single or two event deployment).
- Report the peak altitude and maximum velocity audibly after the flight.

If you are already experienced with rocketry electronics and don't want to read the introductory sections of the manual, please refer to page 28, "QuickStart for Experienced Users", for an explanation of the powerup sequence and StratoLoggerCF-specific operational characteristics.

If you are new to rocketry electronics please take the time to read the manual thoroughly; in addition to learning about operating the altimeter you will also find information about many other topics including proper testing procedures, hints and checklists for two event deployment, making ejection charges, and more.

The *StratoLoggerCF* altimeter utilizes a precision pressure sensor and 24 bit delta sigma analog to digital converter to obtain an extremely accurate measurement of the air pressure surrounding your rocket. As the rocket rises, the pressure decreases, and the altimeter converts the pressure differential to a precise measurement of altitude above launch point according to the US Standard Atmosphere model.

Throughout the entire ascent, the altimeter also calculates the instantaneous and smoothed velocity of your rocket, and uses this information to determine when it has reached apogee (zero vertical velocity). Because of the high resolution of the data, it is able to determine the moment of apogee with phenomenal accuracy, typically within +/- 0.2 seconds. If you use the altimeter to control the deployment of your parachute(s), this precise timing will ensure deployment at minimum velocity, preventing damage such as "zippered" body tubes or "stripped" chutes that can occur with early or late deployment.

The velocity data are also analyzed during flight so that "mach dips" (an apparent drop in altitude due to the increase in pressure when a high performance rocket exceeds the speed of sound) are not incorrectly interpreted as apogee. This *MachLock* feature eliminates the possibility of your drogue chute being ejected during a mach dip, without the need for older-technology mach delay settings. You don't have to worry about setting a mach delay, or having a mach delay interfere with timely deployment on an aborted flight – apogee will be determined correctly regardless of the speed of your rocket without any user intervention.

The altimeter has two electronic outputs for firing parachute deployment ejection charges using electric matches. If you connect a single electric match and associated ejection charge to the apogee output, you will get single event deployment – similar to normal motor-based deployment but with greater accuracy and no worries about selecting the right ejection delay time. You can also use two electric matches and two ejection charges for two event deployment: The charge connected to the apogee output will separate your rocket and eject a small drogue chute at apogee, and the charge connected to the "main" output will deploy a larger chute at an altitude that you select closer to the ground. The next section describes this feature in more detail.

The *StratoLoggerCF* has an on-board data connector that is used for two basic functions: Post-flight retrieval of saved data from the altimeter, and real time data output during flight using the telemetry feature. The optional data transfer kit and software allow the user to transfer flights from the altimeter's internal memory to a computer for storage, display, and manipulation. The data transfer kit can also be used to configure various settings within the altimeter, including nine "presets" of user-specified parameters that can be easily selected at the launch site when a computer may not be available. For advanced users, the telemetry feature can be used to send in-flight data back to the ground during flight using an RF modem (not included), or for experimental payloads that need current altitude data to control functions in real time.

Using Two Event Deployment

Recovery of your rocket can sometimes involve a long hike, especially if it is windy, your field size is limited, and your rocket achieves some serious altitude. Making your parachute smaller is one option to limit the distance your rocket will drift. This has the undesirable side effect of increasing landing velocity, with subsequent damage to your rocket (broken fins, airframe damage, etc).

A better solution is to use the drogue and main deployment ability of the *StratoLoggerCF*. At apogee, an ejection charge connected to the "Drogue" terminal block separates the rocket and deploys a small drogue chute. The rocket descends rapidly under the drogue chute to minimize drift from the launch point. When it has descended to the predetermined "main deployment altitude", a second ejection charge connected to the "Main" terminal block deploys a much larger chute that slows the rocket to a safe speed before landing.

If you usually use a descent rate of 15 FPS to ensure minimal damage to your rocket, and launch to 5,000 feet in a 10 MPH (approximately 15 FPS) wind, your rocket will drift nearly a mile before it lands. However, if you let it fall at 100 FPS from apogee to 500 feet, and then use a larger main chute to get the final 15 FPS landing speed, the drift will be reduced to just over 1,000 feet (about 1/5 of a mile). This is a significant improvement!

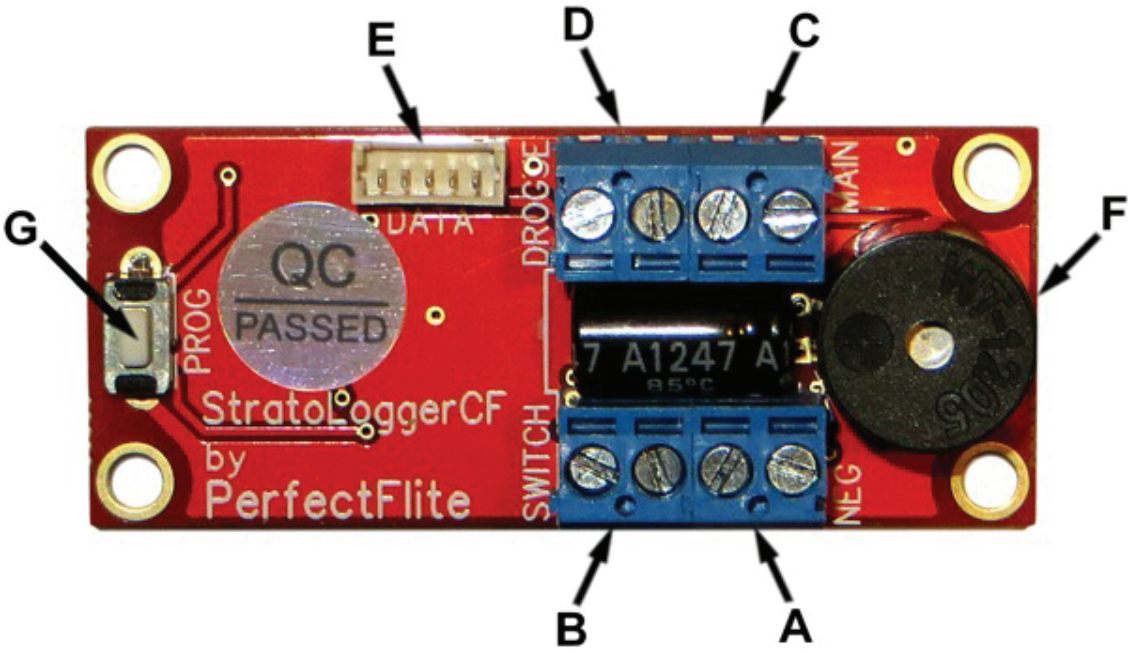
If you will be using two event deployment, the user-defined "main deploy altitude" setting that is reported during altimeter powerup specifies how many feet above the launch point elevation the main chute is to be deployed at. The procedure for changing this setting is described in a later section.

You should set the altitude high enough to ensure that the chute will deploy fully in time to slow the rocket's final descent, but low enough to prevent excessive drift. In most cases a setting of 500 to 900 feet is appropriate. If you have any doubt as to the time it will take for your chute to deploy, choose a number towards the upper end of this range and gradually reduce it if deployment speed allows. For small fields, loosely packed chutes, and windy conditions you may need to drop back to 300 to 400 feet.

Note: Make sure you don't swap the main and drogue wiring to the altimeter! If you mistakenly connect the main ejection charge to the drogue terminals and vice versa, your large main chute will deploy at apogee, defeating the purpose of two event deployment.

Parts Identification

Refer to the picture below to locate the following items:



A) **Battery Terminal Block:** Connect a 4 volt to 16 volt power source here. Ensure that the negative battery terminal is connected to the terminal labeled "NEG". *Polarity (POS/NEG) must be correct or altimeter won't power up. Reverse polarity will not cause damage.*

B) **Power Switch Terminal Block:** Remove factory supplied jumper and connect a power switch here. *Must be connected to an external switch or shorted with a jumper or the altimeter will not power up.*

C) **Main Ejection Output Terminal Block:** Connect to the electric match for the main deployment charge (if used), or leave unconnected otherwise. ***DO NOT SHORT CIRCUIT!***

D) **Drogue Ejection Output Terminal Block:** Connect to the electric match for the drogue/apogee deployment charge (if used), or leave unconnected otherwise. ***DO NOT SHORT CIRCUIT!***

E) **Data I/O Connector:** For connection of the optional data transfer kit or user-supplied in-flight telemetry equipment.

F) **Beeper:** Audibly reports settings, status, etc. via a sequence of beeps.

G) **Preset Program Button:** For selecting and modifying the 9 user settings presets (see pages 20-22).

Installation

The altimeter and battery should be installed in an "avionics bay" inside your rocket. The avionics bay performs a number of functions:

- Provides a secure mounting point for your altimeter and related gear (battery, switch, wiring, etc).
- Isolates the altimeter from high pressure and corrosive residue from ejection charge gasses.
- Provides a facility for mounting and connecting ejection charges if the altimeter will be used for deployment.
- Provides access to the altimeter's power switch from the outside of the rocket.
- Has one or more "static pressure sampling" holes so the altimeter will be exposed to the ambient air pressure surrounding the rocket.

The next few paragraphs will give you some basic ideas for setting up your avionics bay. There are many variations possible; you should plan your installation carefully and research how others have done their installations for additional ideas.

Avionics Bay Construction

An avionics bay is typically constructed of a section of coupler tube to fit the rocket's airframe, with a fixed bulkhead at one end (usually forward) and a removable bulkhead at the other (aft) end. The removable bulkhead allows access to the altimeter and battery between flights. Both bulkheads need to have a good airtight seal so that ejection gas pressure doesn't

get into the interior of the avionics bay. The fixed bulkhead will typically be attached with epoxy, which will seal it as well. The removable bulkhead can be sealed with a large rubber O-ring, gasket, or a thin bead of dried silicone sealant.

Good, sturdy eye bolts facing outward from each bulkhead provide attachment points for the drogue and main shock cords. With larger, heavier rockets you should consider using forged eye bolts with a continuous "O" eye, rather than the more common bent rod eye bolts with a gap in the "O". The forged eye bolts are much stronger, and will be less likely to open up and allow your recovery system to separate under heavy loads. Another alternative for larger-diameter rockets is a "U" bolt with a metal backing plate inside the avionics bay to distribute the forces over a larger area of the bulkhead.

The bulkheads are then connected to each other inside the coupler tube with two (or more) sections of all-thread rod that extend through the bulkheads, with washers and nuts on the outside. This creates a strong connection from one eye bolt to the other one, for integrity of your recovery system's strength. With larger, heavier rockets you may want to use stronger bulkhead material such as thicker plywood, fiberglass, or aluminum.

A plywood or G10 fiberglass "sled" for mounting the altimeter and battery is then attached to the all-thread rod inside the coupler, either directly (e.g. with epoxy), or indirectly on pieces of tubing that slide over the all-thread. The indirect mount allows the sled to be removed for access without removing the all-thread from the fixed bulkhead.

Static Pressure Sampling Holes

You must drill one or more clean-edged holes in the airframe into the avionics bay to allow outside air pressure to be sampled by the altimeter (see table below for recommended sizes). These holes should be as far away from the nosecone shoulder and other body tube irregularities as possible (at least 4 to 5 times the body tube diameter or more) to minimize pressure disturbances being created by turbulent airflow over the body tube. Sand the area around the hole as necessary to eliminate flashing or raised edges. Best performance will be achieved by using four smaller holes distributed at 90 degree intervals around the airframe's circumference instead of a single larger hole. When using four holes, each hole should be ½ the size of a single hole as noted in the table. This will minimize the pressure variations due to wind currents perpendicular to the rocket's direction of travel.

With any high performance rocket, pay particular attention to the size and placement of the holes – do not make them too large or too far forward! If your rocket has an irregular nosecone (e.g. Honest John, Nike Smoke) you should move the holes even further back.

AvBay Diameter	*AvBay Length*	*Single Port Hole Size*	*Four Port Hole Size*
1.6"	6"	.032"	.020" (small pinholes)
2.1"	6"	.048"	.025"
3.0"	8"	.113"	.057"
3.0"	12"	.170"	.085"
3.9"	8"	.202"	.101"
3.9"	12"	.302"	.151"
5.5"	12"	—	.286"
7.5"	12"	—	.5"

Single Port, hole size = Diameter * Diameter * Length * 0.0016
Four Ports, each hole = Diameter * Diameter * Length * 0.0008

Powering the Altimeter

The altimeter's electronics can be powered by any source of 4 volts to 16 volts. All of the electric match firing current must come from the battery; if your ematch requires 3 amps to fire, your battery has to be able to supply this much current. Most commonly-available commercial ematches (e.g. Mtek, Jtek) require less than one ampere to fire, and a good 9 volt alkaline battery can supply more than 3 amps of current. Do not exceed the 5 ampere current limit of the *StratoLoggerCF's* firing circuitry or damage may occur.

Standard 9V batteries can be connected using a battery clip such as the PerfectFlite CAB9V. Make sure that both of the clip's snaps are gripping the battery terminals firmly to prevent power interruption due to vibration. The larger battery terminal or clip terminal should be compressed inward if necessary to ensure a snug fit.

Many other types of batteries (e.g. 12 Volt A23, lithium batteries, LiPo batteries, etc.) can be used to power the altimeter, but smaller batteries may have a low maximum discharge current, which could be insufficient to fire even the lowest current electric matches. ***Especially if you use a non-standard battery or electric match, make sure you ground test the combination before committing it to flight.*** It is a prudent practice to make sure that your chosen battery will fire twice the number of electric matches that you plan to use in flight to ensure a margin of safety. If you will be using a single ematch in flight, make sure your battery will fire two (in parallel) reliably and consistently during tests. If you will be using two ematches per output for redundancy in flight, make sure your battery will fire three or four in testing.

Terminal Block Note

To attach wires to the terminal blocks, loosen the retaining screw (facing upward from the board), insert the stripped wire end from the side, and retighten the screw. Make sure that you strip enough insulation from the wire (~3/16") so the bare wire (not the insulation) is gripped by the contact. Do not allow an excess of bare wire outside the terminal, as it could short-circuit to adjacent parts or wires. Always use solid wire (or tin any stranded wire ends with solder); the loose strands in untinned stranded wire can "escape" during wire insertion and make contact with adjacent terminals. After inserting the wires and tightening the connections, tug the wires with a pair of longnose pliers to ensure that they are gripped tightly. You do not want these connections to loosen in flight!

Power Switch

Connect a suitable ON/OFF switch to the altimeter's power switch terminals. One important consideration for the power switch is that it be "bounce-free" – you do not want the switch to turn off momentarily during vibration or acceleration, as the altimeter could reset and deployment would fail.

The *StratoLoggerCF* can tolerate a power loss of several seconds (depending on battery voltage) without resetting, but it is always wise to use the best quality switches possible.

Note: While the altimeter will continue to operate during momentary power outages, the ejection outputs will not fire if power is absent at the point that they are turned on.

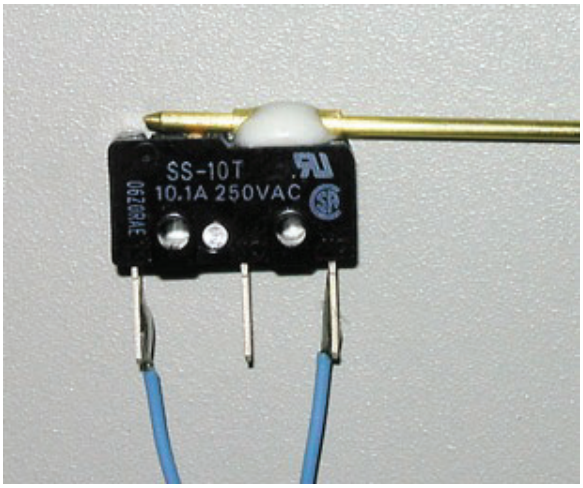
It is best to mount the power switch with the switch movement perpendicular to the travel of the rocket. This will minimize

the forces placed on the switch during acceleration and deceleration, which could inadvertently move the switch to the "off" position. The switch should be inside your rocket, with a means of accessing it from the outside. Having access to the altimeter's on/off switch from outside the rocket is essential. When ejection charges are installed, the altimeter should only be powered up with the rocket fully assembled, on the pad in the upright position. It is also imperative that the switch cannot be accidentally turned off in flight by contact with the shock cord or any airframe parts. *Do not use a slide switch or toggle switch with the actuator on the outside of the rocket!* Keeping the switch entirely inside the avionics bay is good practice, with a provision for activating it from outside at the appropriate time.

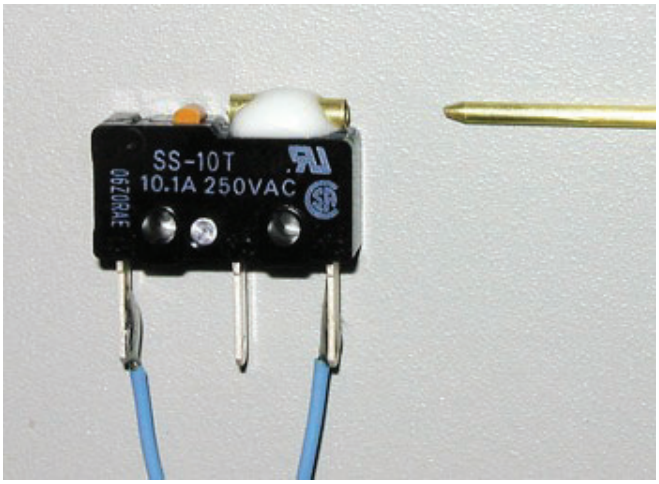
Keyed lock-type switches are often used, as are either alternate action "push on/push off" switches or "pull pin" switches that are activated through a hole in the side of the airframe. If you use any kind of internal switch that needs to be activated through an open hole in the side of the airframe, make sure that the hole (which will then become one of your static pressure sampling holes) doesn't exceed the static port sizing guidelines mentioned above.

A simple and effective pull-pin type switch can be made using a pin plunger microswitch (eg. Omron SS-10T, or PerfectFlite SAS5), a small piece of brass tubing, and a length of brass rod with a sharpened end. The brass tubing is secured to the top of the switch housing with a small amount of epoxy (do *not* use CA, as the outgassing produced during curing can get into the switch and ruin its contacts) such that when the sharpened end of the brass rod is inserted into the tubing it depresses the plunger. The switch assembly is mounted inside the altimeter bay, with a hole for the brass rod leading to the outside. The

Normally Closed terminals of the switch are used in this case, so when the rod is inserted and the plunger is depressed the switch turns off ("opens"). A "remove before flight" flag can be hung from the end of the brass rod to remind you to turn on the altimeter. One advantage to using a Normally Closed switch is that failure of the external mechanical assemblies (brass tube) during flight will NOT turn the altimeter off.



Rod inserted, switch OFF



Rod removed, switch ON

Charge Holders

Ejection charge holders can be incorporated into the avionics bay's fore and aft bulkheads. If you will be making reloadable ejection charges out of short sections of small diameter PVC pipe, matching PVC caps can be screwed to the bulkhead to hold the charges. Adding a small terminal block adjacent to the ejection charge, with wires leading in to the altimeter, makes connecting and removing ejection charge wires a snap. Make sure that any wires going through the bulkhead are sealed – silicone or epoxy works well for this.

Placement

If you will be setting up your rocket for two event deployment, the avionics bay will usually be in the center of the rocket, with the drogue ejection charge facing aft and the main ejection charge facing forward. This is because the altimeter needs to have electrical connection to both the drogue and main charges; if it were placed in the booster section, for instance, the connection to a main chute in the forward section would be broken when the rocket separated at apogee. There are many alternatives to this approach, but placing the altimeter in the middle of the rocket with drogue aft and main forward is generally the simplest and most straightforward.

At apogee, the drogue charge separates the rocket between the booster section and the forward section, which includes the avionics bay, main chute compartment, and nosecone. The booster section and forward section are connected by a long shock cord with a small drogue chute attached. When the rocket has descended to the preset main deploy altitude, the main ejection charge fires, pressurizing the main chute compartment in the forward section of the rocket, forcing the nosecone off and deploying the main chute.

Single event deployment works in a similar manner, except the primary chute is released at apogee. Since there is only one separation point with single event deployment, you have more flexibility as to where the altimeter can be placed. It can be placed in the forward section of the rocket, as in the previous example, or in the booster section (or even inside the fin can).

There are many possible variations to these installation methods. For instance, if your rocket has a limited amount of useable airframe length to work with (e.g. Nike Smoke) you can arrange for two event deployment with a singe separation

point. At apogee, the nosecone is popped and a small chute released. At the main deploy altitude, an ejection charge inside a “parachute cannon” in the booster section deploys the main chute that was stored in the cannon. Another alternative in larger diameter airframes is to deploy a drogue chute aft out of the rear-most centering ring, with the main being deployed behind the nosecone as usual.

Operation

Numerical Reporting

Numbers are reported as a long beep (separator), followed by a pattern of shorter beeps for the individual digits, with a pause before the next digit. You simply count the number of short beeps for each digit place and assemble them together to form a number. You will hear a series of beeps for the first digit (tens of thousands of feet), a short pause, another series of beeps for the next digit (thousands of feet), etc.

Ten beeps are used to indicate the number zero (if zero beeps were used, you would not be able to differentiate between 2200 feet and 22 feet!).

As an example, 12,560' would be reported as:

long beep*-pause-****beep****-pause-****beep-beep****-pause-****beep-beep-beep-beep-beep****-pause- **beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep-beep****-long pause*

Digit	*Reported as:*
0	beep-beep-beep-beep-beep-beep-beep-beep-beep-beep
1	beep
2	beep-beep
3	beep-beep-beep
4	beep-beep-beep-beep
5	beep-beep-beep-beep-beep
6	beep-beep-beep-beep-beep-beep
7	beep-beep-beep-beep-beep-beep-beep
8	beep-beep-beep-beep-beep-beep-beep-beep
9	beep-beep-beep-beep-beep-beep-beep-beep-beep

Powerup

The *StratoLoggerCF* has a number of user-changeable settings that can be modified to tailor its operation to various flight conditions. However, the factory-default settings will be appropriate for most normal flights, and the altimeter can be used right out of the package with no modifications. Just bolt it in, connect power, a switch, and your ejection charges, and you're ready to go. A rundown of the changeable settings and how to modify them will be addressed in a later section.

When the altimeter is turned on, it will report its current settings and other information before readying itself for flight. This is what you will hear:

- If the altimeter detected an abnormal condition on the previous flight, a short siren tone will sound, followed by one or more digits representing the error code(s), and a second siren tone. The error codes are listed below:

  1: **Total power loss during last flight.**

  Downloading the data with the optional DT4U USB interface can help you to determine the exact time of the power loss, which will aid in diagnosing the underlying cause.

  2: **Momentary power loss during last flight.**

  The battery voltage to the altimeter dropped briefly to less than 50% of its initial voltage at some point during the flight. The altimeter's brownout protection allowed the altimeter to continue normal operation, but a loose connection or other issue is likely. Inspecting the downloaded voltage data will aid in diagnosing the underlying cause.

  3: **Drogue current exceeded 6 amps.**

  When the drogue output was activated, the ematch current was greater than 6 amps. The ematch may have been shorted, or an

inappropriate ematch/battery combination is in use. Repeated operation with this condition can lead to damage of the altimeter.

4: **Main current exceeded 6 amps.**

When the main output was activated, the ematch current was greater than 6 amps. The ematch may have been shorted, or an inappropriate ematch/battery combination is in use. Repeated operation with this condition can lead to damage of the altimeter.

5: **Problem detected with FLASH memory.**

The selftest detected a read/write error with the flight data memory. Contact PerfectFlite for assistance.

6: **Problem detected with pressure sensor.**

The selftest detected an error with the pressure sensor. The altimeter will not continue with the powerup sequence if this error is present. DO NOT FLY. Contact PerfectFlite for assistance.

If you get an error code on powerup, please inspect your installation and make any corrections necessary to prevent future problems. *The error will clear automatically after the next flight if new errors are not encountered.*

- A one digit number (range of 1 to 9) corresponding to the currently-selected program preset. The preset stores the main chute deployment altitude setting (and the apogee delay setting, if used). The factory default is preset 3, which equates to main deployment at 700 feet and no apogee delay (see table on page 23).
- A two second pause, and then a three or four digit number (range of 100 feet to 9,999 feet) corresponding to the main deploy altitude setting from currently-selected program preset. This is the altitude that your main chute will deploy at.
- *(optional, only if you have added an apogee delay to the currently selected preset: A two second pause, and then a*

five second continuous tone to warn you that your apogee firing is set to be delayed. If you hear this tone, and don't expect an apogee delay, then: STOP, do not launch, and either modify the preset with a computer or select another preset that does not have an apogee delay.)

- A two second pause, and then a three to six digit number (range of 160 feet to 103,500 feet) representing the apogee altitude of the last flight.
- A two second pause, and then a two or three digit number representing the battery voltage in tenths of a volt (e.g. 9.2 volts would report as 92).
- A two second pause (or more if you have added an optional Powerup Delay using the setup software), and then continuity beeps repeated every 0.8 seconds: A single beep means drogue ematch continuity is OK, two beeps means main ematch continuity is OK, three beeps means both drogue & main have good continuity. If the altimeter remains silent at this point, it means that there is no continuity on either ematch terminal block. If the reported continuity does not match what you expect, inspect your ematch wiring and correct before launching!

While reporting continuity, the altimeter will begin tracking ground level pressure, and will continuously update its internal ground reading to follow fluctuations in ground level pressure until time of launch.

The altimeter is ready to launch at this point.

After flight the altimeter will report in this sequence:

- An extra-long tone to indicate the start of the reporting sequence.
- A three to six digit number representing the peak altitude in feet.
- A long separator tone followed by a two to five digit number representing the maximum velocity during the flight in miles per hour.
- If the "siren delay" number is set to a number greater than zero (the default is 5 seconds, and it is changeable in the setup menu of the download software), the altimeter will wait for the specified siren delay time, and then emit a 10 second warbling siren tone. This will aid in locating the rocket if it is hidden from sight in a tree, tall grass, etc.

  If you do not want to use this feature, set the Siren Delay setting to "0" and it will be disabled.
- After a 10 second period of silence, the sequence repeats until power is disconnected. Flight data and peak altitude are preserved when power is turned off.

Changing Settings in the Field (no Computer)

The Main Deployment Altitude (MDA) setting can be easily changed in the field. There are two ways of accomplishing this: By changing to a different preset with the desired MDA, or by changing the MDA of the preset that you are using. Both methods make use of the PROG button on top of the altimeter.

Refer to table on page 23 for a list of the factory programmed presets and their corresponding settings. Preset number 3 (default, highlighted) will be used until another preset is selected. The Main Deploy column indicates that the main will deploy at 700 feet with this preset. If you want a lower MDA,

you can simply change to a different preset, such as preset 2, which has a main deploy of 500 feet. If you want a higher MDA, select one of the other presets which has a higher deployment altitude.

If you want to use a deployment altitude that isn't listed on the default chart, you can change the deployment setting of any of the presets using the procedure in step 4 on the next page. If you want the main to deploy at 400 feet, 800 feet, or any multiple of 100 feet up to 9,900 feet, you would simply select and then modify one of the presets to have the desired MDA. If you need even more control over deployment altitude, a later section will describe how to change the MDA in 1 foot increments from 100 feet to 9,999 feet using the computer interface.

To change the preset number that will be used in subsequent flights:

Hint: Read the following four steps through before starting in order to familiarize yourself with the sequence. Don't wait until you are out on the field to learn how to change your settings, try it a few times in advance and it will become second nature. Experiment by changing one of the presets to a different value and confirm that you changed it successfully.

1. Hold down the PROG button, then turn on power while continuing to hold the button down (a constant tone will sound while the button is down).
2. Release the button. As soon as the tone stops, tap the button the number of times that corresponds to the preset that you want to select (e.g. tap 4 times to select preset #4). The altimeter will beep to confirm each time you press the button. *If you wait too long before*

entering your number, the altimeter will exit program mode and continue with normal operation.

3. Shortly after you have finished tapping in your preset number, the altimeter will emit another continuous tone. If you don't want to modify the preset (i.e. you are just selecting the preset for use with the flight, but not modifying the Main Deploy Altitude for the preset) just wait for the continuous tone to stop. When the tone stops, the altimeter will proceed to the normal powerup state and report the new settings, last flight altitude, and battery voltage as described in the earlier *"Powerup"* section.
4. *(optional)* If you want to *change* the preset's Main Deploy Altitude in addition to selecting the preset, do not wait for the continuous tone to stop in the preceding step. While the tone is still sounding, press and hold the button again. The tone will change pitch to confirm that you are about to change the preset's setting. When the tone changes, release the button and the tone will stop. You can then tap in a number for the new Main Deploy setting in hundreds of feet (e.g. 9 taps will set to 900 feet, 4 taps would set to 400 feet).

   If you wait too long before entering your number, the altimeter will exit program mode and continue with normal operation.

   Shortly after you have finished adjusting your preset's MDA, the altimeter will proceed to the normal powerup state and report the new settings, last flight altitude, and battery voltage as described earlier.

Factory Default Presets:

Preset	Main Deploy (feet)	Delay Apogee Firing By (seconds)
1	300	0
2	500	0
3*	***700***	***0***
4	900	0
5	1100	0
6	1300	0
7	1500	0
8	1700	0
9	2500	0

** Altimeter uses preset #3 by default until changed by user.*

Changing Settings with a Computer

The presets can also be changed via the download software. This allows you more flexibility: you can change the main deploy altitude in increments of 1 foot, and can enter a delay to cause the apogee firing to be delayed in 1 second increments for multi-altimeter setups or for deploying payloads after apogee. You can also change several other general altimeter parameters that apply to all presets (launch detect altitude, additional powerup delay, rocket locator siren, telemetry, etc).

The following descriptions assume that you have the software running and the altimeter connected to the computer and powered up. Select the "Settings" menu item from the "Altimeter" menu. A screen will appear with the current settings, altimeter model, altimeter serial number, firmware revision level, and total number of flights listed. *Note: You must make the initial connection to the altimeter while the*

settings are being reported; if you wait until the altimeter goes silent (or is beeping continuity beeps) it will not communicate with the computer. This prevents possible electrical noise from interrupting a flight in progress.

Preset Number

To change the currently active preset, simply select the radio button adjacent to the desired preset and click "update". The selected preset will then be used for subsequent flights until it is changed again.

Main Deploy Altitude

To change any of the presets' Main Deployment Altitude settings, just select the text for the MDA in the preset that you want to change, enter a new number, and click "update". The new setting must be in the range of 100 to 9,999 feet; out of range numbers will be replaced with the closest valid numbers. The preset does not need to be selected in order to change the MDA, and you can change as many of the presets' MDAs as you want with a single "update"; you do not need to do them one at a time.

Apogee Delay

The Apogee Delay item is provided so that firing of the drogue output on the altimeter occurs a specified time *after* true apogee. If you have two altimeters (a primary and a redundant secondary backup) connected to separate redundant drogue ejection charges, you can delay the firing of the drogue charge on one of the altimeters to keep them from firing simultaneously. This will prevent possible overpressure and damage to your rocket which could occur if both charges fired at the same instant (you would accomplish the same effect with the main charges by setting them to different MDAs). The Apogee delay can also be utilized to eject payloads at a

predetermined time after apogee, using a second altimeter with no apogee delay to eject the drogue chute for recovery at the proper time.

The apogee delay is set the same way the Main Deploy Altitude is; simply select the old number, enter a new one, and hit "update". The number will be constrained to the range of 0 to 5 seconds.

Caution: For normal operation, the Apogee Delay should be set to "0". If you are not using it for one of the purposes mentioned above, do not change it from the factory setting of "0". Delaying the apogee ejection event can result in damage due to deployment at high speed or impact with ground before deployment. Only use this feature if you are certain of what you are doing!

Launch Detect

You can change the Launch Detect Altitude by selecting the text, entering a new number, and hitting "update". The Launch Detect Altitude controls the point that the altimeter "arms" itself and begins the flight sequence. If a flight doesn't make it to this altitude, the ejection events will never fire and data will not be recorded.

The altimeter stores 28 data points (1.4 seconds) of data prior to the time that it reaches the launch detect altitude. This will include data back to the point that the rocket was on the pad in most cases.

Valid settings range from 160 feet to 300 feet above ground level. The factory default of 160 feet allows for maximum pre-launch data collection combined with reasonable resistance to wind gust induced false triggering. If you must launch in abnormally high wind conditions, the Launch Detect Altitude can be increased for additional resistance.

Powerup Delay

An additional delay can be inserted between the time that the altimeter finishes reporting its settings on powerup and when the continuity beeps start as the altimeter looks for a pressure drop signifying launch. This is typically used when a power switch is not accessible from the outside of the rocket and additional time is needed after power is applied to provide time to close up the altimeter compartment and allow pressure to stabilize before the altimeter begins to look for a valid launch condition.

Warning: If you will be using the drogue or main outputs to activate ejection charges, you MUST make a provision for turning the altimeter on and off from outside the rocket. If you ever have to abort a flight, you need to turn off (disarm) the altimeter before opening the rocket or altimeter compartment. If you open a rocket that has an active altimeter operating, the pressure drop when you pull the rocket sections apart will trigger the altimeter, firing the ejection charges.

Acceptable settings are 0 (no additional delay) to 60 seconds. Factory default setting is 0 seconds.

Siren Delay

Shortly after landing, the altimeter begins its beeping sequence to report peak altitude and maximum velocity, with a pause of about 10 seconds before the sequence repeats. If the Siren Delay is set to a number other than 0 (disabled), the 10 second pause will be preceded by a delay as specified by the Siren Delay value, followed by a 10 second warbling siren from the beeper. This sound makes the rocket easier to locate, even if it is hidden from view by tall grass or other obstacles. The altimeter goes into a low power sleep mode while it is silent so that with the maximum siren delay of 120 seconds a standard

9V alkaline battery will continue to operate for nearly three months. Even if you don't find your rocket the first day, you'll have many more opportunities before it goes silent!

Valid settings are 0 (siren disabled) to 120 seconds. Factory default setting is 5 seconds.

Telemetry

The telemetry option, when enabled, sends altitude information to the data port in real time during the flight. This information can be sent to a ground receiver via a user-supplied RF modem so you can see how high the rocket is at any point from the ground. It can also be used by other custom payload devices so that various functions can be controlled at different altitudes (air sampling, payload release, etc).

The telemetry settings are controlled by a popup menu with three options:

Never: Telemetry is disabled, and no information is sent to the data port in real time.

OnPad: Telemetry is enabled. Altitude information is sent beginning at the same time as the start of the continuity check beeps and continues until the rocket has landed.

OnLaunch: Telemetry is enabled. Altitude information is sent beginning at the launch detect point and continues until the rocket has landed.

More information about the serial port settings and the telemetry data format is available on page 39.

Quickstart for Experienced Users

If you are impatient, the altimeter can be used right out of the package, with no changes to any settings. The default main deploy altitude is 700 feet. This can be changed via the computer interface or by using the "program" button without a computer, please refer to the full setup guide starting on page 20 if you need to change a setting.

No mach delay is necessary with this altimeter. No problem with mach+ flights.

Battery voltage can be 4 to 16 volts, virtually nil current draw for altimeter, battery must supply enough current to fire any connected ematches. Do not exceed 5 amps. Outputs are turned on for 1 second.

Perform ground test(s) as necessary to confirm any non-standard ematch/battery usage and to familiarize yourself with proper operation of the altimeter.

When you first turn the altimeter on you will hear the following parameters reported (numerical format described on page 16, we use 10 beeps for digit 0):

- A siren and error code if an error was encountered during the last flight. See page 17 for explanation of error codes.
- A one digit number (range of 1 to 9) corresponding to the currently-selected program preset. The preset stores the main deploy altitude setting and the apogee delay setting (if used). The factory default is preset 3, which equates to main deployment at 700 feet and no apogee delay.

- A two second pause, and then a three or four digit number (range of 100 to 9,999) corresponding to the main deploy altitude setting from currently-selected program preset. This is the altitude that your main will deploy at.
- *(optional, only if you have added an apogee delay to the currently selected preset: A two second pause, and then a five second continuous tone to warn you that your apogee firing is set to be delayed. If you hear this tone, and don't expect an apogee delay, then: STOP, go back, and either modify the preset with a computer or select another preset that does not have an apogee delay. If you aren't sure what an apogee delay is, refer to page 24)*
- A two second pause, and then a three to six digit number (range of 160 to 103,500) representing the apogee altitude of the last flight.
- A two second pause, and then a two or three digit number representing the battery voltage in tenths of a volt (e.g. 9.2 volts would report as 92).
- A two second pause, and then continuity beeps repeated every 0.8 seconds – a single beep means drogue ematch continuity is OK, two beeps means main ematch continuity is OK, three beeps means both drogue and main have good continuity.

If the reported settings were as you expected them to be, your battery voltage was good, and the proper continuity is being reported, the altimeter is ready for launch.

After flight the altimeter will report in this sequence:

- An extra-long tone to indicate the start of the reporting sequence.

- A three to six digit number representing the peak altitude in feet.
- A long separator tone followed by a two to five digit number representing the maximum velocity during the flight in miles per hour.
- If the “siren delay” number is set to a number greater than zero (default is 5 seconds, changeable in the setup menu of the download software), the altimeter will wait for the specified siren delay time, and then emit a 10 second warbling siren tone to aid in locating the rocket if it is hidden from sight in a tree, tall grass, etc. If you do not want this feature, set the Siren Delay setting to “0” and it will be disabled.
- After a 10 second period of silence, the sequence repeats until power is disconnected. Flight data and peak altitude are preserved when power is turned off.

Additional Useful Information

Shear Pins

Virtually all two event deployment rockets should be set up with shear pins at the separation points. Shear pins hold the rocket sections together until the ejection charge fires so that they don’t separate prematurely due to recoil or drag forces.

If your drogue shock cord is too short, not elastic enough, or the drogue charge is overly energetic, there will be a considerable “jerk” placed on the cord when the drogue ejection charge fires. The forward section of the rocket will be ejected at high speed away from the aft section, and when the shock cord comes to full extension inertia will try to yank the

nosecone out of the forward airframe section. If this happens, the main will come out at apogee, defeating the purpose of two stage deployment.

This can also happen at the fore/aft airframe junctions with heavy rockets and motors with abrupt burnout – the sudden deceleration and aerodynamic drag on the booster section can cause the inertia of the forward section to pull it free from the booster, causing early separation. If your rocket separates and the drogue deploys right at motor burnout, this is a likely cause (it could also be caused by motor blowby if you didn't install the forward O-rings properly).

2-56 or 4-40 nylon screws work well for shear pins, and plastic toothpicks can be used as well for smaller rockets. To install shear pins at the nosecone/main chute airframe junction, install the nosecone and then drill two or more small holes about 1" back from the fore end of the airframe through the airframe and into the nosecone shoulder. Remove the nosecone and reinforce the area around the holes in the airframe. Fiberglass or carbon fiber airframes won't need any reinforcement, but as a minimum with paper tubes, wick some thin CA glue into the tube material around the hole. A better reinforcement consists of grinding out an area of about 1" around the hole on the inside of the airframe to a depth of about .020", and then glue a piece of .015" shim brass into the recess such that it doesn't protrude into the I.D. of the airframe tube. Then redrill the hole in the airframe to include the brass shim material. This will create a strong and sharp shear edge to slice through the shear pins when the ejection charge fires.

After your main chute, chute protection, and shock cord are installed, fit the nosecone in place and install your shear pins in the holes that you drilled earlier. The nosecone will be retained until the ejection charge fires, shearing the pins.

The nosecone/main junction should be pinned in all but the smallest of two stage deployment rockets. The drogue separation point is less critical, as the burnout forces are typically much smaller than the recoil when the shock cord comes to full extension. If your rocket has a heavy forward section, draggy aft section, and a abrupt burnout motor, then you should consider pinning the booster/main junction as well.

The size of your ejection charges may need to be increased to provide enough force to shear the pins, make sure you keep this in mind when sizing and ground testing your ejection charges.

Electric Matches

The *StratoLoggerCF* altimeter can use a wide range of electric matches and electric match substitutes due to its high current outputs and long firing current duration. Bear in mind, however, that the battery must be able to provide enough current to fire the match – it is not augmented in any way by the altimeter. A good quality, fresh 9V alkaline battery can provide 3 to 4 amps of current and will fire many kinds of electric matches. Please refer to the "Powering the Altimeter" section at the beginning of the manual for procedures regarding testing match/battery combinations before flight. Make sure you do not exceed the 5 amp current limitation on the *StratoLoggerCF's* outputs, or internal damage to the altimeter may occur.

If you can obtain them, the best choice is to use commercial electric matches such as the Mtek or Jtek ematch. These matches are constructed in a controlled environment with optimized materials and will provide the best combination of

sensitivity/low energy firing, reliability, and convenience. Even the best ematches can fail, so it is a good idea to use two ematches wired in parallel for each charge – if one match doesn't fire, the other one will, and the ejection will be successful. The commercial ematches need such a small amount of current that two in parallel can be easily fired with a fresh 9V alkaline battery.

The high current output of the *StratoLoggerCF* allows simple ematch substitutes to be made by winding a "filament" of 40 gauge nichrome or copper wire around twinlead leadwire and soldering the ends of the filament to the ends of the leadwire. To ensure reliability, the connections must be soldered, and all traces of soldering flux need to be removed. When activated, the filament glows white hot for an instant before burning through, easily igniting black powder surrounding the filament. Instructions and a starter kit for making these ematch substitutes are available on the PerfectFlite website. To ensure the required 100% reliability, excellent soldering technique and careful attention to the fine work involved is mandatory. If you don't trust your skills in making these, buy something premade instead!

There are also a number of companies that sell electric match substitutes and ejection canisters – a partial listing appears near the end of this manual.

Flashbulbs are sometimes used, but are fragile, expensive, bulky, and prone to accidental triggering by weak electrical currents. Similarly, rocket motor igniters such as Estes igniters, Copperheads, FirstFire, etc should NOT be used – they have high current requirements, burn hot for an extended time which can damage your rocket parts, and are not as reliable as proper ematches or substitutes.

Ejection charges

The ejection charges used to deploy your recovery devices can be purchased commercially or made at home. Since ejection charges contain a quantity of explosive black powder, extreme care must be exercised while constructing and handling them. Keep your face and hands away from the end of any ejection charge that has been loaded with powder! Do not look into or reach inside rocket airframes with live ejection charges loaded, and remember that an accidentally-ejected nosecone can severely damage anything in its path. If you get in the habit of following the preflight checklist located later in the manual, this will ensure that the altimeter is not energized when anything is in the path of the nosecone in case of accidental firing of the charges.

Refillable ejection charge canisters and holders can be made out of small diameter PVC pipe and caps. 3/8" PVC works well for 6" diameter and smaller rockets. A cap is affixed to the outside of your altimeter bay's bulkhead with the open end facing outward. Cut a short (1" to 2") section of PVC pipe and set it on a piece of wax paper. Fill the inside of the pipe with enough epoxy to make a ¼" to 3/8" long "plug" on the inside of the bottom end of the pipe. After the epoxy hardens, peel the wax paper away and your charge canister is ready.

Insert an electric match part way into the open end of the canister and bend the leads over the top to hold it at the right height. The match head needs to be completely covered with black powder, but it should not be buried all the way down at the bottom (if the charge is ignited at the bottom, there is a tendency to blow part of the charge out of the canister unburned).

Add the appropriate amount of FFFFg black powder (as a starting point, multiply the volume of the parachute bay in cubic inches by .007 to get grams of black powder) and gently tap the side of the tube to distribute the black powder around the igniter head. Using a section of 1/8" wooden dowel, carefully press a small ball of flameproof wadding in on top of the black powder so that the powder is completely covered. There is no need to force or pack the charge down, simply press the wadding in place so that it contacts the powder to prevent shifting of loose powder.

*Hint: FFFFg black powder has a specific gravity of about .95 grams/cc. You can make a measuring cup from a spare red capplug – measure the inside diameter and inside depth in centimeters, then calculate the volume (diameter * diameter * depth * 0.788) and multiply by 0.95 to get grams per measuring cupful.*

Add a piece of masking tape across the end of the canister to hold the wadding in, then wrap another piece of tape around the outside of the tube to hold the ends of the first piece of tape in place.

Your ejection charge is now complete. Store loaded ejection charges in a safe manner, with the ematch wire ends shorted together until immediately prior to use. Since the actual amount of black powder necessary can vary based on a number of parameters (powder type, nosecone/coupler to tube friction, shear pins, etc.) you should test your ejection charges on the ground before flight. Start with a little less powder, and increase the amount until the airframe separates reliably. Then add 30 - 50% as a safety factor to account for variations in friction due to humidity, etc.

Ground Testing

Pre-flight testing of your altimeter installation is important to ensure success in flight. Testing can confirm that your battery and ematch selections are compatible, your wiring is correct, your drogue and main charges are connected properly, and your ejection charge is sized appropriately.

Set up your altimeter bay with the battery and ematches you plan on using, but without any black powder ejection charges. If you are using commercial ematches or any other ematch with flammable pyrogen, make sure the ematches are located away from flammable objects or body parts. Turn the altimeter on and wait for the continuity beeps – ensure that they are as expected (three beeps repeated if you are using two event deployment).

Use a shop vac to apply a vacuum to the static pressure sampling hole on your altimeter bay (you will not be able to pull enough vacuum with your lungs due to the leaky nature of most altimeter bays). You can make a "head" for the shop vac hose out of a block of soft foam and carve it to conform to the curvature of your rocket body tube to protect your rocket's finish and to provide maximum vacuum. Shortly after the vacuum "peaks", the drogue ematch should fire. After the drogue match fires, remove the vacuum and the main ematch should fire. Make 100% certain that the ematches fired in the correct order – if you accidentally swap the main and drogue charge wires, your large main chute will deploy at apogee and you will be in for a long walk!

If your wiring, battery, and ematches check out, you can proceed to testing your ejection charges to ensure that they are powerful enough to eject you chutes. *Warning! This procedure can be dangerous if not performed correctly. Review the*

cautions in the "Ejection Charges" section and proceed carefully. This test must be conducted in an open area without unnecessary bystanders. Make sure that there is nothing in the ejection path that could be damaged by the ejected nosecone or other rocket parts. Prepare your rocket as if you were going to launch it, but without the motor. Make sure the altimeter is OFF, install the ejection charge for *only the main chute*, and pack the chute and rigging as if you were going to launch. Lay the rocket down, with the nosecone pointing a few degrees up from horizontal, and restrain the aft section of the rocket. Double check that nothing is in the projected path of the nosecone. Turn the altimeter on and wait for the continuity beeps (you should get two beeps for the main only). With the beeps sounding, apply vacuum from the shop vac to the static sampling port to trigger the altimeter. The continuity beeps will stop, and a few seconds later the nosecone and main chute should be ejected.

Evaluate the force of the ejection and adjust the amount of BP in the charge if necessary. The nose cone should separate cleanly and promptly and the rigging should deploy to approximately the limit of the shock cord. If the nose cone separates sluggishly, add 25% more BP and try again. If the separation force seems excessive, try less BP and repeat the test.

Once the main charge is sized correctly and proper operation is confirmed you can test the drogue separation point. The procedure is essentially the same as that of the main test, with a couple of minor differences. With the drogue test, you will be loading the drogue charge alone (no main charge) and therefore should expect a single continuity beep to confirm proper setup. The entire rocket should be placed in the test position again, confirming that nothing is in the ejection path.

In this test the entire top half of the rocket will be ejected, with more recoil, so make sure the bottom section of the rocket is restrained securely. The most significant difference is that now the static sampling port is in the part of the airframe that will be ejected. When you apply the vacuum to the port, be prepared to pull back quickly because you will only have a couple of seconds before the charge fires.

Evaluate the energy of the drogue charge in the same manner as you did for the main charge. Bear in mind that if your rocket doesn't separate properly at apogee, it will descend at very high speed – if your main charge opens the rocket properly after a ballistic descent from apogee, it will be going so fast that airframe and/or chute damage is almost certain.

A conflicting point to consider is that an overly-energetic drogue deployment charge can cause a large recoil when the shock cord comes to full extension. When this happens, the nose cone could be ejected prematurely, causing the main to deploy near apogee which will result in a long recovery walk. This risk can be minimized by using shear pins on the main separation point and by using a very long and slightly elastic shock cord at the drogue separation point.

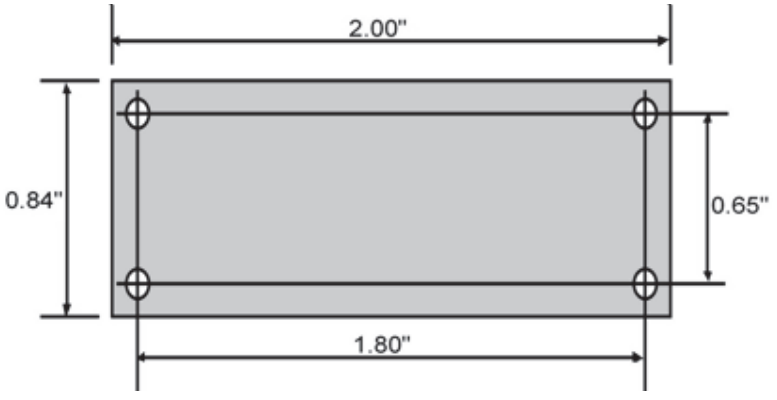
If you look at the "flight" curve from your shop vac tests you may notice that the apogee deployment appears to be delayed several seconds from where you might expect it. This is because the sudden application of a strong vacuum from the shop vac will activate the *MachLock* feature of the altimeter. Once *MachLock* is activated, the altimeter requires the speed to fall below a predetermined threshold for a period of time before looking for apogee conditions. In a normal rocket flight, this will happen gradually as the rocket approaches apogee.

When you jerk the shop vac away, the apparent speed suddenly goes negative instead of slowing gradually, and apogee will not be detected until several seconds later. This will never occur in a normal rocket flight profile.

Mounting Notes

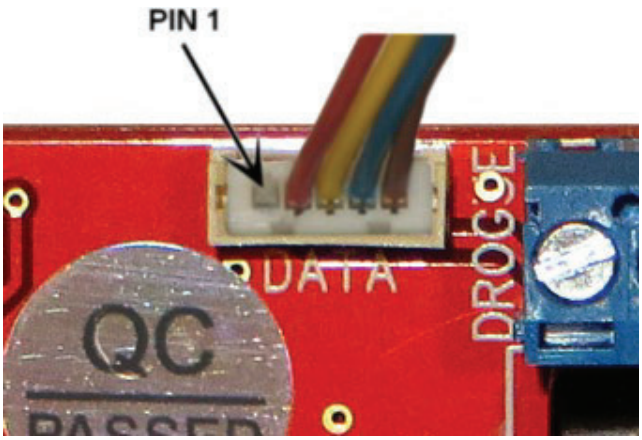
Mounting hardware consisting of 4-40 threaded hex standoffs, nuts, and screws such as the PerfectFlite MH44 can be used to attach the altimeter to a mounting plate in your electronics bay. To prevent contact with any of the components on the altimeter's PCB, make sure that the screw heads have a maximum diameter of 0.219" (7/32") and the hex standoffs have a maximum dimension of 0.188" (3/16") "across the flats". Be cautious when using garden-variety hardware from a box store or other source, as they tend to supply bulkier parts. Do NOT drill out the mounting holes in the PCB to accommodate larger hardware.

The pressure sensor is mounted on the bottom of the board to minimize the chance of sunlight or wind currents entering the sensing hole. Make sure that at least 1/32" clearance is provided between the mounting plate and the face of the pressure sensor to allow for the proper pressure sensor operation.



Telemetry Information

The data connector pinout is shown below. All signals are 3.3V CMOS logic level, and the lines idle "high". Please double-check your cables before connecting anything to the data port; make sure that the *input* to your device is connected to the altimeter's *output*. Do not connect anything to the pins marked "NC". Do not ground any pins other than pin 5, and never apply an external voltage to any of the pins.



Pin#	*Function*
1	N/C
2	+3.3V (do not use)
3	RX data input (unused)
4	TX data output
5	GND

Serial port settings should be configured for 9,600BPS, 8 data bits, no parity, and 1 stop bit. Output data format from the altimeter is ASCII text based, with a <CR> and <LF> character appended to the end of each line.

When telemetry data is selected to start “OnPad”, the first value sent will be the approximate ground elevation, and all subsequent data will be AGL (Above Ground Level) altitudes:

880<CR><LF> {first data point is launch elevation MSL}
0<CR><LF> {all subsequent data points are AGL altitude}
0<CR><LF>
0<CR><LF>
5<CR><LF>
25<CR><LF>
56<CR><LF>
99<CR><LF>
149<CR><LF>
198<CR><LF>
248<CR><LF>
300<CR><LF>
349<CR><LF>
398<CR><LF>
447<CR><LF>
497<CR><LF>

When telemetry data is selected to start “OnLaunch”, all data will be AGL altitudes:

198<CR><LF> {all data points are AGL altitude}
248<CR><LF>
300<CR><LF>
349<CR><LF>
398<CR><LF>
447<CR><LF>
497<CR><LF>

Avionics Bay Manufacturers

Always Ready Rocketry
314 Myrtle Street
Mount Vernon, WA 98273
TEL: (360) 336-3533
sales@alwaysreadyrocketry.com
http://www.alwaysreadyrocketry.com

Giant Leap Rocketry
6061 Hibiscus Drive
Baton Rouge, LA 70808
TEL: (225) 308-1098
FAX: (225) 769-0710
sales@GiantLeapRocketry.com
http://www.giantleaprocketry.com

LOC Precision
P.O. Box 470396
Broadview Heights, OH 44147
TEL: (330) 745-9755
FAX: (330) 745-9754
locprecision@sbcglobal.net
http://wwww.locprecision.com

Electric Match/ Electric Match Substitute Sources

FireFox FX
PO Box 5366
Pocatello, Id 83202
TEL: (208) 237-1976
catalog@firefox-fx.com
http://www.firefox-fx.com

Newtons 3rd
http://www.newtons3rdrocketry.com

Performance Hobbies
TEL: (202) 723-8257
http://www.performancehobbies.com

Pratt Hobbies
2513 Iron Forge Road
Herndon, VA 20171
TEL: (571)221-5820
dad@pratthobbies.com
http://www.pratthobbies.com

QuickBurst
59 Elm CT
Lake Jackson, TX 77566
TEL: (979) 373-6601
info@quickburst.net
http://www.quickburst.net

RocketFlite
http://www.rocketflite.com

Cautions

- Do not touch circuit board traces or components or allow metallic objects to touch them when the altimeter is powered on. This could cause damage to your altimeter or lead to premature ejection charge activation.
- Exercise caution when handling live ejection charges - they should be considered to be explosive devices and can cause injury or damage if handled improperly. Safety glasses should be worn when working with black powder.
- If your altimeter is being used for deployment purposes, do not turn the altimeter ON when live charges are connected until the rocket is on the pad in an upright position. Keep all body parts clear in case of accidental ejection.
- Do not launch your rocket when the wind speed exceeds 20 MPH. If you must launch in gusty wind conditions, increase the Launch Detect Threshold as necessary to prevent accidental ejection caused by strong wind gusts.
- Do not allow the altimeter to get wet. Only operate the altimeter within the environmental limits listed in the specifications section.
- Note battery voltage before each flight and replace or recharge battery if the voltage is low.
- Do not rupture pressure sensor diaphragm with excessive pressure or sharp object.
- Always follow proper operational sequencing as listed in preflight checklist.

Preflight Checklist

- ❑ *Visually inspect all wiring and check that terminal screws are tight and wires secured. Check that battery is secured and battery clip is attached properly. Close and seal avionics bay.*
- ❑ Prep rocket, install engine, do not install engine igniter.
- ❑ Make sure altimeter power switch is OFF.
- ❑ Put on safety glasses if you will be working with BP charges.
- ❑ Install ejection charges (don't forget to load with black powder!) and chute protection. *Make sure all recovery harness points are connected!*
- ❑ Connect ejection charge leads to avionics bay's ejection charge terminals, making sure that wires do not short together or short to anything else. *Do not exchange drogue and main charge wires!*
- ❑ Have your rocket inspected by RSO if applicable, install engine igniter, and place rocket on launch pad.
- ❑ Turn altimeter power switch ON. *If you hear a repeating error siren, turn altimeter OFF and do not launch until problem is corrected.* The altimeter's settings will be reported; confirm that the Preset Number and Main Deployment Altitude are set properly. Last flight altitude will then be reported, followed by battery voltage. Make sure battery voltage is within your expectations.
- ❑ Next, ejection charge continuity will be annunciated by a series of one, two, or three beeps. *Do not launch if continuity status is not as expected! Ejection charges are "armed" at this point: Keep body parts clear!*
- ❑ If continuity is being reported as expected, attach launch system leads to engine igniter and launch!

Specifications:

Power:	4V – 16V, nominal 9V battery
Current consumption:	1.5 ma
Output current:	Do not exceed 5 amperes
	(actual current is battery dependent)
Output “on” time:	1.0 second
Launch detect:	160’ to 300’ AGL, default 160’
Main deploy altitude:	100’ AGL to 9,999’ AGL
Maximum altitude:	100,000’ MSL
Altitude resolution:	1’ up to 38,000’MSL
	< 2’ to 52,000’MSL
	< 5’ to 72,000’MSL
Analog to Digital Converter:	24 bit Sigma Delta
Calibration accuracy:	+/- 0.05% typical
Measurement precision:	+/- (0.1% reading + 1 foot) typical
Flight data logged:	Altitude, temperature, battery voltage
Number of flights stored:	16
Recording time per flight:	Over 18 minutes
Sample rate:	20 samples per second
Operational temperature:	-40C to +85C (-40F to +185F)
Dimensions:	2.0”L x 0.84”W x 0.5”H
Weight:	0.38 oz.

Warranty

All PerfectFlite products include a full three year/36 month warranty against defects in parts and workmanship. Should your PerfectFlite product fail during this period, call or email our Customer Service department for information about returning your product. The warranty applies to the altimeter only, and does not cover the rocket, motor, or other equipment. This warranty does not cover damage due to misuse, abuse, alteration, or operation outside of the recommended operating conditions included with your product. Broken pressure sensor diaphragms due to puncture or exposure to ejection charge pressure/hot gasses are NOT covered under this warranty.

Liability

Due care has been employed in the design and construction of this product so as to minimize the dangers inherent in its use. As the installation, setup, preparation, maintenance, and use of this equipment is beyond the control of the manufacturer, the purchaser and user accept sole responsibility for the safe and proper use of this product. The principals, employees, and vendors of the manufacturer shall not be held liable for any damage or claims resulting from any application of this product. If the purchaser and user are not confident in their ability to use the product in a safe manner it should be returned to the point of purchase immediately. Any use of this product signifies acceptance of the above terms by the purchaser and user.

David Antaki
Project RP1

Appendix M3
Geox Powder Potassium Nitrate MSDS

NAR L1 & L2 Technical Report

June 28th, 2019

Goex Powder, Inc.

Material Safety Data Sheet

MSDS-BP (Potassium Nitrate)

Revised 3/17/09

PRODUCT INFORMATION	
Product Name	Black Powder
Trade Names and Synonyms	N/A
Manufacturer/Distributor	GOEX Powder, Inc.(DOYLINE, LA) & various international sources
Transportation Emergency	800-255-3924 (24 hrs – CHEM TEL)

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

The prevention of accidents in the use of explosives is a result of careful planning and observance of the best known practices. The explosives user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosives are dangerous and must be carefully transported, handled, stored, and used following proper safety procedures either by or under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulations, or ordinances. ALWAYS lock up explosive materials and keep away from children and unauthorized persons. If you have any questions or doubts as to how to use any explosive product, DO NOT USE IT before consulting with your supervisor, or the manufacturer, if you do not have a supervisor. If your supervisor has any questions or doubts, he should consult the manufacturer before use.

HAZARDOUS COMPONENTS				
Material or Components	%	CAS NO.	TLV	PEL
Potassium nitrate	70-76	007757-79-1	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite[1]	Trace	007782-42-5	15 mppct (TWA)	2.5 mg/m³
N/A = Not assigned NE = Not established				

[1] Not contained in all grades of black powder.

P.O. Box 659, Doyline, LA 71023-0659, (318) 382-9300
www.goexpowder.com

9530608

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PHYSICAL DATA	
Boiling Point	N/A
Vapor Pressure	N/A
Vapor Density	N/A
Solubility in Water	Good
Specific Gravity	1.70 – 1.82 (mercury method) 1.92 – 2.08 (pycnometer)
PH	6.0 – 8.0
Evaporation Rate	N/A
Appearance and Odor	Black granular powder. No odor detectable.

HAZARDOUS REACTIVITY	
Instability	Keep away from heat, sparks, and open flames. Avoid impact, friction and static electricity.
Incompatibility	When dry, black powder is compatible with most metals; however, it is hygroscopic and when wet, attacks all common metals except stainless steel. Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.
Hazardous decomposition	Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization	Polymerization will not occur.

FIRE AND EXPLOSION DATA	
Flashpoint	Not applicable
Auto Ignition Temperature	Approx. Range: 392°F-867°F / 200°C-464°C
Explosive temperature (5 sec)	Ignites @ approx. 427°C (801°F)
Extinguishing media	Water
Special fire fighting procedures	ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES. Try to keep fire from reaching explosives. Isolate area. Guard against intruders. Division 1.1 Explosives (heavily encased): Evacuate the area for 5,000 feet (approximately 1 mile) if explosives are heavily encased. Division 1.1 Explosives (not heavily encased): Evacuate the area for 2,500 feet (approximately ½ mile) if explosives are not heavily encased. Division 1.1 Explosives (all): Consult U.S. DOT Emergency Response Guide 112 for further details.

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Unusual fire and explosion hazards	Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

HEALTH HAZARDS	
General	Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulation and ordinances.
Carcinogenicity	None of the components of Black Powder are listed as a carcinogen by NTP, IARC, or OSHA.

FIRST AID	
Inhalation	Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention. Avoid when possible.
Eye and skin contact	Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.
Ingestion	Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting. Avoid when possible.
Injury from detonation	Seek prompt medical attention.

SPILL OR LEAK PROCEDURES	
Spill/leak response	Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in clean up procedures. Carefully pick up spills with non-sparking and non-static producing tools.
Waste disposal	Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with Federal Regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).

SPECIAL PROTECTION INFORMATION	
Ventilation	Use only with adequate ventilation. (If required)
Respiratory	None
Eye	None
Gloves	Impervious rubber gloves. (If required)
Other	Metal-free and/non-static producing clothes

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SPECIAL PRECAUTIONS
• Keep away from friction, impact, and heat and open flame. Do not consume food, drink, or tobacco in areas where they may become contaminated with these materials. • Contaminated equipment must be thoroughly water cleaned before attempting repairs. • Use only non-spark producing tools. • No smoking.

STORAGE CONDITIONS
Store in a cool, dry place in accordance with the requirements of Subpart K, ATF: Explosives Law and Regulations (27 CFR 55.201-55.219).

SHIPPING INFORMATION		
Proper shipping name	Black Powder	
Hazard class	1.1D	
UN Number	UN0027	
DOT Label & Placard	DOT Label	EXPLOSIVES 1.1D
	DOT Placard	EXPLOSIVES 1.1
Alternate shipping	Limited quantities of GOEX black powder (1# cans only) may be transported as "Black powder for small arms – flammable solid" pursuant to U.S. Department of Transportation 49 CFR.	

The information contained in this Material Safety Data Sheet is based upon available data and believed to be correct; however, as such has been obtained from various sources, including the manufacturer, military and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. GOEX, Incorporated, has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, GOEX, Incorporated, cannot anticipate nor control the many situations in which the product or this information may be used; there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole responsibility of each user of the product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

For further information contact: GOEX Powder, Incorporated
P. O. Box 659
Doyline, LA 71023-0659
Telephone Number: (318) 382-9300
Fax Number: (318) 382-9303

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BLACK POWDER

FRICTION TEST
PA

Steel – Snaps
Fiber – Unaffected

IMPACT TEST
PA

16 Inches (10% Point)

ELECTROSTATIC DISCHARGE TEST

Bureau of Mines
0.8 Joules (Confined)
12.5 Joules Unconfined)

STABILITY

75° C International Heat Test – 0.31% Loss
Vacuum Stability – 0. 5cc @ 100° C

BRISANCE – Sand Test 8 gm.

VELOCITY

In the open, trains of black powder burn very slowly, measurable in seconds per foot. Confined, as in steel pipe, speeds of explosions have been timed at values from 560 feet per second for very coarse granulations to 2,070 feet per second for the finer granulations. Confinement and granulation will affect the values.

CHEMICAL DECOMPOSITION

Use water to dissolve the potassium nitrate. By leeching out the potassium nitrate, the residue of sulfur and charcoal is non-explosive but combustible when dry – dispose separately.

SPECIAL REQUIREMENTS:

Black Powder is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

When dry, it is compatible with most metals. However, it is hydroscopic and when wet, attacks all common metals except stainless steel.

CAUTION: Explosives must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials and other similar materials, situations and equipment. Explosives include propellants and pyrotechnics.

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David Antaki

Project RP1

Appendix M4
Rocketmaterials.org Sheer Pin Strengths

NAR L1 & L2 Technical Report

June 28th, 2019

http://www.rocketmaterials.org/datastore/cord/Shear_Pins/index.php Go AUG OCT FEB
17 captures 26
11 Aug 2011 - 8 Oct 2018 2011 2013 2015
About this capture



Shear Pins

Last updated 08/19/2004

The test fixture is made of a carbon fiber coupler and a length of 38mm body tube. 3/4" plywood bulkheads were epoxied into each section and a welded eyebolts were secured with nuts washers. Several holes were drilled in the assembly to test various shear pin sizes and quantities. The picture on the left shows the test fixture. The picture on the right shows it in action, testing four #4 nylon screws. Click on them to see a larger image.



The first thing you'll notice is the high number of tests. I was not comfortable with the variation in data. I was using my small 500 lb load cell that was calibrated from 0 to 500 lbs with a 0.00005 lbs resolution. The accuracy is +/- 0.0001 lbs. The column below "Peak Load Each Pin" should all be the same for the same size pin. The rate of loading for this test was 20 IPM.

Warning: Including set-up pieces, well over 150 shear pins were mutilated and killed in these tests!

#2 Nylon Screws

# of Pins	Peak Load (lbs)	Peak Load (Each Pin)
2	53.123	26.56
2	45.952	22.98
2	50.848	25.42
2	51.799	25.90
2	47.924	23.96
Avgs	***49.93***	***24.64***
3	62.637	20.88
3	60.569	20.19
3	64.395	21.47
3	62.413	20.80
3	68.760	22.92
3	66.643	22.21

#4 Nylon Screws

# of Pins	Peak Load (lbs)	Peak Load (Each Pin)
2	81.304	40.65
2	85.148	42.57
2	75.944	37.57
2	80.391	40.20
2	80.908	40.45
	80.75	***40.30***
3	119.273	39.76
3	110.999	37.00
3	99.969	33.32
3	113.554	37.85
3	116.208	38.73
3	121.121	40.37
3	123.689	41.23

http://www.rocketmaterials.org/datastore/cord/Shear_Pins/index.php Go AUG OCT FEB
17 captures 26
11 Aug 2011 - 8 Oct 2018 2011 2013 2015 About this capture

4	86.855	21.71	4	152.368	38.09
4	78.771	19.69	4	142.026	35.51
4	84.269	21.07	4	160.489	40.12
4	85.617	21.40	4	153.302	38.33
4	90.402	22.60	4	154.766	38.69
			4	160.368	40.09
Avgs	***84.44***	***21.36***		***152.38***	***38.21***

Discussion

It can be seen that when using only two shear pins: 1) the average peak load is higher for each pin and, 2) the spread within the average is greater. (The spread within an average is known as sigma.) This was true for both the #2 screws and the #4 screws. It was determined that only using two pins allowed the assembly to cock to one side causing a binding effect, thereby increasing the load variance (sigma) and average.

Using three or more pins eliminated this binding effect, producing a much lower sigma and much more consistent results.

How to use this data

Using shear pins is a tried and true method of keeping a recovery compartment secure prior to deployment. Friction fitting a coupler works, but is not consistent. We can see that using nylon screws create a consistent and predictable way of securing your coupler assembly. Knowing the load to overcome during ejection is a helpful way to determine how much ejection powder you need to both shear the pins and eject your recovery system. Remember that you still need to ground test your recovery system but using nylon screws creates a predictable and consistent recovery system.



Below is the same test as described above. The fixture was made the same way, but is made from 2.25" USR white glassine cardboard tubing. The holes were drilled and stiffened with liberal amounts of Cyanoacrylate. The #4 screws began to tear up the tubing rather quickly. The tubing held up rather nicely to the #2 screws.

There is not enough data to draw any conclusions.

#2 Nylon Screws

# of Pins	Peak Load (lbs)	Peak Load (Each Pin)
3	34.163	

#4 Nylon Screws

# of Pins	Peak Load (lbs)	Peak Load (Each Pin)
3	60.727	

#6 Nylon Screws

# of Pins	Peak Load (lbs)	Peak Load (Each Pin)
3	181.380	60.46

Below are tests using polystyrene fork tines. These were tested in the carbon fiber fixture. The notes column on the right describes the hole size in which they were tested. The results vary widely, most likely due to the taper in the tines and probable inconsistencies in the material.

Although many people use them, this test shows that using fork tines is a poor idea. There is absolutely no consistency or predictability.

http://www.rocketmaterials.org/datastore/cord/Shear_Pins/index.php Go AUG OCT FEB
17 captures 26
11 Aug 2011 - 8 Oct 2018 2011 2013 2015
About this capture

3	8.853	#2 Holes
3	1.414	#2 Holes
3	55.191	#4 holes
3	102.927	#4 holes
2	24.527	#2 holes
2	65.254	#4 holes

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David Antaki

Project RP1

Appendix M5
Calculating Shock Cord Length (Apogee)

NAR L1 & L2 Technical Report

June 28th, 2019

Apogee Components

PEAK OF FLIGHT

NEWSLETTER

In This Issue

What Length of Elastic Shock Cord?



Cover Photo: The Quest Lil' Grunt rocket kit gets prepped for launch. Get yours at: www.ApogeeRockets.com/Rocket_Kits/Skill_Level_3_Kits/Lil_Grunt

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ISSUE 348 SEPTEMBER 24, 2013

What Length of Elastic Shock Cord?

By Bruce and Nicholas Fette

I recently began a downscale build of the Gila Monster [1] design, scaling all dimensions to match a 5.5" body tube. I previously built a half scale model in Arizona, but I needed a smaller version for East Coast use (considering the rocket eating trees). The original Gila Monster was built by the "HillBilly Rocketry from Arizona" and flown at Superstition Space Modeling Society, Turkeyfest in Nevada, and other western ranges (see Figure 1). As I was completing the build, the question of how long and how strong the shock cords should be came up. So I did some research to derive an analysis-based answer.



Figure 1 – Gila Monster – Build and flown by the "Arizona Hillbillies" of Superstition Space Modeling Society.

Background: For rockets using A,B and C motors and weighing less than a pound, and with parachutes less than 12 inches, a ¼" rubber band about 2 feet long seems appropriate (www.ApogeeRockets.com/Building_Supplies/Parachutes_Recovery_Equipment/Shock_Cord/3_8in_x_6-foot_Rubber_Ribbon). But as we get into larger rockets with F & G motors weighing up to 3 pounds, a real shock absorbing shock cord makes sense. Even more so, for Level 1 and Level 2. Then the recommendations change again for Level 3. In this article, I hope to walk through my logic of shock cord design.

Many folks have different ideas on how to design or select a shock cord. Studying the question on the web I found a common recommendation that the shock cord should be 3 times as long as the overall rocket length. I also found use of Kevlar of various sizes. But it seemed to me that for rockets under 10 pounds, perhaps the shock cord could absorb the shock of ejection and parachute inflation. I was already planning and expecting to use elastic strap as my shock cord, having previously used it successfully in all of my Level 1 and Level 2 rockets. 1" elastic strap can be found in Joann's Fabrics and Craft, and G Street Fabrics, and can be purchased (cut) from a roll in most reasonable lengths for shock cords.

I typically like to make a strong coupler sized tube by cutting a small slice out of a body tube and epoxying it back together, then epoxying a ½" nylon strap about 1 foot long to the inside, and use a few T nuts to bolt it to the inside of the body tube just above the fin case (see Figure 2). I attach my 1" elastic shock cord to this using a loop tied into the elastic strap, and to the nose cone, or to the electronics bay at a ¼ x 20 steel eye bolt. But I decided to calculate how long this elastic shock cord should be.

First, I needed to know the properties of the elastic

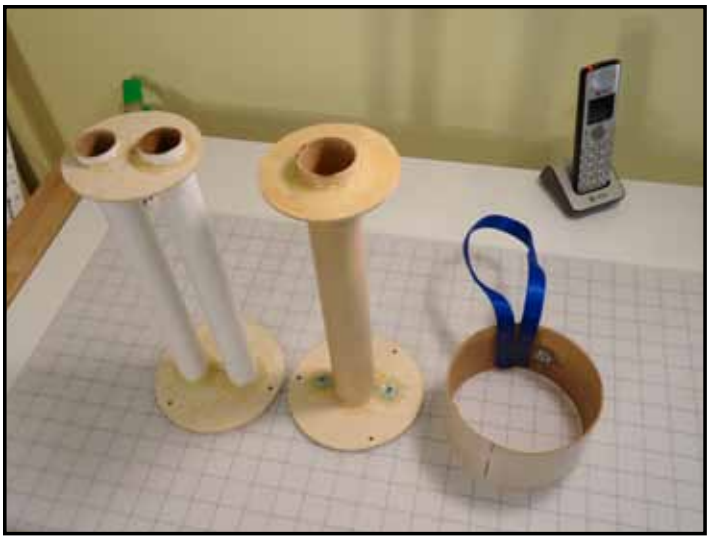


Figure 2 – A coupler tube with a nylon loop is bolted to the body tube above the fin case, and the elastic shock cord is looped around the nylon loop. This simplifies repair and refurbishment.

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What Length Of Elastic Shock Cord?



Figure 3 – Test Stand for measuring spring constant and break point properties of elastic strap.

cord. I clamped a 70 pound scale and ruler to a 2x4 (see Figure 3). I took a 10 foot length of strap, and wrapped it into 4 loops with a total of 8 parallel strands from my finger up to the weight scale. The scale measured the force on the 8 strands as I pulled down, and the ruler measured how long the 8 strands were stretched out, from the scale hook to my finger. I recorded the stretch length at each increase of 5 pounds, until it didn't stretch any more (see Figure 4 on the next page). I also did the same with 8 wraps of 10' x ½" elastic and with 30' x ¼" elastic.

Next I pulled as hard as possible on just a single loop (effectively two lengths in parallel to the scale), and recorded the force that would break the loop, for the ½" and ¼" elastic straps. Data for these measurements is shown in Table 1, and the corresponding graphs. Yes, it is a little amazing how strong it is beyond the point where it doesn't stretch any more.

The Two Forces On Shock Cords

The shock cord must endure two forces:

1) The force as the nose or electronics bay reaches the full length of the shock cord following ejection.

2) Then immediately after, the force of the parachute opening while the rocket wants to fall much faster than the parachute will allow.

Let's look at each factor, and the effect on the shock cord.

Continued on page 4



Continued from page 3

What Length Of Elastic Shock Cord?

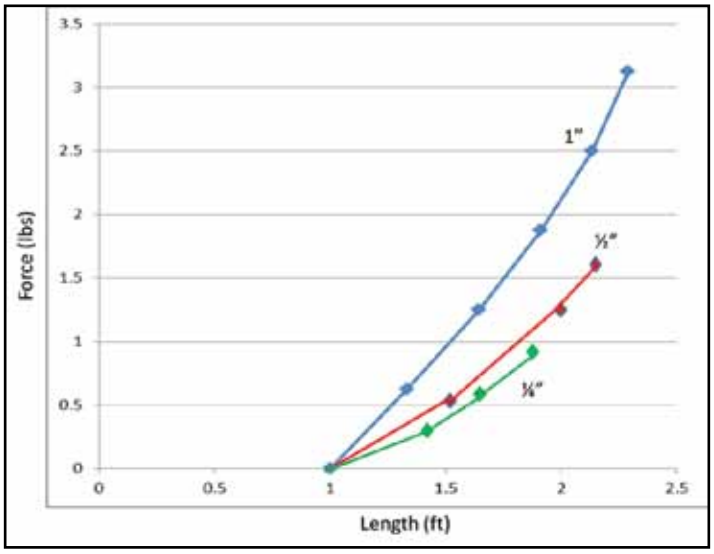


Figure 4 – Spring force measurement curves for elastic strap of ¼", ½" and 1" width. All curves normalized to a length of 1 foot, and stopped at the point where it was no longer easily stretching. The ¼" elastic broke at 26 lbs and the ½" broke at 27 lbs. The 1" sustained 34 lbs (scale limit of 70 lbs for 2 strands) without breaking.

Ejection Separation Force

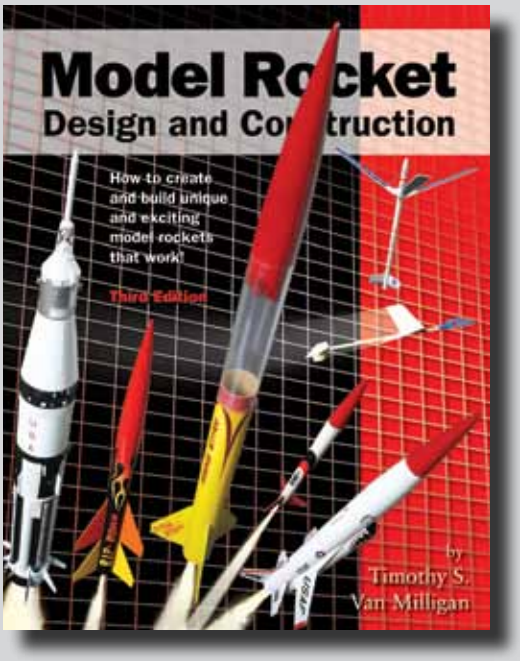
Ejection and stretching the shock cord to its limit is the first thing that happens. The ejection force is a little like a cannon shooting something out of a barrel. Here I will explore the arithmetic to determine how much energy must be absorbed as the nose cone or electronics bay speeds away from the lower half of the rocket rocket with the fin case. The goal is to absorb this energy rather than just letting the rocket parts be abruptly halted by a shock cord with no stretch. If the shock cord doesn't stretch when it fully extends, then often some plywood breaks or some steel eye bolt attachment will get bent out of shape *(which is why a forged eye bolt is often used: www.ApogeeRockets.com/Building_Supplies/Misc._Hardware/1_4-inch_Forged_Eye_Bolt).*

Bear with me as we walk through the math of calculating this energy and how long the shock cord should be to absorb it.

First we need to know how much black powder is spent in ejection. I measured the black powder in an Aerotech G motor, and to the resolution of my scale it looks like 0.9 gram. I have not found data on larger motors, and I am not going to tear them apart to measure. On Vern Knowles web site [2], there is a discussion of how much BP to use for ejection charges, and the corresponding equations that enable calculating the pressure in the ejection cavity as a function of cavity volume, surface area of the bulkhead, and the amount of black powder.

From the amount of pressure, we can calculate the force on the bulkhead that will propel the nose cone / electronics bay. The length of the coupler tube defines what distance the nose cone/electronics bay will travel when being pushed by this pressure. If you use shear pins, then the energy to accomplish the shear must be subtracted

Continued on page 5



Model Rocket Design and Construction

By Timothy S. Van Milligan

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APOGEE COMPONENTS

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What Length Of Elastic Shock Cord?

from the available energy propelling the nose cone/electronics bay.

So the electronics bay is accelerated from the fin case by a force applied over a distance, and thus develops kinetic energy. This energy can be measured in foot pounds or Newton meters. Energy in Newton meters is directly equal to energy in Joules. Please note that using more BP than required to assure safe ejection results in considerably more force and more energy to absorb, so while many may use 4 g of BP, 2 g is surely enough for Level 1 rockets without shear pins.

That energy can be absorbed into the elastic shock cord. The force of the shock cord pulling back on the nose cone/electronics bay increases as the cord stretches, just like most springs. The energy absorbed is captured in an equation based on this spring constant and the distance it stretches. The shock cord should be long enough to absorb all of this energy before it reaches its stretch limit.

Forces on the Level 1 Rocket

So here are the properties of my Baby Gila Monster, which we will use to analyze the ejection:

- Body Diameter – 5.36" / 0.136 m
- E-Bbay Surface area – 22.56 sq in / 0.014647 sq m
- Cavity Length to base of electronics bay – 14.5" / 0.369 m
- Length of E-Bay coupler – 6.25" / 0.159 m
- Spring constant of 1" elastic – 3.125/lbs for a stretch of 1.29 ft = 2.42 lbs/ft of stretch, or 13.89 n for a stretch of 1.28m or 10.86 n/m
- Black Powder – 1g
- Weight of Rocket (dry) – 7 lbs

Converting the elastic spring constant to metric is a little more complicated. If we take a 1 meter length and stretch it to 2.29 m we will also get 3.125 lbs. We convert 3.125 lbs to Newtons by multiplying by 4.445 so the metric spring constant is 13.89 Newtons/m.

Vern Knowle's web site derives the equations for converting grams of BP to pressure starting with:

PV=NRT

This is the ideal gass equation from physics:

Pressure * Volume = Mass * $R_{gas\ constant}$ * Temperature.

Vern Knowles gives us the burning temperature of Black Powder as 3307 degrees. He also provides the simplifying equation:

$N=0.006*D^2*L$ (grams) and $N=0.00052*F*L$

where N is grams of BP, D is diameter in inches, L is

Continued on page 6



Continued from page 5

What Length Of Elastic Shock Cord?

length of cavity in inches, F is force applied to the bulkhead.

The first equation defines how much BP will produce 15 psi, where D and L are in inches. However, 15 psi results in 338 lbs of force, far more force than I expect to need. My rocket weighs about 10 pounds, so less than 100 lbs of force will overcome the friction of the electronics bay coupling, including wind resistance on the nosecone. 1g of black powder will produce 132.6 lbs of force.

That force is applied over a distance of the length of the coupler. In metric equivelant of 132 lbs is 587 newtons, 6.25" is 0.159m so the energy applied to eject the E-bay is 587*.159 = 93.4 newton meters (or Joules)

The shock cord absorbs energy by the equation $E=1/2 * K * DL^2$ or $DL = SQRT (E/(0.5*K))$

Where K is the spring coefficient of the shock cord and DL is the stretched distance of the shock cord.

DL = sqrt (93.4/(0.5*10.86)) = 4.14 m

So 4.14 meters when stretched, is 1.82 m when not stretched. To be conservative, we need at least 2 m of shock cord to absorb the ejection energy of 1g BP in my Baby Gila Monster cavity. I will be happier with more length because of the inexact measurement of black powder, since my scale doesn't have very fine resolution.

Measuring BP

Recently I purchased a PerfectFilte Stratologger (www.ApogeeRockets.com/Electronics_Payloads/Altimeters/PerfectFlite_StratoLogger_Altimeter). The corresponding manual [4] is excellent and includes an equation for figuring out just how much BP is a gram, since it is very hard to come by a scale that can measure 1.0 gram (the closest thing seems to be an Ozeri Digital Kitchen Scale model ZK14-B, which can resolve thousandths of a pound, and 1 gram is 0.0022 of a pound and so it shows 1 gram as 0.002). The Stratologger manual says specific gravity of BP is 0.95 grams/cc, so if you have a "yellow nozzle cap plug measure the inside diameter and depth in centimeters, then calculate volume," and from the volume calculate the grams as follows:

Grams BP = "(0.7854*diameter*diameter*depth)*0.95"

Table 1 provides the depth measurement in mm for a yellow nozzle cap, for a Coca Cola red bottle cap, a PVC end cap, and a small vial for BP amounts from 1 to 4 grams.

Continued on page 7

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What Length Of Elastic Shock Cord?



Figure 5: Measuring black powder without a scale by calculating volume of the container. Here is a yellow nozzle cap, a Coca Cola red bottle cap, a PVC end cap, and a small medical vial.

		BP depth mm			
	cap dia (mm)	1g	2g	3g	4g
yellow cap dia - cesaroni 29 & 38 mm nozzle cap	20.25	3.3	6.5	9.8	13.1
red Coca Cola 12 oz bottlecap	26.25	1.9	3.9	5.8	7.8
Small PVC end cap	21.2	3.0	6.0	8.9	11.9
clear plastic vial	9.1	16.2	32.4	48.6	64.7

Table 1: The container measurement depth for calculating the amount of black powder.

Chute Opening Forces

If you design your rocket and delay perfectly, and there is absolutely no wind, the rocket will pop the chute exactly at apogee and with zero velocity. This doesn't happen very often. If the delay is early or late, the rocket has substantial velocity when the chute pops. And if there is any wind, the rocket weather cocks toward the wind and has substantial velocity as it reaches apogee. I am reminded of this because it seems that when I switched from an Aerotech G motor with 7 second delay to a Cesaroni G drilled down to a 7 second delay, the Cesaroni motor seemed to be about 2 seconds later than apogee, and kept me very excited until the chute popped.

So I did a study to see what velocity the rocket would have at what delay after apogee. Using Rocksim V9, I programmed the motor delay in 1 second steps beyond apogee, from 1 second late, to 4 seconds late, and recorded the velocity at ejection as reported by Rocksim (a handy feature) see figure 6.

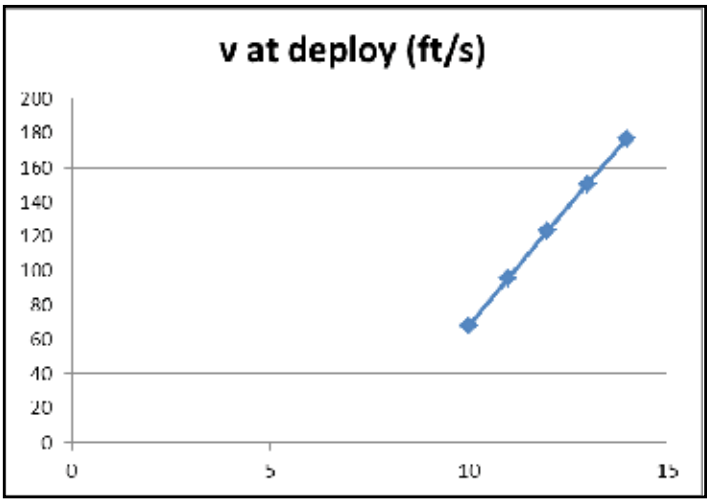


Figure 6 – Velocity of my rocket (ft/s) at moment of ejection in 1 second steps after apogee from Rocksim.

Since all things are accelerated by gravity the same way, these will approximately estimate velocity for any rocket that has low aerodynamic drag. As we can see, just a little excess delay can result in considerable velocity.

Then I used the Coefficient of Drag from Rocksim's parachute model, and the equations from Wikipedia[3] to

Continued on page 8

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Continued from page 7

What Length Of Elastic Shock Cord?

calculate drag force for several sizes of drogue parachute ranging from 12 inch to 48 inches at the velocity of the rocket at the time of ejection. The drag force will apply immediately to the shock cord as soon as the parachute pops and the shock cord stretches out.

Yes, eventually the rocket slows down until the velocity of the rocket and parachute drag matches the weight of the spent rocket. So there is a substantial spike in stress on the shock cord until it slows down. As we can see in Table 2, using a large drogue chute can create enough force to break an elastic shock cord. Similarly, having the ejection delay be more than 4 seconds later than apogee can result in a very large force.

Chute Diameter (in)	force at 95.7 ft/s	force at 123.2 ft/s	force at 150.4 ft/s	force at 176.9 ft/s
12	6.37	10.56	15.73	21.76
20.7	18.95	31.41	46.81	64.76
36	57.32	95.00	141.58	195.87
48	101.91	168.89	251.70	348.22
60	159.23	263.90	393.29	544.09
75	248.80	412.34	614.51	850.14

Table 2. Pounds of force on the parachute at ejection for various deployment velocities. Breakage tension on a single piece of 1" elastic strap is somewhat above 34 pounds.

Cdrag = dragforce/(0.5*rho*V^2 * A) or dragforce = 0.5 * Cdrag * rho * V^2 * A (all metric units)

Note that Rocksim reports a Cd for the parachute of 0.75, Wikipedia reports a rho of 1.2 kg/m^3, and it takes a great deal of care to convert everything to metric units, and back to pounds of force.

So we now see that the elastic shock cord can easily experience sufficient force to break if the ejection is late, or if the chute is large. With long shock cords, the rocket will lose momentum due to air friction drag after ejection, so longer than minimum length is better.

My Level 2 Rocket

I was able to use this same design methodology for my Level 2, which was small enough and light enough. However, I recognize that for a body over 10 lbs, it is really important to be sure that all forces can stay sufficiently below breakage.

Level 3

For my Level 3 Rocket, I used 1" nylon strap risers (greater than 1200 lbs breakage tension) 20 feet long for shock cord both above and below the electronics bay. Note that this gives the entire rocket and electronics bay a considerable jolt when it reaches fully stretched, and at this point, yes, it is a good idea to get welded or forged eyebolts, and to use at least ¾" of birch plywood. For those really big projects everything just has to be built really strong. But if you can put about 10 loops of 1" shock cord as the last 2 feet, then the shock can be sufficiently reduced to reduce likelihood of breakage at full extension.

References

[1] Web sites regarding the Gila Monster Photos: http://www.ahpra.org/gila.htm

[2] Vern Knowles Web site about BP and ejection charges: http://www.vernk.com/EjectionChargeSizing.htm

[3] Wikipedia Drag Coefficient: http://en.wikipedia.org/wiki/Drag_coefficient

[4] Stratologger SL100 Users Manual, PerfectFlite, p. 36



David Antaki
Project RP1

Appendix M6
Cesaroni Pro38 Reload Instructions

NAR L1 & L2 Technical Report

June 28th, 2019

Pro38® High-Power Reloadable Rocket Motor System

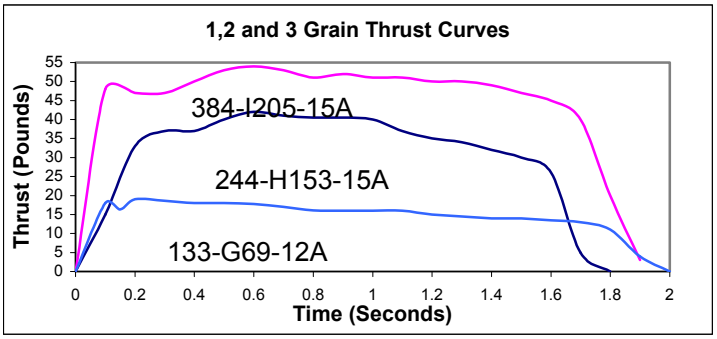
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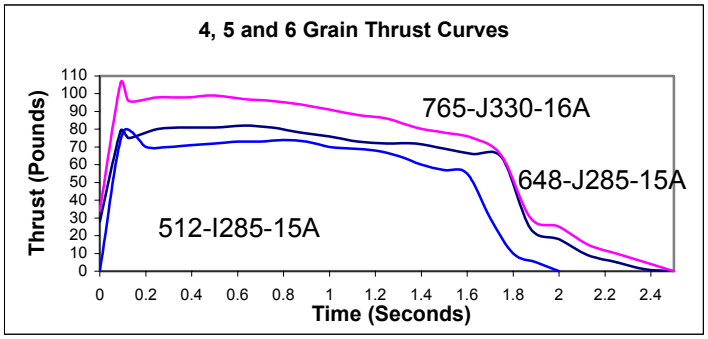
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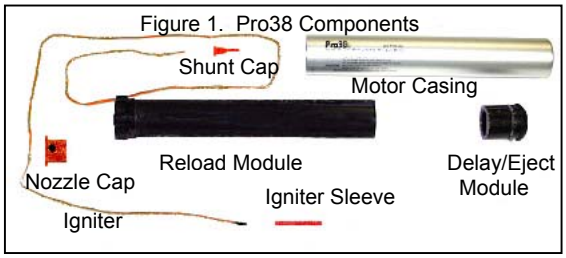


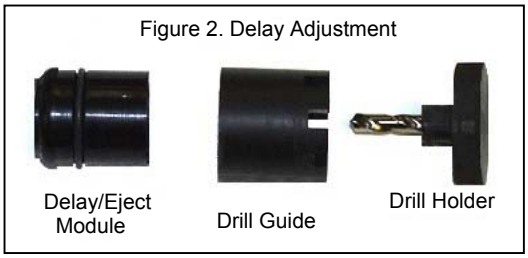
You will see that we've added a number to the front of the standard motor type code system. This number indicates the total impulse of the motor in Newton-seconds. For example, 800J360-15A is an 800Ns "J" motor, with 360N average thrust and a 15s *adjustable* delay

Assembly and Operating Instructions

WARNING

Read and follow the Safety Code of the Tripoli Rocketry Association (TRA).
Comply with all Federal, State and local laws in all activities with high-power rockets.





Step 1 – Time Delay Adjustment

Each motor is equipped with a full-length delay grain which provides the delay time shown in the motor designation. This delay may be *reduced* by 3,5,7, or 9 seconds as required down to the minimum delay time allowed for the motor type. Refer to the following table to select the proper adjustment for your application:

Delay designation in motor type code:	Delay adjustment and resulting delay time:				
	None	**-3**	**-5**	**-7**	**-9**
-12A	12s	9s	7s	5s	3s
-13A	13s	10s	8s	6s	4s
-15A	15s	12s	10s	8s	6s

NOTE: The ejection charge on all ***Pro38***® motors is 1.3g of FFFFG black powder. If additional ejection charge is required, do not remove white cap. Instead, add additional powder on top of white cap and seal cavity with tape.

CAUTION

Work in a tidy area, away from other rocket motors and materials, well away from any open flame or heat source.
Perform delay adjustments in the field during rocket preparation. Delay adjustments are irreversible, and safer if done outside.

- Remove the delay/ejection module (Figure 1) from the reload kit liner. Return the reload kit to the package and store safely away during the delay adjustment operation. Check the drill guide and drill holder (Figure 2) for debris and clean if required before proceeding.
- Select the delay adjustment desired, rotate the drill holder to the appropriate notch in the drill guide and seat the drill holder tab into the drill guide notch.
- Holding the drill guide and drill holder together in one hand, insert the delay module into the drill guide cavity until the drill bit touches the delay material. Rotate the drill holder clockwise while applying light pressure. Drill into the delay material until the drill guide bottoms out against the delay material. Rotate the drill for several more revolutions in order to clear the delay material from the hole.
- Remove the delay module from the guide. Empty any residue from the module.
- For safety, we recommend that you dispose of the delay residue by soaking it in water for a minimum of 1 hour then discarding the residue. A small zip-lock bag or plastic container filled with water is ideal and will safely dissolve the oxidizer from the delay material. This aqueous solution is not harmful to septic or sewage systems.

NOTE: If using an electronic recovery system, remove the white plastic disc from the end of the delay/ejection module and transfer the powder to your remote ejection charge holder and follow the recovery system instructions. Reinstall the module into the reload assembly.

Step 2 – Motor Assembly

- Inspect the motor casing for damage. Discard if damaged. Modification of the casing can cause property damage or result in serious personal injury.
- Leave the protective cap on the nozzle until you are ready to install the igniter.
- Using a gentle twisting motion, insert the delay/ejection module into the forward end of the plastic liner as far as it will go. A small gap between the forward end of the liner and the shoulder on the delay/ejection module as shown (Figure 3) is normal.
- Insert the reload kit into the rear end of the motor casing and thread into the casing. Tighten firmly by hand. The assembly is designed to have a small gap between the thrust ring and the rear end of the motor casing. If the gap (Figure 4) is more than 1/16" (1.6 mm), check the assembly carefully and re-assemble. **Note**: if you find assembly difficult by hand, you may *carefully* grip the reload kit thrust ring with slip-joint pliers for assembly or removal.

Step 3 – Igniter Installation

NFPA 1127 – Code for High Power Rocketry, 1995 edition, states the following:

"2-12.4 A person shall install an ignition device in a high-power rocket motor at the launcher or within the area designated by the safety monitor. The rocket shall be pointed in a safe direction during and after installation of the ignition device."

This rule must be followed when **removing** or **installing** igniters for **ANY** reason.

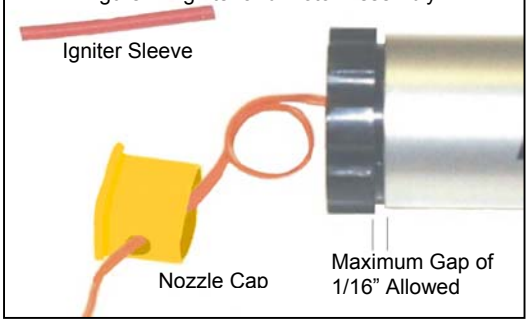
WARNING

The yellow shunt cap must remain in place on the igniter leads until the rocket is placed on the pad and is ready for igniter hook-up. If the cap is lost or missing, twist the bare igniter leads together several times **BEFORE** proceeding with igniter installation. **NEVER** check continuity of an electric igniter after it has been installed in a rocket motor unless done remotely from launch control while all personnel are in the safe location for rocket launch.

Figure 3. Reload Assembly



Figure 4. Igniter and Motor Assembly



Igniter specifications*:

Bridgewire resistance:
1.2 – 1.8Ω

Rated all-fire current:
1.2 Amps for 10 milliseconds

Typical response:
2.3ms @ 1.2 Amps

(*) These are manufacturer's specs. CTI assumes no responsibility for their use or misinterpretation

- Carefully uncoil the igniter leads. Remove any kinks or twists and straighten the wires for about 24" (60 cm) from the igniter head. Remove the yellow nozzle cap from the motor and feed the shunted ends of the igniter leads through the inside of the nozzle cap and out through the hole. Remove igniter sleeve.
- Insert the igniter head into the nozzle and push until it stops against the top of the motor core. With the igniter in this position, bend a loop into the igniter leads one cap length from the nozzle exit (Figure 4).
- Slide the nozzle cap up to the loop made in the previous step and firmly push the yellow nozzle cap over the nozzle to retain the igniter.
- Remove the shunt and separate the wire leads **ONLY** while the rocket is installed on the pad and the launch control system is rendered safe (i.e. disarmed and shunted where applicable).

WARNING

Never store rocket motors with igniters installed. Do not install igniters until the rocket motor is installed in the rocket vehicle and the rocket vehicle is completely prepared and ready for launch. If weather, safety or other conditions result in a delay of the launch, disconnect all igniters from the launch system and replace the shunts. If the launch is aborted for any reasons, remove the igniters from the motors and install the shunts.

Step 4 – Post Firing

CAUTION

Your ***Pro38***® rocket motor may be hot after firing. Allow the motor to cool COMPLETELY before proceeding.

- Unscrew the reload kit from the motor casing and discard - there are no reusable parts. If the delay module remains in the motor casing after removal of the reload assembly, push it out through the forward end of the motor case with a wooden or plastic tool. Be careful not to dent or scratch the motor casing in any way. The use of metal tools is **NOT** recommended.
- Ordinarily, the motor casing will not require any post-flight cleanup. In the event that any combustion residue remains, the casing should be cleaned as soon as possible with hot soapy water and a non-abrasive cloth. When not is use, store the motor casing in its original package for protection. Care must be taken not to dent the motor casing or to damage the internal threads.

MEANS OF DISPOSAL: Remove forward closure and remove propellant grains from plastic liner. Discard plastic liner and nozzle assembly. Place forward closure and grains in a shallow hole in the ground, away from any combustibles, install igniter in forward grain in contact with the igniter pellet, secure with tape if necessary. Ignite electrically from distance of 10 meters (min). Wait until flames cease. Remnants may be disposed of with household garbage.

First Aid: If ingested, induce vomiting. Burns from flames are to be treated as regular burns with normal first aid procedures. In either case, seek medical attention.

Cesaroni Technology Incorporated ("**CTI**") certifies that it has exercised reasonable care in the design and manufacture of its products. We do not assume any responsibility for product storage, transportation or usage. **CTI** shall not be held responsible for any personal injury or property damage resulting from the improper handling, storage or use of their products. The buyer assumes all risks and liabilities and accepts and uses **CTI** products on these conditions. No warranty either expressed or implied is made regarding ***Pro38***® products, except for replacement or repair, at **CTI's** option, of those products which are proven to be defective in manufacture within one (1) year from the date of original purchase. For repair or replacement under this warranty, please contact your point of purchase. Proof of purchase will be required. Your province may provide additional rights not covered by this warranty.

⇒ Check out our web site at http://www.Pro-X.ca for tech tips, FAQ's, user feedback and photos, or e-mail us at Pro38@cesaroni.net

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David Antaki
Project RP1

Appendix M7
Level 2 Certification Test Question Pool

NAR L1 & L2 Technical Report

June 28th, 2019

NAR Level 2 Exam Question Pool

A	**Applicable Regulations**	**10 from 22**
B	**Storage**	**1 from 3**
C	**Range and Safety Practices**	**20 from 55**
D	**Rocket Stability**	**3 from 8**
E	**Rocket Motor Designations**	**3 from 9**
Total Questions		**37 from 97**
Passing Grade		**32 of 37 Correct Answers**

Reference Criterion: Certification of a user shall require proof that the user has a level of knowledge and competence in handling, storing, and using a high power solid-propellant rocket motor and high power rockets that is acceptable to the certifying organizations."
NFPA 1127 5.4.1(2)

Section A - Applicable Regulations (10 questions from 22)

A1) Which of the following National Fire Protection Association standards provides a code for high power rocketry?

A) NFPA 1122
B) NFPA 1124
C) NFPA 1125
D) NFPA 1127

The answer is “D“. NFPA 1127 is the Code for High Power Rocketry. NFPA 1122 is the Code for Model Rocketry; NFPA 1124 is the Code for the Manufacture, Transportation, and Storage of Fireworks; NFPA 1125 is the Code for the Manufacture of Model Rocket and High Power Rocket Motors.

A2) What part of the Federal Aviation Regulations govern rocket activity?

A) Part 95
B) Part 97
C) Part 101
D) Part 125

The answer is “C“. Rocket activity is codified in Part 101, Moored Balloons, Kites, Unmanned Rockets, and Unmanned Free Balloons.

A3) What is the maximum launch weight allowable for a rocket which does not require FAA waiver?

A) 4 ounces (113 grams)
B) 4.4 ounces (125 grams)
C) 1 pound (453 grams)
D) 3.3 pounds (1500 grams)

The answer is “D“. Part 101 no longer requires a waiver for the operation of model rockets (class 1 rockets) weighing less than 3.3 pounds (1500 grams).

A4) What is the maximum propellant weight allowable for a rocket which does not require an FAA waiver?

A) 4 ounces (113 grams)
B) 4.4 ounces (125 grams)
C) 1 pound (453 grams)
D) 3.3 pounds (1500 grams)

The answer is “B“. Part 101 does not govern the operation of model rockets (class 1 rockets) using less than 125 grams of propellant.

A5) What is the maximum total impulse allowable for a rocket which does not require an FAA waiver?

A) 80 Newton-seconds
B) 160 Newton-seconds
C) 320 Newton-seconds
D) There is no impulse limit

The answer is “D“. Part 101 does not specify any impulse limits.

A6) What is the maximum launch weight allowable for a rocket when complying with the FAR 101 regulations for no waiver required?

A) 4 ounces (113 grams)
B) 4.4 ounces (125 grams)
C) 1 pound (453 grams)
D) 3.3 pounds (1500 grams)

The answer is “D“. Part 101 allows operation of class 1 model rockets weighing no more than 3.3 pounds (1500 grams) without a waiver.

A7) What is the maximum propellant weight allowable for a rocket without needing an FAA waiver?

A) 4 ounces (113 grams)
B) 4.4 ounces (125 grams)
C) 1 pound (453 grams)
D) 3.3 pounds (1500 grams)

The answer is “B“. Part 101 allows operation of class 1 model rockets using not more than 4.4 ounces (125 grams) of propellant without an FAA waiver.

A8) Which of the following is a requirement for high power certification [Note: Excludes NAR Jr. HPR program]:

A) The ability to understand written English instructions
B) A minimum of 18 years of age
C) A citizen of the United States of America
D) No felony convictions

The answer is “B“. Refer to paragraph 5.4.1 of NFPA 1127.

A9) What is the maximum total impulse permitted in a high power rocket per NFPA 1127?

A) 81,920 Newton-seconds
B) 40,960 Newton-seconds
C) 20,480 Newton-seconds
D) There is no limit provided the FAA altitude waiver requirements are not exceeded

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The answer is “B“. Refer to paragraph 4.9.2 of NFPA 1127.

A10) What is the maximum allowable weight for a high power rocket permitted per NFPA 1127?

A) 100 pounds
B) 400 pounds
C) 3069 pounds
D) There is no limit provided the rocket weighs less than 1/3 of the average certified thrust of the motors intended to be ignited at launch

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The answer is “D“. Refer to NFPA 1127 paragraph 4.9.1.

A11) What is the minimum age for user certification? [Note: Excludes NAR Jr. HPR program]

A) 16 years old
B) 18 years old
C) 21 years old
D) 25 years old

The answer is “B“. Refer to NFPA 1127, paragraph 5.4.1.

A12) Which of the following characteristics does *NOT* meet the definition of a High Power Rocket Motor?

A) Total impulse is more than 160 Newton-seconds
B) The motor uses a “composite“ propellant
C) Average thrust greater than 80 Newtons
D) Propellant weight greater than 125 grams

The answer is “B“. Refer to NFPA 1127, paragraph 3.3.15.1.

A13) Which of the following is (are) true of a complex high power rocket per NFPA 1127?

A) The rocket is multi-staged or propelled by a cluster of rocket motors
B) The rocket contains electrical or electronic devices intended for control of the rockets functions, e.g. staging, recovery initiation
C) The rocket uses other than parachute or streamer recovery, e.g. helicopter or glide recovery
D) Both “A“ and “B“ above

The answer is “A“. Refer to NFPA 1127, paragraph 3.3.13.1.1.

A14) A launch site is defined as containing areas for which of the following activities?

A) Launching
B) Recovery
C) Parking
D) All of the above

The answer is “D“. Refer to NFPA 1127, paragraph 3.3.9.

A15) A person shall fly a high power rocket only in compliance with:

A) NFPA 1127
B) Federal Aviation Administration Regulations, Part 101
C) Federal, state, and local laws, rules, regulations, statutes, and ordinances
D) All of the above

The answer is ”D”. Refer to NFPA 1127, paragraph 4.3.

A16) Which of the following statements is always true concerning the definition of a hybrid rocket motor?

A) The fuel component is composed of either paper or plastic
B) The fuel is in a different physical state (solid, liquid, or gaseous) than the oxidizer
C) The oxidizer component is nitrous oxide
D) Both ”A” and ”C” above”

The answer is ”B”. Refer to NFPA 1127, paragraph 3.3.15.2, for the definition of a hybrid rocket motor.

A17) Per the ATF-Explosives Law and Regulation (Orange Book) what kind of explosive material is black powder?

A) High Explosive
B) Low Explosive
C) Blasting Agent
D) Non-explosive

The answer is ”B”. Refer to Section 555.202 (b) of Federal Explosives Law and Regulations (Orange Book), 9/2007 revision.

A18) The minimum age for an explosive permit application is:

A) 16 years or older
B) 18 years or older
C) 21 years or older
D) 25 years or older

The answer is ”C”. Refer to Federal Explosives Law and Regulations (Orange Book), 9/2007 revision, 555.49(b)(1).

A19) Which of the following statements are true concerning the definition of a High Power Rocket Motor?

A) Total impulse is less than 81,920 Newton-seconds
B) The total impulse is more than 160 Newton-seconds
C) Both A and B above
D) The motor must use either fiberglass or metal case materials

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The answer is "B". Refer to NFPA 1127, paragraph 13.3.15.1, for the definition of a high power rocket motor.

A20) A certified individual wants to purchase a "L" motor reloadable casing at a launch. Which of the following is true?

A) He must possess an Explosives User's Permit
B) He does not require an Explosives User's Permit
C) He must pay in advance for the motor purchase
D) He must use the reload kit on the same day as purchase

The answer is B, APCP HPR motors are no longer regulated and motor casings were never regulated.

A21) Which of the following (hypothetical) rocket motors is *NOT* a High Power Rocket?

A) An F90 with 40 grams of propellant
B) An H60 with 62 grams of propellant
C) A G35 with 66 grams of propellant
D) All of the above are High Power Rocket Motors

The answer is "C". A High Power Rocket Motor has more than 160 Newton-seconds of total impulse, ***or*** an average thrust greater than 80 Newtons, ***or*** more than 125 grams of propellant.

"A" has an average thrust greater than 80 Newtons; "B" has more than 160 Newton-seconds of total impulse (it's an H motor); "C" does not have more than 125 grams of propellant. Refer to NFPA 1125, 2010 edition

A22) What does FAA FAR 101.29 require you to provide specifications on in filing an FAA waiver?

A) Estimated number of rockets
B) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s)
C) Description of the launcher(s) planned to be used, including any airborne platform(s)
D) Description of recovery system
E) Highest altitude, above ground level, expected to be reached,
F) Launch site latitude, longitude, and elevation
G) Any additional safety procedures that will be followed
H) All the above

The Answer is H, please see all the FAA waiver requirements and the sample document(s) to fill out at: http://www.nar.org/cabinet/waiverinst.html

Section B - Storage Requirements only for regulated materials*

(1 questions from 3)

B1) What is the maximum net weight of regulated materials that may be stored in an indoor Type 4 magazine?

A) 10 pounds
B) 25 pounds
C) 50 pounds
D) 100 pounds

The answer is “C“. Refer to NFPA 1127, paragraph 4.19.2.

B2) Which of the following is *NOT* a requirement for an indoor magazine?

A) The magazine must be painted red.
B) The magazine must bear the words “EXPLOSIVES KEEP FIRE AWAY“.
C) The magazine must bear the words “50 POUND MAXIMUM“
D) The lettering is printed in white letters at least 3 inches high

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The answer is “C“. Refer to NFPA 1127, paragraph 4.19.2.1.

B3) According to NFPA, in which of the following locations can a Type 4 magazine be permitted, assuming the authority having jurisdiction and the BATF approve?

A) In the attached garage of a single family residence
B) In the utility or laundry room of a multi-family residence
C) In the bedroom closet for a non-smoker resident
D) Anywhere inside the house at least 10 feet away from flame producing appliances (stove, water heater, etc.)

The answer is “A“. Refer to NFPA 1127, paragraph 4.19.2.2 through 4.19.2.4.

*note APCP HPR motors and reloads are no longer a regulated material

Section C - Range and Safety Practices (20 questions from 55)

C1) What is the maximum launch angle, measured from vertical, for a high power rocket?

A) 10 degrees
B) 15 degrees
C) 20 degrees
D) 25 degrees

The answer is “C“. Refer to Section 7 of the NAR High Power Rocket Safety Code and NFPA 1127, paragraph 4.12.3.

C2) What is the maximum wind velocity allowable for launch operations?

A) 20 miles per hour
B) 25 miles per hour
C) 15 miles per hour
D) 30 miles per hour

The answer is “A“. Refer to Section 9 of the NAR High Power Rocket Safety Code and NFPA 1127, paragraph 4.17.2.

C3) The minimum launch site dimension for your field is 1500 feet. Assuming no public highways or occupied buildings in the area, what is the minimum distance between the launch site boundary and the launcher for a 320 Newton-second motor?

A) 100 feet
B) 320 feet
C) 750 feet
D) The launcher may be located anywhere on the launch site to compensate for wind

---

The answer is “A“. The launcher shall be no closer than the Minimum Personnel Distance from any boundary of the launch site, and the Minimum Personnel Distance for an H motor (320 N-sec) is 100 feet. Refer to Section 11 of the NAR High Power Rocket Safety Code and NFPA 1127, paragraph 4.15.4.

C4) You plan to break the altitude record for H motors with a flight to 10,900 feet. You have a field that is 6000 feet by 6000 feet. You have an FAA waiver up to 12,000 feet. Assuming no public highways or occupied buildings are in the area, what is the minimum distance between the launch site boundary and the launcher for an H-powered altitude record attempt?

A) 100 feet
B) 1500 feet
C) 3000 feet
D) The launcher may be located anywhere on the launch site to compensate for wind.

The answer is “A“. The launcher shall be no closer than the Minimum Personnel Distance from any boundary of the launch site, and the Minimum Personnel Distance for an H motor (320 N- sec) is 100 feet. Refer to Section 11 of the NAR High Power Rocket Safety Code and NFPA 1127, paragraph 4.15.4.

C5) The FAA has granted a waiver for high power rocket flight to 18000 feet for your event. Flights up to that altitude are expected. What is the minimum launch site dimension?

A) 1800 feet
B) 4500 feet
C) 9000 feet
D) 18,000 feet

The answer is “C“. The size of the launch site is no less than one half (1/2) of the maximum altitude expected, calculated, simulated, or granted (by FAA waiver/authority having jurisdiction). Refer to Section 10 of the NAR High Power Rocket Safety Code and NFPA 1127, paragraph 4.14.2

C6) The FAA has granted a waiver for high power rocket flight to 2500 feet for your 2xN cluster-powered rocket. What are the minimum launch site dimensions?

A) 500 feet
B) 1250 feet
C) 1500 feet
D) 4000 feet

The answer is “D“. The minimum size of the launch site is no less than one-half (1/2) of the maximum altitude expected, calculated, simulated, or granted (by FAA waiver/authority having jurisdiction), or 1500 feet, whichever is greater. However, in this case, the launcher has to be the minimum personnel distance (which for an O-impulse cluster is 2000’) from the edges of the launch site, even for a waiver of only 2500 feet. Refer to NFPA 1127, paragraphs 4.14.2 (2), and to the NAR High Power Rocket Safety Code.

C7) In no case* shall the minimum launch site dimension be less than _____ the estimated altitude of the high power rocket or _____.

A) 1/4, 1500 feet
B) 1/2, 1500 feet
C) 1/4, 2500 feet
D) 1/2, 2500 feet

The answer is "B". Refer to the NAR High Power Rocket Safety Code, **Excepting for this special provision that enables motors defined as HPR by NFPA but not requiring an FAA waiver to be launched on somewhat smaller launch sites than would otherwise be required* ["For high power rockets containing motors with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 g, and a maximum expected altitude of less than 610 m (2000 ft), the minimum dimensions of the launch site shall be permitted to be 305 m (1000 ft). "]

C8) Your launch site borders on an interstate freeway. What is the minimum distance allowable for location of a high power launch pad from the interstate freeway?

A) 750 feet
B) 1500 feet
C) 3000 feet
D) 5280 feet (1 mile)

The correct answer is "B". Refer to NAR High Power Rocket Safety Code, **Excepting for this special provision that enable motors defined as HPR by NFPA but not requiring an FAA waiver to be launched on somewhat smaller launch sites than would otherwise be required* ["For high power rockets containing motors with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 g, and a maximum expected altitude of less than 610 m (2000 ft), the minimum dimensions of the launch site shall be permitted to be 305 m (1000 ft). "]

C9) A farm owner offers you his farm for a launch site. His house is located in the middle of the farm, which is two (2) miles square. What is the minimum distance allowable for location of a high power launch pad from the owner's house, assuming it is occupied?

A) 750 feet
B) 1500 feet
C) 3000 feet
D) You cannot launch unless the house is empty

The answer is "B". Refer to NFPA 1127, and NAR High Power Rocket Safety Code. When occupied structures or busy roads are near the launch site, a 1500 foot minimum separation is required between the launcher and the road or building. Note that you will have to define a launch site on the farm that does not contain the occupied house, and for which you can place the pads at least 1500 feet from the occupied house. **Excepting for this special provision that enable motors defined as HPR by NFPA but not requiring an FAA waiver to be launched on somewhat smaller launch sites than would otherwise be required*. See questions above as well.

C10) A farm owner offers you his farm for a launch site. His house is located in the middle of the farm, which is one quarter (1/4) mile by one quarter (1/4) mile square. Assuming you can get an FAA waiver for 2500 feet, can you conduct a high power launch from this farm?

A) Yes
B) Yes, but the pads have to be the minimum personnel distance from the edge of the field
C) Yes, but the house has to be empty
D) No

The answer is “D“. See the NAR High Power Rocket Safety Code Section 10, and Paragraph 4.14.1 through 4.14.2 of NFPA 1127. The launch site must be at least 1500 feet square, and may not contain occupied buildings. You may be able to construct a launch site using part of that farm and that of a neighbor, if the adjoining land has no occupied buildings. If the pads for this larger site are within 1500’ of the house, the house has to be unoccupied. . **Excepting for this special provision that enable motors defined as HPR by NFPA but not requiring an FAA waiver to be launched on somewhat smaller launch sites than would otherwise be required*. See questions above as well.

C11) What is the minimum safe distance from a high power rocket containing a single “I“ motor?

A) 200 feet
B) 100 feet
C) 75 feet
D) 50 feet

The answer is “B“. Refer to Table 4.16.3 of NFPA 1127, and the minimum distance table in the NAR High Power Rocket Safety Code.

C12) What is the minimum safe distance from a high power rocket containing three (3) “H“ motors?

A) 200 feet
B) 100 feet
C) 75 feet
D) 50 feet

The answer is “A“. Refer to Table 4.16.3 of NFPA 1127, and the minimum distance table in the NAR High Power Rocket Safety Code.

C13) What is the minimum safe distance from a high power rocket containing two (2) "K" motors?

A) 50 feet
B) 100 feet
C) 300 feet
D) 500 feet

The answer is "D". Refer to Table 4.16.3 of NFPA 1127, and the minimum distance table in the NAR High Power Rocket Safety Code.

C14) Which of the following igniters may be ignited by the continuity test of some launch controllers?

A) Nichrome wire
B) Flashbulbs
C) Very low current electric matches
D) Both "B" and "C" above

The answer is "D". Refer to the "Handbook of Model Rocketry" by G. Harry Stine, 6th edition, Chapter 6 on "Ignition and Ignition Systems", page 94. Some electric matches are not affected by continuity tests; consult the manufacturer for further information.

C15) In the event of a misfire how long should you wait before approaching the launch pad?

A) 15 seconds
B) 60 seconds
C) 5 minutes
D) As soon as signs of smoke are gone

The answer is "B". Refer to paragraph 4.18.4 of NFPA 1127, and NAR High Power Rocket Safety Code.

C16) Which of the following is most likely to cause catastrophic failure of a black powder rocket motor?

A) Temperature cycling
B) Electromagnetic fields
C) Vibration
D) High altitude

The answer is “A“. Temperature cycling is the primary cause of black powder rocket motor catastrophic failure. Temperature cycling cause expansion and contraction of the black powder grain and motor casing causing delamination between the case and propellant grain and cracks within the grain. The delamination and cracks expose additional burning surface that increases combustion pressures. The result is a motor failure. Note that shock or vibration can also damage a black powder rocket motor, however thermal cycling is the most likely cause of failure. Refer to the May and June 1992 issue of American Spacemodeling magazine, page 10, the article “A Theoretical Analysis of Why Black Powder Model Rocket Motors Fail“.

C17) Unless the motor manufacturer instructs otherwise, igniters for clustered rocket motors should be wired together in:

A) Series
B) Parallel
C) Short Circuit
D) Open

The answer is “B“. If the igniters are wired in series the first igniter to burn out opens the circuit preventing any other igniters from receiving electrical power. Parallel connections allow all of the igniters to independently receive electrical power. Some motor manufacturers may suggest series connections for electric match-based ignition methods; always follow manufacturer’s instructions.

C18) When should igniters installed in rocket motors be checked for continuity?

A) Any time
B) Only in an enclosed shelter
C) Only on the launch pad when ready for launch
D) Igniters should never be checked for continuity while installed in a rocket motor

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The answer is “C“. Continuity is typically checked by the launch controller when the rocket is placed on the launch pad. This is considered safe practice because the number of personnel around the model is at a minimum and the model is pointed skyward which minimizes the hazard in the event of inadvertent ignition.

C19) Which of the following is the preferred method for attaching fins to a high power rocket?

A) Tube surface mounting
B) “Wedge“ mount
C) “Though the wall“ mounting
D) All fin mounting methods are all equally strong; it does not matter

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The answer is “C“. Through the wall mounting is stronger because the model is supported and attached to the rocket at two locations. The fins are attached to the motor tube and the body tube. In cases where through the wall mounting is not feasible, “wedge“ mounting may be possible. Wedge mounting places the fin at the junction of two tubes; this mounting is typically used in cluster models. Surface mounting, like that used in most model rocket kits, is not recommended for high power rockets.

C20) Which of the following adhesives should not be used on rubber (or elastic) shock cord components?

A) Slow-curing epoxy adhesives
B) Cyanoacrylate glues (super glue)
C) Aliphatic resin-based (yellow) glues
D) White “Elmer’s“ glue

The answer is “B“. Cyanoacrylate glues will chemically attack rubber or elastic shock cord components allowing them to break when stretched.

C21) Which of the following adhesives is most likely to be weakened under humid or wet weather conditions?

A) Slow-curing epoxy adhesives
B) Cyanoacrylate glues (super glue)
C) Aliphatic resin based glues
D) White “Elmer’s“ glue

The answer is “D“. White glues are weakened under high humidity conditions. Use aliphatic base (wood or carpenter’s) glues instead of white glue.

C22) Which of the following adhesives is the best choice for motor mount construction using phenolic motor tubes?

A) Slow-curing epoxy adhesives
B) Cyanoacrylate glues (super glue)
C) Aliphatic resin based glues
D) “Hot melt“ adhesives

The answer is “A“. Epoxies can be used to easily form fillets at the bond joints which provide an increase in strength. Epoxies also bridge gaps in loose-fitting parts to improve bond strength. One caution when using epoxies is that they are relatively heavy; they can reduce model stability by making the model tail heavy. Cyanoacrylate glues are not recommended for motor mount construction because they tend to soak into paper/cardboard body tube materials and are poor gap fillers. Aliphatic resin (yellow) glues, when properly applied, can be used for cardboard, wood, and paper components, but do not bond as well to phenolic materials. Hot melt adhesives should never be used for motor mount applications because they weaken with heat.

C23) The centering rings provided with your high power kit are a loose fit around the phenolic motor tube. Which of the following adhesives is the best choice for a strong joint?

A) Slow-curing epoxy adhesives
B) Cyanoacrylate glues (super glue)
C) Aliphatic resin based glues
D) “Hot melt“ adhesives

The answer is “A“. Epoxies can be used to easily form fillets at the bond joints which provide an increase in strength. Epoxies also bridge gaps in loose fitting parts to improve bond strength. One caution when using epoxies is that they are relatively heavy; they can reduce model stability by making the model tail heavy. Cyanoacrylate glues are not recommended for motor mount construction because they tend to soak into paper/cardboard body tube materials and are poor gap fillers. Aliphatic resin (yellow) glues, when properly applied, can be used for cardboard, wood, and paper components, but do not bond as well to phenolic materials. Hot melt adhesives should never be used for motor mount applications because they weaken with heat.

C24) A small hole is typically recommended near the top, but below the nosecone or payload section shoulder, of a high power rocket's booster section. Why?

A) This hole allows excessive ejection charge pressures to vent to reduce shock cord stress
B) The hole is used to give air pressure readings for on board altimeters
C) The hole vents internal air pressure as the rocket gains altitude to prevent internal air pressure from prematurely separating the model
D) The hole allows easy verification that a parachute is installed

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The answer is "C". Air pressure external to the rocket decreases as the rocket ascends. Trapped pressure within the model can prematurely separate the model. The hole vents this internal air pressure to prevent separation. Note that the hole size is dependent on model size; larger models require larger holes. Use caution in locating the hole such that the nosecone (or stage coupler) does not block the hole. Also, position the hole such that ejection charge pressure is not vented before ejecting the recovery system from the body tube.

C25) When clustering combinations of black powder and composite motors, which type of rocket motor should be ignited first?

A) Composite rocket motors should be ignited first
B) Black powder rocket motors should be ignited first
C) It does not matter which motors are ignited first
D) Clusters should never mix composite and black powder motors

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The answer is "A". Composite rocket motors are slower to ignite than black powder motors. The concern is that the model will leave the launch pad before the composite motor has ignited.

C26) Why should composite motors be ignited first in a mixed composite and black powder cluster?

A) Composite motors are more difficult and take longer to ignite
B) Composite motors are more likely to "cato" than black powder motors
C) The exhaust products from black powder motors prevent composite motor ignition
D) Composite rocket motors are more powerful than black powder motors

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The answer is "A". Composite rocket motors are harder to ignite than black powder motors. The concern is that the model will leave the launch pad before the composite motor has ignited.

C27) If individual igniters are used for igniting a clustered model's motors, which of the following statements is typically true:

A) The launch control must have an audible as well as visual indication of igniter continuity.
B) The launch control must provide additional current to ignite the additional igniters
C) The launch control must provide higher voltage to ignite the additional igniters
D) The launch control must use a car battery as a power source

---

The answer is "B". Parallel wiring used in cluster ignition models "shares" the current among all the igniters. If the ignition circuit is marginal those igniters which are slightly more sensitive will ignite before their mates. The model may leave the launcher prior to full ignition of the cluster. Common practice is to use a battery which can deliver higher currents than dry cells; automotive, motorcycle, and "gell cell" batteries are common. Increased voltage will not significantly improve cluster ignition reliability. House voltage, 110 volts AC, should never be used for ignition systems.

C28) What is (are) the advantages of using a "relay" type launch control?

A) It is cheaper than a non-relay launch control
B) The relay allows a better indication of igniter continuity
C) It can deliver more power to the rocket motor igniters
D) Both "B" and "C" above

The answer is "C". A relay launch system uses a relay to switch the power needed for rocket motor ignition. The battery is usually placed adjacent to the launch pad which allows for shorter power wires. The shorter power wires minimize the normal loss of power that occurs over long wire lengths (remember that several hundred feet of wire may be required to reach a high power launch pad). The wires going to the launch officer only carry the power required to operate the relay; this power is typically much less than that required by an igniter.

C29) Petroleum based lubricants should not be used with the oxygen or nitrous oxide systems used in hybrids. Why?

A) They thicken when exposed to oxygen or nitrous oxide
B) They lose their lubricating properties when exposed to oxygen or nitrous oxide
C) There is a risk of spontaneous ignition or explosion
D) The lubricant can promote corrosion of the metal components in the presence oxygen or nitrous oxide

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The answer is "C". Petroleum lubricants are a fuel. Oxygen rich environments are more likely to use petroleum based lubricants as a fuel that could cause a risk of spontaneous ignition

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C30) Which of the following safety hazards may be associated with hybrid rocket motors?

A) High pressure gas, low temperatures (frostbite)
B) Low temperatures (frostbite)
C) Corrosive materials
D) High pressure gas

The answer is “A“. The pressure within a nitrous oxide cylinder used with hybrid rocket motors is approximately 750 psi. When filling or venting the nitrous oxide cylinder individuals need to use caution to avoid having high pressure gas or liquid impinge on skin or eyes. Oxidizer cylinders need to be inspected after crashes for damage that may compromise their structural integrity. Nitrous oxide boils at -127 degrees F. Partially filling and allowing the liquid to drain (boil-off) from a nitrous oxide cylinder is a technique used to pre-chill the nitrous oxide cylinder in some motor applications (called shock chilling). The low temperatures achievable through this method may present a hazard to exposed skin.

C31) The range safety officer says that your model is unsafe to fly. Who has the authority to overturn this ruling:

A) The Launch Control Officer (LCO)
B) The individual who “checked-in“ the model
C) Three certified high power fliers who agree the model is safe
D) The safety monitor’s (RSO) decision cannot be overturned by anybody

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The answer is “D“. The range safety officer’s decision is final. If the flier can produce additional information which shows the safety of the model, e.g. simulations, previous flight data, then the flier should present the information to the range safety officer.

C32) Parachute ejection systems that sense barometric pressure for activation need a vent to the outside in their compartment because:

A) This hole allows excessive ejection charge pressures to vent
B) The hole is used to give outside air pressure readings
C) The hole vents internal air pressure as the rocket gains altitude to prevent internal air pressure from prematurely separating the model
D) The hole allows easy verification that the battery is installed

---

The answer is “B“. Air pressure external to the rocket decreases as the rocket ascends. Most barometric ejection systems trigger after detecting a minimum in the outside barometric pressure (which happens near apogee). The hole allows the sensor to “see“ the outside pressure. Use caution in locating the hole such that the nosecone (or stage coupler) does not block the hole.

C33) Which of the following individuals has the final authority in permitting a high power rocket to fly?

A) The launch control officer (LCO)
B) The range safety officer (RSO)
C) The check-in officer
D) The rocket owner

The answer is “B“. The range safety officer’s decision is final.

C34) Which of the following individuals has the ultimate responsibility to ensure that the rocket was built in a safe manner?

A) The launch control officer (LCO)
B) The safety monitor (range safety officer or RSO)
C) The rocket owner/builder
D) All of the above

The answer is “C“. Range personnel can do inspections to catch lapses in construction quality or rocket design errors but the owner/builder bears all responsibility for the “goodness“ and safety of the model.

C35) Parachute ejection systems that sense barometric pressure can malfunction during supersonic flight because:

A) Aerodynamic heating changes the values of electronic components
B) The outside pressure distribution is not continuous around the model
C) Static discharges will “zap“ sensitive electronic components
D) Both answers “A“ and “B“ are correct

The answer is “B“. During supersonic flight shock waves are generated off various model features. The pressure distribution across the shock wave is not continuous. The pressure change across the shock wave may fool the ejection system logic causing a premature ejection.

C36) Your rocket was returned from its flight with “zipper“ damage where the shock cord tore through the model. What is the most likely cause:

A) Parachute ejection occurred too soon after motor burnout
B) Parachute ejection occurred too late after apogee
C) Parachute ejection occurred at apogee on a vertical flight
D) Both “A“ and “B“

The answer is “D“. “Zippers“ are caused when the model is moving too quickly during parachute deployment. Ejection too soon after burnout does not allow the model to slow down. Ejection too late after apogee allows the model to gain velocity. Ejection at apogee is best because the model velocity is lowest. Even then, a zipper can occur if the horizontal velocity of the rocket is high enough (due to weathercocking, for example).

C37) Your payload section, with heavy payload, separated from your model immediately after motor burnout. What might be the cause?

A) The center of pressure at burnout was behind the center of gravity for the model
B) The payload shoulder was too loose in the body tube
C) The rocket motor had a failure of its delay system
D) Both “B“ and “C“ are correct

The answer is “D“. Delay train failures do happen and can cause this problem. More often, though, “drag separation“ causes this problem and is mistaken for a motor failure. Drag separation is caused by the drag on the aft section of the model being higher than the drag of the forward section. The difference in drag causes the aft section to be pulled away from the forward section. This problem is more pronounced with heavier forward sections because the momentum of the forward section tends to carry it away. Preflight inspection should confirm that the forward section cannot separate under its own weight. More sophisticated models will use some form of positive retention, e.g. shear pins, to prevent premature separation.

C38) What is the distance around a launcher for a “J“ powered model that must be cleared of easy to burn material, assuming the motor isn’t “sparky?“

A) 10 feet
B) 30 feet
C) 50 feet
D) 75 feet

The answer is “C“. Refer to paragraph 4.15.1 of NFPA 1127, and Section 7 and the minimum distance table in the NAR High Power Rocket Safety Code.

C39) What is the distance around a launcher for a rocket using a 3-motor cluster of J motors that must be cleared of easy to burn material, assuming the motors aren’t “sparky?“

A) 10 feet
B) 30 feet
C) 50 feet
D) 75 feet

The answer is “D“. Refer to paragraph 4.15.1 of NFPA 1127, and Section 7 and the minimum distance table in the NAR High Power Rocket Safety Code.

C40) What is the distance around a launcher to clear of all combustible and burnable materials for a rocket using a single J motor that burns a titanium sponge to emit sparks?

A) 30 feet
B) 50 feet
C) 75 feet
D) 150 feet

The answer is “C“. Refer to paragraph 4.15.2 of NFPA 1127, and Section 7 and the minimum distance table in the NAR High Power Rocket Safety Code.

C41) What is “titanium sponge?“

A) A substitute for ejection wadding
B) An ingredient used in some rocket motors that causes them to eject sparks in the exhaust
C) An effective cleaning tool for high power rocket motor casings
D) A lightweight material used in nose cones on supersonic rockets

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The answer is “B“.

C42) Consequences of inadequate motor retention can include:

A) The motor being ejected at apogee instead of the parachute, resulting in two falling objects
B) The motor being ejected from a cluster, and flying on its own, under power
C) The motor flying through the rocket, destroying it
D) All of the above

The answer is “D“. The most common result of inadequate motor retention is that the motor is ejected when the deployment charge fires. A free-falling HPR motor is a safety hazard, and the rocket may not eject its recovery system and also become a hazard.

There have been documented cases of motors “falling out“ of cluster mounts and then igniting, turning them into missiles. It is important to provide good retention in both directions, as motors can also break loose and fly through the rocket during boost.

C43) According to NAR studies, the vast majority of unsuccessful flights fail because of:

A) Rocket designs that are unstable
B) Rocket motor malfunctions
C) Recovery system failures
D) Rockets that are structurally unsound

The answer is “C“. 75% of flight failures are due to recovery system problems. See chapter two of *Launching Safely in the 21st Century: Final Report of the Special Committee on Range Operation and Procedure to the National Association of Rocketry.*

C44) The kinetic energy of a descending rocket is a function of:

A) Its mass
B) Its velocity
C) Its mass times its velocity
D) Its mass times the square of its velocity

The answer is "D". Kinetic energy is a function of 1/2 the mass times the square of the velocity (KE=1/2mvA2) . A forty pound rocket at 30 feet per second has a KE of one half times (18.1 kg) times 9.1 meters per second squared, or 759 joules. A bowling ball has about 58 joules, a batted ball has about 147 joules, a .357 Magnum has about 740 joules, and a fall from a second floor window has about 3780 joules. See chapter two of *Launching Safely in the 21st Century: Final Report of the Special Committee on Range Operation and Procedure to the National Association of Rocketry.*

C45) You have an excellent flying field, except that when the winds are from the northwest at over 10 mph, rockets often drift into neighboring fields where you don't have permission to fly. Your alternatives include:

A) Limit flights to lower altitudes so rockets stay on the field
B) Move the launch pad closer to the NW edge of the field, provided there are no roads or houses within 1500 feet
C) Don't fly on days with problematic winds
D) All of the above

The answer is "D". See Section 13 of the NAR High Power Rocket Safety Code and paragraph 4.17.1 of NFPA 1127. Other alternatives include using dual deployment, smaller parachutes, and tilted launch rods.

C46) At what time is it allowed for onboard energetics and/or electronic controls to be activated and when shall they be inhibited?

A) The function of firing circuits and onboard energetics shall be inhibited until the high power rocket is in the launching position, than they can be activated when non-essential personal leave the pad area.
B) When the rocket is in the prep area.
C) Both "A" and "D"
D) The function of firing circuits and onboard energetics shall be inhibited prior to removing the high power rocket from the launching position, and doing so only when non-essential personal are not in the pad area

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The answer is "C". Refer to paragraph 4.13 of NFPA 1127 version effective August 1st, 2012. Note that many altimeters require that the rocket be on the pad, in a vertical orientation, in order to properly initialize: Always follow manufacturer's instructions!

C47) What equipment is required at launch sites?

A) Fire Suppression devices such as fire extinguishers
B) First aid kits
C) Fire suppression devices and First aid kits
D) Fire suppression devices, First aid kits, and a way of communicating with everyone on the launch site

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The answer is “D“. See Section 6 of the NAR High Power Rocket Safety Code and paragraphs 4.14.3 and 4.18.3.1 of NFPA 1127.

C48) You have an unproven design for a high power rocket. Which of the following is *NOT* an acceptable means to ensure that it is safe to fly?

A) Fly it as a “heads up“ flight on the first flight
B) Fly a smaller (non-HPR) scale model
C) Perform a swing test
D) Use a simulation program

The answer is “A“. See Section 6 of the NAR High Power Rocket Safety Code and paragraph 4.8.2 of NFPA 1127.

C49) Your high-power rocket lands in a power line. Which of the following is true?

A) You can retrieve it if the power line is on a wooden (not metal) pole
B) You must leave it alone and you must call the power company
C) You can retrieve it if you have a non-conductive tool, such as a “hot-stick“
D) You can retrieve it if part of it is already on the ground

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The answer is “B“. See Section 13 of the NAR High Power Rocket Safety Code and paragraph 4.10.5 and 4.10.6 of NFPA 1127.

C50) Your field is 1500 x 1500 feet, and your FAA waiver is 3000 feet AGL. If you use parachutes sized to bring your rocket down at 20 feet per second, what is the maximum wind you can fly in for rockets that fly to the waiver altitude?

A) You are limited only by the HPR maximum wind of 20 miles per hour
B) You can fly at 15 mph, if you have the pads at the upwind edge of the field and tilt into the wind
C) You can fly in winds up to about 6 miles an hour, if you have the pads at the upwind edge of the field and the rocket flies vertically
D) This field can only be used in calm winds for flights to the waiver altitude

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The answer is “C“. With a 20 feet per second descent rate, a rocket takes 150 seconds to fall 3000 feet. In 20 mph (30 fps) winds, the rocket will drift 4400 feet downwind, and out of your launch site, which is contrary to Section 13 of the NAR High Power Rocket Safety Code and paragraph 4.17.1 of NFPA 1127. Placing the rocket at the edge of the launch site and launching into the wind may keep the recovery on the field, but it means the ascending trajectory is beyond the boundaries of the launch site, contrary to Section 9 of the NAR High Power Rocket Safety Code and paragraph 4.17.1 of NFPA 1127. At six miles per hour, the rocket will travel 1320 feet horizontally, and you may be able to fly within the boundaries of the launch site.

C51) When can launch organizers operate in violation of the NAR Safety Code?

A) The property owner consents
B) The local authorities give written permission
C) Local laws are followed and two thirds of the NAR Board of Trustees give written permission for a project that offers commensurate levels of safety
D) Never

The answer is “C“. In unusual circumstances, when launch organizers can demonstrate equal or better safety can be maintained, the NAR Board of Trustees can approve an alternate method of compliance with the spirit of the safety code. It takes a two-thirds majority, and local laws have to be complied with. Local laws almost always allow for a similar “waiver“ of regulations to be granted, so it is in theory possible for a launch to be conducted that would otherwise violate some provision of NFPA 1127. This gives Association members a way to conduct launches to explore, among other things, the effectiveness of the safety code itself. It also removes any excuse for NOT following the safety code!

C52) Which of the following is *not* a required feature of a rocket motor ignition system?

A) A removable interlock device is in series with the launch switch
B) The system is electrically operated
C) The launching switch will return to the “off“ position when released
D) An audible or visual indicator shows continuity through the rocket motor igniter

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The answer is “D“. Refer to NFPA 1127, paragraphs 4.13.1 and 4.13.2.

C53). Which of the following are prohibited activities for participants prepping or launching high power rockets and for spectators in the prepping areas?

A) Consumption of alcohol
B) Use of medication that could affect judgment, movement, or stability
C) Both “A“ and “B“ above
D) None of the above

The answer is “C“. Refer to NFPA 1127, paragraph 6.1 (11).

C54) High power rocket motors, motor reloading kits, and pyrotechnic modules shall be stored at least _____ away from smoking, open flames, and other sources of heat.

A) 10 feet
B) 25 feet
C) 50 feet
D) 75 feet

The answer is “B“. Refer to paragraph 4.19.1 of NFPA 1127.

C55). What extra constraints and launch distances cover launches when launching three or more high power rockets simultaneously?
A) The LCO shall appoint a score keeper to see which rocket wins the liftoff
B) The minimum spectator and participant distance shall be the value set forth in Table 4.16.3 for a complex rocket with the same total installed impulse but not more than 610 m (2000 ft), or 1.5 times the highest altitude expected to be reached by any of the rockets, whichever is less.
C) Both “B“ and “D“
D) The LCO should in best practice appoint a spotter for each of the rockets to be able to warn the LCO of any unsafe flight or recovery anomalies.

The answer is “C“. Refer to 4.16.3.3 NFPA 1127 version effective August 1st, 2012.

Section D - Rocket Stability (3 questions from 8)

D1) For a rocket to be stable which of the following statements is true?

A) The center of pressure (CP) must be behind the center of gravity (CG)
B) The center of pressure (CP) must be in front of the center of gravity (CG)
C) The rocket must have fins
D) The length of the body tube must be at least 5 times the model diameter

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The answer is “A“. Refer to the “Handbook of Model Rocketry“ by G. Harry Stine, 6th edition, Chapter 9 on “Stability“. Note references on pages 137 and 138.

D2) An unstable rocket can be made stable by:

A) Adding sufficient weight to the nosecone
B) Removing sufficient weight from the nosecone
C) Moving the fins sufficiently forward towards the nosecone
D) Making the rocket sufficiently shorter

The answer is “A“. To make the rocket stable the center of gravity (C.G.) must be moved forward of the center of pressure (C.P.). Adding weight to the nosecone moves the C.G. forward. Removing weight from the nosecone moves the C.G. aft which is incorrect. Moving the fins forward towards the nosecone moves the C.P. forward which is also incorrect. Finally, making the rocket shorter reduces the correcting moments produced by the aerodynamic forces at the C.P.; the reduced moment makes the rocket less stable.

D3) Rocket stability can be estimated by:

A) Center of pressure “Barrowman“ equations
B) “Cardboard cutout“ method
C) Determining the relative positions of the center of pressure and center of gravity
D) Stability cannot be estimated before a test flight.

The answer is “C“. Refer to the “Handbook of Model Rocketry“ by G. Harry Stine, 6th edition, Chapter 9 on “Stability“. Note Figure 9-6 on page 138. Center of pressure equations and the cardboard cutout method only allow you to determine the center of pressure of the model; the center of gravity location must also be known to determine stability.

D4) A rocket's center of pressure can be estimated by:

A) The "Barrowman" method
B) Finding the point where the model balances
C) "Cardboard cutout" method
D) Both "A" and "C" above

The answer is "D". The "Barrowman" method is a set of equations developed by J. Barrowman for estimating model rocket stability. More sophisticated methods are available to cover conditions not covered by the Barrowman method, e.g. supersonic flight. Refer to the "Handbook of Model Rocketry" by G. Harry Stine, 6th edition, Chapter 9 on "Stability". Note references on pages 140 and 14, Appendix II, and Appendix IV.

D5) An unstable rocket can usually be made more stable by:

A) Using a shorter nosecone
B) Increasing the size of the aft fins
C) Using a larger, heavier rocket motor
D) Increasing the rocket diameter

The answer is "B". To make the rocket stable the center of pressure (C.P.) must be moved aft of the center of gravity (C.G.). Adding larger fins on the aft portion of the model moves the center of pressure aft. A shorter nosecone removes weight from the nose moving the C.G. aft which is incorrect. A larger, heavier rocket motor has the same affect of moving the C.G. aft. Finally, increasing the rocket diameter has essentially no effect on its stability.

D6) During boost a rocket powered by a solid rocket motor tends to become:

A) Less stable in flight
B) More stable in flight
C) No change in stability
D) Unstable

The answer is "B". During powered flight the solid rocket motor consumes its fuel causing the aft end of the rocket to become lighter. This moves the C.G. forward and enhances stability. This can be seen in instances where an unstable rocket becomes stable partway during the rocket motor burn; this is also particularly dangerous because the now stable rocket may be pointed in any direction.

D7) Which of the following can cause unstable flight?

A) Weak tubes or couplers that permit airframe bending
B) Misaligned motor mount tube or motor nozzle
C) Inadequate airspeed leaving the launch tower on a breezy day
D) All of the above

The answer is “D“. Rockets that bend in flight can loop under power, as can rockets with misaligned thrust vectors caused by crooked motor tubes or nozzles. Rockets that launch too slowly may be subjected to high angles of attack due to the wind. High angles of attack move the CP forward, which can cause a rocket to go unstable. In addition, slow airspeed means that the corrective action of the fins may not be sufficient to compensate for forces causing pitch or yaw.

D8) As a rule of thumb, how far should the center of pressure be from the center of gravity?

A) The center of pressure should be at the same location as the center of gravity
B) The center of pressure should be at least 1.0 body tube diameters behind the center of gravity
C) The center of pressure should be at least 1.0 body tube diameters ahead of the center of gravity
D) The center of pressure should be 1.0 body tube diameters ahead of the fin leading edge; the center of gravity does not matter

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The answer is “B“. Refer to the “Handbook of Model Rocketry“ by G. Harry Stine, 6th edition, Chapter 9 on “Stability“. Note references on pages 141 through 146.

Section E - Rocket Motor Designations (2 questions from 9)

E1) What does the “H“ in the motor designation H100-5 stand for?

A) It is the first letter in the manufacturer’s name
B) It indicates the total power range or impulse range of the rocket motor
C) It indicates the total thrust of the rocket motor
D) It indicates that the motor uses black powder as a propellant

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The answer is “B“. In a rocket motor designation the alphabetic character indicates the total impulse (or total power) for the rocket motor. High power rocket motors are rated as follows: “H“ = 160.01 to 320.00 Newton-seconds, “I“ = 320.01 to 640.00 Newton-seconds, “J“ = 640.01 to 1280.00 Newton-seconds, “K“ = 1280.01 to 2560.00 Newton-seconds, “L“ = 2560.01 to 5120.00 Newton- seconds, “M“ = 5120.01 to 10240.00 Newton-seconds, “N“ = 10240.01 to 20480.00 Newton-seconds, “O“ = 20480.01 to 40960.00 Newton-seconds. Note that the total allowable impulse doubles with each letter class.

E2) What does the “100“ in the motor designation H100-5 stand for?

A) It is the peak thrust in pounds of the rocket motor
B) It is the rocket motor burn time in seconds
C) It is the average thrust in Newtons of the rocket motor
D) It is the manufacturer’s retail price code

The answer is “C“. In a rocket motor designation the number before the dash is the average thrust in Newtons of the rocket motor. Divide this number by 4.45 for the average thrust in pounds.

E3) What does the “5“ in the motor designation H100-5 stand for?

A) It is the rocket motor burn time
B) It is the peak thrust (in kilograms) of the rocket motor
C) It is the average thrust of the rocket motor
D) It is the ejection charge delay time

The answer is “D“. In the standard designation system for rocket motors the number after the dash indicates the delay in seconds between rocket motor burnout and ejection charge operation. Note that a “0“ (zero) delay indicates a booster rocket motor; the propellant grain is exposed and no delay or ejection charge is used. A “P“ may also be used; this indicates that the end of the motor where the ejection charge and delay train normally reside is plugged.

E4) What are the units of measurement for the “100“ in the motor designation H100-5?

A) Newtons per second
B) Newtons
C) Newton-seconds
D) feet per second

The answer is “B“. In a rocket motor designation the number before the dash is the average thrust in Newtons of the rocket motor. Divide this number by 4.45 for the average thrust in pounds.

E5) What is the maximum total impulse for a “J“ rocket motor?

A) 320.00 Newton-seconds
B) 640.00 Newton-seconds
C) 1280.00 Newton-seconds
D) 2560.00 Newton-seconds

The answer is “C“. In a rocket motor designation the alphabetic character indicates the total impulse (or total power) for the rocket motor. High power rocket motors are rated as follows:

“H“ = 160.01 to 320.00 Newton-seconds, “I“ = 320.01 to 640.00 Newton-seconds, “J“ = 640.01 to 1280.00 Newton-seconds, “K“ = 1280.01 to 2560.00 Newton-seconds, “L“ = 2560.01 to 5120.00 Newton- seconds, “M“ = 5120.01 to 10240.00 Newton-seconds, “N“ = 10240.01 to 20480.00 Newton-seconds, “O“ = 20480.01 to 40960.00 Newton-seconds.

E6) Assuming that each motor has the full allowable impulse, how many “H“ motors have the same total impulse as a single “J“ motor?

A) 3
B) 1
C) 2
D) 4

The answer is “D“. An full “H“ motor has a maximum allowable total impulse of 320.00 Newton-seconds and a full “J“ motor has a maximum total impulse of 1280.00 Newton-seconds thus it takes four (4) full “H’s“ to equal one (1) full “J“.

E7) You have an H64-8 rocket motor which has been certified to have a total impulse of 320.00 Newton seconds. What is the approximate burn time for this motor?

A) 3 seconds
B) 5 seconds
C) 8 seconds
D) 10 seconds

The answer is “B“. Divide the total impulse by the average thrust to determine the motor burn time. 320 (Newton-seconds) divided by 64(Newtons) = 5 (seconds).

E8) The manufacturer’s test data shows a total impulse of 690 Newton-seconds for your motor. What impulse class does your motor represent?

A) “H“
B) “I“
C) “J“
D) “K“

The answer is “C“. Refer to the answer for question E5 above.

E9) The manufacturer’s test data shows an average thrust of 100 Newtons for 6 seconds for your motor. What impulse class does your motor represent?

A) “H“
B) “I“
C) “J“
D) “K“

The answer is “B“. The total impulse is calculated by multiplying the average thrust by burn time. In this case the total impulse is 600 Newton-seconds. Refer to question E5 above for the letter versus total impulse class table.

David Antaki
Project RP1

Appendix M8
Motor Classes

Designation Letters and Associated Impulses

NAR L1 & L2 Technical Report

June 28th, 2019

Class (Base 26)	Total Impulse (N·s)	Total Impulse (lbf·s)	Aerospace Vehicle or Rocket(s)	US Requirements
Micro	0–0.3125	0–0.07		
1/4A	0.3126–0.625	0.071–0.14		
1/2A	0.626–1.25	0.141–0.28		
A	1.26–2.50	0.281–0.56		
B	2.51–5.00	0.561–1.12		
C	5.01–10.0	1.121–2.25		
D	10.01–20.0	2.251–4.5		
E	20.01–40.0	4.51–8.99		
F	40.01–80.0	8.991–18.0		
G	80.01–160	18.01–36.0		Largest model rocket motor according to TRA and NAR.
H	160.01–320	36.01–71.9		Level 1 Certification required from Tripoli or NAR. Under 125g propellant is Federal Aviation Administration exempt.
I	320.01–640	71.9–144		
J	640.01–1,280	144.01–288		Level 2 Certification required from Tripoli or NAR.
K	1,280.01–2,560	288.01–576		
L	2,560.01–5,120	576.01–1,151		
M	5,120.01–10,240	1,151.01–2,302		Level 3 Certification required from Tripoli or NAR.
N	10,240.01–20,560	2,302.01–4,604		
O	20,560.01–40,960	4,604.01–9,208		
P	40,960–81,920	9,210–18,400		FAA/AST Permit or License required.
Q	81,920–163,840	18,400–36,800		
R	163,840–327,680	36,800–73,700		
S	327,680–655,360	73,700–147,000	WAC Corporal CSXT GoFast DARE's Stratos III	Largest motor used by amateurs.

The remainder of this chart is an application of consumer rocket nomenclature to professional rockets which do not use this nomenclature at all.				
T	655,360– 1,310,000	147,000– 295,000		
U	1,310,000– 2,620,000	295,000– 589,000	Atlas 5 Solid Boosters Apollo launch escape rocket	
V	2,620,000– 5,240,000	589,000– 1,180,000	Bloodhound SSC hybrid rocket	
W	5,240,000– 10,500,000	1,180,000– 2,360,000		
X	10,500,000– 21,000,000	2,360,000– 4,710,000	Lambda 4S	
Y	21,000,000– 41,900,000	4,710,000– 9,430,000	Vanguard GEM-40 SRB	
Z	41,900,000– 83,900,000	9,430,000– 18,900,000	Black Arrow Mercury-Redstone	
AA	83,900,000– 168,000,000	18,900,000– 37,700,000	Falcon 1	
AB	168,000,000– 336,000,000	37,700,000– 75,400,000	M-V	
AC	336,000,000– 671,000,000	75,400,000– 151,000,000	Ariane 3 LGM-25C Titan II	
AD	671,000,000– 1,340,000,000	151,000,000– 302,000,000	Vostok Delta II Space Shuttle SRB	
AE	1,340,000,000– 2,680,000,000	302,000,000– 603,000,000	Falcon 9 v1.1 Falcon 9 Full Thrust Delta IV Heavy	
AF	2,680,000,000– 5,370,000,000	603,000,000– 1,210,000,000	Atlas V Heavy Falcon Heavy	
AG	$5.37*10^9$– $10.7*10^9$	$1.21*10^9$– $2.41*10^9$	Space Shuttle Saturn V	
AH	$10.7*10^9$– $21.4*10^9$	$2.41*10^9$– $4.82*10^9$	Ares V Long March 9	

Reference [15]

David Antaki
Project RP1

Appendix R1
NFPA 1122 2002 Edition

NAR L1 & L2 Technical Report

June 28th, 2019

NFPA 1122

Code for

Model Rocketry

2002 Edition

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This edition of NFPA 1122, *Code for Model Rocketry*, was prepared by the Technical Committee on Pyrotechnics and acted on by NFPA at its May Association Technical Meeting held May 19–23, 2002, in Minneapolis, MN. It was issued by the Standards Council on July 19, 2002, with an effective date of August 8, 2002, and supersedes all previous editions.

This edition of NFPA 1122 was approved as an American National Standard on July 19, 2002.

Origin and Development of NFPA 1122

NFPA 1122 was created originally as a tentative code by the Technical Committee on Pyrotechnics as NFPA 41L, *Code for Model Rocketry*. It was adopted tentatively in 1967 and adopted officially by the Association in May 1968. In November 1976, a major revision of NFPA 41L, including its redesignation as NFPA 1122L*, Code for Unmanned Rockets*, was adopted. The 1976 edition was revised by the Technical Committee on Pyrotechnics in 1980 to eliminate the "L" designation and to delete the requirements for cold propellant model rocket motors, which no longer are allowed because of their use of chlorofluorocarbons (Freon 12™). Other technical changes were made at that time. Those revisions were adopted at the 1981 NFPA Fall Meeting, and the new document became the 1982 edition. Amendments to the 1982 edition were processed at the 1986 NFPA Fall Meeting, resulting in the 1987 edition. Because of the rapid progress in consumer rocket technology and the emergence of the commercial space transportation industry, the 1987 edition was amended, and its title was changed back to NFPA 1122, *Code for Model Rocketry*, for the 1994 edition.

For the 1997 edition, the terminology and provisions relating to reloadable solid propellant model rockets and reloadable solid propellant model rocket motors were incorporated into the document for consistency with changes made to federal regulations that affected the model rocketry industry. These changes in federal regulations occurred after the previous edition of this code was adopted. These changes are reflected throughout the document.

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In addition, the citations for federal regulations were updated throughout the document to reflect changes made to those regulations since the last edition of the code was prepared.

Other changes were editorial in nature to bring the document into conformance with the NFPA *Manual of Style*.

The 2002 edition includes a new edition of the National Association of Model Rocketry, *Model Rocket Safety Code*. Other changes include deleting material covered by NFPA 1125 that is no longer needed in NFPA 1122. The code also was revised to comply with the NFPA *Manual of Style*.

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Committee Scope: This Committee shall have primary responsibility for documents on the manufacture, transportation, and storage of consumer and display fireworks, pyrotechnic special effects, and model and high power rocket motors. This Committee shall have primary responsibility for the use of display fireworks and for model and high power rocketry, and the construction, launching, and other operations that involve model and high power rocket motors. The Committee shall have primary responsibility for documents on the wholesale and retail sale and storage of consumer fireworks.

The Committee does not have responsibility for documents on the use of consumer fireworks by the general public; on the use of pyrotechnic special effects before a proximate audience; on the manufacture, transportation, storage, or use of military, automotive, agricultural, and industrial pyrotechnics.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

NFPA 1122
Code for
Model Rocketry
2002 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Information on referenced publications can be found in Chapter 2 and Annex E.

Chapter 1 Administration

1.1 Scope.

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1.1.1 This code shall apply to the design, construction, limitation of propellant mass and power, and reliability of model rocket motors and model rocket motor reloading kits and their components, produced commercially for sale to or for use by the public for purposes of education, recreation, and sporting competition.

1.1.2 This code also shall apply to the design and construction of model rockets propelled by model rocket motors specified in 1.1.1.

1.1.3 This code also shall apply to the conduct of launch operations of model rockets specified in 1.1.2.

1.1.4 This code shall not apply to the design, construction, production, manufacture, fabrication, maintenance, launch, flight, test, operation, use, or other activity that is connected with a rocket or rocket motor where carried out or engaged in by any of the following:

(1) National, state, or local government

(2) Individual, firm, partnership, joint venture, corporation, or other business entity engaged as a licensed business in the research, development, production, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, or rocket components or parts

(3) Colleges or universities

1.1.5 This code shall not apply to the design, construction, fabrication, maintenance, production, manufacture, launch, flight, test, operation, or use of rocket-propelled model aircraft that sustain their mass against the force of gravity by aerodynamic lifting surfaces that support the aircraft during the entire duration of its flight in the air, but shall apply to the model rocket motors and their components that provide the propulsion for such model aircraft.

1.1.6 This code shall not apply to model or toy rockets propelled by pressurized-liquid rocket motors containing less than 250 ml (8.45 fl oz) of water.

1.1.7 This code shall not apply to fireworks rockets or pyrotechnic rockets as defined in NFPA 1123*, Code for Fireworks Display*.

1.1.8 This code shall not apply to NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks and Pyrotechnic Articles*.

1.1.9 This code shall not apply to NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*.

1.1.10 This code shall not apply to high power rocketry as defined in NFPA 1127, *Code for High Power Rocketry*.

1.2 Purpose.

1.2.1 The purpose of this code shall be to ensure the availability of commercial model rocket motors and components that meet standards of safety and reliability to ensure that the creative and experimental use of model rocket devices by the public is reasonably safe.

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1.2.2 The purpose of this code also shall be to discourage the making and launching of homemade rockets and other rocket-like vehicles propelled by, or intended to be propelled by, homemade rocket-propulsion devices.

1.2.3 The purpose of this code also shall be to discourage experiments with explosive or highly energetic rocket propellants, construction of homemade rocket-propulsion motors, and attempted launchings or operations of these homemade rocket devices, thereby minimizing deaths and injuries.

1.3 Code Adoption Requirement.

This code shall be administered and enforced by the authority having jurisdiction designated by the governing authority. *(See Annex D for sample wording for enabling legislation.)*

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this code and shall be considered part of the requirements of this document.

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 1123, *Code for Fireworks Display,* 2000 edition.

NFPA 1124, *Code for the Manufacture, Transportation, and Storage of Fireworks and Pyrotechnic Articles,* 1998 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* 2001 edition.

NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience,* 2001 edition.

NFPA 1127, *Code for High Power Rocketry,* 2002 edition.

2.3 Other Publications.

2.3.1 U.S. Government Publications.

U.S. Government Printing Office, Washington, DC 20402.

Title 14, *Code of Federal Regulations*, Parts 101.1–101.25, "Federal Aviation Administration Regulations."

Title 16, *Code of Federal Regulations*, Part 1500.85 (8) and (9), "Consumer Product Safety Commission Regulations."

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Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* **Approved.** Acceptable to the authority having jurisdiction.

3.2.2* **Authority Having Jurisdiction (AHJ).** The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3.2.3* **Code.** A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.5* **Listed.** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.6 Shall. Indicates a mandatory requirement.

3.2.7 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Certified Motor. A commercially manufactured rocket motor that has been certified by a recognized testing organization acceptable to the authority having jurisdiction to meet the certification requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

3.3.2 Commercial Manufacturer. Any individual, firm, partnership, joint venture, corporation, or other business entity engaged in research, development, production, preparation, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, rocket propellant, delay or ejection modules, or rocket components or parts.

3.3.3 High Power Rocket. A rocket that (1) is propelled by one or more high power rocket motors; (2) is propelled by a combination of model rocket motors having an installed total

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impulse of more than 320 N-sec (71.9 lb-sec); (3) is propelled by a combination of model rocket motors having more than a total of 125 g (4.4 oz) of propellant weight; or (4) weighs more than 1500 g (53 oz) with motor(s) installed.

3.3.4 High Power Rocket Motor. A rocket motor that has more than 160 N-sec (36 lb-sec) but no more than 40,960 N-sec (9208 lbs-sec) of total impulse or an average thrust greater than 80 N (18 lbf) or more than 62.5 g (2.2 oz) of propellant, and that otherwise meets the other requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

3.3.5 Installed Total Impulse. The combined total impulse of all rocket motors installed in a rocket and intended to be ignited during the launch and flight of the rocket.

3.3.6* Model Rocket. A rocket that (1) weighs no more than 1500 g (53 oz)with motors installed; and (2) is propelled by one or more model rocket motors having an installed total impulse of no more than 320 N-sec (71.9 lb-sec); and (3) contains no more than a total of 125 g (4.4 oz) of propellant weight.

3.3.7 Model Rocket Engine. See 3.3.8, Model Rocket Motor.

3.3.8* Model Rocket Motor. A rocket motor that has a total impulse of no greater than 160 N-sec (36 lb-sec), an average thrust of no greater than 80 N (18 lbf), and a propellant weight of no greater than 62.5 g (2.2 oz), and that otherwise meets the other requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

3.3.9 Module. A pyrotechnic component of a reloadable model rocket motor in which the chemical composition is loaded into a finished assembly by the manufacturer.

3.3.10* Motor Reloading Kit. A product manufactured by a commercial manufacturer that contains the components and parts used to reload and reuse a reloadable rocket motor casing.

3.3.11 Propellant. The material(s) utilized in a rocket motor that produces thrust by the discharge of a working fluid generated by combustion, decomposition, change of state, or other operation of such material contained within the rocket motor.

3.3.12 Rocket. A device that ascends into the air without the use of aerodynamic lifting forces acting against gravity and that is propelled by one or more rocket motor(s).

3.3.13 Rocket Engine. See 3.3.14, Rocket Motor.

3.3.14* Rocket Motor. A device containing propellant that provides the force or thrust to cause a rocket to move.

3.3.14.1 Reloadable Rocket Motor. A rocket motor that has been manufactured so that the user can load, reload, and reuse the pressure-resisting body or casing using the parts and components of a motor reloading kit.

3.3.14.2 Solid Propellant Rocket Motor. A rocket motor that contains a fuel and an oxidizer in solid form and whose force or thrust is produced by the combustion of the fuel and oxidizer.

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3.3.15 Structural Parts. The load-bearing parts of a model rocket, specifically, the nose cone, body tube, and fins.

Chapter 4 Requirements for Model Rocket Construction, Operation, and Motor Storage

4.1* Model Rocket Operations.

A model rocket shall comply with the requirements of construction and operation as set forth in 14 CFR 101.1 through 101.25, "Federal Aviation Administration Regulations."

4.2 Model Rocket Materials.

4.2.1 A model rocket's structural parts, including the body, nose cone, and fins, shall be made of paper, wood, or plastic and shall contain no metal parts.

4.2.2 A model rocket motor casing that is metallic, reloadable, and meets the specifications in this code shall be permitted.

4.2.3 A model rocket motor shall be assembled with all pyrotechnic ingredients preloaded into a cylindrical paper or similarly constructed nonmetallic tube that does not fragment into sharp, hard pieces.

4.3* Model Rocket Recovery.

4.3.1 A model rocket shall have a means for returning it to the ground (for example, a parachute) so it can be flown again.

4.3.2 All recovery wadding used in a model rocket shall be flame resistant.

4.4* Model Rocket Weight Limits.

4.4.1 A model rocket shall weigh no more than 453 g (16 oz) at lift-off, including propellant.

4.4.2 A model rocket shall use no more than 113 g (4 oz) of propellant, unless one of the following is met:

(1)* A model rocket that weighs in excess of 453 g (16 oz) but not more than 1500 g (53 oz), including propellant, shall be permitted if the Federal Aviation Administration notice requirements are met.

(2) A model rocket that uses more than 113 g (4 oz) but less than or equal to 125 g (4.4 oz) of propellant, shall be permitted if the Federal Aviation Administration notice requirements are met.

4.5 Model Rocket Power Limits.

A model rocket's installed motor(s) shall produce a total impulse of no more than 320 N-sec (72 lb-sec).

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4.6 Model Rocket Payloads.

A model rocket shall not carry a payload that is designed to be flammable, explosive, or harmful to persons or property.

4.7 Model Rocket Flight Paths.

A model rocket shall not be launched on a flight path aimed at a target.

4.8 Model Rocket Launch Site.

A model rocket shall be launched outdoors in a cleared area, free of tall trees, power lines, buildings, and dry brush and grass.

4.9 Model Rocket Launch Site Size.

The launch site shall be at least as large as specified in Table 4.9.

Table 4.9 Minimum Launch Site Dimensions

Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Site Dimension	
		m	ft
0 – 1.25	¼ A and ½ A	15	50
1.26 – 2.50	A	30	100
2.51 – 5.00	B	61	200
5.01 – 10.00	C	122	400
10.01 – 20.00	D	152	500
20.01 – 40.00	E	305	1000
40.01 – 80.00	F	305	1000
80.01 – 160.00	2F (or 1G)	305	1000
160.01 – 320.00	4F (or 2G)	457	1500

4.9.1 For a circular area, the minimum launch site dimension shall be the diameter, and for a rectangular area it shall be the shortest side.

4.9.2 A model rocket with an installed total propellant weight exceeding 113 g (4 oz) but less than or equal to 125 g (4.4 oz) shall comply with the additional operating notice requirements as set forth in 14 CFR 101.3 through 101.25, "Federal Aviation Administration Regulations."

4.9.3 Type G motors with an installed total impulse of more than 80 N-sec (18 lb-sec), but not more than 160 N-sec (36 lb-sec), shall be permitted to be used by individuals 18 years old and older.

4.9.4 As an alternative to the minimum launch site dimensions of Table 4.9, the size of the launch site shall meet one of the following criteria:

(1) It shall be not less than one-half the maximum altitude as stated by the manufacturer for the model rocket and motor(s) combination being flown.

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(2) It shall be of a size approved by the authority having jurisdiction based on flight demonstration or data required to substantiate the anticipated altitude.

4.10 Model Rocket Launchers.

A model rocket shall be launched from a stable launch device that provides rigid guidance until it has reached a speed adequate to ensure a safe flight path.

4.11 Model Rocket Launcher Eye Safety.

4.11.1 To prevent accidental eye injury, the launcher shall be placed so the end of the rod is above eye level, or the end shall be capped when approaching it.

4.11.2 The launch rod shall be capped or disassembled when not in use and shall not be stored in an upright position.

4.12 Model Rocket Launch Safety.

4.12.1 The launcher shall have a blast deflector device to prevent the motor exhaust from hitting the ground directly.

4.12.2 The area around a launch device shall be cleared of brown grass, dry weeds, or other easy-to-burn materials.

4.13 Model Rocket Ignition System.

4.13.1 The system used to launch a model rocket shall be remotely controlled and electrically operated.

4.13.2 The system shall have a launching switch that returns to the "off" position when released.

4.13.3 The system shall be equipped with a removable safety interlock in series with the launch switch.

4.14 Spectator Distances.

4.14.1 All persons shall remain at least 4.6 m (15 ft) from the model rocket during ignition of a model rocket motor with an installed total impulse of 30 N-sec (6.7 lb-sec) or less.

4.14.2 All persons shall remain at least 9 m (30 ft) from the model rocket during ignition of a model rocket motor with an installed total impulse of more than 30 N-sec (6.7 lb-sec).

4.15 Spectator Notification.

4.15.1 All people in the launch area shall be made aware of the pending model rocket launch.

4.15.2 An audible 5-second countdown to launch shall take place.

4.16 Model Rocket Misfires.

If a model rocket misfires, no person shall approach the launcher until 1 minute has elapsed

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and the safety interlock has been removed or the battery has been disconnected from the ignition system.

4.17 Model Rocket Launch Conditions.

4.17.1 A model rocket shall not be launched in a wind of more than 32 km/h (20 mph).

4.17.2 A model rocket shall not be launched into a cloud.

4.17.3 A model rocket shall not be launched near an aircraft in flight.

4.17.4 A model rocket shall not be launched at an angle greater than 30 degrees from vertical.

4.18* Model Rocket Retrieval Safety.

No attempt shall be made to retrieve a model rocket from a power line or other life-threatening area.

4.19 Model Rocket Motor Requirements.

4.19.1 Only commercially manufactured, certified model rocket motors or motor reloading kits or components as specified in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* shall be used.

4.19.2 No person shall dismantle, reload, or alter a single-use model rocket motor.

4.19.3 No person shall alter the components of a reloadable model rocket motor or use the contents of a reloadable rocket motor reloading kit for a purpose other than those specified by the manufacturer's instructions for the reloadable rocket motor or reloading kit.

4.20 Residential Storage of Model Rocket Motors and Motor Components.

4.20.1 Not more than 23 kg (50 lb) net weight of solid propellant model rocket motors, motor reloading kits, or motor components shall be stored at a residence.

4.20.2 Not more than 11 kg (25 lb) net weight of solid propellant model rocket motors, motor reloading kits, or motor components stored at a residence shall be permitted to be stored in the living quarters.

4.20.3 Provisions for the storage of more than 23 kg (50 lb) net weight of solid propellant model rocket motors, motor reloading kits, or motor components at a residence shall be subject to the approval of the authority having jurisdiction.

Chapter 5 Prohibited Activities

5.1 Prohibited Activities.

The following activities shall be prohibited by this code:

(1) Using model rocket motors, motor reloading kits, or components for the primary

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purpose of producing a spectacular display of color, light, sound, or any combination thereof

(2) Using a model rocket or model rocket motor, motor reloading kit, or component as a weapon

(3) Using a model rocket, model rocket motor, motor reloading kit, or component contrary to the instructions for its use

(4) Tampering with any model rocket motor or motor reloading kit or component in any manner or to any degree that is contrary to the purpose for which the model rocket motor, motor reloading kit, or component is designed and intended to be used

(5) Making, operating, launching, flying, testing, activating, discharging, or other experimentation with model rocket motors, motor reloading kits, or motor components that have not been certified in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*

(6) Selling, offering for sale, exposing for sale, purchasing, making, or using fuse, wick, or other ignition devices intended to be activated by a handheld flame for the purpose of starting or igniting a model rocket motor

(7) Exhibiting statements in writing, in advertising, or on packaging that certification in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* has been obtained, when such certification has not been obtained, has been withdrawn, or has been denied

(8) Reloading any expendable solid propellant model rocket motor with any material after that motor has been operated

(9) Reloading any reloadable model rocket motor with any material or by any means not specifically provided or recommended by the manufacturer

(10) Purchasing or using by persons 17 years old or younger of Type G model rocket motors that do not meet the specifications of 16 CFR 1500.85(8) and (9), "Consumer Product Safety Commission Regulations."

(11) Purchasing or using by persons 17 years old or younger of reloadable model rocket motors or motor reloading kits that do not meet the specifications of 16 CFR 1500.85(8) and (9), "Consumer Product Safety Commission Regulations."

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment,

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or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A.3.2.5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.6 Model Rocket. A model rocket has structural parts made of paper, wood, and breakable plastic; it has a means for its return to the ground so it can be flown again; and its primary use is for purposes of education, recreation, and sporting competition.

A.3.3.8 Model Rocket Motor. Where the term *model rocket motor* is used in this code, it includes both assembled, reloadable model rocket motors and manufactured, expendable model rocket motors.

A.3.3.10 Motor Reloading Kit. The components and parts normally include a propellant module(s), a new model rocket motor nozzle, new insulation components, prepackaged delay and ejection modules, an electrical igniter, and the parts necessary to seal the casing during operation.

A.3.3.14 Rocket Motor. The force or thrust is created by the discharge of gas generated by combustion, decomposition, change of state, or other operation of materials contained, carried, or stored solely within the rocket motor or rocket and not dependent on the outside environment for reaction mass.

A.4.1 The following is an excerpt from 14 CFR 101.1, "Federal Aviation Administration Regulations":

(a) This part prescribes rules governing the operation in the United States of the following:

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(1) ...

(2) ...

(3) Any unmanned rocket except:

(i) Aerial fireworks displays; and,

(ii) Model rockets:

(a) Using not more than four ounces of propellant;

(b) Using a slow-burning propellant;

(c) Made of paper, wood, or breakable plastic, containing no substantial metal parts, and weighing not more than 16 ounces, including the propellant; and

(d) Operated in a manner that does not create a hazard to persons, property, or other aircraft.

A.4.3 Models should be launched only during daylight hours.

A.4.4 A model rocket should weigh no more than the motor manufacturer's recommended maximum lift-off weight for the motors used or should use motors recommended by the kit manufacturer.

A.4.4.2(1) See 14 CFR 101.1 through 101.25, "Federal Aviation Administration Regulations."

A.4.18 It is recommended that, if a model rocket becomes entangled in a power line, the utility company or other appropriate authority be notified.

Annex B Model Rocket Safety Code of the National Association of Rocketry

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1

The Model Rocket Safety Code provides guidance applicable to activities involving model rockets for education, recreation, and sporting competition. The National Association of Rocketry also publishes an annotated version of the *Model Rocket Safety Code.*

Model Rocket Safety Code

National Association of Rocketry

Adopted February 2001

(1) *Materials*. I will use only lightweight, non-metal parts for the nose, body, and fins of

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my rocket.

(2) *Motors*. I will use only certified, commercially-made model rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer.

(3) *Ignition System*. I will launch my rockets with an electrical launch system and electrical motor igniters. My launch system will have a safety interlock in series with the launch switch, and will use a launch switch that returns to the "off" position when released.

(4) *Misfires*. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

(5) *Launch Safety*. I will use a countdown before launch, and will ensure that everyone is paying attention and is a safe distance of at least 4.6 m (15 ft) away when I launch rockets with D motors or smaller, and 9.1 m (30 ft) when I launch larger rockets. If I am uncertain about the safety or stability of an untested rocket, I will check the stability before flight and will fly it only after warning spectators and clearing them away to a safe distance.

(6) *Launcher*. I will launch my rocket from a launch rod, tower, or rail that is pointed to within 30 degrees of the vertical to ensure that the rocket flies nearly straight up, and I will use a blast deflector to prevent the motor's exhaust from hitting the ground. To prevent accidental eye injury, I will place launchers so that the end of the launch rod is above eye level or will cap the end of the rod when it is not in use.

(7) *Size*. My model rocket will not weigh more than 1500 grams (53 ounces) at liftoff and will not contain more than 125 grams (4.4 ounces) of propellant or 320 N-sec (71.9 lb-s) of total impulse. If my model rocket weighs more than one point (453 grams) at liftoff or has more than 4 ounces (113 grams) of propellant, I will check and comply with Federal Aviation Administration regulations before flying.

(8) *Flight Safety*. I will not launch my rocket at targets, into clouds, or near airplanes, and will not put any flammable or explosive payload in my rocket.

(9) *Launch Site*. I will launch my rocket outdoors, in an open area at least as large as shown in Table B.1, and in safe weather conditions with wind speeds no greater than 20 miles per hour. I will ensure that there is no dry grass close to the launch pad and that the launch site does not present risk of grass fires.

(10) *Recovery System*. I will use a recovery system such as a streamer or parachute in my rocket so that is returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

(11) *Recovery Safety*. I will not attempt to recover my rocket from power lines, tall trees,

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(10) *Recovery System*. I will use a recovery system such as a streamer or parachute in my rocket so that is returns safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

(11) *Recovery Safety*. I will not attempt to recover my rocket from power lines, tall trees, and other dangerous places.

Table B.1 Launch Site Dimensions

Installed Total Impulse (N-sec)	Equivalent Motor Types	Minimum Site Dimensions (ft)
0.00 - 1.25	¼ A, ½ A	50
1.26 - 2.50	A	100
2.51 – 5.00	B	200
5.01 – 10.00	C	400
10.01 – 20.00	D	500
20.01 – 40.00	E	1,000
40.01 – 80.00	F	1,000
80.01 – 160.00	G	1,000
160.01 – 320.00	Two Gs	1,500

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Annex C Glossary

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Aero Model.

A miniature, unmanned flying device that includes the category of *model rocket* as defined in 3.3.6.

C.2 Skyrocket or Rockets with Sticks.

Fireworks rockets not intended for re-use that meet the definition of *skyrocket* or *missile-type rocket* in the hazardous materials regulations of 49 CFR 172 and 173, "Department of Transportation Regulations." Fireworks rockets approved for transportation by DOT normally are classed as Fireworks UN 0335, Explosive 1.3G (formerly Class B Explosive, Special Fireworks) or Fireworks UN 0336, Explosive 1.4G (formerly Class C Explosive, Common Fireworks), depending on the quantity of pyrotechnic composition contained in the rocket. Skyrockets use a wooden stick for flight guidance and stability, while missile-type rockets use fins.

Annex D Sample Ordinance Adopting NFPA 1122

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1

The following sample ordinance is provided to assist a jurisdiction in the adoption of this code and is not part of this code.

ORDINANCE NO. _____

An ordinance of the *[jurisdiction]* adopting the *[year]* edition of NFPA *[document number]*, *[complete document title]* documents listed in Chapter 2 of that *[code, standard]*; prescribing regulations governing conditions hazardous to life and property from fire or explosion; providing for the issuance of permits and collection of fees; repealing Ordinance No. _____ of the *[jurisdiction]* and all other ordinances and parts of ordinances in conflict therewith; providing a penalty; providing a severability clause; and providing for publication; and providing an effective date.

BE IT ORDAINED BY THE *[governing body]* OF THE *[jurisdiction]*:

SECTION 1 That the *[complete document title]* and documents adopted by Chapter 2, three (3) copies of which are on file and are open to inspection by the public in the office of the *[jurisdiction's keeper of records]* of the *[jurisdiction]*, are hereby adopted and incorporated

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into this ordinance as fully as if set out at length herein, and from the date on which this ordinance shall take effect, the provisions thereof shall be controlling within the limits of the *[jurisdiction]*. The same are hereby adopted as the *[code, standard]* of the *[jurisdiction]* for the purpose of prescribing regulations governing conditions hazardous to life and property from fire or explosion and providing for issuance of permits and collection of fees.

SECTION 2 Any person who shall violate any provision of this code or standard hereby adopted or fail to comply therewith; or who shall violate or fail to comply with any order made thereunder; or who shall build in violation of any detailed statement of specifications or plans submitted and approved thereunder; or failed to operate in accordance with any certificate or permit issued thereunder; and from which no appeal has been taken; or who shall fail to comply with such an order as affirmed or modified by or by a court of competent jurisdiction, within the time fixed herein, shall severally for each and every such violation and noncompliance, respectively, be guilty of a misdemeanor, punishable by a fine of not less than $ _____ nor more than $_____ or by imprisonment for not less than _____ days nor more than _____ days or by both such fine and imprisonment. The imposition of one penalty for any violation shall not excuse the violation or permit it to continue; and all such persons shall be required to correct or remedy such violations or defects within a reasonable time; and when not otherwise specified the application of the above penalty shall not be held to prevent the enforced removal of prohibited conditions. Each day that prohibited conditions are maintained shall constitute a separate offense.

SECTION 3 Additions, insertions, and changes — that the *[year]* edition of NFPA *[document number]*, *[complete document title]* is amended and changed in the following respects:

List Amendments

SECTION 4 That ordinance No. _____ of *[jurisdiction]* entitled *[fill in the title of the ordinance or ordinances in effect at the present time]* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

SECTION 5 That if any section, subsection, sentence, clause, or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The *[governing body]* hereby declares that it would have passed this ordinance, and each section, subsection, clause, or phrase hereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.

SECTION 6 That the *[jurisdiction's keeper of records]* is hereby ordered and directed to cause this ordinance to be published.

[NOTE: An additional provision may be required to direct the number of times the ordinance is to be published and to specify that it is to be in a newspaper in general circulation. Posting may also be required.]

SECTION 7 That this ordinance and the rules, regulations, provisions, requirements, orders, and matters established and adopted hereby shall take effect and be in full force and effect *[time period]* from and after the date of its final passage and adoption.

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Annex E Informational References

E.1 Referenced Publications.

The following documents or portions thereof are referenced within this code for informational purposes only and are thus not part of the requirements of this document unless also listed in Chapter 2.

E.1.1 NFPA Publications. (Reserved)

E.1.2 Other Publications.

E.1.2.1 NAR Publications. National Association of Rocketry, P.O. Box 177, 1311 Edgewood Drive, Altoona, WI 54720.

Model Rocket Safety Code of the National Association of Rocketry, 2001.

List of Certified Model Rocket Motors.

E.1.2.2 TRA Publication. Tripoli Rocketry Association, P.O. Box 970010, Orem, UT 84097.

List of Certified Model Rocket Motors.

E.1.2.3 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 14, *Code of Federal Regulations*, Parts 101.1–101.25, "Federal Aviation Administration Regulations."

Title 49, *Code of Federal Regulations*, Parts 172–173, "Department of Transportation Regulations."

E.2 Informational References. (Reserved)

E.3 References for Extracts. (Reserved)

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David Antaki

Project RP1

Appendix R2

NFPA 1127 2002 & 2008 Editions

NAR L1 & L2 Technical Report

June 28th, 2019

NFPA 1127

Code for

High Power Rocketry

2002 Edition

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This edition of NFPA 1127, *Code for High Power Rocketry*, was prepared by the Technical Committee on Pyrotechnics and acted on by NFPA at its May Association Technical Meeting held May 19–23, 2002, in Minneapolis, MN. It was issued by the Standards Council on July 19, 2002, with an effective date of August 8, 2002, and supersedes all previous editions.

This edition of NFPA 1127 was approved as an American National Standard on July 19, 2002.

Origin and Development of NFPA 1127

Starting in 1978, the technical progress in solid propellant rocket motors, rocket airframe materials, bonding agents, and construction techniques gave rise to a new form of nonprofessional rocketry based on model rocketry but using larger and more powerful commercially made solid propellant rocket motors in larger and heavier rocket airframes. This new activity is called high power rocketry. Flying activities have taken place throughout the United States in locations where the authority having jurisdiction has been permissive of the activity and where the Federal Aviation Administration has granted waivers to Part 101 of the Federal Aviation Administration Regulations. After over two decades of operational experience, safety rules, operational procedures, and other facets of the activity have been worked out and tested. A new organization, the Tripoli Rocketry Association, Inc., has been working with the National Association of Rocketry, with longtime representation on the NFPA Technical Committee on Pyrotechnics. Both organizations have contributed to the development of national standards.

The code contains instructional guidelines and specific standards for the design, construction, limitation of charge and power, and reliability of all high power rocket motors manufactured for sale to users; for the qualification and certification of users; for the design and construction of high power rockets propelled by these motors; and for the conduct of tests, launchings, and other operations involving rockets so that hazards are minimized.

The NFPA Technical Committee on Pyrotechnics believes that a separate NFPA code for

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high power rocketry is essential because of significant differences in operations and to prevent confusion of the two activities in the minds of public safety officials. High power rocket activities should be allowed within the specifications of this code to guide our science-minded citizens safely.

The 1998 edition included a completely revised Chapter 3 that incorporated requirements and safety provisions for hybrid motor technology. The committee also created a table of clearance distances to promote fire safety in the vicinity of the launch pad. Chapter 5 was revised to be consistent with federal regulations for the storage of low explosives (high power rocket motors and motor reloading kits).

The 2002 edition of this code presents a reorganized document in order to correlate this code with NFPA 1122, *Code for Model Rocketry*, and NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*. Requirements applicable to high power rocket motor manufacturing, motor testing, and certification have been moved to NFPA 1125. This document has also undergone revision to comply with the NFPA *Manual of Style*.

Technical Committee on Pyrotechnics

Randall W. A. Davidson, *Chair*
Risk International & Associates, CA [SE]

Kenneth L. Kosanke, *Secretary*
PyroLabs, Incorporated, CO [SE]

Dane Boles, Quest Aerospace, A Division of Toy Biz & Marvel Enterprises, Inc., AZ [M]

Richard Bowes, Canadian Explosives Research Laboratory/CANMET, Canada [RT]

W. G. Bulifant, III, Dominion Fireworks, Inc., VA [U]

Jose R. Colon, Connecticut Department of Public Safety, CT [E]
Rep. International Fire Marshals Association

John A. Conkling, Chestertown, MD [M]
Rep. American Pyrotechnics Association

Hugh Council, California Dept. of Forestry & Fire Protection, CA [E]

Thomas DeWille, Luna Tech Incorporated, AL [M]

Vernon Estes, Canon City, CO [SE]

Gary A. Fadorsen, Pyrotech International Inc., OH [IM]

Felix J. Grucci, Jr., Fireworks by Grucci, Inc., NY [M]

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Garry Hanson, Precocious Pyrotechnics, Inc., MN [M]
Rep. National Fireworks Association

Lansden E. Hill, Jr., E. E. Hill & Son, Inc./Pyro Shows, TN [U]

Alfred J. Hogan, Reedy Creek Improvement District, FL [E]

Bruce E. Kelly, Orem, UT [U]
Rep. Tripoli Rocketry Association, Inc

John Kitchens, City of Los Angeles Fire Department, CA [E]

Gerald R. Laib, NSWC, Code 950X, MD [SE]

Robert L. Markle, U.S. Coast Guard, DC [E]

Dale C. Miller, Falls Church, VA [SE]

J. Patrick Miller, Hardin-Simmons University, TX [U]
Rep. National Association of Rocketry

David J. Pier, MP Associates, Incorporated, CA [M]

Michael W. Platt, Hinton, WV [M]
Rep. High Power Rocket Manufacturers & Dealers Association

Mary Roberts, Estes Industries, CO [M]

Gary C. Rosenfield, Industrial Solid Propulsion, Inc., NV [M]

David S. Shatzer, US Bureau of Alcohol, Tobacco & Firearms, DC [E]

James R. Souza, Pyro Spectaculars, Inc., CA [U]

John R. Steinberg, Pyrotechnics Guild International, Inc., MD [U]

Charles Weeth, LaCrosse, WI [U]
Rep. La Crosse Skyrockers Inc.

John J. Weinbrecht, Virginia Beach Fire Department, VA [E]

Dan Westcott, Gadsden Fire Department, AL [E]
Rep. NFPA Fire Service Section

Alternates

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Arthur H. Barber, III, Springfield, VA [SE]
(Alt. to V. Estes)

Scott Bartel, Black Sky Research, CA [U]
(Alt. to B. E. Kelly)

Gary E. Brown, Pyro Spectaculars, Inc., CA [U]
(Alt. to J. R. Souza)

Kevin T. Brueckner, Fireworks and Stage FX America, Inc., CA [M]
(Alt. to G. Hanson)

Mark B. Bundick, First Chicago Capital Markets, IL [U]
(Alt. to J. P. Miller)

Steve A. Coman, RES Specialty Pyrotechnics Inc., MN [U]
(Alt. to J. R. Steinberg)

Ettore Contestabile, Canadian Explosives Research Laboratory/CANMET, Canada [RT]
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Patrick C. Ferguson, Onalaska, WI [U]
(Alt. to C. Weeth)

H. Stephen Frantz, Western Enterprises, Inc., OK [U]
(Alt. to L. E. Hill, Jr.)

Felix J. (Phil) Grucci, Fireworks by Grucci, Inc., NY [M]
(Alt. to F. J. Grucci, Jr.)

Paul C. Hans, P. Hans & Company, Inc., AZ [M]
(Alt. to G. C. Rosenfield)

Julie L. Heckman, American Pyrotechnics Association, MD [M]
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Joseph A. Domanico, U.S. Department of the Army, MD [RT]

Patrick M. Race, U.S. Consumer Product Safety Commission, DC [C]

Rosemary Veigel Cooper, U.S. Department of Labor, IL [E]
Rep. Occupational Safety and Health Administration

Gary Zeller, Zeller International, NY

Guy R. Colonna, NFPA Staff Liaison

Committee Scope: This Committee shall have primary responsibility for documents on the manufacture, transportation, and storage of consumer and display fireworks, pyrotechnic special effects, and model and high power rocket motors. This Committee shall have primary responsibility for the use of display fireworks and for model and high power rocketry, and the construction, launching, and other operations that involve model and high power rocket motors. The Committee shall have primary responsibility for documents on the wholesale and retail sale and storage of consumer fireworks.

The Committee does not have responsibility for documents on the use of consumer fireworks by the general public; on the use of pyrotechnic special effects before a proximate audience; on the manufacture, transportation, storage, or use of military, automotive, agricultural, and industrial pyrotechnics.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

NFPA 1127
Code for
High Power Rocketry
2002 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates

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that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex B lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the appropriate technical committee.

Information on referenced publications can be found in Chapter 2 and Annex B.

Chapter 1 Administration

1.1 Scope. (Reserved)

1.2 Purpose.

1.2.1 The purpose of this code shall be to ensure the availability of high power rocket motors and motor components that meet national standards of safety and reliability stated herein to certified users.

1.2.2 The purpose of this code shall be to establish guidelines for reasonably safe operation of high power rockets to protect the user and the public.

1.2.3 The purpose of this code shall be to discourage the following to minimize deaths and injuries:

(1) Experiments with explosive or highly energetic rocket propellants

(2) Construction of homemade rocket propulsion motors

(3) Attempted launches or operation of homemade rocket devices

1.3 Application.

This code shall apply to the design, construction, limitation of propellant mass and power, and reliability of high power rocket motors and motor components produced commercially for sale or for use by a certified user for education, recreation, and sporting competition.

1.3.1 This code also shall apply to the design and construction of high power rockets propelled by the high power rocket motors specified in Section 1.3.

1.3.2 This code shall apply to the conduct of launch operations of high power rockets specified in 1.3.1.

1.3.3 This code shall not apply to the design, construction, production, manufacture, fabrication, maintenance, launch, flight, test, operation, use, or other activity connected with a rocket or rocket motor where carried out or engaged in by the following entities:

(1) National, state, or local government

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(2) An individual, a firm, a partnership, a joint venture, a corporation, or other business entity engaged as a licensed business in the research, development, production, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, or rocket components or parts

(3) College or university

1.3.4 This code shall not apply to the design, construction, fabrication, production, manufacture, maintenance, launch, flight, test, operation, or use of rocket-propelled model aircraft that sustain their mass against the force of gravity by aerodynamic lifting surfaces for the duration of their flight in air but shall apply to high power rocket motors and their components that provide propulsion for such model aircraft.

1.3.5 This code shall not apply to model or toy rockets propelled by pressurized liquid.

1.3.6 This code shall not apply to the following:

(1) Model rockets as specified in NFPA 1122, *Code for Model Rocketry*

(2) Fireworks rockets, skyrockets, and rockets with sticks as defined in NFPA 1123, *Code for Fireworks Display*, or NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience*

Chapter 2 Referenced Publications

2.1 General.

The documents or portions thereof listed in this chapter are referenced within this code and shall be considered part of the requirements of this document.

2.2 NFPA Publications.

National Fire Protection Association, 1 Batterymarch Park, P. O. Box 9101, Quincy, MA 02269-9101.

NFPA 1122, *Code for Model Rocketry,* 2002 edition.

NFPA 1123, *Code for Fireworks Display,* 2000 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* 2001 edition.

NFPA 1126, *Standard for the Use of Pyrotechnics before a Proximate Audience,* 2001 edition.

2.3 Other Publications.

2.3.1 U.S. Government Publications.

U.S. Government Printing Office, Washington, DC 20402.

Title 14, *Code of Federal Regulations*, Chapter 1, Subchapter F, Part 101, Paragraphs 101.1

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through 101.25, “Federal Aviation Administration Regulations,” or revisions or amendments thereto.

Title 27, *Code of Federal Regulations*, Part 55, Subpart H, Section 55.1.4.1.

Title 49, *Code of Federal Regulations*, Part 178.

Title 49, *United States Code*, Section 1348, 72 Statute 749, Section 307, “Airspace Control and Facilities.”

Chapter 3 Definitions

3.1 General.

The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* **Approved.** Acceptable to the authority having jurisdiction.

3.2.2* **Authority Having Jurisdiction (AHJ).** The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.

3.2.3* **Code.** A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.5* **Listed.** Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.6 Shall. Indicates a mandatory requirement.

3.2.7 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Area.

3.3.1.1 Launch Site Parking Area. An area designated by the range safety officer for parking spectator vehicles.

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3.3.1.2 Launching Area. An area designated by the range safety officer in which high power rockets are placed on a launching device and ignited.

3.3.1.3 Prepping Area. An area designated by the range safety officer where high power rockets and high power rocket motors are prepared for launch.

3.3.1.4 Recovery Area. An area designated by the range safety officer for the recovery of high power rockets.

3.3.1.5 Spectator Area. An area designated by the range safety officer where spectators view a high power rocket launch.

3.3.2 Arm. To render an igniter from a safe (no energy) condition to a ready-to-fire condition.

3.3.3 Certified. Approved or endorsed authoritatively.

3.3.4* Certified Motor. A commercially manufactured rocket motor that has been certified by a recognized testing organization, acceptable to the authority having jurisdiction, to meet the certification requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

3.3.5* Certified User. An individual, a distributor, or a seller who has been tested or otherwise examined by a recognized organization that is acceptable to the authority having jurisdiction and has been found to be qualified to purchase, possess, and use high power rocket motors.

3.3.6 Commercial Manufacturer. Any individual, firm, partnership, joint venture, corporation, or other business entity engaged in research, development, production, preparation, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, rocket propellant, delay or ejection modules, or rocket components or parts.

3.3.7 Flight Cylinder. A high-pressure container used in a hybrid rocket motor system to contain pressurized liquid or gas.

3.3.7.1 Sealed Flight Cylinder. A flight cylinder used in a hybrid rocket motor system into which the pressurized liquid or gas can be loaded prior to launch and stored for an indefinite period.

3.3.7.2 Vented Flight Cylinder. A flight cylinder used in a hybrid rocket motor system that continuously vents the pressurized liquid or gas to the atmosphere during the motor fill and ignition procedures.

3.3.8 Inhabited Building. Any building regularly occupied in whole or in part as a habitation for human beings, or any church, schoolhouse, railroad station, store, or other structure where people are accustomed to assemble.

3.3.9 Installed Total Impulse. The combined total impulses of all rocket motors installed in a rocket and intended to be ignited during the launch and flight of the rocket.

3.3.10 Launch Site. An area used for high power rocket activities that includes (1) a prepping area(s), (2) a launching area(s), (3) a recovery area(s), (4) a spectator area(s), and

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(5) a spectator parking area(s).

3.3.11 Module. A pyrotechnic component of a hybrid or solid propellant reloadable rocket motor in which the chemical composition is loaded into a finished assembly by the manufacturer.

3.3.12 Motor Reloading Kit. A product manufactured by a commercial manufacturer that contains the components and parts used to reload and reuse a reloadable rocket motor casing.

3.3.13 Propellant. The material(s) utilized in a rocket motor that produces thrust by the discharge of a working fluid generated by combustion, decomposition, change of state, or other operation of such material contained within the rocket motor.

3.3.14* Range Safety Officer (RSO). A certified user with overall responsibility for the safety, setup, and launching of all rockets at a high power rocket launch.

3.3.15 Rocket. A device that ascends into the air without use of aerodynamic lifting forces acting against gravity and that is propelled by one or more rocket motors.

3.3.15.1 High Power Rocket. A rocket vehicle that (1) is propelled by one or more high power rocket motors; or (2) is propelled by a combination of model rocket motors having an installed total impulse of more than 320 N-sec (71.9 lb-sec); or (3) is propelled by a combination of model rocket motors having more than a total of 125 g (4.4 oz) of propellant weight; or (4) weighs more than 1500 g (53 oz) with motor(s) installed.

3.3.15.1.1 Complex High Power Rocket. A high power rocket that is multistaged or propelled by two or more rocket motors.

3.3.15.2 Model Rocket. A rocket that (1) weighs more than 1500 g (53 oz) with motors installed; and (2) is propelled by one or more model rocket motors having an installed total impulse of no more than 320 N-sec (71.9 lb-sec); and (3) contains no more than a total of 125 g (4.4 oz) of propellant weight.

3.3.16 Rocket Engine. See 3.3.17, Rocket Motor.

3.3.17 Rocket Motor. A device containing propellant that provides the force or thrust to cause a rocket to move. [**1122**:3.3]

3.3.17.1 High Power Rocket Motor. A rocket motor that has more than 160 N-sec (36 lb-sec) but no more than 40,960 N-sec (9208 lb-sec) of total impulse, or an average thrust greater than 80 N, or more than 62.5 g (2.2 oz) of propellant, and that otherwise meets the other requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

3.3.17.2 Hybrid Rocket Motor. A rocket motor that utilizes a fuel and an oxidizer in different physical states (solid, liquid, or gaseous).

3.3.17.3 Model Rocket Motor. A rocket motor that has a total impulse of no greater than 160 N-sec (36 lb-sec), an average thrust of no greater than 80 N, a propellant weight of no greater than 62.5 g (2.2 oz), and that otherwise meets the other requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*.

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3.3.17.4 Reloadable Rocket Motor. A rocket motor that has been manufactured so that the user can load, reload, and reuse the pressure-resisting body or casing using the parts and components of a motor reloading kit.

3.3.17.5 Solid-Propellant Rocket Motor. A rocket motor that contains a fuel and an oxidizer in solid form and whose force or thrust is produced by the combustion of the fuel and oxidizer.

3.3.18 Safety Monitor. See 3.3.14, Range Safety Officer.

3.3.19* Skyrockets or Rockets with Sticks. Commercially manufactured fireworks rockets not intended for reuse.

3.3.20 Spectator. A nonparticipant whose primary purpose is to view a rocket launch.

3.3.21 Structural Parts. The load-bearing parts of a rocket.

Chapter 4 Requirements for High Power Rocket Construction and Operation

4.1 Range Safety Officer Requirements and Responsibilities.

4.1.1 The range safety officer shall have knowledge of NFPA 1127, *Code for High Power Rocketry*.

4.1.2 The range safety officer shall possess the technical competency of high power rocketry safety as determined by the authority having jurisdiction.

4.1.3 The range safety officer shall have the authority to intervene and control any safety aspect of a high power rocket launch when, in his or her judgment, a potential or actual danger, accident, or unsafe condition exists.

4.2 User Certification.

Only a certified user shall be permitted to launch a high power rocket.

4.3 Operating Clearances.

High power rockets shall only be launched in compliance with the following:

(1) This code

(2) Title 49, *United States Code*, Section 1348, 72 Statute 749, Section 307, "Airspace Control and Facilities," Federal Aviation Act of 1958, from 14 CFR 101, "Federal Aviation Administration Regulations," or later revisions or amendments thereto

(3) Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances

4.4 Preflight Inspection.

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4.4.1 A high power rocket shall be inspected by the range safety officer to determine whether it meets the provisions of this code.

4.4.2 A high power rocket shall not be launched if the range safety officer determines that it does not meet the provisions of this code.

4.5 High Power Rocket Motors and Motor Components.

4.5.1* Only certified high power rocket motors or motor reloading kits or motor components shall be used in a high power rocket.

4.5.2 A single-use high power rocket motor shall not be dismantled, reloaded, or altered.

4.5.3 The components of a reloadable high power rocket motor shall not be altered.

4.5.4 A high power rocket motor or its components shall not be used in a manner or for a purpose other than that specified by the high power rocket motor manufacturer in the instructions.

4.5.5 Warning and other labels applied on the flight cylinder of a hybrid rocket motor shall not be removed.

4.5.6 Vented flight cylinders of a hybrid rocket motor shall be filled and unloaded at a distance equal to or greater than that shown for their motor class in Table 4.16.4.

4.5.7 A package containing a high power motor reloading kit shall not be opened until the user is ready to install the motor reloading kit parts, including the propellant module(s), in the reloadable high power rocket motor casing.

4.6 Rocket Construction.

A high power rocket shall be constructed to withstand the operating stresses and retain structural integrity under the conditions encountered during flight.

4.7 Rocket Airframe Materials.

A high power rocket intended to be propelled by one or more high power rocket motors shall be constructed using lightweight materials such as paper, wood, rubber, plastic, fiberglass, or, when necessary, ductile metal so that the rocket conforms to the other requirements of this code.

4.8 Stability.

The stability of a high power rocket shall be checked by its user prior to launch.

4.8.1 If requested by the range safety officer, the user shall provide documentation of the location of the center of pressure and the center of gravity of the high power rocket.

4.8.2 If the stability of the rocket cannot be determined, or if the rocket is determined to be unstable, it shall not be launched.

4.9 Weight and Power Limits.

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4.9.1 The maximum liftoff weight of a high power rocket shall not exceed one-third (⅓) of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

4.9.2 A high power rocket shall be launched with any combination of motors having 40,960 N-sec (9208 lb-sec) of total impulse or less.

4.10 Recovery.

4.10.1 A high power rocket shall be launched only if it contains a recovery system that returns all parts of the rocket to the ground intact so it can be launched again.

4.10.2 A high power rocket launched with an installed total impulse greater than 2560 N-sec (576 lb-sec) shall use an electronically actuated recovery system as either a primary or backup deployment method.

4.10.3* The person who prepares the high power rocket for flight shall install only flame-resistant recovery wadding if the design of the rocket necessitates the use of wadding.

4.10.4 No attempt shall be made to catch a high power rocket as it approaches the ground.

4.10.5 No attempt shall be made to retrieve a high power rocket from a power line or other life-threatening area.

4.10.6 If a high power rocket becomes entangled in a power line, the utility company or other appropriate authority shall be notified.

4.11 Payloads.

4.11.1* A high power rocket shall not carry a flammable or explosive payload.

4.11.2 No high power rocket shall be used to launch a vertebrate animal.

4.12 Launching Devices.

4.12.1 A high power rocket shall be launched from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a predictable flight path.

4.12.2 The launching device shall incorporate a jet deflector if necessary to prevent the rocket motor exhaust from impinging directly on flammable materials.

4.12.3 A launching device shall not be used to launch a high power rocket at an angle greater than 20 degrees from vertical.

4.13 Ignition Systems.

4.13.1 A high power rocket shall be launched using an ignition system that is remotely controlled, is electrically operated, and contains a launching switch that returns to the “off” position when released.

4.13.2 The ignition system shall contain a removable safety interlock device in series with the launch switch.

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4.13.3 The launch system and igniter combination shall be designed, installed, and operated so that liftoff of the rocket occurs within 3 seconds of actuation of the launch system.

4.13.4 If the rocket is to be propelled by a cluster of rocket motors designed to be ignited simultaneously, the ignition scheme that is used shall have been previously tested or proven capable of igniting all rocket motors intended for launch ignition within 1 second following ignition system activation.

4.13.5 An ignition device shall be installed in a high power rocket motor only at the launcher or within the prepping area.

4.13.6 A high power rocket shall be pointed away from the spectator area and other groups of people during and after installation of the ignition device.

4.13.7 Firing circuits shall not be armed with the rocket in other than a launching position.

4.14* Launch Site.

4.14.1 A high power rocket shall be launched only in an outdoor area where tall trees, power lines, and buildings do not present a hazard.

4.14.2 The dimension of the launch site shall be one of the following:

(1) Not less than one-half the maximum altitude expected, calculated, or simulated, or as granted by an FAA waiver or the authority having jurisdiction

(2) As specified in Table 4.14.2

Table 4.14.2 Launch Site Dimensions

Installed Total Impulse [N-sec (lb-sec)]	Equivalent Motor Type	Minimum Site Dimensions			
		m	km	ft	mi
160.01–320.00 (36.01–72.00)	H	457	0.5	1,500	0.3
320.01–640.00 (72.01–144.00)	I	914	1.0	3,000	0.6
640.01–1,280.00 (144.01–288.00)	J	1,609	1.6	5,280	1.0
1,280.01–2,560.00 (288.01–576.00)	K	1,609	1.6	5,280	1.0
2,560.01–5,120.00 (576.01–1151.00)	L	3,219	3.2	10,560	2.0
5,120.01–10,240.00 (1151.01–2302.00)	M	4,828	4.8	15,840	3.0
10,240.01–20,480.00 (2302.01–4604.00)	N	6,437	6.4	21,120	4.0
20,480.01–40,960.00 (4604.01–9208.00)	O	8,047	8.0	26,400	5.0

4.14.2.1 For a circular area, the minimum launch site dimension shall be the diameter in

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meters (feet).

4.14.2.2 For a rectangular area, the minimum launch site dimension shall be the shortest side in meters (feet).

4.14.3 The minimum launch site dimension shall be not less than 457 m (1500 ft).

4.14.4 Fire suppression devices and first aid kits shall be located at the launch site during the launch of a high power rocket.

4.15 Launcher Location.

4.15.1 The area that encircles a launch pad shall be cleared of brown grass, dry weeds, and other easy-to-burn materials for a diameter equal to at least that specified in Table 4.15.1.

Table 4.15.1 Launcher Clear Distances

Installed Total Impulse [N-sec (lb-sec)]	Launcher Equivalent Motor Type	Minimum Clear Distance	
		m	ft
160.01–320.00 (36.01–72.00)	H	15	50
320.01–640.00 (72.01–144.00)	I	15	50
640.01–1,280.00 (144.01–288.00)	J	15	50
1,280.01–2,560.00 (288.01–576.00)	K	23	75
2,560.01–5,120.00 (576.01–1151.00)	L	30	100
5,120.01–10,240.00 (1151.01–2302.00)	M	38	125
10,240.01–20,480.00 (2302.01–4604.00)	N	38	125
20,480.01–40,960.00 (4604.01–9208.00)	O	38	125

4.15.2 For a high power rocket using a motor(s) with titanium sponge, the minimum clear distance shall be multiplied by a factor of 1.5.

4.15.3 The high power rocket launch pad clear distance from the following locations shall be permitted to be equal to one-half the launch site dimension or 457 m (1500 ft), whichever is greater:

(1) A building inhabited without the approval of the authority having jurisdiction and the documented approval of the owner(s) of the inhabited building(s), if the inhabited building(s) is unoccupied during the launch

(2) A public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch

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4.16 Spectator and Participant Distances.

4.16.1 No person shall be permitted to be at a location that is closer to the launch of a high power rocket than the person launching the rocket and those persons authorized by the range safety officer.

4.16.2 All spectators shall remain within an area determined by the range safety officer.

4.16.3 All spectators shall remain behind the range safety officer and the person launching the rocket.

4.16.4 No person shall be permitted to be at a location that is closer to the launch of a high power rocket than the applicable minimum spectator and participant distance set forth in Table 4.16.4.

Table 4.16.4 Minimum Spectator and Participant Distance (Complex High Power Rocket)

Installed Total Impulse		Equivalent Motor Type	Minimum Spectator and Participant Distance		Minimum Spectator and Participant Distance (Complex Rocket)	
N-sec	lb-sec		m	ft	m	ft
160.00–320.00	36.00–72.00	H	30	100	61	200
320.01–640.00	72.01–144.00	I	30	100	61	200
640.01–1,280.00	144.01–288.00	J	30	100	61	200
1,280.01–2,560.00	288.01–576.00	K	61	200	91	300
2,560.01–5,120.00	576.01–1151.00	L	91	300	152	500
5,120.01–10,240.00	1151.01–2302.00	M	152	500	305	1000
10,240.01–20,480.00	2302.01–4604.00	N	305	1000	457	1500
20,480.01–40,960.00	4604.01–9208.00	O	457	1500	610	2000

4.16.5 Parking area distance shall be equal to at least the spectator and participant distance set forth in Table 4.16.4.

4.17 Launch Operations.

4.17.1 No person shall ignite and launch a high power rocket horizontally, at a target, or so that the rocket's flight path goes into clouds or beyond the boundaries of the launch site.

4.17.2 No person shall launch a high power rocket if the surface wind at the launcher is more than 32 km/h (20 mph).

4.17.3 No person shall operate a high power rocket in a manner that is hazardous to aircraft.

4.18 Launch Control.

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4.18.1 A high power rocket shall be launched only with the knowledge, permission, and attention of the range safety officer.

4.18.2 Except for those individuals with mobility restrictions, all persons in the launching, prepping, spectator, and parking areas during a countdown and launch shall stand and face the launcher if requested to do so by the range safety officer.

4.18.3 The launching of a high power rocket shall be preceded by a 5-second countdown that is audible throughout the launching, spectator, and parking areas.

4.18.4 A high power rocket that has misfired shall not be approached until all of the following have occurred:

(1) The safety interlock has been engaged.

(2) One (1) minute has passed.

(3) The range safety officer has given permission for one person to approach the misfired rocket to inspect it.

4.19 Storage of High Power Rocket Motors, Motor Reloading Kits, and Pyrotechnic Modules.

4.19.1 High power rocket motors, motor reloading kits, and pyrotechnic modules shall be stored at least 7.6 m (25 ft) from smoking, open flames, and other sources of heat.

4.19.2 Not more than 23 kg (50 lb) of net propellant weight of high power rocket motors, motor reloading kits, or pyrotechnic modules subject to the storage requirements of 27 CFR 55 shall be stored in a Type 3 or a Type 4 indoor magazine.

4.19.2.1 The indoor magazine shall be painted red, and the top shall bear the following words in white letters at least 76 mm (3 in.) high:

EXPLOSIVES – KEEP FIRE AWAY

4.19.2.2 The indoor magazine shall not be located in residence.

4.19.2.3 The indoor magazine shall be permitted to be located in a detached garage or outbuilding.

4.19.2.4 The indoor magazine shall be permitted to be located in an attached garage in a single-family residence where approved by the authority having jurisdiction and the Bureau of Alcohol, Tobacco, and Firearms.

4.19.2.5 Pyrotechnic high power solid-propellant rocket motors, motor reloading kits, modules, or any other solid-propellant motor products that are exempt under 27 CFR 55 shall be stored in a recloseable, noncombustible container.

4.19.3 Large-quantity storage shall comply with both of the following requirements:

(1) Quantities greater than 22.7 kg (50 lb) of net propellant weight of high power rocket motors, motor reloading kits, or pyrotechnic modules subject to the storage requirements of 27 CFR 55 shall be stored in a Type 4 or greater outdoor magazine.

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(2) The Type 4 or greater magazine shall meet the distance requirements in Table 4.19.3.

Table 4.19.3 Storage Distances for Low Explosives

Weight Over		Weight Not Over		Distance from Inhabited Building		Distance from Public Railroad and Highway		Distance from Aboveground Magazine	
kg	lb	kg	lb	m	ft	m	ft	m	ft
0	0	454	1,000	23	75	23	75	15	50
454	1,000	2,268	5,000	35	115	35	115	23	75
2,268	5,000	45,36	10,000	46	150	46	150	30	100
4,536	10,000	90,72	20,000	58	190	58	190	38	125
9,072	20,000	13,608	30,000	66	215	66	215	44	145
13,608	30,000	18,144	40,000	72	235	72	235	47	155
18,144	40,000	22,680	50,000	76	250	76	250	50	165
22,680	50,000	27,216	60,000	79	260	79	260	53	175
27,216	60,000	31,751	70,000	82	270	82	270	56	185
31,751	70,000	36,287	80,000	85	280	85	280	58	190
36,287	80,000	40,823	90,000	90	295	90	295	59	195
40,823	90,000	45,360	100,000	91	300	91	300	61	200
45,360	100,000	90,718	200,000	114	375	114	375	76	250
90,718	200,000	136,078	300,000	137	450	137	450	91	300

Source: Table is extracted from 27 CFR 55 (BATF regulations for the storage of explosive materials).

4.19.4 High power rocket motors, motor reloading kits, and pyrotechnic modules shall be stored in accordance with all applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.

4.19.5 A high power rocket motor shall not be stored with an ignition element installed.

Chapter 5 High Power Rocket Motor User Certification

5.1 Sales Only to Certified Users.

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A high power rocket motor or motor reloading kit shall be sold to, shipped to, stored by, and used only by certified users.

5.2 User Permit Requirements.

Where required by 27 CFR 55, a "User of Low Explosives Permit" shall be obtained prior to both of the following:

(1) Acquisition by a certified user of a high power solid-propellant rocket motor(s) or motor reloading kit(s) in a state other than that in which the user resides

(2) Transportation by a certified user of a high power solid-propellant rocket motor(s) or motor reloading kit(s) to a state other than that in which the user resides

5.3 Maintenance of Sales Records.

5.3.1 High power rocket motor manufacturers, distributors, and sellers shall maintain a list of those certified users to whom they have sold high power rocket motors or motor reloading kits that includes the following information:

(1) Name and address of the purchaser

(2) Name and address of the national user organization that has certified the user

(3) Type and number of high power solid-propellant rocket motors or motor reloading kits sold to the certified user

(4) Date of sale and shipment of high power rocket motors or motor reloading kits to the certified user

5.3.2 The manufacturer, distributor, or seller shall make available, on request, the records specified in 5.3.1 to any law enforcement person or the authority having jurisdiction.

5.3.3 The records specified in 5.3.1 shall be kept for 5 years from the date of sale.

5.4 User Certification Provisions.

5.4.1 Certification of a user shall require both of the following:

(1) Proof that the user is at least 18 years old

(2) Proof that the user possesses a level of knowledge and competence in handling, storing, and using a high power solid-propellant rocket motor and high power rockets that is acceptable to the certifying organization

5.4.2 The certifying organization shall maintain a list of all persons it has certified as high power rocket motor users.

5.4.2.1 The list of certified users shall be updated not less than once every 30 days.

5.4.2.2 Upon request and receipt of applicable fees, if any, confirmation of an active member's user certification shall be provided to the following:

(1) Law enforcement official or authority having jurisdiction

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(2) Manufacturer of high power rocket motors and motor reload kits

(3) Retailer licensed to sell, distribute, or offer for sale high power rocket motors and motor reloading kits

Chapter 6 Prohibited Activities

6.1 Prohibited Acts.

The following activities shall be prohibited by this code:

(1) Use of a high power rocket motor for the primary purpose of producing a spectacular display of color, light, sound, or any combination thereof, other than the addition of chemical additives to the propellant for the purpose of producing brightly colored exhaust plume, spark, or smoke effects

(2) Use of a high power rocket or high power rocket motor as a weapon or against a target

(3) Tampering with or using a high power rocket motor, motor reloading kit, or module in a manner or to an extent that is contrary to the purpose for which the high power rocket motor or motor reloading kit is designed and intended to be used

(4) Selling, offering for sale, exposing for sale, or making available a rocket motor or motor reloading kit that does not comply with the requirements of this code and that has not been certified in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*

(5) Making, operating, launching, flying, testing, activating, discharging, or otherwise experimenting with high power rocket motors, motor reloading kits, or pyrotechnic modules that have not been certified in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* other than for the purpose of evaluation of new high power rocket motor technology by a recognized national user organization or an authority having jurisdiction, provided that all other requirements of this code are met and all activities are in accordance with applicable laws, regulations, and ordinances.

(6) Selling, offering for sale, exposing for sale, purchasing, making, or using fuses, wicks, or other ignition devices intended to be activated by a handheld flame for the purpose of starting or igniting a high power rocket motor

(7) Affixing to a high power rocket motor or motor reloading kit a statement of compliance with the regulations or a statement of certification required by NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors,* or statements in writing in advertising or on the package that certification according to NFPA 1125 has been obtained, where such certification has not been obtained, has been withdrawn, or has been denied

(8) Reloading or reusing of any expendable, disposable, solid- or hybrid-propellant high

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power rocket motor with any material once the motor has been operated, or reloading of any reloadable, solid- or hybrid-propellant high power rocket motor with any material or by any means not specifically certified

(9) Selling or transfer of a high power rocket motor or motor reloading kit to any person who is not a certified user, other than the transfer of a single high power rocket motor or motor reloading kit for the purpose of user certification

(10) Possession, storage, or use of a high power rocket motor or motor reloading kit by any person who is not a certified user, other than the possession, storage, or use of a single high power rocket motor or motor reloading kit for the purpose of user certification

(11) Participation by persons in prepping or launching of high power rockets, including spectators in the prepping areas, who have consumed alcohol, narcotics, medication, or drugs that could affect judgment, movement, or stability

(12) Transportation of high power rocket motors, motor reloading kits, or modules in a manner contrary to the regulations of 49 CFR, Part 178, U.S. Department of Transportation

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

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A.3.2.3 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A.3.2.5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.4 Certified Motor. Recognized testing organizations that certify high power rocket motors include, but are not limited to, Tripoli Rocketry Association, Inc., the National Association of Rocketry, and their successor organizations.

A.3.3.5 Certified User. A certified user includes, but is not limited to, an individual who has licenses or certificates from Tripoli Rocketry Association, Inc., the National Association of Rocketry, or their successor organizations.

A.3.3.14 Range Safety Officer (RSO). At a high power rocket launch with only one certified user, the certified user also acts as the range safety officer.

A.3.3.19 Skyrockets or Rockets with Sticks. Such fireworks rockets are classified as Class 1.3G or 1.4G explosives in accordance with 49 CFR U.S. Department of Transportation regulations.

A.4.5.1 For a list of commercially manufactured, certified high power rocket motors or motor reloading kits or motor components, the person can check with the authority having jurisdiction. In some instances, the authority having jurisdiction utilizes lists maintained by the Tripoli Rocketry Association and the National Association of Rocketry or their successor organization(s).

A.4.10.3 It is recommended that disposable recovery wadding be biodegradable to address environmental concerns.

A.4.11.1 The requirement of 4.11.1 is not intended to include ejection or staging devices required for the proper operation of the high power rocket.

A.4.14 First-aid facilities or medical help suitable to the number of participants and spectators at the launch site and the maximum size, weight, and power of the rockets operated should be made available.

Annex B Informational References

B.1 Referenced Publications.

The following documents or portions thereof are referenced within this code for informational purposes only and are thus not part of the requirements of this document unless also listed in Chapter 2.

B.1.1 NFPA Publications. (Reserved)

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B.1.2 Other Publications.

B.1.2.1 NAR Publication. National Association of Rocketry, P.O. Box 177, 1311 Edgewood Drive, Altoona, WI 54720 (www.nar.org).

List of Certified High-Power Rocket Motors.

B.1.2.2 TRA Publication. Tripoli Rocketry Association, P.O. Box 970010, Orem, UT 84097 (www.tripoli.org).

List of Certified High-Power Rocket Motors.

B.1.2.3 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Title 49, *Code of Federal Regulations*.

B.2 Informational References. (Reserved)

B.3 References for Extracts.

The following documents are listed here to provide reference information, including title and edition, for extracts given throughout this code as indicated by a reference in brackets [ ] following a section or paragraph. These documents are not a part of the requirements of this document unless also listed in Chapter 2 for other reasons.

NFPA 1122, *Code for Model Rocketry*, 2002 edition.

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NFPA 1127

Code for

High Power Rocketry

2008 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex D. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex D.

Chapter 1 Administration

1.1 Scope. (Reserved)

1.2 Purpose.

1.2.1 The purpose of this code shall be to establish guidelines for reasonably safe operation of high power rockets to protect the user and the public.

1.2.2 The purpose of this code shall be to discourage the following to minimize deaths and injuries:

(1) Experiments with explosive or highly energetic rocket propellants
(2) Construction of homemade rocket propulsion motors
(3) Attempted launches or operation of homemade rocket devices

1.3 Application. This code shall apply to the design, construction, limitation of rocket propellant mass and power, and reliability of high power rocket motors and motor components produced commercially for sale or for use by a certified user for education, recreation, and sporting competition.

1.3.1 This code also shall apply to the design and construction of high power rockets propelled by the high power rocket motors specified in Section 1.3.

1.3.2 This code shall apply to the conduct of launch operations of high power rockets specified in 1.3.1.

1.3.3 This code shall not apply to the design, construction, production, manufacture, fabrication, maintenance, launch, flight, test, operation, use, or other activity connected with a rocket or rocket motor where carried out or engaged in by the following entities:

(1) National, state, or local government
(2) An individual, a firm, a partnership, a joint venture, a corporation, or other business entity engaged as a licensed business in the research, development, production, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, or rocket components or parts
(3) College or university

1.3.4 This code shall not apply to the design, construction, fabrication, production, manufacture, maintenance, launch, flight, test, operation, or use of rocket-propelled model aircraft that sustain their mass against the force of gravity by aerodynamic lifting surfaces for the duration of their flight in air, but shall apply to high power rocket motors and their components that provide propulsion for such model aircraft.

1.3.5 This code shall not apply to model or toy rockets propelled by pressurized liquid.

1.3.6 This code shall not apply to the following:

(1) Model rockets as specified in NFPA 1122, *Code for Model Rocketry*
(2) Fireworks rockets, skyrockets, and rockets with sticks as defined in NFPA 1123, *Code for Fireworks Display*, or NFPA 1126, *Standard for the Use of Pyrotechnics Before a Proximate Audience*

1.4 Enforcement. This code shall be administered and enforced by the authority having jurisdiction (AHJ) designated by the governing authority. *(See Annex C for sample wording for enabling legislation.)*

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this code and shall be considered part of the requirements of this document

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 1122, *Code for Model Rocketry*, 2008 edition.

NFPA 1123, *Code for Fireworks Display*, 2006 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, 2007 edition.

NFPA 1126, *Standard for the Use of Pyrotechnics Before a Proximate Audience*, 2006 edition.

2.3 Other Publications.

2.3.1 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.

Title 14, Code of Federal Regulations, Chapter 1, Subchapter F, Part 101, Paragraphs 101.1–101.25, "Federal Aviation Administration Regulations," or revisions or amendments thereto.

Title 27, Code of Federal Regulations, Part 55, Subpart H, Section 55.1.4.1, "Commerce in Explosives."

Title 49, Code of Federal Regulations, Part 178, "Specifications for Packagings."

Title 49, United States Code, Section 1348, 72 Statute 749, Section 307, "Airspace Control and Facilities."

2.3.2 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 495, *Explosive Materials Code*, 2006 edition.

NFPA 1122, *Code for Model Rocketry*, 2008 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, 2007 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this code. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3* Code. A standard that is an extensive compilation of provisions covering broad subject matter or that is suitable for adoption into law independently of other codes and standards.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.5* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.6 Shall. Indicates a mandatory requirement.

3.2.7 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Area.

3.3.1.1 *Launch Site Parking Area.* An area designated by the range safety officer for parking spectator vehicles.

3.3.1.2 *Launching Area.* An area designated by the range safety officer in which high power rockets are placed on a launching device and ignited.

3.3.1.3 *Prepping Area.* An area designated by the range safety officer where high power rockets and high power rocket motors are prepared for launch.

3.3.1.4 *Recovery Area.* An area designated by the range safety officer for the recovery of high power rockets.

3.3.1.5 *Spectator Area.* An area designated by the range safety officer where spectators view a high power rocket launch.

3.3.2 Arm. To render an igniter from a safe (no energy) condition to a ready-to-fire condition.

3.3.3* Certified Motor. A commercially manufactured rocket motor that has been certified by a recognized testing organization, acceptable to the authority having jurisdiction, to meet the certification requirements set forth in NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors.*

3.3.4* Certified User. An individual, a distributor, or a seller who has been tested or otherwise examined by a recognized organization that is acceptable to the authority having jurisdiction and has been found to be qualified to purchase, possess, and use high power rocket motors.

3.3.5 Commercial Manufacturer. Any individual, firm, partnership, joint venture, corporation, or other business entity engaged in research, development, production, preparation, testing, maintenance, or supply of rockets, rocket motors, rocket propellant chemicals, rocket propellant, delay or ejection modules, or rocket components or parts.

3.3.6 Flight Cylinder. A high-pressure container used in a hybrid rocket motor system to contain pressurized liquid or gas.

3.3.6.1 *Sealed Flight Cylinder.* A flight cylinder used in a hybrid rocket motor system into which the pressurized liquid or gas can be loaded prior to launch and stored for an indefinite period.

3.3.6.2 *Vented Flight Cylinder.* A flight cylinder used in a hybrid rocket motor system that continuously vents the pressurized liquid or gas to the atmosphere during the motor fill and ignition procedures.

3.3.7 Inhabited Building. Any building or structure regularly used in whole or part as a place of human habitation. **[495, 2006]**

3.3.8 Installed Total Impulse. The combined total impulses of all rocket motors installed in a rocket and intended to be ignited during the launch and flight of the rocket.

3.3.9 Launch Site. An area used for high power rocket activities that includes (1) a prepping area(s), (2) a launching area(s), (3) a recovery area(s), (4) a spectator area(s), and (5) a spectator parking area(s).

3.3.10 Module. A pyrotechnic component of a hybrid or solid propellant reloadable rocket motor in which the chemical composition is loaded into a finished assembly by the manufacturer.

3.3.11 Motor Reloading Kit. A product manufactured by a commercial manufacturer that contains the components and parts used to reload and reuse a reloadable rocket motor casing.

3.3.12* Range Safety Officer (RSO). A certified user with overall responsibility for the safety, setup, and launching of all rockets at a high power rocket launch.

3.3.13 Rocket. A device that ascends into the air without use of aerodynamic lifting forces acting against gravity and that is propelled by one or more rocket motors.

3.3.13.1 ***High Power Rocket.*** A rocket vehicle that (1) is propelled by one or more high power rocket motors; or (2) is propelled by a combination of model rocket motors having an installed total impulse of more than 320 N-sec (71.9 lb-sec); or (3) is propelled by a combination of model rocket motors having more than a total of 125 g (4.4 oz) of propellant weight; or (4) weighs more than 1500 g (53 oz) with motor(s) installed.

3.3.13.1.1 ***Complex High Power Rocket.*** A high power rocket that is multistaged or propelled by two or more rocket motors.

3.3.13.2 ***Model Rocket.*** A rocket that (1) weighs more than 1500 g (53 oz) with motors installed; and (2) is propelled by one or more model rocket motors having an installed total impulse of no more than 320 N-sec (71.9 lb-sec); and (3) contains no more than a total of 125 g (4.4 oz) of propellant weight. [**1122,** 2008]

3.3.14 Rocket Engine. See 3.3.15, Rocket Motor.

3.3.15 Rocket Motor. A device containing propellant that provides the force or thrust to cause a rocket to move. [**1122,** 2008]

3.3.15.1 ***High Power Rocket Motor.*** A rocket motor that has more than 160 N-sec (36 lb-sec) but no more than 40,960 N-sec (9208 lb-sec) of total impulse, or that produces an average thrust of greater than 80 N (18 lbf), or that contains greater than 62.5 g (2.2 oz) of propellant. [**1125,** 2007]

3.3.15.2 ***Hybrid Rocket Motor.*** A rocket motor that utilizes a fuel and an oxidizer in different physical states (solid, liquid, or gaseous).

3.3.15.3 ***Model Rocket Motor.*** A rocket motor that has a total impulse of no greater than 160 N-sec (36 lb-sec), an average thrust of no greater than 80 N (18 lbf), and a propellant weight of no greater than 62.5 g (2.2 oz).

3.3.15.4 ***Reloadable Rocket Motor.*** A rocket motor that has been designed and manufactured so that the user can load, reload, and reuse the pressure-containing body or casing using the parts and components of a motor reloading kit. [**1125,** 2007]

3.3.15.5 ***Solid-Propellant Rocket Motor.*** A rocket motor that contains a fuel and an oxidizer in solid form and whose force or thrust is produced by the combustion of the fuel and oxidizer.

3.3.16 Rocket Propellant. The material(s) utilized in a rocket motor that produces thrust by the discharge of a working fluid generated by combustion, decomposition, change of state, or other operation of such material contained within the rocket motor.

3.3.17 Safety Monitor. See 3.3.12, Range Safety Officer (RSO).

3.3.18* Skyrockets or Rockets with Sticks. Commercially manufactured fireworks rockets not intended for reuse.

3.3.19 Spectator. A nonparticipant whose primary purpose is to view a rocket launch.

Chapter 4 Requirements for High Power Rocket Construction and Operation

4.1 Range Safety Officer Requirements and Responsibilities.

4.1.1 The RSO shall have knowledge of NFPA 1127, *Code for High Power Rocketry.*

4.1.2 The RSO shall possess the technical competency of high power rocketry safety as determined by the AHJ.

4.1.3 The RSO shall have the authority to intervene and control any safety aspect of a high power rocket launch when, in his or her judgment, a potential or actual danger, accident, or unsafe condition exists.

4.2 User Certification. Only a certified user shall be permitted to launch a high power rocket.

4.3 Operating Clearances. High power rockets shall only be launched in compliance with the following:

(1) This code
(2) Title 49, United States Code, Section 1348, 72 Statute 749, Section 307, "Airspace Control and Facilities," Federal Aviation Act of 1958, from 14 CFR 101, "Federal Aviation Administration Regulations," or later revisions or amendments thereto
(3) Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances

4.4 Preflight Inspection.

4.4.1 A high power rocket shall be inspected by the RSO to determine whether it meets the provisions of this code.

4.4.2 A high power rocket shall not be launched if the RSO determines that it does not meet the provisions of this code.

4.5 High Power Rocket Motors and Motor Components.

4.5.1* Only certified high power rocket motors or motor reloading kits or motor components shall be used in a high power rocket.

4.5.2 A single-use high power rocket motor shall not be dismantled, reloaded, or altered.

4.5.3 The components of a reloadable high power rocket motor shall not be altered.

4.5.4 A high power rocket motor or its components shall not be used in a manner or for a purpose other than that specified by the high power rocket motor manufacturer in the instructions.

4.5.5 Warning and other labels applied on the flight cylinder of a hybrid rocket motor shall not be removed.

4.5.6 Vented flight cylinders of a hybrid rocket motor shall be filled and unloaded at a distance equal to or greater than that shown for their motor class in Table 4.16.3.

4.5.7 A package containing a high power motor reloading kit shall not be opened until the user is ready to install the motor reloading kit parts, including the rocket propellant module(s), in the reloadable high power rocket motor casing.

4.6 Rocket Construction. A high power rocket shall be constructed to withstand the operating stresses and retain structural integrity under the conditions encountered during flight.

4.7 Rocket Airframe Materials. A high power rocket intended to be propelled by one or more high power rocket motors shall be constructed using lightweight materials such as paper, wood, rubber, plastic, fiberglass, or, when necessary, ductile metal so that the rocket conforms to the other requirements of this code.

4.8 Stability. The stability of a high power rocket shall be checked by its user prior to launch.

4.8.1 If requested by the RSO, the user shall provide documentation of the location of the center of pressure and the center of gravity of the high power rocket.

4.8.2 If the stability of the rocket cannot be determined, or if the rocket is determined to be unstable, it shall not be launched.

4.9 Weight and Power Limits.

4.9.1 The maximum liftoff weight of a high power rocket shall not exceed one-third (⅓) of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

4.9.2 A high power rocket shall be launched with any combination of motors having 40,960 N-sec (9208 lb-sec) of total impulse or less.

4.10 Recovery.

4.10.1 A high power rocket shall be launched only if it contains a recovery system that is designed to return all parts of the rocket to the ground intact and at a landing speed at which the rocket does not present a hazard.

4.10.2 A high power rocket launched with an installed total impulse greater than 2560 N-sec (576 lb-sec) shall use an electronically actuated recovery system as either a primary or backup deployment method.

4.10.3* The person who prepares the high power rocket for flight shall install only flame-resistant recovery wadding if the design of the rocket necessitates the use of wadding.

4.10.4 No attempt shall be made to catch a high power rocket as it approaches the ground.

4.10.5 No attempt shall be made to retrieve a high power rocket from a power line or other life-threatening area.

4.10.6 If a high power rocket becomes entangled in a power line, the utility company or other appropriate authority shall be notified.

4.11 Payloads.

4.11.1* A high power rocket shall not carry a flammable or explosive payload.

4.11.2 No high power rocket shall be used to launch a vertebrate animal.

4.12 Launching Devices.

4.12.1 A high power rocket shall be launched from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a predictable flight path.

4.12.1.1* When the wind at launch exceeds 5 mph, the launch guidance device shall be of a length to ensure that the rocket reaches a safe speed before its departure from the device.

4.12.2 The launching device shall incorporate a jet deflector if necessary to prevent the rocket motor exhaust from impinging directly on flammable materials.

4.12.3 A launching device shall not be used to launch a high power rocket at an angle greater than 20 degrees from vertical.

4.13 Ignition Systems.

4.13.1 A high power rocket shall be launched using an ignition system that is remotely controlled, is electrically operated, and contains a launching switch that returns to the "off" position when released.

4.13.2 The ignition system shall contain a removable safety interlock device in series with the launch switch.

4.13.3 The launch system and igniter combination shall be designed, installed, and operated so that liftoff of the rocket occurs within 3 seconds of actuation of the launch system.

4.13.4 If the rocket is to be propelled by a cluster of rocket motors designed to be ignited simultaneously, the ignition scheme that is used shall have been previously tested or proven capable of igniting all rocket motors intended for launch ignition within 1 second following ignition system activation.

4.13.5 An ignition device shall be installed in a high power rocket motor only at the launcher or within the prepping area.

4.13.6 A high power rocket shall be pointed away from the spectator area and other groups of people during and after installation of the ignition device.

4.13.7 Firing circuits shall not be armed with the rocket in other than a launching position.

4.14* Launch Site.

4.14.1 A high power rocket shall be launched only in an outdoor area where tall trees, power lines, buildings, and persons not involved in the rocket launch do not present a hazard.

4.14.2 The minimum dimensions of the launch site shall be the greater of the following:

(1) Not less than one-half the maximum altitude expected, calculated, or simulated, or as granted by an FAA waiver or the AHJ
(2) 457 m (1500 ft) or twice the minimum spectator and participant distance specified in Table 4.16.3, whichever is greater, for any rocket that is flown

4.14.2.1 For a circular area, the minimum launch site dimension shall be the diameter in meters (feet).

4.14.2.2 For a rectangular area, the minimum launch site dimension shall be the shortest side in meters (feet).

4.14.3 Fire suppression devices and first aid kits shall be located at the launch site during the launch of a high power rocket.

4.15 Launcher Location.

4.15.1 The area that encircles a launch pad shall be cleared of brown grass, dry weeds, and other easy-to-burn materials for a diameter equal to at least that specified in Table 4.15.1.

4.15.2 For a high power rocket using a motor(s) with titanium sponge, the minimum clear distance shall be multiplied by a factor of 1.5.

4.15.3 The high power rocket launching area shall be located at least 457 m (1500 ft) or the minimum spectator and participant distance for the largest high power rocket permitted to be flown, whichever is greater, from the following locations:

Table 4.15.1 Launcher Clear Distances

Installed Total Impulse		Launcher Equivalent Motor Type	Minimum Clear Distance	
N-sec	lb-sec		m	ft
0.00–160.00	0.00–36.00	G or smaller	0	0
160.01–320.00	36.01–72.00	H	15	50
320.01–640.00	72.01–144.00	I	15	50
640.01–1,280.00	144.01–288.00	J	15	50
1,280.01–2,560.00	288.01–576.00	K	23	75
2,560.01–5,120.00	576.01–1151.00	L	30	100
5,120.01–10,240.00	1151.01–2302.00	M	38	125
10,240.01–20,480.00	2302.01–4604.00	N	38	125
20,480.01–40,960.00	4604.01–9208.00	O	38	125

(1) An inhabited building that is occupied
(2) A public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch

4.15.4 The high power rocket launching area shall be located no closer to any boundary of the launch site than the minimum spectator and participant distance specified in Table 4.16.3 for the largest high power rocket to be flown.

4.16 Spectator and Participant Distances.

4.16.1* All spectators shall remain within an area determined to be safe by the RSO, with respect to the prevailing wind conditions and types of rockets to be flown.

4.16.2 All spectators shall remain behind the RSO and the person launching the rocket.

4.16.3 No person shall be permitted to be at a location that is closer to the launch of a high power rocket than the applicable minimum spectator and participant distance set forth in Table 4.16.3, except as allowed in 4.16.3.1.

4.16.3.1 If the launch system or flight requires, the RSO shall be permitted to allow launch personnel to be no closer than one-half of the distance set forth in Table 4.16.3 or 152 m (500 ft), whichever is greater.

4.16.4 Parking area distance shall be equal to at least the spectator and participant distance set forth in Table 4.16.3.

4.17 Launch Operations.

4.17.1 No person shall ignite and launch a high power rocket horizontally, at a target, or so that the rocket's flight path during ascent phase is intended to go into clouds, directly over the heads of spectators, or beyond the boundaries of the launch site, or so that the rocket's recovery is likely to occur in spectator areas or outside the boundaries of the launch site.

4.17.2 No person shall launch a high power rocket if the surface wind at the launcher is more than 32 km/h (20 mph).

4.17.3 No person shall operate a high power rocket in a manner that is hazardous to aircraft.

4.18 Launch Control.

4.18.1 A high power rocket shall be launched only with the knowledge, permission, and attention of the RSO, and only under conditions where all the requirements of this code have been met.

4.18.2 Except for those individuals with mobility restrictions, all persons in the launching, prepping, spectator, and parking areas during a countdown and launch shall stand and face the launcher if requested to do so by the RSO.

4.18.3 The launching of a high power rocket shall be preceded by a 5-second countdown that is audible throughout the launching, spectator, and parking areas.

Table 4.16.3 Minimum Spectator and Participant Distance (Complex High Power Rocket)

Installed Total Impulse		Equivalent Motor Type	Minimum Spectator and Participant Distance		Minimum Spectator and Participant Distance (Complex Rocket)	
N-sec	lb-sec		m	ft	m	ft
0.00–160.00	0.00–36.00	G or smaller	3	10	9	30
160.01–320.00	36.01–72.00	H	30	100	61	200
320.01–640.00	72.01–144.00	I	30	100	61	200
640.01–1,280.00	144.01–288.00	J	30	100	61	200
1,280.01–2,560.00	288.01–576.00	K	61	200	91	300
2,560.01–5,120.00	576.01–1151.00	L	91	300	152	500
5,120.01–10,240.00	1151.01–2302.00	M	152	500	305	1000
10,240.01–20,480.00	2302.01–4604.00	N	305	1000	457	1500
20,480.01–40,960.00	4604.01–9208.00	O	457	1500	610	2000

4.18.3.1 A system shall be provided that permits the RSO to immediately warn all participants and spectators of rocket flight event anomalies that present a hazard to them.

4.18.4 A high power rocket that has misfired shall not be approached until all of the following have occurred:

(1) The safety interlock has been engaged.
(2) One (1) minute has passed.
(3) The RSO has given permission for one person to approach the misfired rocket to inspect it.

4.19 Storage of High Power Rocket Motors, Motor-Reloading Kits, and Pyrotechnic Modules.

4.19.1 High power rocket motors, motor reloading kits, and pyrotechnic modules shall be stored at least 7.6 m (25 ft) from smoking, open flames, and other sources of heat.

4.19.2 Not more than 23 kg (50 lb) of net rocket propellant weight of high power rocket motors, motor reloading kits, or pyrotechnic modules subject to the storage requirements of 27 CFR 55, "Commerce in Explosives," shall be stored in a Type 3 or a Type 4 indoor magazine.

4.19.2.1 The indoor magazine shall be painted red, and the top shall bear the following words in white letters at least 76 mm (3 in.) high:

EXPLOSIVES — KEEP FIRE AWAY

4.19.2.2 The indoor magazine shall not be located in a residence.

4.19.2.3 The indoor magazine shall be permitted to be located in a detached garage or outbuilding.

4.19.2.4 The indoor magazine shall be permitted to be located in an attached garage in a single-family residence, where approved by the AHJ and the Bureau of Alcohol, Tobacco, Firearms, and Explosives.

4.19.2.5 Pyrotechnic high power solid-propellant rocket motors, motor reloading kits, modules, or any other solid-propellant motor products that are exempt under 27 CFR 55, "Commerce in Explosives," shall be stored in a reclosable, noncombustible container.

4.19.3 Large-quantity storage shall comply with both of the following requirements:

(1) Quantities greater than 22.7 kg (50 lb) of net rocket propellant weight of high power rocket motors, motor reloading kits, or pyrotechnic modules subject to the storage requirements of 27 CFR 55, "Commerce in Explosives," shall be stored in a Type 4 or greater outdoor magazine.
(2) The Type 4 or greater magazine shall meet the distance requirements in Table 4.19.3.

4.19.4 High power rocket motors, motor reloading kits, and pyrotechnic modules shall be stored in accordance with all applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.

4.19.5 A high power rocket motor shall not be stored with an ignition element installed.

Chapter 5 High Power Rocket Motor User Certification

5.1 Sales Only to Certified Users. A high power rocket motor or motor reloading kit shall be sold to, shipped to, stored by, and used only by certified users.

5.2 User Permit Requirements. Where required by 27 CFR 55, "Commerce in Explosives," a "User of Low Explosives Permit" shall be obtained prior to both of the following:

(1) Acquisition by a certified user of a high power solid-propellant rocket motor(s) or motor reloading kit(s) in a state other than that in which the user resides
(2) Transportation by a certified user of a high power solid-propellant rocket motor(s) or motor reloading kit(s) to a state other than that in which the user resides

5.3 Maintenance of Sales Records.

5.3.1 High power rocket motor manufacturers, distributors, and sellers shall maintain a list of those certified users to

Table 4.19.3 Storage Distances for Low Explosives

Weight Over		Weight Not Over		Distance from Inhabited Building		Distance from Public Railroad and Highway		Distance from Aboveground Magazine	
kg	lb	kg	lb	m	ft	m	ft	m	ft
0	0	454	1,000	23	75	23	75	15	50
454	1,000	2,268	5,000	35	115	35	115	23	75
2,268	5,000	45,36	10,000	46	150	46	150	30	100
4,536	10,000	90,72	20,000	58	190	58	190	38	125
9,072	20,000	13,608	30,000	66	215	66	215	44	145
13,608	30,000	18,144	40,000	72	235	72	235	47	155
18,144	40,000	22,680	50,000	76	250	76	250	50	165
22,680	50,000	27,216	60,000	79	260	79	260	53	175
27,216	60,000	31,751	70,000	82	270	82	270	56	185
31,751	70,000	36,287	80,000	85	280	85	280	58	190
36,287	80,000	40,823	90,000	90	295	90	295	59	195
40,823	90,000	45,360	100,000	91	300	91	300	61	200
45,360	100,000	90,718	200,000	114	375	114	375	76	250
90,718	200,000	136,078	300,000	137	450	137	450	91	300

Source: Table is extracted from 27 CFR 55, "Commerce in Explosives" (BATF regulations for the storage of explosive materials).

whom they have sold high power rocket motors or motor reloading kits that includes the following information:

(1) Name and address of the purchaser
(2) Name and address of the national user organization that has certified the user
(3) Type and number of high power solid-propellant rocket motors or motor reloading kits sold to the certified user
(4) Date of sale and shipment of high power rocket motors or motor reloading kits to the certified user

5.3.2 The manufacturer, distributor, or seller shall make available, on request, the records specified in 5.3.1 to any law enforcement person or the AHJ.

5.3.3 The records specified in 5.3.1 shall be kept for 5 years from the date of sale.

5.4 User Certification Provisions.

5.4.1 Certification of a user shall require both of the following:

(1) Proof that the user is at least 18 years old
(2) Proof that the user possesses a level of knowledge and competence in handling, storing, and using a high power solid-propellant rocket motor and high power rockets that is acceptable to the certifying organization

5.4.2 The certifying organization shall maintain a list of all persons it has certified as high power rocket motor users.

5.4.2.1 The list of certified users shall be updated not less than once every 30 days.

5.4.2.2 Upon request and receipt of applicable fees, if any, confirmation of an active member's user certification shall be provided to the following:

(1) Law enforcement official or AHJ
(2) Manufacturer of high power rocket motors and motor reload kits
(3) Retailer licensed to sell, distribute, or offer for sale high power rocket motors and motor reloading kits

Chapter 6 Prohibited Activities

6.1 Prohibited Acts. The following activities shall be prohibited by this code:

(1) Use of a high power rocket motor for the primary purpose of producing a spectacular display of color, light, sound, or any combination thereof, other than the addition of chemical additives to the rocket propellant for the purpose of producing brightly colored exhaust plume, spark, or smoke effects
(2) Use of a high power rocket or high power rocket motor as a weapon or against a target
(3) Tampering with or using a high power rocket motor, motor reloading kit, or module in a manner or to an extent that is contrary to the purpose for which the high power rocket motor or motor reloading kit is designed and intended to be used
(4) Selling, offering for sale, exposing for sale, or making available a rocket motor or motor reloading kit that does not comply with the requirements of this code and that has not been certified in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*
(5) Making, operating, launching, flying, testing, activating, discharging, or otherwise experimenting with high power rocket motors, motor reloading kits, or pyrotechnic modules that have not been certified in accordance with NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, other than for the purpose of evaluation of new high power rocket motor technology by a recognized national user organization or an AHJ, provided that all other requirements of this code are met and all activities are in accordance with applicable laws, regulations, and ordinances.
(6) Selling, offering for sale, exposing for sale, purchasing, making, or using fuses, wicks, or other ignition devices intended to be activated by a handheld flame for the purpose of starting or igniting a high power rocket motor
(7) Affixing to a high power rocket motor or motor reloading kit a statement of compliance with the regulations or a statement of certification required by NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, or statements in writing in advertising or on the package that certification according to NFPA 1125 has been obtained, where such certification has not been obtained, has been withdrawn, or has been denied
(8) Reloading or reusing of any expendable, disposable, solid- or hybrid-propellant high power rocket motor with any material once the motor has been operated, or reloading of any reloadable, solid- or hybrid-propellant high power rocket motor with any material or by any means not specifically certified
(9) Selling or transfer of a high power rocket motor or motor reloading kit to any person who is not a certified user, other than the transfer of a single high power rocket motor or motor reloading kit for the purpose of user certification
(10) Possession, storage, or use of a high power rocket motor or motor reloading kit by any person who is not a certified user, other than the possession, storage, or use of a single high power rocket motor or motor reloading kit for the purpose of user certification
(11) Participation by persons in prepping or launching of high power rockets, including spectators in the prepping areas, who have consumed alcohol, narcotics, medication, or drugs that could affect judgment, movement, or stability
(12) Transportation of high power rocket motors, motor reloading kits, or modules in a manner contrary to the regulations of 49 CFR 178, "Specifications for Packagings," U.S. Department of Transportation

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations, procedures, equipment, or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The authority having jurisdiction may also refer to the listings or labeling practices of an

organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.3 Code. The decision to designate a standard as a "code" is based on such factors as the size and scope of the document, its intended use and form of adoption, and whether it contains substantial enforcement and administrative provisions.

A.3.2.5 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

A.3.3.3 Certified Motor. Recognized testing organizations that certify high power rocket motors include, but are not limited to, Tripoli Rocketry Association, Inc., the National Association of Rocketry, and their successor organizations.

A.3.3.4 Certified User. A certified user includes, but is not limited to, an individual who has licenses or certificates from Tripoli Rocketry Association, Inc., the National Association of Rocketry, or their successor organizations.

A.3.3.12 Range Safety Officer (RSO). At a high power rocket launch with only one certified user, the certified user also acts as the RSO.

A.3.3.18 Skyrockets or Rockets with Sticks. Such fireworks rockets are classified as Class 1.3G or 1.4G explosives in accordance with 49 CFR 173.50, U.S. Department of Transportation regulations.

A.4.5.1 For a list of commercially manufactured, certified high power rocket motors or motor reloading kits or motor components, the person can check with the AHJ. In some instances, the AHJ utilizes lists maintained by the Tripoli Rocketry Association, Inc., the National Association of Rocketry, or their successor organization(s).

A.4.10.3 It is recommended that disposable recovery wadding be biodegradable to address environmental concerns.

A.4.11.1 The requirement of 4.11.1 is not intended to include ejection or staging devices required for the proper operation of the high power rocket.

A.4.12.1.1 As a rocket leaves the launch device, it is subject to wind-induced aerodynamic factors that increase the chance of unstable flight. The effects of these factors can be mitigated by ensuring that the typical rocket leaves the launcher at a velocity of 3 to 4 times the maximum wind speed prevailing at the time of launch.

A.4.14 First-aid facilities or medical help suitable to the number of participants and spectators at the launch site and the maximum size, weight, and power of the rockets operated should be made available.

A.4.16.1 Computer simulation and practice has shown that positioning of spectators cross-wind from the launching area is an effective method to mitigate impact risk due to recovery anomalies.

Annex B *High Power Rocket Safety Code* of the National Association of Rocketry

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 The *High Power Rocket Safety Code* provides a concise summary of the specific user safety practices applicable to activities involving launching high power rockets.

High Power Rocket Safety Code
National Association of Rocketry
Adopted July 2006

1. Certification. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.

2. Materials. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.

3. Motors. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 ft of these motors.

4. Ignition System. I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. If my rocket has onboard ignition systems for motors or recovery devices, these will have safety interlocks that interrupt the current path until the rocket is at the launch pad.

5. Misfires. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.

6. Launch Safety. I will use a 5-second countdown before launch. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table, and that a means is available to warn participants and spectators in the event of a problem. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable.

7. Launcher. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 mph I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the

ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 if the rocket motor being launched uses titanium sponge in the propellant.

8. Size. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 lb-sec) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

9. Flight Safety. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 mph. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. Launch Site. I will launch my rocket outdoors, in an open area where trees, power lines, buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 ft, whichever is greater.

11. Launcher Location. My launcher will be at least one half the minimum launch site dimension, or 1500 ft (whichever is greater) from any inhabited building, or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. Recovery System. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. Recovery Safety. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground. *(See Table B.1.)*

Annex C Sample Ordinance Adopting NFPA 1127

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 The following sample ordinance is provided to assist a jurisdiction in the adoption of this code and is not part of this code.

ORDINANCE NO. _____

An ordinance of the *[jurisdiction]* adopting the *[year]* edition of NFPA *[document number]*, *[complete document title]*, and documents listed in Chapter 2 of that *[code, standard]*; prescribing regulations governing conditions hazardous to life and property from fire or explosion; providing for the issuance of permits and collection of fees; repealing Ordinance No. _____ of the *[jurisdiction]* and all other ordinances and parts of ordinances in conflict therewith; providing a penalty; providing a severability clause; and providing for publication; and providing an effective date.

BE IT ORDAINED BY THE *[governing body]* OF THE *[jurisdiction]*:

SECTION 1 That the *[complete document title]* and documents adopted by Chapter 2, three (3) copies of which are on file and are open to inspection by the public in the office of the [jurisdiction's keeper of records] of the [jurisdiction], are hereby adopted and incorporated into this ordinance as fully as if set out at length herein, and from the date on which this ordinance shall take effect, the provisions thereof shall be controlling within the limits of the *[jurisdiction]*. The same are hereby adopted as the *[code, standard]* of the *[jurisdiction]* for the purpose of prescribing regulations governing conditions hazardous to life and property from fire or explosion and providing for issuance of permits and collection of fees.

SECTION 2 Any person who shall violate any provision of this code or standard hereby adopted or fail to comply therewith; or who shall violate or fail to comply with any order made thereunder; or who shall build in violation of any detailed statement of specifications or plans submitted and approved thereunder; or fail to operate in accordance with any certificate or permit issued thereunder; and from which no appeal has been taken; or who shall fail to comply with such an order as affirmed or modified by a court of competent jurisdiction, within the time fixed herein, shall severally for each and every such violation and noncompliance, respectively, be guilty of a misdemeanor, punishable by a fine of not less than $ _____ nor more than $_____ or by imprisonment for not less than _____ days nor more than _____ days or by both such fine and imprisonment. The imposition of one penalty for any violation shall not excuse the violation or permit it to continue; and all such persons shall be required to correct or remedy such violations or defects within a reasonable time; and when not otherwise specified the application of the above penalty shall not be held to prevent the enforced removal of prohibited conditions. Each day that prohibited conditions are maintained shall constitute a separate offense.

SECTION 3 Additions, insertions, and changes — that the *[year]* edition of NFPA *[document number]*, *[complete document title]* is amended and changed in the following respects:

List Amendments

SECTION 4 That ordinance No. _____ of *[jurisdiction]* entitled *[fill in the title of the ordinance or ordinances in effect at the present time]* and all other ordinances or parts of ordinances in conflict herewith are hereby repealed.

SECTION 5 That if any section, subsection, sentence, clause, or phrase of this ordinance is, for any reason, held to be invalid or unconstitutional, such decision shall not affect the validity or constitutionality of the remaining portions of this ordinance. The *[governing body]* hereby declares that it would have passed this ordinance, and each section, subsection, clause, or phrase hereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.

SECTION 6 That the *[jurisdiction's keeper of records]* is hereby ordered and directed to cause this ordinance to be published.

[NOTE: An additional provision may be required to direct the number of times the ordinance is to be published and to specify that it is to be in a newspaper in general circulation. Posting may also be required.]

SECTION 7 That this ordinance and the rules, regulations, provisions, requirements, orders, and matters established and adopted hereby shall take effect and be in full force and effect *[time period]* from and after the date of its final passage and adoption.

Table B.1 Minimum Distance Table

Installed Total Impulse (N-sec)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft)	Minimum Personnel Distance (ft)	Minimum Personnel Distance (Complex Rocket) (ft)
0–320.00	H or smaller	50	100	200
320.01–640.00	I	50	100	200
640.01–1,280.00	J	50	100	200
1,280.01–2,560.00	K	75	200	300
2,560.01–5,120.00	L	100	300	500
5,120.01–10,240.00	M	125	500	1000
10,240.01–20,480.00	N	125	1000	1500
20,480.01–40,960.00	O	125	1500	2000

Note: A complex rocket is one that is multi-staged or that is propelled by two or more rocket motors.
Source: National Association of Rocketry.

Annex D Informational References

D.1 Referenced Publications. The documents or portions thereof listed in this annex are referenced within the informational sections of this code and are not part of the requirements of this document unless also listed in Chapter 2 for other reasons.

D.1.1 NFPA Publications. (Reserved)

D.1.2 Other Publications.

D.1.2.1 NAR Publications. National Association of Rocketry, P.O. Box 407, Marion, IA 52302.
High Power Rocket Safety Code, 2006.

D.1.2.2 U.S. Government Publications. U.S. Government Printing Office, Washington, DC 20402.
Title 49, Code of Federal Regulations, Part 173.50.

D.2 Informational References.

D.2.1 NAR Publications. National Association of Rocketry, P.O. Box 407, Marion, IA 52302.
Comprehensive CAR/NAR/TRA Rocket Motor Certification List.

D.2.2 TRA Publications. Tripoli Rocketry Association, Inc., P.O. Box 970010, Orem, UT 84097.
Comprehensive CAR/NAR/TRA Rocket Motor Certification List.

D.3 References for Extracts in Informational Sections.
NFPA 1122, *Code for Model Rocketry*, 2008 edition.

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David Antaki

Project RP1

Appendix R3
NAR High Power Rocket Safety Code

NAR L1 & L2 Technical Report

June 28th, 2019

HIGH POWER ROCKET SAFETY CODE

1. **Certification**. I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. **Materials**. I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. **Motors**. I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will not allow smoking, open flames, nor heat sources within 25 feet of these motors.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launch pad or in a designated prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. **Misfires**. If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. **Launch Safety**. I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. **Launcher**. I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that dry grass is cleared around each launch pad in accordance with the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.
8. **Size**. My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.

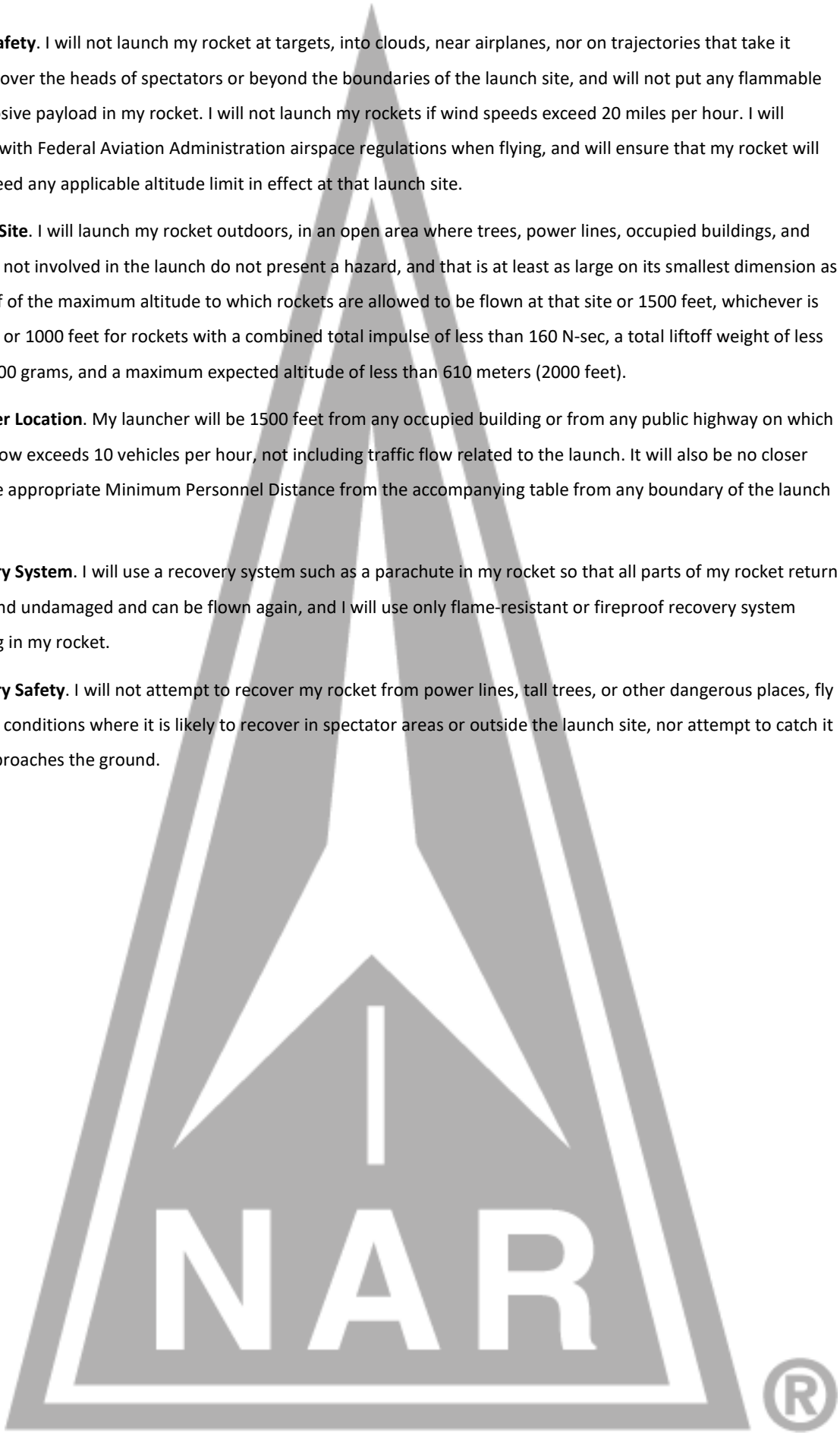
9. **Flight Safety**. I will not launch my rocket at targets, into clouds, near airplanes, nor on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.

10. **Launch Site**. I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).

11. **Launcher Location**. My launcher will be 1500 feet from any occupied building or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.

12. **Recovery System**. I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.

13. **Recovery Safety**. I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it is likely to recover in spectator areas or outside the launch site, nor attempt to catch it as it approaches the ground.



MINIMUM DISTANCE TABLE

Installed Total Impulse (Newton-Seconds)	Equivalent High Power Motor Type	Minimum Diameter of Cleared Area (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 — 320.00	H or smaller	50	100	200
320.01 — 640.00	I	50	100	200
640.01 — 1,280.00	J	50	100	200
1,280.01 — 2,560.00	K	75	200	300
2,560.01 — 5,120.00	L	100	300	500
5,120.01 — 10,240.00	M	125	500	1000
10,240.01 — 20,480.00	N	125	1000	1500
20,480.01 — 40,960.00	O	125	1500	2000

Note: A Complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

Revision of August 2012

David Antaki
Project RP1

Appendix R4
FAA Regulations Part 101

NAR L1 & L2 Technical Report

June 28th, 2019

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Title 14: Aeronautics and Space

PART 101—MOORED BALLOONS, KITES, AMATEUR ROCKETS, UNMANNED FREE BALLOONS, AND CERTAIN MODEL AIRCRAFT

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AUTHORITY: 49 U.S.C. 106(f), 106(g), 40101 note, 40103, 40113-40114, 45302, 44502, 44514, 44701-44702, 44721, 46308, Sec. 336(b), Pub. L. 112-95, 126 Stat. 77.

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Subpart A—General

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§101.1 Applicability.

(a) This part prescribes rules governing the operation in the United States, of the following:

(1) Except as provided for in §101.7, any balloon that is moored to the surface of the earth or an object thereon and that has a diameter of more than 6 feet or a gas capacity of more than 115 cubic feet.

(2) Except as provided for in §101.7, any kite that weighs more than 5 pounds and is intended to be flown at the end of a rope or cable.

(3) Any amateur rocket except aerial firework displays.

(4) Except as provided for in §101.7, any unmanned free balloon that—

(i) Carries a payload package that weighs more than four pounds and has a weight/size ratio of more than three ounces per square inch on any surface of the package, determined by dividing the total weight in ounces of the payload package by the area in square inches of its smallest surface;

(ii) Carries a payload package that weighs more than six pounds;

(iii) Carries a payload, of two or more packages, that weighs more than 12 pounds; or

(iv) Uses a rope or other device for suspension of the payload that requires an impact force of more than 50 pounds to separate the suspended payload from the balloon.

(5) Any model aircraft that meets the conditions specified in §101.41. For purposes of this part, a model aircraft is an unmanned aircraft that is:

(i) Capable of sustained flight in the atmosphere;

(ii) Flown within visual line of sight of the person operating the aircraft; and

(iii) Flown for hobby or recreational purposes.

(b) For the purposes of this part, a *gyroglider* attached to a vehicle on the surface of the earth is considered to be a kite.

[Doc. No. 1580, 28 FR 6721, June 29, 1963, as amended by Amdt. 101-1, 29 FR 46, Jan. 3, 1964; Amdt. 101-3, 35 FR 8213, May 26, 1970; Amdt. 101-8, 73 FR 73781, Dec. 4, 2008; 74 FR 38092, July 31, 2009; Docket FAA-2015-0150, Amdt. 101-9, 81 FR 42208, June 28, 2016]

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§101.3 Waivers.

No person may conduct operations that require a deviation from this part except under a certificate of waiver issued by the Administrator.

[Doc. No. 1580, 28 FR 6721, June 29, 1963]

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§101.5 Operations in prohibited or restricted areas.

No person may operate a moored balloon, kite, amateur rocket, or unmanned free balloon in a prohibited or restricted area unless he has permission from the using or controlling agency, as appropriate.

[Doc. No. 1457, 29 FR 46, Jan. 3, 1964, as amended at 74 FR 38092, July 31, 2009]

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§101.7 Hazardous operations.

(a) No person may operate any moored balloon, kite, amateur rocket, or unmanned free balloon in a manner that creates a hazard to other persons, or their property.

(b) No person operating any moored balloon, kite, amateur rocket, or unmanned free balloon may allow an object to be dropped therefrom, if such action creates a hazard to other persons or their property.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 12800, 39 FR 22252, June 21, 1974, as amended at 74 FR 38092, July 31, 2009]

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Subpart B—Moored Balloons and Kites

SOURCE: Docket No. 1580, 28 FR 6722, June 29, 1963, unless otherwise noted.

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§101.11 Applicability.

This subpart applies to the operation of moored balloons and kites. However, a person operating a moored balloon or kite within a restricted area must comply only with §101.19 and with additional limitations imposed by the using or controlling agency, as appropriate.

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§101.13 Operating limitations.

(a) Except as provided in paragraph (b) of this section, no person may operate a moored balloon or kite—

(1) Less than 500 feet from the base of any cloud;

(2) More than 500 feet above the surface of the earth;

(3) From an area where the ground visibility is less than three miles; or

(4) Within five miles of the boundary of any airport.

(b) Paragraph (a) of this section does not apply to the operation of a balloon or kite below the top of any structure and within 250 feet of it, if that shielded operation does not obscure any lighting on the structure.

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§101.15 Notice requirements.

No person may operate an unshielded moored balloon or kite more than 150 feet above the surface of the earth unless, at least 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation:

(a) The names and addresses of the owners and operators.

(b) The size of the balloon or the size and weight of the kite.

(c) The location of the operation.

(d) The height above the surface of the earth at which the balloon or kite is to be operated.

(e) The date, time, and duration of the operation.

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§101.17 Lighting and marking requirements.

(a) No person may operate a moored balloon or kite, between sunset and sunrise unless the balloon or kite, and its mooring lines, are lighted so as to give a visual warning equal to that required for obstructions to air navigation in the FAA publication “Obstruction Marking and Lighting”.

(b) No person may operate a moored balloon or kite between sunrise and sunset unless its mooring lines have colored pennants or streamers attached at not more than 50 foot intervals beginning at 150 feet above the surface of the earth and visible for at least one mile.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 1580, 28 FR 6722, June 29, 1963, as amended by Amdt. 101-4, 39 FR 22252, June 21, 1974]

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§101.19 Rapid deflation device.

No person may operate a moored balloon unless it has a device that will automatically and rapidly deflate the balloon if it escapes from its moorings. If the device does not function properly, the operator shall immediately notify the nearest ATC facility of the location and time of the escape and the estimated flight path of the balloon.

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Subpart C— Amateur Rockets

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§101.21 Applicability.

(a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with §101.25(b)(7)(ii) and with any additional limitations imposed by the using or controlling agency.

(b) A person operating an unmanned rocket other than an amateur rocket as defined in §1.1 of this chapter must comply with 14 CFR Chapter III.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.22 Definitions.

The following definitions apply to this subpart:

(a) *Class 1—Model Rocket* means an amateur rocket that:

(1) Uses no more than 125 grams (4.4 ounces) of propellant;

(2) Uses a slow-burning propellant;

(3) Is made of paper, wood, or breakable plastic;

(4) Contains no substantial metal parts; and

(5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) *Class 2—High-Power Rocket* means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) *Class 3—Advanced High-Power Rocket* means an amateur rocket other than a model rocket or high-power rocket.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.23 General operating limitations.

(a) You must operate an amateur rocket in such a manner that it:

(1) Is launched on a suborbital trajectory;

(2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;

(3) Is unmanned; and

(4) Does not create a hazard to persons, property, or other aircraft.

(b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008]

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§101.25 Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets.

When operating *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets, you must comply with the General Operating Limitations of §101.23. In addition, you must not operate *Class 2-High Power Rockets* or *Class 3-Advanced High Power* Rockets—

(a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;

(b) At any altitude where the horizontal visibility is less than five miles;

(c) Into any cloud;

(d) Between sunset and sunrise without prior authorization from the FAA;

(e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;

(f) In controlled airspace without prior authorization from the FAA;

(g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:

(1) Not less than one-quarter the maximum expected altitude;

(2) 457 meters (1,500 ft.);

(h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and

(i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

[74 FR 38092, July 31, 2009, as amended by Amdt. 101-8, 74 FR 47435, Sept. 16, 2009]

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§101.27 ATC notification for all launches.

No person may operate an unmanned rocket other than a Class 1—Model Rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours before and no more than three days before beginning the operation:

(a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;

(b) Date and time the activity will begin;

(c) Radius of the affected area on the ground in nautical miles;

(d) Location of the center of the affected area in latitude and longitude coordinates;

(e) Highest affected altitude;

(f) Duration of the activity;

(g) Any other pertinent information requested by the ATC facility.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008, as amended at Doc. No. FAA-2007-27390, 74 FR 31843, July 6, 2009]

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§101.29 Information requirements.

(a) *Class 2—High-Power Rockets.* When a Class 2—High-Power Rocket requires a certificate of waiver or authorization, the person planning the operation must provide the information below on each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 2 rocket expected to be flown:

(1) Estimated number of rockets,

(2) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s),

(3) Description of the launcher(s) planned to be used, including any airborne platform(s),

(4) Description of recovery system,

(5) Highest altitude, above ground level, expected to be reached,

(6) Launch site latitude, longitude, and elevation, and

(7) Any additional safety procedures that will be followed.

(b) *Class 3—Advanced High-Power Rockets.* When a Class 3—Advanced High-Power Rocket requires a certificate of waiver or authorization the person planning the operation must provide the information below for each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 3 rocket expected to be flown:

(1) The information requirements of paragraph (a) of this section,

(2) Maximum possible range,

(3) The dynamic stability characteristics for the entire flight profile,

(4) A description of all major rocket systems, including structural, pneumatic, propellant, propulsion, ignition, electrical, avionics, recovery, wind-weighting, flight control, and tracking,

(5) A description of other support equipment necessary for a safe operation,

(6) The planned flight profile and sequence of events,

(7) All nominal impact areas, including those for any spent motors and other discarded hardware, within three standard deviations of the mean impact point,

(8) Launch commit criteria,

(9) Countdown procedures, and

(10) Mishap procedures.

[Doc. No. FAA-2007-27390, 73 FR 73781, Dec. 4, 2008, as amended at Doc. No. FAA-2007-27390, 74 FR 31843, July 6, 2009]

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Subpart D—Unmanned Free Balloons

SOURCE: Docket No. 1457, 29 FR 47, Jan. 3, 1964, unless otherwise noted.

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§101.31 Applicability.

This subpart applies to the operation of unmanned free balloons. However, a person operating an unmanned free balloon within a restricted area must comply only with §101.33 (d) and (e) and with any additional limitations that are imposed by the using or controlling agency, as appropriate.

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§101.33 Operating limitations.

No person may operate an unmanned free balloon—

(a) Unless otherwise authorized by ATC, below 2,000 feet above the surface within the lateral boundaries of the surface areas of Class B, Class C, Class D, or Class E airspace designated for an airport;

(b) At any altitude where there are clouds or obscuring phenomena of more than five-tenths coverage;

(c) At any altitude below 60,000 feet standard pressure altitude where the horizontal visibility is less than five miles;

(d) During the first 1,000 feet of ascent, over a congested area of a city, town, or settlement or an open-air assembly of persons not associated with the operation; or

(e) In such a manner that impact of the balloon, or part thereof including its payload, with the surface creates a hazard to persons or property not associated with the operation.

[Doc. No. 1457, 29 FR 47, Jan. 3, 1964, as amended by Amdt. 101-5, 56 FR 65662, Dec. 17, 1991]

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§101.35 Equipment and marking requirements.

(a) No person may operate an unmanned free balloon unless—

(1) It is equipped with at least two payload cut-down systems or devices that operate independently of each other;

(2) At least two methods, systems, devices, or combinations thereof, that function independently of each other, are employed for terminating the flight of the balloon envelope; and

(3) The balloon envelope is equipped with a radar reflective device(s) or material that will present an echo to surface radar operating in the 200 MHz to 2700 MHz frequency range.

The operator shall activate the appropriate devices required by paragraphs (a) (1) and (2) of this section when weather conditions are less than those prescribed for operation under this subpart, or if a malfunction or any other reason makes the further operation hazardous to other air traffic or to persons and property on the surface.

(b) No person may operate an unmanned free balloon below 60,000 feet standard pressure altitude between sunset and sunrise (as corrected to the altitude of operation) unless the balloon and its attachments and payload, whether or not they become separated during the operation, are equipped with lights that are visible for at least 5 miles and have a flash frequency of at least 40, and not more than 100, cycles per minute.

(c) No person may operate an unmanned free balloon that is equipped with a trailing antenna that requires an impact force of more than 50 pounds to break it at any point, unless the antenna has colored pennants or streamers that are attached at not more than 50 foot intervals and that are visible for at least one mile.

(d) No person may operate between sunrise and sunset an unmanned free balloon that is equipped with a suspension device (other than a highly conspicuously colored open parachute) more than 50 feet along, unless the suspension device is colored in alternate bands of high conspicuity colors or has colored pennants or streamers attached which are visible for at least one mile.

(Sec. 6(c), Department of Transportation Act (49 U.S.C. 1655(c)))

[Doc. No. 1457, 29 FR 47, Jan. 3, 1964, as amended by Amdt. 101-2, 32 FR 5254, Mar. 29, 1967; Amdt. 101-4, 39 FR 22252, June 21, 1974]

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§101.37 Notice requirements.

(a) *Prelaunch notice:* Except as provided in paragraph (b) of this section, no person may operate an unmanned free balloon unless, within 6 to 24 hours before beginning the operation, he gives the following information to the FAA ATC facility that is nearest to the place of intended operation:

(1) The balloon identification.

(2) The estimated date and time of launching, amended as necessary to remain within plus or minus 30 minutes.

(3) The location of the launching site.

(4) The cruising altitude.

(5) The forecast trajectory and estimated time to cruising altitude or 60,000 feet standard pressure altitude, whichever is lower.

(6) The length and diameter of the balloon, length of the suspension device, weight of the payload, and length of the trailing antenna.

(7) The duration of flight.

(8) The forecast time and location of impact with the surface of the earth.

(b) For solar or cosmic disturbance investigations involving a critical time element, the information in paragraph (a) of this section shall be given within 30 minutes to 24 hours before beginning the operation.

(c) *Cancellation notice:* If the operation is canceled, the person who intended to conduct the operation shall immediately notify the nearest FAA ATC facility.

(d) *Launch notice:* Each person operating an unmanned free balloon shall notify the nearest FAA or military ATC facility of the launch time immediately after the balloon is launched.

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§101.39 Balloon position reports.

(a) Each person operating an unmanned free balloon shall:

(1) Unless ATC requires otherwise, monitor the course of the balloon and record its position at least every two hours; and

(2) Forward any balloon position reports requested by ATC.

(b) One hour before beginning descent, each person operating an unmanned free balloon shall forward to the nearest FAA ATC facility the following information regarding the balloon:

(1) The current geographical position.

(2) The altitude.

(3) The forecast time of penetration of 60,000 feet standard pressure altitude (if applicable).

(4) The forecast trajectory for the balance of the flight.

(5) The forecast time and location of impact with the surface of the earth.

(c) If a balloon position report is not recorded for any two-hour period of flight, the person operating an unmanned free balloon shall immediately notify the nearest FAA ATC facility. The notice shall include the last recorded position and any revision of the forecast trajectory. The nearest FAA ATC facility shall be notified immediately when tracking of the balloon is re-established.

(d) Each person operating an unmanned free balloon shall notify the nearest FAA ATC facility when the operation is ended.

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Subpart E—Special Rule for Model Aircraft

SOURCE: Docket FAA-2015-0150, Amdt. 101-9, 81 FR 42208, June 28, 2016, unless otherwise noted.

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§101.41 Applicability.

This subpart prescribes rules governing the operation of a model aircraft (or an aircraft being developed as a model aircraft) that meets all of the following conditions as set forth in section 336 of Public Law 112-95:

(a) The aircraft is flown strictly for hobby or recreational use;

(b) The aircraft is operated in accordance with a community-based set of safety guidelines and within the programming of a nationwide community-based organization;

(c) The aircraft is limited to not more than 55 pounds unless otherwise certified through a design, construction, inspection, flight test, and operational safety program administered by a community-based organization;

(d) The aircraft is operated in a manner that does not interfere with and gives way to any manned aircraft; and

(e) When flown within 5 miles of an airport, the operator of the aircraft provides the airport operator and the airport air traffic control tower (when an air traffic facility is located at the airport) with prior notice of the operation.

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§101.43 Endangering the safety of the National Airspace System.

No person may operate model aircraft so as to endanger the safety of the national airspace system.

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Need assistance?