

# BOUNDER

Balloon Cut-Down Device



## User Guide

Rev. 4 – September 2019

### Introduction

The *Boulder* combines four common balloon devices into a single, self-contained package.

- Pre-programmable cut-down device that can sever a line during the balloon flight. If two are used, then redundant flight termination is assured.
- Flight computer that monitors and records pressure and temperature.
- High-altitude GPS tracker that logs position data in both CSV and KML formats.
- Thermal management device that maintains a constant temperature to ensure proper operation throughout the flight.

## Boulder Operating Specifications

<b>Parameter</b>	<b>Min</b>	<b>Typ.</b>	<b>Max</b>	<b>Unit</b>
Operating: Temperature	-80	-	60	°C
Operating: Time (firmware defined)	-	-	18	hours
Operating: Time at cold (heater active)	6	10	18	hours
Operating: Heater Set Point	-60	-10	60	°C
Operating: Battery Type	2x Li/FeS2 AA Batteries			
Trigger: Mission Elapsed Time	1	-	1080	minutes
Trigger: Minimum Atmospheric Pressure	8	-	1200	mBar
Trigger: Rapid Descent Arm Pressure	8	-	1200	mBar
Trigger: GPS Altitude	1	-	32,500	meters
Trigger: GPS Geofence Longitude	-180	-	180	degrees
Trigger: GPS Geofence Latitude	-90	-	90	degrees
Sensor: Pressure	8	-	1200	mBar
Sensor: Temperature	-60	-	120	°C
Sensor: GPS Altitude	-	-	50,000	meters
Sensor: GPS Altitude Accuracy	±150	±5	-	meters
Sensor: GPS Horizontal/Vertical Velocity	-	-	100	m/s
Mechanical: Mass (no Enclosure or Batteries)	28	30	32	
Mechanical: Mass (incl. Enclosure & Batteries)	66	68	70	g
Mechanical: Suspended Payload Mass	0	-	5.5	Kg
Mechanical: Size in Foam Enclosure	102mm long, 75mm diameter			
Mechanical: Size without Foam Enclosure	94mm long, 33mm diameter			
Rigging: Dacron Line (break strength)	30	50	80	lb

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# 1 Checklist

## Pre-Flight

### **a. Program Bounder**

- i. Configure *Bounder* Settings in CFG.TXT file
- ii. Insert the micro-SD card
- iii. Install Two Batteries
- iv. Momentarily power-on for pre-flight check, ~10 seconds
- v. Remove the batteries and micro-SD card
- vi. Verify correct settings are in log file generated on micro-SD card
- vii. Reinstall the micro-SD card and two batteries

### **b. Flight Train Rigging**

- i. Connect *Bounder* to Balloon
- ii. Attach *Bounder* to Parachute or Payload
- iii. Slide on the radiative battery cover
- iv. Check All Flight-Train Connections

## Launch

### **c. Inflate Balloon**

### **d. Activate Bounder**

- i. Press Power-On Button, listen for indicator tones
  1. Bach's organ toccata indicates success
  2. 5Hz beeping indicates problem—unit inoperable
- ii. Start Ground Timer, if MET Trigger enabled
- iii. Join & Tape Enclosure Closed with Kapton tape

### **e. Launch**

## Recovery

### **f. Post-Flight**

- i. Remove Batteries
- ii. Download and Analyze Data from Bounder

## 2 Interface

### Micro-SD Card

The *Boulder* is configured via a “CFG.TXT” text file on the micro-SD card. If this file does not exist on the micro-SD card when the *Boulder* is powered on, one will be created with a MET Trigger of one minute and all other triggers off.

If the GEO Trigger is enabled in the “CFG.TXT” file when the *Boulder* is powered on, a “GEO.KML” file will be created/updated with the GeoFence bounding box shown with a light-blue box. This file will allow you to verify that the GeoFence is where you intended it to be.

The *Boulder* creates two data log files each time it is powered on. Both of these files will be numbered the same, for example “001.CSV” and “001.KML”. The CSV file’s header is used to verify that the trigger settings were interpreted correctly from the “CFG.TXT” file. It also contains the recorded data at 1Hz.

The KML file contains 1/10 Hz position data. The point where the burn-wires were activated is noted with a “Termination” pin.

### Power-On Button

Pressing this button will turn the *Boulder* on. Repeated pressing or constant pressing will have no impact on the *Boulder*’s operation except a negligibly higher power draw from the batteries. It can not turn off the *Boulder*, remove one of the batteries to accomplish that.

The Indicator LED flashes are visible through this button.



## Audio Tunes

**Initial Tune:** When the *Bounder* powers on, the intro to Bach's Toccata and Fugue in D Minor will play at the completion of a successful power-on sequence.

**ERROR Tune:** If an error is detected during the power-on sequence, a rapid continuous beeping will play. The *Bounder* is unusable while this rapid continuous beeping is sounding.

**GPS Lock Tune:** When the *Bounder's* GPS first acquires a valid GPS position fix a two-note tune will play. A lower note plays for 100ms, followed by a higher note for 900ms. Assuming the *Bounder* maintains a good view of the sky, then an accurate and valid GPS position will be updated at 1 Hz from this point onwards.

**Burn-Wire Activation Tune:** A single note will be played twice in the following pattern: two-second note, two-second silence, two-second tone, two-second silence, burn-wire activation.

## Indicator LED

The *Bounder* has one LED, visible through the power-on button. In normal operations, the status LED will flash at 1/2Hz until GPS lock is acquired (0.5-12 minutes); at which point it will flash at 1Hz for the duration of the flight.

If there is an error, the STATUS LED will flash rapidly, indicating that the *Bounder* is unusable until the error is corrected.

## Error Mode

The *Bounder* will enter Error Mode if any of the following problems are encountered:

- Micro-SD Card Problem—No card present, incorrect formatting, or no available space
- Broken Burn-Wire—One or more of the burn-wires was determined to be broken
- Pressure Sensor Problem—An issue was detected with an onboard sensor
- GPS Problem—An issue was detected with the onboard GPS sensor

## 3 Programming

### Create CFG.TXT File on Empty micro-SD Card

1. Insert an empty FAT32 formatted micro-SD card into the *Boulder*
2. Insert two batteries
3. Press the Power-On button and wait for the power-on tune to play
4. Remove the batteries and then the micro-SD card

### Program Desired Triggers

5. Mount the micro-SD card on a computer and open the “CFG.TXT” file
6. Set any combination of the five trigger options
7. Save the file, unmount the micro-SD card from the computer

### Verify Triggers Correctly Set

8. Insert the programmed micro-SD card into the *Boulder*
9. Insert two batteries
10. Press the Power-On button and wait for the power-on tune to play
11. Remove the batteries and the micro-SD card from the *Boulder*
12. Insert the micro-SD card into the computer and open up the latest xxx.CSV file
13. Confirm that the Settings at the top of the xxx.CSV file correspond to the desired settings in CFG.TXT.
  1. If not, see *Troubleshooting: CFG.TXT Programming Issues* and repeat steps 8-13
14. Programmed micro-SD card, proceed to the Rigging instructions on Page #10

### Other Programable Options

**Heater Set Point:** This is the temperature as which the heater turns on. The heater ensures that the batteries and sensors remain in an operable temperature range. For proper operation, it is recommended to operate with this set point at or above -15°C.

**Power Save Mode:** When enabled, the GPS will use a low-power mode. Assuming the *Boulder* maintains a good view of the sky, no-heater power consumption will be reduced by approximately 65%. The tradeoff is, in conditions where the *Boulder* is powered-on without a good view of the sky (ie indoors), GPS Lock may be greatly delayed when this setting is enabled.

## 4 Trigger Options

### MET – Maximum Mission Elapsed Time

This trigger activates after a user-specified amount of time elapses. The Mission Elapsed Time (*MET*) can range from 1 minute to 1080 minutes (18 hours). This trigger can be disabled by setting it to ‘OFF’.

Example: You would like the *Boulder* to sever the line 120 minutes after power-on. The CFG.TXT line would read:

```
[MET=120], Mission Elapsed Time Trigger (1 to 1080 min)
```

### MAP – Minimum Atmospheric Pressure

This trigger activates once the device measures a user-specified atmospheric pressure level during balloon ascent. The Minimum Atmospheric Pressure (MAP) value can range from 1200 mBar (approximately 1.5km or 5,000ft below sea-level) to 8 mBar (approximately 30km or 100,000ft). This trigger can be disabled by setting it to ‘OFF’.

Example: You would like to sever the Device Line when the *Boulder* measures a pressure of 75 mBar or less. The CFG.TXT line would read:

```
[MAP=75], Min Atmospheric Pressure Trigger (8 to 1200 mBar)
```

### RDT – Rapid Descent Trigger

The Rapid Descent (*RD*) trigger activates when it senses a rapid and sustained pressure increase, like after the balloon bursts. Unlike the *MET* and *MAP* triggers, this setting provides an arming condition for the *RD Trigger*. When the *Boulder* measures an atmospheric pressure less than the *ARM Pressure* value, the *RD Trigger* will be armed. Only while armed will the *RD Trigger* be able to sever the *Device Line* in the event the *Boulder* starts measuring a rapid and sustained pressure increase. The *RD trigger* is disabled when the measured atmospheric pressure is greater than the *ARM Pressure*.

The *ARM Pressure* value can range from 1200 mBar (approximately 1.5km or 5,000ft below sea-level) to 8 mBar (approximately 30km or 100,000ft). This trigger can be completely disabled by setting it to ‘OFF’.

Example: You would like the *Boulder* to arm the *RD Trigger* at pressures below 250 mBar or above approx 10km altitude. The CFG.TXT line would read:

```
[RDT=250], Rapid Descent Trigger ARM Pressure (8 to 1200 mBar)
```



## GAT – GPS Altitude Trigger

This trigger activates above a user-specified altitude. The GPS Altitude trigger (*GAT*) can range from 1 meter to 32,500 meters above the geodetic model. This trigger can be disabled by setting it to ‘OFF’.

Example: You would like the *Boulder* to sever the line at an altitude of 28,000 meters. The CFG.TXT line would read:

```
[GAT=28000], GPS Altitude Trigger (1 to 32,500 m)
```

Note: The altitude reported by GPS can contain a larger error than the horizontal position. “Generally, Altitude error is specified to be [1.5 x Horizontal error specification](#).” The *Boulder* does not filter or average the altitude and relies completely on what the GPS is reporting to determine whether or not the burn-wires should be activated. As a result, the *Boulder* is not designed or intended to operate where altitudes need to be more accurately determined to less than ±150m.

## GEO – GPS GeoFence Trigger

This trigger activates when the GPS position is reported to be **outside** of a pre-defined area. The GPS GeoFence trigger (*GEO*) allows the user to specify a region of any size bounded by a min/max latitude and min/max longitude. This trigger can be disabled by setting it to ‘OFF’.

Note: The *Boulder* expects and uses **lat/lon numbers with 5 decimal places**. Any variation from this will cause errors.

Example: You would like the *Boulder* to sever the line when it moves outside of a region bounded by the following longitude coordinates: -70.58500, -70.59000, and latitude coordinates: 41.59500, 41.60000. The CFG.TXT lines would read:

```
[GEO=1], GPS GeoFence Trigger (1 = Enabled)
  [GX1=-70.58500], GPS Lon Min (-180 to 180)
  [GX2=-70.59000], GPS Lon Max
  [GY1=41.59500], GPS Lat Min (-90 to 90)
  [GY2=41.60000], GPS Lat Max
```

### **Method for Determining GPS GeoFence Coordinates**

- 1) Open Google Earth
- 2) Zoom to the desired GeoFence region
- 3) Select the “Add Polygon” tool
- 4) Place a polygon point in one corner of the desired GeoFence region
- 5) Place a second polygon point in the opposite corner of the desired GeoFence region
- 6) Click “OK” on the “New Polygon” window to close it
- 7) Right-Click on the new, “Untitled Polygon” under the “Places” list
- 8) Select “Save Place As” and select a location and name for the file
- 9) Choose KML File Type, then select OK

- 10) Open the file you just saved in a text editor
- 11) Look for the coordinates. Example:

```
<coordinates>
-70.5857335399473,41.59513011441263,0
-70.5857335399473,41.59693338708662,0
-70.5918077928395,41.60213011441263,0
</coordinates>
```
- 12) Copy and paste the two latitude and two longitude values from this into the CFG.TXT file. The *Bounder* will automatically arrange the min/max if you enter them in backwards
  - 1) From the example above:
    - 1) Min LON: -70.59000
    - 2) Max LON: -70.58500
    - 3) Min LAT: 41.59500
    - 4) Max LAT: 41.60000
  - 2) NOTE: the *Bounder* expects and uses **lat/lon numbers with 5 decimal places**
- 13) Once the CFG.TXT file has been modified and saved, insert the micro-SD card into the *Bounder* and insert two batteries.
- 14) After the power-on tune plays, remove the batteries and then the micro-SD card.
- 15) Mount the micro-SD card back into the computer and open the GEO.KML file.
  - 1) The GEO.KML file is created/updated every time the GEO Trigger is enabled when the device is powered on.
- 16) A light-blue polygon box will indicate where the GeoFence is understood to be by the *Bounder*.

## 5 Rigging

This section covers how to connect the *Boulder* into your flight-train to ensure proper termination or cut-down when programmed.



A few notes of caution:

- The burn-wires on the *Boulder* are thin and fragile. Excessive direct pressure can cause them to break. Never press down on them directly with your finger.
- Trim any excess line after the knots. Excess line can tangle and not allow the Balloon Line to separate from the Device Line. This is especially important for lighter payloads.

### Line to be Cut

Typically the *Boulder* is rigged to cut the flight-train line attaching the balloon. Cutting the line immediately under the balloon is recommended to ensure it can't tangle during ascent with any other lines, preventing it from releasing after being cut. It also helps ensure that the *Boulder* doesn't interfere with the parachute during descent, which is usually tied below the *Boulder* by a 2+ meter length of line.



The line to be cut, Balloon Line (pictured as black below), is attached to the *Boulder* with a [San Diego Jam Knot](#) and passes directly over the burn-wires. The knot allows the loop around the *Boulder* to tighten, but not loosen, thus ensuring that there is always good contact between the line and the burn-wires.

Retention Line  
To Parachute or Payload

Balloon Line



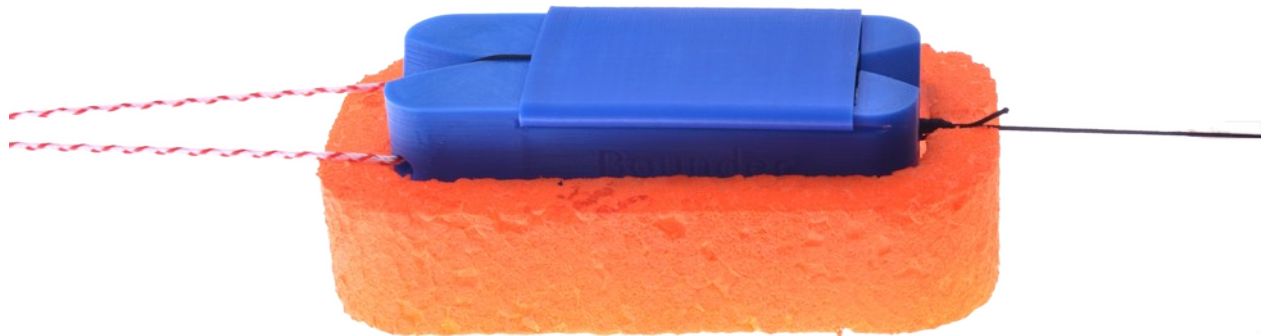
The retention line (pictured as red/white above) is tied through the provided hole to ensure the *Bounder* isn't lost after burn-wire activation.

## Insulation

### *Foam Enclosure*

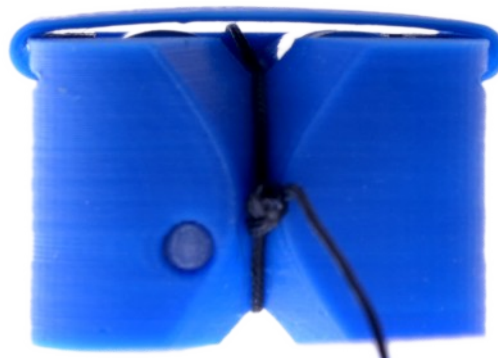
The *Bounder* ships with a two-part, light-weight extruded polypropylene foam enclosure. This enclosure both insulates the Bounder during flight and protects it during landing.

The foam enclosure has a small notch at one end. This is to ensure the Balloon Line can pass freely through the enclosure after it is cut.



### *Radiative Shield*

The *Bounder* ships with a radiative insulation device. This device slides over the batteries and helps ensure that they stay warm at high altitudes. Please ensure the batteries are not touching it after installation.



### **Redundant Termination**

It is possible to use two *Bounders*, configured as pictured to the right, to provide redundant termination for a latex balloon flight.

Explanation from top to bottom:

- The latex balloon (not shown) is attached to the Woffin. Once the line below is cut by a *Bounder*, the balloon will rapidly ascend until it bursts.
- A large swivel is used so that *Balloon Line* can be shared between two *Bounders*. Once one *Bounder* cuts, the free end will pass through the swivel, releasing the balloon.
- Two *Bounders* are attached together with a wrape of tape around their foam enclosures. Only one half of each *Bounder*'s two-part foam enclosure is pictured for clarity.
- The *Retention Line* is looped through both *Bounders* and attached to either the parachute or payload—depending on how the flight-train is laid out. If attached to the parachute, additional line between the parachute and *Bounders*' *Retention Line* is recommended so that during descent the *Bounders* do not impact the parachute's deployment.



## 6 Data Analysis

### The CSV Data File

#### Header

This section contains information about the *Boulder* and the settings it used for the flight. Please reference this section when confirming that the Boulder used the intended settings in the Programming → Verify Triggers section of this manual. If this section differs from your CFG.TXT file, please check for typos and resolve before flight. An example of what it may look like:

```

<!--          Balloon Boulder Cut-Down
              Balloon Ascent Technologies LLC
              https://loonatec.com

-->

<!-- Settings -->
Hardware      SN-4.02
Firmware      v8
[MET=1]       Mission Elapsed Time Trigger (1 to 1080 min)
[MAP=OFF]     Min Atmospheric Pressure Trigger (8 to 1200 mBar)
[RDT=OFF]     Rapid Descent Trigger ARM Pressure (8 to 1200 mBar)
[GAT=OFF]     GPS Altitude Trigger (1 to 32500 m)
[GEO=OFF]     GPS GeoFence Trigger (1 = Enabled)
  [GX1=-70.58500]  GPS Lon Min (-180 to 180)
  [GX2=-70.59000]  GPS Lon Max
  [GY1=41.59500]   GPS Lat Min (-90 to 90)
  [GY2=41.60000]   GPS Lat Max
[HSP=-10]     Heater Set Point (-60 to 60 C)
[PSM=1]       Power Save Mode (OFF or 1)

<!-- Modules -->
Burn-wires    GOOD
Pressure      GOOD
GPS           GOOD

```

#### Data

- Time (s)                      Internal timer, starts counting from 0 at power-on
- Status Flags                 An 'X' in this column denotes this flag is activated
  - SEF                            Sensor Error Flag, invalid data from pressure sensor
  - HTR                            Heater Flag, the battery heater is active

- BWO Burn-Wire 0 continuity failed (updated every 10 seconds)
- BW1 Burn-Wire 1 continuity failed (updated every 10 seconds)
- Trigger Flags
  - An 'X' in these columns denotes which trigger activated the burn-wires. The 'X' is present only during the activation sequence; it is no longer present once the sequence is complete.
  - MET Mission Elapsed Time trigger
  - MAP Minimum Atmospheric Pressure trigger
  - RD Rapid Descent trigger
  - GAT GPS Altitude trigger
  - GEO Geofence trigger
- Measurements
  - Pres Atmospheric pressure, in millibar (hPa)
  - Temp The *Bounder's* internal temperature, in °C
  - Batt The battery voltage (updated every 10 seconds)  
Note: the voltage is not accurate during burn-wire activation
  - numSV Number of GPS Satellites currently used by the GPS module
  - Lat \* GPS latitude in degree decimal
  - Lon \* GPS longitude in degree decimal
  - Alt \* GPS altitude in meters above Ellipsoid
  - Date \* GPS date in YYYYMMDD format
  - Time \* GPS time in HH:MM:SS format
  - gSpeed \* GPS ground speed in m/s
  - vSpeed \* GPS vertical speed in m/s
  - heading \* GPS heading in degrees

Notes:

Unless otherwise noted, each data value is updated for every entry line.

\* Only populated when a valid GPS Lock is achieved.

## The KML Data File

This file allows rapid plotting of the flight path in applications such as Google Earth.

Note: it is only updated every 10 seconds and is not time-stamped. For higher resolution data that includes a timestamp, please use the values from the CSV file.

## The GEO.KML File

This file allows easy verification that the geofence is in the intended and proper location. Open it with an application such as Google Earth. Please reference this file when going through the Programming → Verify Triggers section of this manual.

The point where the burn-wires were activated is noted with a “Termination” pin. The flight-path before the “Termination” event is separate from the flight-path after the event.

Note: this file is only generated and updated at startup when the GEO trigger is enabled.



## 7 Troubleshooting

### Error Indicated

A 5 flash per second by the *Indicator LED* and rapid beeping indicates a malfunction. The *Bounder* will not operate correctly when this pattern is flashing. **Do not fly**. Possible causes include:

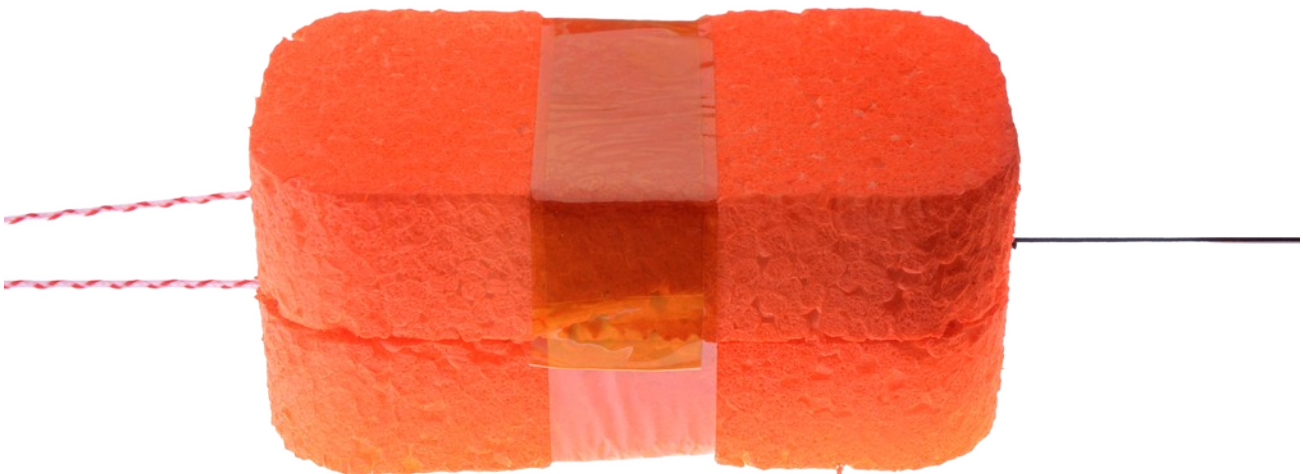
- **Broken Burn-Wire:** Check the two burn-wires to see if either is broken
- **Micro-SD Card:** Check that a card is inserted and has a good connection (reseat)
- **Sensor Malfunction:** contact Balloon Ascent Technologies for repair

Check the latest CSV file for the error code(s). Each error will be denoted with a line starting with “ERR”.

### Device Will Not Turn On

The device should turn on within 1 second of the power-on button being pressed. Possible causes:

- The power-on button not fully being depressed and actuating the switch
- Check the battery orientation
- Install new batteries. The Energizer L91 batteries should not be stored in hot conditions for extended periods of time (months). In that condition they self discharge more quickly.



## CFG.TXT Programming Issues

The CFG.TXT file contains precisely formatted instructions for the *Boulder*. Any typos in this file will likely result in undesirable results. This is why the *Programming* instructions suggest you let the *Boulder* verify the file after changes are made. This is done by quickly powering on the *Boulder* and letting it create a new xxx.CSV file. At the top of this new xxx.CSV file will be the current trigger settings, as interpreted by the *Boulder*.

To help avoid possible confusion, here is a brief overview of how the command is formatted:

[GAT=32000], GPS Altitude Trigger (1 to 32500 m)

- [ Designates the beginning of the instruction
- GAT Instruction name
- = Separator between instruction name and value
- 320000 Desired instruction value
- ] Designates the end of the instruction
- , For CSV file formatting, not interpreted
- GPS Altitude Trigger (1 to 32500 m) A comment, not interpreted

## 8 Consumables

### Batteries

The Bounder has been designed to use primary lithium batteries in the ‘AA’ size. The Lithium/Iron Disulfide (Li/FeS<sub>2</sub>) chemistry has proven to work well, even at the low temperatures experienced on balloon flights. Possible suppliers of these batteries include:

- Energizer [Ultimate Lithium L91](#) AA Battery
- Varta [Ultra Lithium 6106](#) (FR14505) AA Battery
  - Note: the 6106 is rated at 18% less capacity than the L91 battery (2.9Ah vs 3.5Ah)

While the *Bounder* will operate on standard alkaline batteries, it is strongly recommend against using them due to their poor performance at cold.



### Memory Card

Any SD/SDHD micro-SD card should work with the Bounder. We recommend using the SD Memory Card Formatter

(<https://www.sdcard.org/downloads/formatter/>) from the SD Association to format new cards. Using the OS formatting utility (Mac OSX or Windows) can cause problems.

### Rigging Line

Below are some of the rigging line options that we have used and liked. The Green-Spot line is our preferred line due to it being widely available and how well it the burn-wires cut it. The Nano cord holds knots well and comes in a wide variety of colors. The Twisted Nylon line is super stretchy and can help dampen jerks and bounces on long flight-trains during the flight.

Green-Spot Dacron Fishing Line. Some manufacturers include: [Izorline](#) or [Cortland](#)

Atwood Rope Nano Cord: <https://atwoodrope.com/collections/nano-cord>

Twisted Nylon Mason Line: Home Depot, Amazon, [Erin](#), etc.

## 9 Safety Precautions and Recommendations

### Regulatory

Always adhere to the regulations governing high-altitude ballooning applicable in the country of operation. In the United States, high-altitude balloon flights are governed by “FAA Part 101”.

### Touch Hazard

The *Bounder’s* two burn-wires are fragile and produce high temperatures when activated. Never press-down on or touch the burn-wires.

### Falling Payload Hazard

Always clear the launch area prior to launch. While unlikely, balloon or line failure after release may result in a falling payload impacting the ground before the parachute fully deploys.

The owner shall be liable for any damages resulting from any use of the Bounder and other related materials, and shall defend, hold harmless and indemnify Balloon Ascent Technologies LLC, officers, employees and agents, against any and all claims, suits, actions, costs, counsel fees, expenses, damages, judgments and decrees, by reason of any person or property being injured or damaged directly or indirectly by use of the Bounder or activities arising therefrom.