

Blue Raven User's Guide

Updated September 15 2023 for new capabilities.

Introduction

The Blue Raven is designed to be amateur rocketry's most capable altimeter, chock full of sophisticated features. At the same time, its mobile app interface is designed to be intuitive and easy enough to use to make a user's manual optional. **For those who would prefer to skip or skim the manual, the Quick Start Highlights Section gives key pieces of information that you will want to know. Please read it.** The rest of the manual provides in-depth information including detailed instructions on the optional USB interface.

Quick Start Highlights

Pre-launch:

- Mount the Blue Raven in any orientation. For the apogee charge to be on-time, vent the av-bay, rigidly mount the Blue Raven inside the airframe, or preferably both.
- The Blue Raven can be damaged by reversing the battery polarity.
- The Blue Raven connects the output terminal to ground (battery -) to fire a charge. This means that the other side of the charge needs to be connected to the + side of the battery, preferably through a switch.
- 1S (3.7V) lipo are recommended. 9V batteries are o.k. A new feature of the Blue Raven is that if the output current goes over 4 Amps, the Blue Raven will now reduce the average current to 4 Amps, so large capacity lipos are now o.k.
- The App is released in the Apple App Store and Google Play under "Featherweight UI" and released versions can be installed with this method. Sometimes, newer builds that have not yet been generally released through the stores are available through TestFlight (iOS) and FireBase (Android) by clicking on the link on [the Blue Raven product page, here](#).
- If an over-the-air firmware update is interrupted, the Blue Raven will revert to a firmware application that does not show any outward signs that the Blue Raven is powered on, (no LEDs for example) but is still accessible under the Devices screen as "STM_OTA". Click on this device to connect to it, and then select "Update firmware" under the three-dot menu on the right.
- The Blue Raven only connects to one phone at a time, so if it's not connecting to your phone, check that your Bluetooth is enabled, and it's not already paired to another phone in the vicinity.
- Resetting to default settings is recommended for most rockets. With the default settings, the Blue Raven fires the Apo and 3rd channels at apogee, even if there is a sensor failure. The Main and the 4th channels fire the main chute at 700 feet and 500 feet, respectively. The Main and 4th channels are set up identically except for the deployment altitude. The main and 4th channels will also fire early in the event of excessive descent rate due to a failed apogee deployment.

- If you modify the deployment output settings using the custom screen, be sure to review both the primary and secondary settings. Whichever set of conditions is true first will fire the output.
- Run a simulated flight to get familiar with the features and capabilities of the phone. But do not run a simulation while you have charges connected to the outputs, unless you want them to fire, because the simulated flights fire charges just like real flights.
- Re-calibration of the accelerometers isn't needed for a safe, successful flight. But if you want the best quality inertial navigation and recorded data performance, I recommend re-calibrating within a week of the flight.

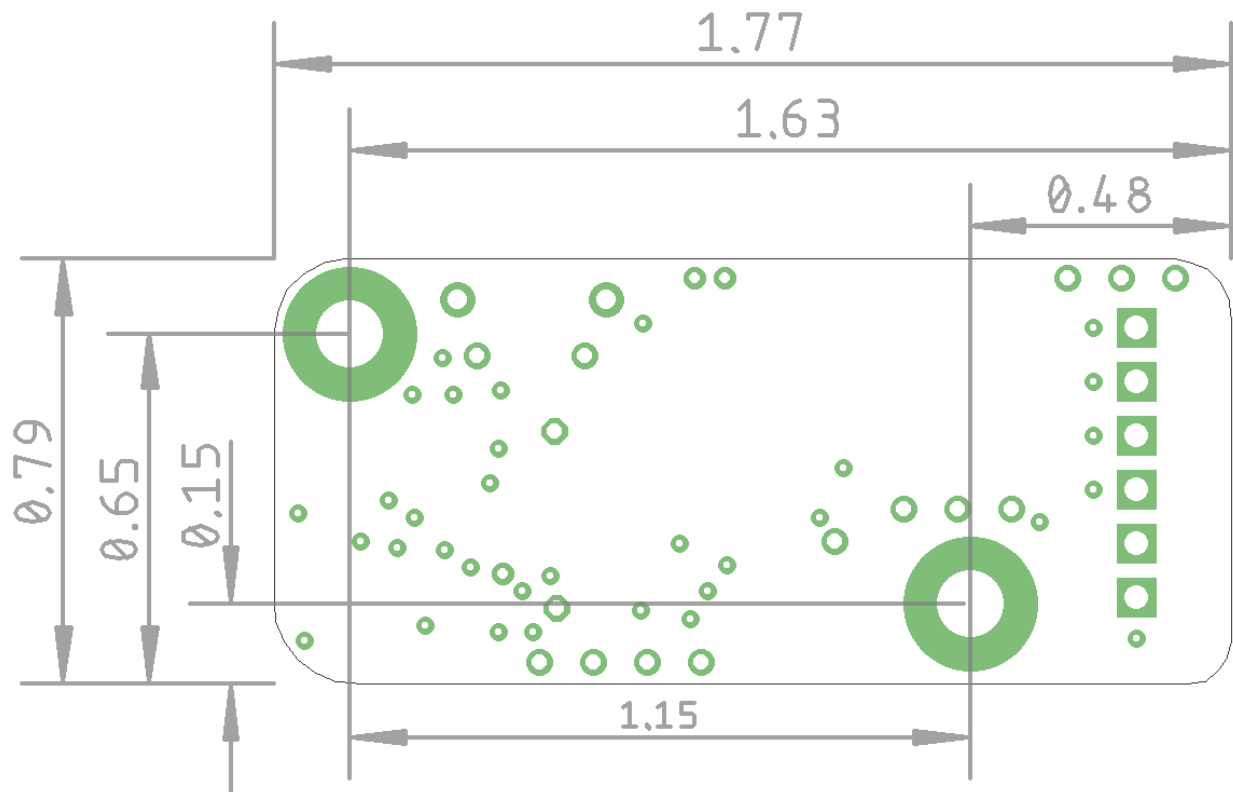
At the pad:

- When the Blue Raven is using default settings, all you need to do to make it ready for launch is power it up and wait at least 20 seconds. If both memory banks are full of flight data, the oldest one will be erased automatically to make room for the new flight. This can take up to a few minutes if a long flight is being erased.
- The live data screen shows the readiness for launch of all the measurements. Before launch, read each measurement on the screen and think about if it is valid. Green means go. Red means not ready for launch. Unused channels show up as red, but that's o.k. if it's a channel you're intentionally not using. It's also o.k. if the 400G accel and the gyro briefly show red from noise, especially if there is gusty wind at the pad.
- The beeps are optional and can be turned off in the upper right corner of the live data screen. The first beeps after power-up are a high/low/high example, then the battery voltage rounded down to the nearest Volt. Then if the barometric and accelerometer sensors are healthy, the continuity status of the 4 output channels is beeped out, in order of Apo, Main, 3rd, 4th. Low beep indicates less than 3.80V. A high beep indicates greater than 3.80V. The continuity beeps are repeated every few seconds.
- If a channel is set up to perform an airstart motor ignition, it will start out in a disarmed state when the Blue Raven is powered up. Don't forget to arm it at the pad when the rocket is ready to fly. The other output function options (chute deployments, in particular) are armed at power-up.

After the flight:

- If you keep the app up and running on your phone during the launch, it will automatically download the flight summary data as you walk up to your rocket, and start downloading the low rate and high rate data. There is so much recorded data to download that it can take a long time, but it's o.k. to review the flight summary data or change to the live data screen as long as you go back to the flight screen to let the downloading complete. Don't start a new flight, a simulated flight, or a ground test before the downloading is complete, if you want to preserve that flight data.

Blue Raven mounting and electrical connections



The size, mounting holes, terminal locations and assignments, and the power interface to the Blue Raven are identical to that of the Raven4. The mounting holes are compatible with 4-40 screws and two are provided. The Blue Raven's mounting holes are electrically connected to ground. Be sure to use the correct polarity when applying power. Note that each deployment output channel fires by connecting the output terminal to the ground (Gnd) terminal. This is known as an open-drain circuit and it means that one end of the ematch or igniter must be connected to the + side of the battery, and the other end connected to the Blue Raven terminal. Unlike the previous Ravens, the Blue Raven can be installed in any orientation, including horizontal, or skewed by any amount, and the operation will be unaffected.

Avoiding common installation problems

Provide vent holes from the avionics bay where the Blue Raven is installed, to the ambient atmosphere. Ideally these should be located on a cylindrical part of the airframe so that the air flows past the hole parallel to the hole opening. Adding several small holes is preferred to one or two larger holes so that the pressure measurement is less affected by wind at the pad or rocket orientation after the first deployment. Although there is no hard and fast rule for vent hole sizing, several online resources provide a reasonable starting point, such as <https://rocketrycalculator.com/rocketry-calculator/test-vent-port/>. If the vent holes are relatively large or the av-bay volume is relatively small, the recorded barometric pressure will be noisier than necessary. If the vent holes are relatively small and the av-bay is large, the measurements will be smoother but will lag the external pressure and may not fully catch up to the external pressure at apogee. The default deployment settings of the Blue Raven will work based on gyro and accelerometer measurements for apogee deployments even if the av-bay is sealed, but the main chute deployment won't work without the Blue Raven being exposed to the ambient air pressure.

The measurements of the barometric sensor in the Blue Raven are sensitive to light. Mount it in an av-bay that does not permit direct sunlight to hit the barometric sensor, by locating vent holes away from the sensor. Otherwise, the barometric sensor can have spurious readings during the rocket's motion if a shaft of sunlight passes across the sensor. This effect could provide misleading recorded data, though the Blue Raven's deployment logic has filters and persistence checks that are designed to prevent impact of this potential effect on deployment outputs.

Mount the Blue Raven rigidly to the airframe. If the Blue Raven's mounting orientation relative to the rocket can change under boost due to flexing of av-bay components, the accuracy of the inertial navigation will be degraded.

Keep the av-bay sealed against deployment charge pressure. Although the Blue Raven's deployment logic incorporates filters and persistence checks to prevent transient pressure changes from affecting the deployments, the recorded data will have misleading results if pressurized gas from a deployment charge is allowed to enter the av-bay and temporarily raise its pressure.

Beeper and LEDs

The Blue Raven has a red, green, and blue LED, and a beeper to communicate status in addition to the Bluetooth and USB interfaces. At power up, the Blue Raven beeps with a high frequency, low frequency, and then high frequency, pauses and then beeps the input battery voltage rounded down to the nearest volt, one beep per volt. Each high beep is accompanied by a green flash of the LED, and each low beep has a red flash of the LED. After the battery voltage is beeped out, the Blue Raven periodically beeps the status of the voltage input to each channel with a series of 4 beeps, one beep per channel starting with the Apo channel and moving on to the Main, 3rd and 4th channels. A high beep indicates that an ematch or igniter is electrically connected and not broken open. A low beep indicates that an ematch or igniter is disconnected or failed open. The threshold for continuity detection is 3.8V, which means that the battery supplying the pyro charges needs to have a voltage at least that high for the continuity indications to work.

The blue LED indicates Bluetooth radio activity. The LED flash is initially less frequent to indicate the Bluetooth radio is advertising but not yet connected. After the Bluetooth connection is established, the blue LED flashes more frequently.

The green LED flashes along with the high beeps to indicate that a deployment output is connected.

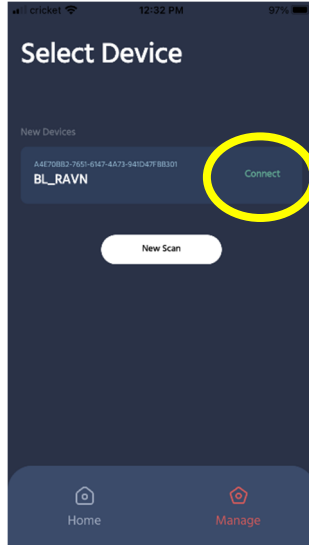
The red LED flashes along with the low beeps to indicate low/no deployment output continuity voltage. It also turns on when the on-board flash memory is active, for example right after power-up when a previous flight's data is being erased to make room for a new flight, and during the flight when flight data is being written to flash memory.

Updating the Blue Raven to the latest version of embedded software

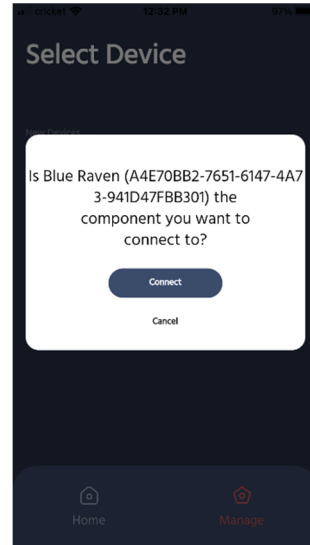
The Blue Raven uses a custom phone application on iOS and Android which provides the primary user interface to the Blue Raven, and updates the Blue Raven's embedded software over the air via its Bluetooth connection.



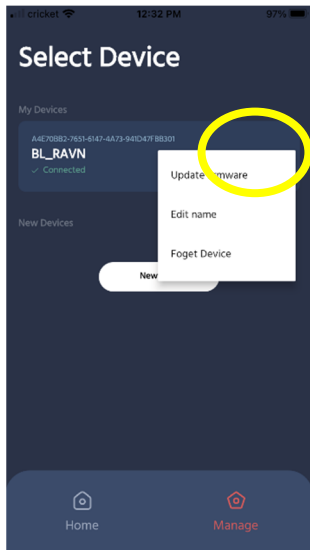
Click the "Manage" icon.



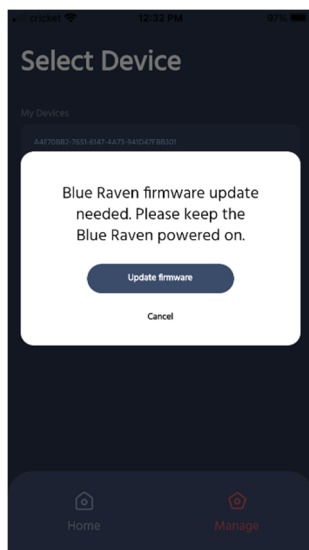
Click the "Connect" button



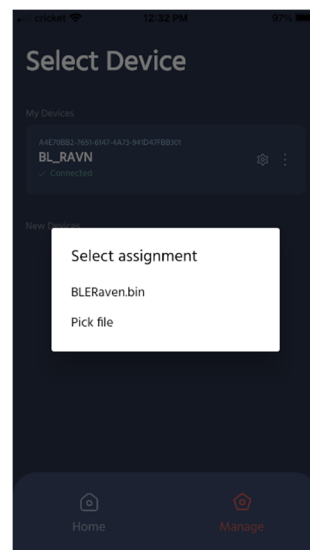
Click "Connect"



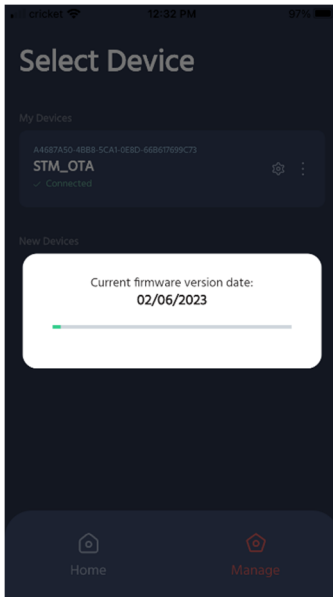
Click the dots and Update Firmware



Click Update firmware



Select BLERaven.bin



The new firmware will now start loading.

After the new embedded software has finished downloading, the Blue Raven will restart.

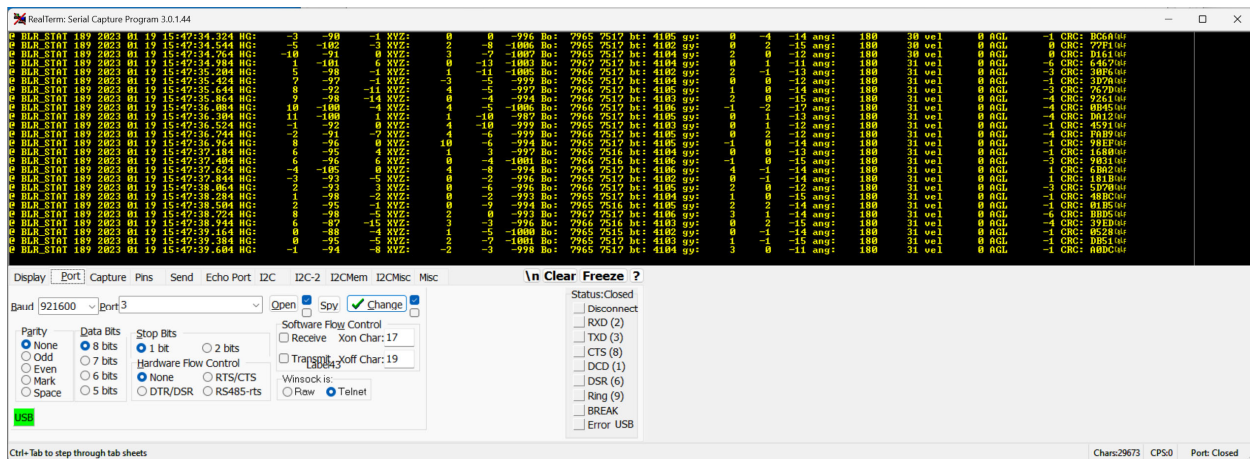
USB Serial connection (optional)

Power up the Blue Raven before connecting a micro-USB cable to your computer. Note that many, if not most, USB micro cables are only for charging and do not have data connections. Use a serial terminal program such as [RealTerm 3.0.44](#) or [Putty](#) to interact with the Blue Raven. I use RealTerm 3.0.44 and any examples/discussion will be based on that program, but others should also work.

The Blue Raven uses STMicro's Virtual Comm Port (VCP) drivers for the serial connection. Drivers should load automatically the first time you plug in a powered Blue Raven. With the VCP drivers, the baud rate you select in the terminal program is ignored, and data is transferred at USB full speed. There is no parity checking. In RealTerm, go to the port tab, select the port that is used for the Blue Raven (unplug and plug it in to see what port is being used by the Blue Raven) and click the "open" button. The "open" button toggles between opening and closing the port. In RealTerm, if you unplug while the comm port is open, an error dialog box will pop up that needs to be closed before you can re-open the comm port. Unfortunately, this pop-up dialog box is often hidden behind the main RealTerm window, but you can bring it to the front using the Windows tool tray.

USB Live status message (optional)

When the Blue Raven is powered and working, and connected to the serial program, it will output a live status message 5 times per second. The scrolling message looks like this:



The first field, “@ BLR_STAT” is a message type that you can use for filtering during post-processing. Every output message type has a message-type mnemonic and a time/date stamp. The date stamp currently starts with the build time/date and increments from there. Later, this time/date will be set by the phone over Bluetooth.

The following are basic descriptions of the next fields, with [] indicating that the software puts real values:

HG: [hi-G Accel X Gs x 100] [hi-G Accel Y Gs x 100] [hi-G Accel Z Gs x 100]

XYZ: [Accel X Gs x1000] [Accel Y Gs x1000] [Accel Z Gs x1000]

Bo: [Baro pressure, atm x10000] [Baro temperature, deg F x100]

bt: [Battery voltage, mV]

gy: [gyro X deg/sec x100] [gyro Y deg/sec x100] [gyro Z deg/sec x100]

ang: [tilt angle, degrees x10] [roll angle, degrees]

vel [vertical velocity from inertial sensors, feet/sec]

AGL [Altitude above ground level from baro sensor, feet]

CRC: [16-bit CRC for the preceding text]

The accelerometer values above have a mild low-pass filter applied. When a calibration is active, the accelerometer values have a much stronger low-pass filter applied.

USB Serial Commands (optional)

Commands are sent in RealTerm via the “Send” tab. Enter the text to be sent in the entry box and click the “as ASCII” button to send the string all at once. Typing a command into the terminal window one character at a time is not supported. All of the available commands are described in the following sections. The specific text to send is formatted in **<bold courier font>**, surrounded by angle brackets that are to be left out. Square brackets indicate numeric values.

Deployment setting introduction and background

Three levels of customization and flexibility are available for the Blue Raven’s deployment settings. 1. The Blue Raven’s default deployment settings provide reliable, fault-tolerant settings right out of the box for most rockets with apogee deployments or apogee/main chute dual deployments. 2. The Blue Raven phone app makes it easy to assign common functions like apogee or main deployments, airstarts or stage

separations, with customization options tailored to those functions, such as main chute deployment altitude or airstart maximum tilt angle. 3. Finally, the deployment logic and settings for each of the four Blue Raven channels are very customizable with 22 flight options and events to choose from, primary and secondary settings, and thresholds for event detection that are user-selected independently for each channel.

Factory Default settings

Apogee Deployments

The Blue Raven default settings assign two outputs for firing a charge at the highest point of the rocket's flight (apogee). The primary output is assigned to the channel labeled "Apo" on the board, and the channel labeled "3rd" is by default the backup output. Firing a charge at apogee can be used for deploying a parachute for a single-deployment rocket, for separating rocket sections, and/or deploying a smaller drogue chute for a rocket that has dual deployments.

With the default settings for the "Apo" channel, the Blue Raven first checks for motor burnout and then detects apogee based on fault-tolerant apogee detection logic that fires when 2 of 3 independent sensor methods detect apogee. The three sensor votes are barometric pressure increasing (altitude decreasing), gyro-based flight tilt exceeding 90 degrees, and accel-only velocity estimate of less than 0 feet/second.

The default settings on the "3rd" channel are for backup apogee deployments. The Blue Raven checks for barometric pressure increasing, but only when the accelerometer-measured velocity estimate is low enough that transonic or supersonic speeds won't affect the pressure readings. This is the same logic used in the Raven3 and Raven4 altimeters for the backup apogee.

Lower-altitude dual deployments

For rockets configured for dual deployments, the main chute is deployed at lower altitudes to reduce the drift of the rocket in the wind. The default settings for the channels labeled "Main" and "4th" are for primary and backup main chute deployments, respectively.

The default settings for the "Main" channel will fire after apogee at 700 feet above ground level (AGL). The default settings for the "4th" channel turn on the output during the descent after the apogee channel has fired when altitude falls below a lower threshold of 500 feet AGL. The 4th channel can thus be used as a backup for the main deployment charge, or by itself to deploy the chute at a lower altitude.

Function-based deployment settings with tailored customization

The Blue Raven phone app makes it easy to customize the output channels for your application. Standard output functions like apogee and main chute deployments, stage separation, and motor airstarts can be assigned to any of the four hardware channels on the board. Each function has a setup screen with commonly-adjusted settings that are relevant for that function, for example deployment altitude for the main chute function, or tilt limits for the airstart function.

<Description of phone app screens to be added>

Full customization of deployment logic

With the custom settings option, all of the possible logic settings and thresholds are available for each channel. Each channel has a primary set and a secondary set of events that can be checked. When all the selected events of either the primary or the secondary set are true, then the channel turns on. The "<" (less than) or ">" (greater than) symbols in the table below show the condition that makes an event true. For example, the AGL1 event becomes true when the altitude is less than 700 feet, and it is false

otherwise. All thresholds are checked 50 times per second. Except for the NOMANG and apogee checks, each of the following checks can become true or false every time the Blue Raven watches that condition, regardless of the previous state. The “nominal ascent” check controlled by the NOMANG threshold is latched for the remainder of the flight after the first time it goes false, and the apogee event is latched true after apogee is detected.

The following events have thresholds that are individually adjustable for each channel:

Event Mnemonic		Default Value	Units and typical use case
AGL1	<	700	Feet. Barometric altitude for main chute deployment
AGL2	>	1000	Feet. Barometric altitude for altitude-based staging ignition
FANG1	<	7.0	Degrees. Max allowable current tilt angle
FANG2	>	12.0	Degrees. Trigger an output when FANG2 angle is exceeded
FUTANG	>	15.0	Degrees. Future (+3 sec) expected tilt trigger
NOMANG	<	60.0	Degrees. Maximum tilt angle for nominal ascent. Latched when false.
Tval1	<	2.5	Seconds. Inhibit output after time delay
Tval2	>	5.0	Seconds. Enable output after time delay
Vel1	<	400	Feet/sec. Transonic inhibit to avoid barometric glitches
Vel2	>	300	Feet/sec. Inhibit stage ignition if going too slowly
Bvel1	<	-200	Feet/sec. Baro upward velocity. Early main deployment if apogee charge fails and rocket is falling too fast. Threshold is automatically adjusted proportional to barometric pressure to account for lower density at high altitudes
BURNCOUNT	>	1	The burnout count increments each time a positive change in velocity of at least 40 feet/second has occurred followed by a deceleration of at least 5 feet per second. This can be used to gate events after a configurable number of stage burns are complete. This is necessary for a 3 rd stage staging/ignition logic to be distinct from 2 nd stage staging logic

Three other options apply for each channel:

Option	Option type	Description with default values and use cases
latch	True/False	Default false. When true, if the output is turned on, it will stay on until landing is detected. When false, the output will be on for 1.0 seconds. (latch option planned not yet implemented)
Delay	[number of milliseconds]	Milliseconds. (Default is 1500.) The output countdown delay timer starts after the checked events are true. When the timer expires the output will fire regardless of whether the checked events are still true.
Manual arm	True/False	When false (default for deployments), the channel is enabled at power up. When true, the channel will not fire in flight unless a manual software arming step has taken place pre-launch (default for airstarts)

In addition to the channel-specific events shown above, there are rocket-level flight events that can also be part of any channel's deployment logic.

Rocket Event	Event description and use cases
Liftoff Detected	Always required before any deployment.
Apogee Detected	This fault-tolerant event detection is latched true when 2 of 3 sensor evaluations detect apogee: Baro pressure increasing, total velocity is < 0, Gyro-based tilt angle > 90. This event is checked for the default apogee and main deployment logic, and is latched true for the rest of the flight.
Pressure Increasing	A version of the barometric pressure with a strong low-pass filter (slow changing) is used to detect when the rocket is encountering increasing atmospheric pressure (i.e. descending). This event is checked in the 3 rd channel's default deployment logic.
Apo channel fired	This event turns true 1.5 seconds after the apogee deployment channel first turns on. This is a check to ensure that any transient events associated with the apogee deployment are complete. This check is used for the default main deployment primary set of checks.
Main channel fired	Similar to the Apo channel fired, but for the Main channel.
3 rd channel fired	Similar to the Apo channel fired, but for the 3 rd channel.
4 th channel fired	Similar to the Apo channel fired, but for the 4 th channel.

Deployment options selectable via USB command

Though the Bluetooth interface will provide complete control over the deployment logic settings, including which events are checked, and the thresholds for the checks, the USB interface currently only supports selection of 4 pre-canned options with the following commands: `<default>`, `<2nd stage>`, `<sustainer>`, and `<3 stage sim>`. After the command is sent, the settings are modified if necessary and stored in flash memory. Then the flash is read back and a hexadecimal representation of which events are checked is displayed. The status is paused for 5 seconds. The current deployment settings can be displayed by sending the command `<get deploy>`.

The following tables show which events are checked and what the thresholds are for the four selectable options:

Default deployment configuration (<default> command):

	Unit	Apo	Apo bkp	Main	Main bkp	3rd	3rd bkp	4th	4th bkp
Channel Events									
AGL < AGL1	feet			<700				<500	<500
AGL > AGL2	feet								
Flight angle < FANG1	deg								
Flight angle > FANG2	deg								
Future Angle > FUTANG	deg								
Time < TVAL1	sec								
Time > TVAL2	sec								
Total Velocity < VEL1	ft/sec					<400	<400		
Total Velocity > VEL2	ft/sec								
Baro velocity < BVEL	ft/sec				<-200				
Burnout counter > BURNCOUNT		>=1	>=1	>=1	>=1	>=1	>=1	>=1	>=1
Channel is armed		Check	Check	Check	Check	Check	Check	Check	Check
Flight Event Register (FER)									
Liftoff detected		Check	Check	Check	Check	Check	Check	Check	Check
Apogee detected		Check	Check	Check	Check				
Pressure Increasing						Check	Check		
Burnout Coast									
Apo Fired				Check				Check	Check
Main Fired									
3rd Fired									
4th Fired									

Sustainer (<sustainer> command):

Function					Airstart , angle-limited		Airstart near-vertical	
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	Apo	Apo bkp	Main	Main bkp	3rd	3rd bkp	4th	4th bkp
Channel Events								
AGL < AGL1			<700	<700				
AGL > AGL2					>600	>600	>600	>600
Flight angle < FANG1					<18	<18	<15	<15
Flight angle > FANG2								
Future Angle > FUTANG					>12	>12		
Time < TVAL1								
Time > TVAL2								
Total Velocity < VEL1					<800	<800	<460	<460
Total Velocity > VEL2								
Baro velocity < BVEL								
Burnout counter > BURNCOUNT	>=1	>=1	>=1	>=1	>=1	>=1	>=1	>=1
Channel is armed	Check	Check	Check	Check	Check	Check	Check	Check
Flight Event Register (FER)								
Liftoff detected	Check	Check	Check	Check	Check	Check	Check	Check
Apogee detected	Check	Check	Check	Check				
Pressure Increasing								
Burnout Coast								
Apo Fired			Check					
Main Fired								
3rd Fired								
4th Fired								

This set of deployment options above is intended for the 2nd stage of a 2-stage rocket. The Apogee and Main deployments are not modified from the defaults. The airstart is intended to be delayed until either the speed is low enough to approach the optimal ignition velocity, or the angle gets high enough to be a problem for downrange distance. See discussion and analysis [in the Rocketry Forum](#). For the sustainer of a 3-stage rocket, the burncount would need to be increased to >=2.

2nd stage of 3-stage flight (<2nd stage> command):

Function			Airstart 2 nd stage		2 nd /3 rd Separat ion		Airstart near vert	
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	Apo	Apo bkp	Main	Main bkp	3rd	3rd bkp	4th	4th bkp
Channel Events								
AGL < AGL1								
AGL > AGL2			Check	Check			Check	Check
Flight angle < FANG1			Check	Check			Check	Check
Flight angle > FANG2								
Future Angle > FUTANG			Check	Check				
Time < TVAL1								
Time > TVAL2								
Total Velocity < VEL1			Check	Check			Check	Check
Total Velocity > VEL2								
Baro velocity < BVEL								
Burnout counter > BURNCOUNT	>=1	>=1	>=1	>=1	>=2	>=1	>=1	>=1
Channel is armed	Check	Check	Check	Check	Check	Check	Check	Check
Flight Event Register (FER)								
Liftoff detected	Check	Check	Check	Check	Check	Check	Check	Check
Apogee detected	Check	Check	Check	Check				
Pressure Increasing								
Burnout Coast								
Apo Fired			Check					
Main Fired								
3rd Fired								
4th Fired								

This set of deployment options above is intended for the 2nd stage of a 3-stage rocket. The Apogee channel is set to deploy a parachute at 2nd stage apogee. The airstart is intended to be delayed until either the speed is low enough to approach the optimal ignition velocity, or the angle gets high enough to be a problem for downrange distance. See discussion and analysis [in the Rocketry Forum](#). The 3rd channel is assigned to fire a stage separation charge immediately after the second stage burnout.

Flight Simulation

The Blue Raven flight simulation capability verifies that deployment settings work as expected before a real flight, and familiarizes the user with the Blue Raven's flight data recording and analysis features. While the Blue Raven is sitting on the ground, a simulated flight will make the Blue Raven behave just as

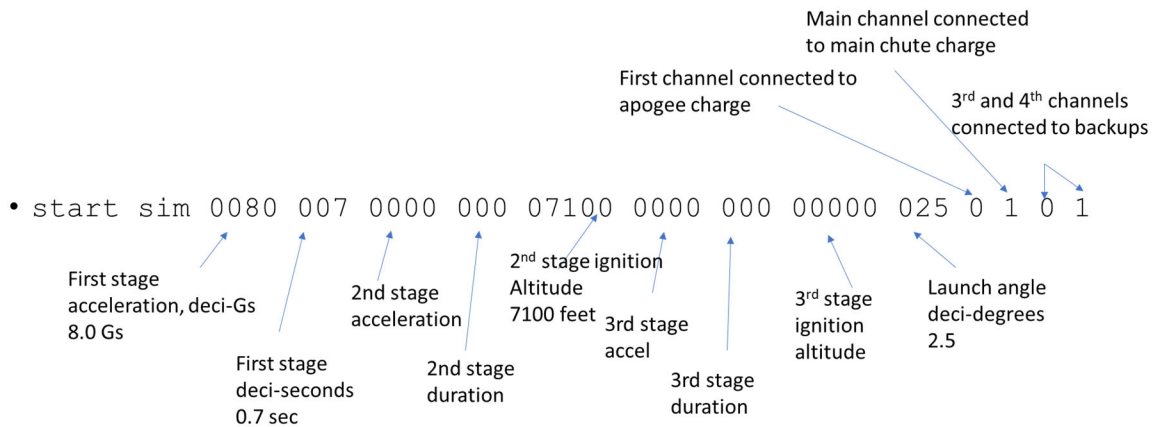
if it is flying through all the flight dynamics it would experience in a real flight. The Blue Raven will react by turning on the real output channels under the conditions it would during the flight, and the flight data is recorded just as it would be in a real flight to let the user review the deployment events and the conditions that triggered them. Events that are driven by Blue Raven outputs that affect a real flight's dynamics, including apogee deployment, main chute deployment, and 2nd and 3rd stage motor airstarts can also be simulated and triggered by the real output deployment settings of any of the output channels. Physical effects such as launch angle, atmospheric density changing with altitude, aerodynamic drag, and rocket configuration changes are included in the simulation so that the deployment logic can be fully tested.

Phone App Simulation Interface

(A description of the phone screens and interface will go here)

USB Serial simulation interface (optional)

All of the parameters that specify the simulation options are included in one long command, as shown below for a short single-stage flight with default deployment settings:



1.

The command has a fixed length and each of the parameters must be located at the fixed positions as shown above. This example command is also provided as text below so that it can be copied from this manual and pasted into the serial terminal:

```
start sim 0080 010 0000 000 07100 0000 000 00002 025 0 1 0 1
```

Each of up to three burns are described with 2 parameters: acceleration and burn duration. Motors that are not present are specified with zeroes for acceleration and duration.

Airstarts in second and third stages can be triggered at a fixed altitude parameter in the sim command, or by connecting the virtual motor to an actual deployment output using the last four parameters.

The last 4 parameters use a code for each output to tell the simulation what events should happen when the output fires during the flight. The codes are:

Code	Simulated event
0	Increase the simulated drag to be consistent with a small drogue chute
1	Increase the simulated drag to be consistent with a deployed main chute
2	Ignite a simulated second stage motor
3	Ignite a simulated third stage motor

9	No connection
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The four codes correspond to the 4 output channels, Apo, Main, 3rd and 4th respectively. Note that a simulation event can be connected to multiple channels. In the example above, this is used to connect both the Apo and 3rd channels to the simulated apogee deployment, and the Main and 4th channels to the simulated main chute deployment. Another use case is to connect an airstart to two output channels in parallel so that different combinations of conditions could be used to start the motor.

Other Simulation Notes

The simulated flight dynamics are added onto the actual measurements made by the accelerometers and gyros during the flight, so be sure to keep the Blue Raven still during the simulation to prevent changes in tilt orientation which would cause unexpected behavior in the simulation.

Changing the Blue Raven operating mode

The Blue Raven powers up into prelaunch mode, which makes the Blue Raven ready for launch. The status of the deployment connections is beeped out, and the accelerometer and gyro pad offsets are periodically updated. The command `<checkout>` puts the Blue Raven into a mode where the beeps are turned off and the pad offsets are zeroed so that the accelerometer calibration can be observed. The command `<prelaunch>` puts the Blue Raven back into prelaunch mode, and ready for launch as long as a simulation has not yet been run since the last power cycle.

The other modes, liftoff and landed, happen automatically after liftoff conditions are detected in prelaunch mode, and after landing is detected while in liftoff mode. A power cycle is necessary after a simulated or actual flight before the next flight, to ensure that that all internal states are reset correctly. The mode commands are planned to be accessible only through the USB connection, to avoid the possibility of an accidental launch while the Blue Raven is in checkout mode.

Accelerometer Calibration

The Blue Raven has 3-axis accelerometers that can be re-calibrated by the user to compensate for sensor calibration drift that can occur over time. Re-calibrating within a few days prior to launch is recommended for best inertial navigation performance, but is not necessary for general purpose deployment control.

To calibrate the accelerometers via the USB connection, start with the command `<cal start>`. The low-pass filtering of the accelerometer data is increased so that small changes can be observed. Next, position the Blue Raven with any of the edges aligned vertically. One axis of the low-range accelerometer should be near 1.0 or -1.0 Gs, while the other axes should be near zero. When the values match this condition, send the command `<cal axis>`. This records the filtered accelerometer values at the time the command was sent. Next, reposition the Blue raven into another of the 6 positions and repeat the command. The order of the orientations does not matter because the Blue Raven identifies which axis is up. Once all 6 orientations have been recorded, command `<cal stop>`. If all 6 orientation recordings are valid, the Blue Raven will respond with a message that the new calibration is complete. If the number of positions with valid readings is less than 6 when cal stop is commanded, the calibration attempt is rejected and will need to be started over. Any calibration axis can be redone during the calibration before `<cal stop>` is commanded.

Flight Data Recording and Post-Flight Downloads

The Blue Raven records three sets of data for each flight:

1. Flight summary data such as maximum altitude and speed
2. Low rate data, which includes a large number of measurements recorded at 50 Hz
3. High Rate data, which includes a smaller set of measurements recorded at 500 Hz.

There is flash memory space in the Blue Raven for two flights. If there is no free space available when the unit is powered up, the oldest flight data is erased.

All three sets of data are downloaded automatically over Bluetooth once the flyer gets back in range of the rocket after the flight. The summary data is downloaded first so that the flight performance is immediately available for review while the other data sets are downloaded in the background. This can take several minutes.

Phone interface to downloaded data

(to be added)

Summary data via the optional USB interface

To download the most recent flight summary, the command is **<summary>**. An example of summary data output following the example simulated flight is shown below:

@ SUMMARY 706

Rocket: Adrian's BRav

Build: 02/14/2023 11:19:58000

Launch: 02/14/2023 11:23:31920

landing time: 11:24:14680

pad accel: -220 -34 -9868 mag: 0

rail_direction: -721 -34 -9973

accel pad offsets: 2 0 116

hi-g pad offsets: 8867 7824 9333

flash active: B1 compl: B1 last_hr: 7A900 last_lr: 503F00

apogee h_vel: 22

max motor accel: 80

max drag accel: 1

drogue vel@main: -924

main_avg_vel: 256

burnout_tilt: 44

tilt_efficiency: 931

ascent roll ang: 26

pad_AS_L: 6806

max deploy accel: 0 154 2 9

max landing accel: 398

max alt: 897 max vel: 228 CRC: 6FA7

Summary value interpretation

Rocket: Adrian's BRav

The first line is the user-defined name, up to 13 characters. Name is set with `<set name [name]>` command.

Build: 02/14/2023 11:19:58000

Launch: 02/14/2023 11:23:31920

landing time: 11:24:14680

The next line of the summary is the build date and time of the firmware that's on the Blue Raven. Next are the launch and landing date and times.

pad accel: -220 -34 -9868 mag: 0

rail_direction: -721 -34 -9973

The pad accel is the measurement of the accelerometers while the rocket was sitting still, in units of Gs x 10,000. The rail direction is the direction of the first motion of the launch, in the sensor coordinate frame,

normalized to a vector magnitude of 10,000. This rail direction is assumed to be aligned with the axis of the rocket, and is what is compared to the direction of gravity when calculating the rocket tilt.

accel pad offsets: 2 0 116

hi-g pad offsets: 8867 7824 9333

On the pad, the Blue Raven knows what the magnitude of gravity is supposed to be, and if it measures a pad acceleration that has a slightly different magnitude, it uses that difference to adjust the accelerometer offset values in the direction of the measured gravity direction. The pad offsets for both the low-range and hi-range accelerometers are displayed in units of Gs x 10,000. In the example case, the low-range accelerometer's z-axis value was adjusted by 0.0116 Gs based on the on-pad measurements, while the Hi-G z-axis value was adjusted by 0.933 Gs.

flash active: B1 compl: B1 last_hr: 7A900 last_lr: 503F00

The next line of the summary displays flash memory status which can be ignored by most users. The first part shows which of the two flash banks are active and which has the most recent completed data (B1 or B2 for bank 1 or bank 2). The last recorded flash address of the flight for the low-rate and high-rate data sets is given next.

apogee h_vel: 22

Apogee h-vel gives the estimated horizontal velocity at apogee, in feet/second.

max motor accel: 80

max drag accel: 1

Max motor accel is the maximum acceleration measured between liftoff and motor burnout, given in units of Gs x10. In the example the max acceleration during the motor burn is 8.0 Gs. Max drag accel is the maximum measured acceleration between motor burnout and apogee, also given in units of Gs x 10. In the example, the max drag acceleration is 0.1 Gs.

drogue vel@main: -924

main_avg_vel: 264

The drogue vel@main is the estimated velocity of the rocket just before main deployment, based on the barometric sensor. It is shown in units of feet/second x 10. In the example the velocity is 92.4 ft/second downward. The main_avg_vel statistic is calculated as the average barometric velocity during a 5-second period, 6 seconds after main deployment. It is shown in feet/second x 10. In the example, the avg main velocity is 26.4 feet/second.

burnout_tilt: 44

tilt_efficiency: 931

ascent roll ang: 26

The burnout tilt is the rocket tilt at burnout, shown in degrees x 10. In the example, the tilt at burnout is 4.4 degrees. The tilt efficiency is a ratio of the vertical velocity at motor burnout compared to an estimate of what it would have been if the flight were perfectly vertical. In this example, the tilt efficiency is 93.1%. The roll angle prior to apogee was 26 degrees (with a manual roll movement during the sim

pad_AS_L: 6806

The pad ASL is the altitude above sea level, in feet, based on the barometric pressure. Simulated flights start from the measured altitude of the actual unit at the start of the sim. In this example, the sim was started in the suburbs of Denver with an altitude of 6806 feet.

max deploy accel: 0 154 2 9

The max deployment accelerations are the maximum accelerations measured during the 1-second firing of each of the four deployment outputs, displayed in units of Gs x10. This measurement is taken 500 times per second. For real flights, the maximum acceleration during the 1-second firing could come from the deployment charge itself, or from aerodynamic changes immediately after the charge goes off. In the case of the simulation, the only source of acceleration is the aerodynamic drag. In this example, the simulation had 0 Gs of acceleration during the apogee deployment, 15.4 Gs after the main deployment due to the increased drag from the simulated main chute, 0.2 Gs during the apogee backup event, and 0.9 G during the main backup event.

max landing accel: 398

The max landing accel is based on the highest recorded acceleration in the 10 seconds prior to landing detection. The units are Gs x10, so in this example the landing Gs were 39.8. The landing Gs are simulated by assuming that all simulated vertical velocity is taken out with an impulse spread over one 20 msec simulation cycle.

max alt: 897 max vel: 228 CRC: 50E5

The last line of the summary displays the apogee altitude in feet, and the maximum velocity in feet/second. In this example the max altitude was 897 feet and the max velocity was 228 feet/second.

Downloading flight data

Downloading with RealTerm

Data sent to the terminal window can be saved using the interface under the “Capture” tab. In RealTerm, file names cannot have spaces. Enabling “Direct Capture” and “Display” are recommended.

Low Rate Data

The command for downloading the low-rate data is `<download 1>`. The format of the downloaded data starts with the mnemonic `@ LOG_LOW` followed by the length of the string, and the time and date of the flight in `[year] [month] [day] [hour] [minute] [second]` format. The next fields have the flight data as shown below:

```
[sync code] Bo: [temperature from baro sensor] [pressure in atm x 50,000]
V: [Battery mV] [Apo mV] [Main mV] [3rd mV] [4th mV] [output current, mA]
Vel: [Upward velocity ft/sec] [Down-range ft/sec] [Cross-range ft/sec]
Pos: [Inertial Nav Altitude (ft)] [Down-range feet] [Cross-range feet]
ang: [tilt angle, deg x10] [roll angle, deg] [future tilt angle, degx10]
FER: [flight event register code] [Apo FER] [Main FER] [3rd FER] [4th FER]
CRC: [16b Bypass CRC code for line of text]
```

The sync code is a millisecond counter recorded in both the low-rate and high-rate data so that the two data sets can be aligned with each other. The sync code rolls over every 250 msec. The velocity and

position data are given in ground-relative inertial coordinates (rather than rocket axes), which is possible due to the rocket attitude propagation performed on-board using the gyro measurements. These measurements are only reasonably accurate as long as the rocket experiences rotation rates within the measurement range of the gyros (± 2000 deg/sec). If the rocket has rates beyond that (often the case for small rockets immediately after chute deployment), the rocket will lose track of which way is up, and the effect of gravity will generate large errors on the position and velocity estimates. Other normal gyro and accelerometer measurement errors can also contribute to significant errors in the velocity and position estimates, particularly in the horizontal directions.

The tilt angle is the angle between the rocket's axis and vertical. The Blue Raven can be mounted in any orientation, and so it measures which direction, relative to its sensors, is the rocket axis by measuring the direction of the initial motion while the rocket is on the rail.

The roll angle is a simple integration over time of the measured roll rate perpendicular to the rocket axis. It does not take into account how motion in other axes affects the rocket orientation.

The future angle is an estimate of what the tilt angle will be, three seconds into the future, based on the rocket's horizontal and vertical velocity, and assuming that the rocket's fins will keep it pointed in the direction of travel. This measurement is a useful trigger for igniting an upper stage, because it compensates for the additional tilt that can occur during the ignition delay.

There are five Flight event registers: One rocket-level Flight Event Register that records the flight events that affect all channels (such as apogee detection). Each of the 4 output channels has a separate channel flight event register, which is governed by a set of independent event thresholds for each channel. The values are hex-encoded binary values that use one bit for each event.

High Rate Data

The command for downloading the high-rate data is `<download h>`. The format of the downloaded data starts with the mnemonic `@ LOG_HIR` followed by the length of the string, and the time and date of the flight in `[year] [month] [day] [hour] [minute] [second]` format. The next fields have the flight data as shown below:

```
[sync code] [gyro X deg/s x100] [gyro Y deg/s x100] [gyro Z deg/s x100]
[Accel X Gs x100] [Accel Y Gs x100] [Accel Z Gs x100] [Quaternion X x 30000]
[Quaternion Y x 30000] [Quaternion Z x 30000] [Quaternion magnitude x 30000]
```

The sync code is the same as for the low rate data. The gyro data is raw data in the sensor axis. The acceleration data is taken from the ± 32 G range accelerometers as long as the high-rate accelerometers read lower magnitude than 32 Gs. For measurements above 32 Gs, the high-range accelerometer measurements are recorded.

The quaternion values are recorded with the rotation axis first and the magnitude term fourth. They are scaled up by a factor of 30,000 to fit into signed 16-bit integers.

Other USB commands

Flash data deletion

Although the Blue Raven automatically deletes flight data and configuration data as necessary to make room for new data, commands for erasing the configuration data and the flight data are `<erase config>` and `<erase data>`, respectively. If the configuration data is erased, the default parameters are loaded.

LED and Beep control

The commands `<beeps on>` and `<beeps off>` enable and disable the automatic beeps.

The command `<LED [color] [state]>` can directly control the LEDs. The color code is 0=Red, 1=Green and 2 = Blue. 3 in the color code can be used to enable and disable the manual control LED events. 1 = hold manual state 0 = use background LED control.

Appendix A: All USB Commands