RRC3 – Rocket Recovery Controller 3
User Manual

Revision 1.60

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Introduction

Overview

The Rocket Recovery Controller 3 (RRC3) is a barometric dual-deploy altimeter, with the features of high-end units, at the cost of those with a more modest feature set. In addition to basic dual-deploy capability, the RRC3 is a multi-flight recording unit, allowing you to fly all day, without the need to stop and download data in between flights.

Two-stage (or dual) deployment is preferable to single parachute or streamer recovery systems for high-power rocketry. Recovery of large, heavy rockets with a small parachute or streamer alone does not supply enough drag to safely recover the rocket without damage. An adequately sized parachute deployed at a high altitude may cause the rocket to drift out of the launch area, making recovery difficult if not impossible.

Two stage (or dual) deployment recovery systems either separate the rocket airframe into two sections or eject a small drogue parachute or streamer at apogee, allowing the rocket to descend at a rapid yet controlled rate. When the rocket descends to a predetermined altitude above its initial launch elevation, it then deploys the main parachute, allowing the rocket to make a safe landing.

Primary Features

- Drogue and Main outputs
- Configurable Deployment operations
- Configurable Main and Arming altitudes
- User-selectable beep frequency
- Configurable third "Aux" output
- 15 flight memory @ ~28 minutes per flight
- Live data streaming and telemetry capability

Specifications

Microcontroller	16MHz 16-bit MSP430 Series mCU
Onboard Flight memory	8Mbit SST Flash Memory
Pressure/Temperature sensor	MSI MS5607 Pressure sensor with 24 bit ΔΣ ADC
Operational Ranges	Standard Unit (40K/100K MSL) / Xtreme Unit (100K MSL)
Arming Mode	Barometric
Minimum altitude for arming	100 feet (adjustable)
Battery	3.5 volts to 10 volts
Test Current	17μa to 50 μa (battery dependent)
Firing Current	3 amps for 1 second (Drogue / Main)
Dimensions	23.5mm x 99.5mm (0.925" x 3.917")

Handling Precautions

- Always handle the RRC3 in a static-free, grounded environment
- Never touch/handle the RRC3 when it is armed and connected to live pyrotechnic charges
- Always allow the RRC3 to adjust to ambient temperature conditions prior to arming and flying
- Always prepare your rocket and recovery system components with the RRC3 powered off
- Never cycle the RRC3 power switch off, then immediately back on (allow at least 10 seconds).

RRC3 System Options

- Computer USB interface board, for configuration and data download via *mDACS* PC software
- Bluetooth interface board for Smartphone configuration and data download
- LCD interface terminal for field configuration of unit and field review of flight data
- Combo GPS/Telemetry board for live downlink of location/data stream
- PerfectFlite DT2/DT3 interface adapter for the configuration/download from RRC3
- Wiring harnesses for custom interface of Comm and Auxiliary Output
- Auxiliary Pyro Expansion board, providing additional output channels and timing
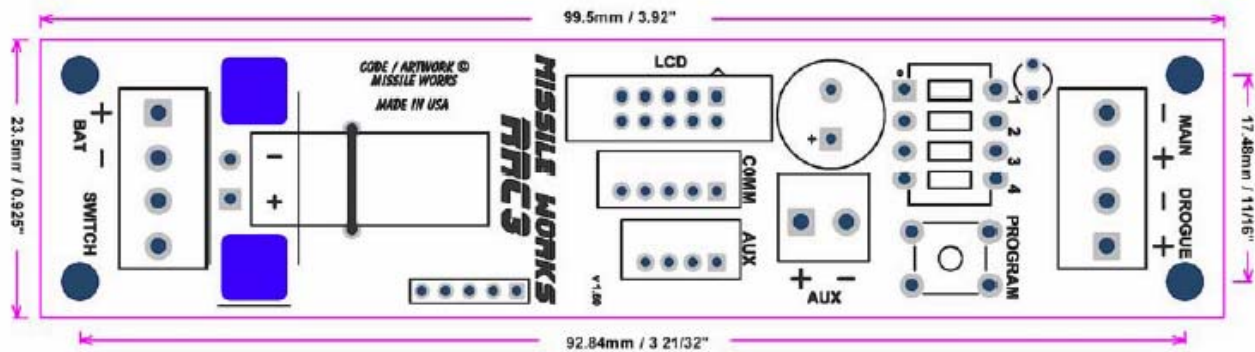
Default Base Settings

- Arming Altitude — 300' AGL
- Main Deployment Altitude — 500' AGL
- Deployment Mode — Drogue @ Apogee / Main @ AGL altitude
- Audio Options — Continuity Beep
- Units — Feet / Feet per second
- Low Voltage Lockout — Disabled
- Piezo Tone — 1.04 KHz
- Drogue Delay — 1 second (Used in Backup Mode only)

NOTE: You can reset the settings of the RRC3 back to these defaults using the following procedure:

- Push and Hold the programming pushbutton.
- Apply power to the RRC3 while the pushbutton is pressed (the LED will flicker).
- Continue holding down the pushbutton for approximately 5 seconds.
- Release the pushbutton when it beeps (refer to POST codes in the **Operational Modes** section).
- Shut the RRC3 off.

Installation

Altimeter Mounting

The RRC3 does not have an "up" orientation, and can be mounted in any convenient orientation. It is important to mount the altimeter securely, preventing it from suffering damage during flight.

When planning the layout of your altimeter bay, in addition to mounting the RRC3, be sure to provide secure mounting for the battery. An unsecured battery can break free during recovery events, resulting in damage to the altimeter.

4/40 screw hardware is recommended to mount the RRC3 onto the altimeter bay "sled" of the rocket. Nylon standoffs or insulated washers are also required to provide clearance for the barometric sensor located on the bottom side of the circuit board.

The altimeter bay section used for the RRC3 must be a sealed chamber with a static pressure ports (see the next section for port sizing). The sealing of the chamber is necessary for several reasons:

- Isolates the electronics from the ejection-charge heat, residue, and over-pressure

- Isolates the electronics from the aerodynamic pressure and vacuum during flight

- Provides uniform static pressure equilibrium to ambient pressure during flight

IMPORTANT: Inadequate sealing of the electronics bay or exposure of the electronics to ejection charge heat, BP residue, or pressure will cause the RRC3 to malfunction.

IMPORTANT: Black powder residue is extremely corrosive to the circuit board and its components. Always clean off any inadvertent residue immediately to avoid long-term damage to the unit.

Static Pressure Ports

Barometric altimeters require equalization of the air pressure inside the altimeter bay and the air pressure outside the rocket. To provide this, one or more static pressure ports are required. While one port can be used, to reduce spurious readings due to wind across a single port, multiple equally spaced ports is recommended.

Static ports should be located where they are not affected by anything which can cause turbulence in the airflow over the port. This includes rail buttons, screw heads, nosecones and transitions – the farther the static port(s) can be located from such items, the better.

The sizing of static port(s) requires that you first calculate the volume of the electronics bay as follows:

Volume = Bay Radius (inches) x Bay Radius (inches) x Bay Length (inches) x 3.14

Next, use the appropriate single port formula to calculate the size of a single port:

For volumes < 100   Single Port Diameter (inches) = Volume / 400

OR

For volumes >= 100   Single Port Diameter = 2 x SQRT (Volume / 6397.71)

If you plan to use multiple ports (recommended), determine how many ports to use (a minimum of 3 is recommended), then calculate the size of each port using these multi-port formulas:

Single Port Area = (Single Vent Diameter / 2) x (Single Vent Diameter / 2) x 3.14

Multi Port Diameter = 2 x SQRT ((Single Vent Area / # of holes) / 3.14)

Power and Wiring Considerations

The RRC3 is designed to be operated with a standard 9-volt alkaline battery. Standard 9V alkalines are an optimal choice, providing an inexpensive and widely available battery type with secure snap connectors. Always purchase and use premium alkaline batteries.

Other battery types can be used, including NiCd, NiMH, LiPo, or other battery chemistries. Your battery choice must source and maintain an absolute minimum of 3.5 volts, and also be limited to a maximum of 10 volts.

It should be noted that 9V alkaline batteries can source a maximum discharge current of about 3 amps into a short. The Drogue, Main, and Aux outputs of the RRC3 are rated for 3A service. When using other batteries chemistries that can source higher discharge currents, users should ensure the output connections to the Drogue, Main, and Aux are not shorted, and the connected electronic match loads do not exceed 3A to avoid damaging the unit.

The brownout capacitor is optimized to prevent an over-current brownout condition when operating the RRC3 with a 9 volt battery. Lower battery voltages reduce the total brownout time capability of the capacitor. If you do choose to use a lower voltage battery than 9V, ensure your battery has adequate voltage/power reserve to prevent a brownout condition during flight due to a voltage dip, and that you pay extra attention to the loads required by your e-matches.

Nominal power consumption for the RRC3 is approximately 6ma. When beeping or flashing however, power consumption can jump up to ≈35ma. During Pre-launch on the pad, and Post Flight after recovery, the altimeter will beep and flash the LED. During flight operations, the LED will illuminate when the velocity discriminator lockout conditions are active.

IMPORTANT: Always use a battery system of 10 Volts or less to avoid damaging the RRC3

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IMPORTANT: Always load-test your battery prior to flight to ensure adequate power reserve for reliable operation and ignition of the ejection charges. Inadequate sizing of an external battery system or high-current demands on the battery system during event initiation may lead to power and processor brown-out conditions, resulting in recovery failure.

In addition, it is important to pay attention to battery polarity – the positive terminal on the battery must be connected to the positive terminal (marked with a + sign) on the altimeter. Connecting the battery backwards will not damage the unit, however the altimeter won't operate.

Stranded 20-22 AWG wire is recommended for the battery and power switch terminals.

Power Switch Considerations

In addition to providing a power source, a power switch should be connected to the switch terminals (next to the power terminals) on the altimeter. The switch used can be as simple as a pair of wires which are twisted together prior to flight (i.e. "twist and tape"), or as complex as a magnetically activated solid-state switch.

Switches which provided positive, bounce-free contact, such as twisted wires, high quality rotary or lever switches, push on/off, and screw switches, are recommended for their simplicity and reliability.

If you do use the "twist and tape" method, please use the following guidelines:

- *Do Not poke the wires back into the airframe after making a connection.* When the wires are poked back into the airframe, this creates a safety issue should the rocket need to be disarmed and removed from the pad for any reason, as it is difficult, if not impossible, to fish the wires back out of the hole.

- Maintain positive contact of the stripped wire ends while twisting them together to avoid power bobbles which can lead to brownouts or other undesired results, including potential output event activations due to potential undefined states of operation.

- It is best to tape the leads, after twisting them, then tape them to the airframe, or poke the end into another hole on the airframe, leaving a length of wire exposed and accessible on the outside of the airframe.

If your using an "active" switch that sources power and is polarity dependent, the (+) battery power switch terminal is located adjacent to the battery negative terminal. The switched (+) power terminal is the other switch terminal.

Drogue and Main Ejection Charge Connections

The RRC3 is designed to be used with low current electric matches (Daveyfire, Oxral, MTEK, JTEK), or low current motor igniters (Quest Q2G2).

It's also extremely important that you pay attention and validate that you connect your drogue ejection charge to the drogue terminals and the main ejection charge to the main terminals. These terminals are clearly marked on the board with positive and negative designations.

The RRC3 employs the use of an "Open Drain MosFET" device to activate the ejection charges. The battery voltage is always present on the (+) terminal while power is applied to the RRC3, and the (-) terminal is a high resistance connection that prevents any current flow until the MosFET is gated on at the appropriate event time.

IMPORTANT: NEVER attach live ejection charges with the altimeter powered ON. Always connect live ejection charges with the altimeter powered OFF.

Always pre-measure your deployment charge matches or igniters for a nominal resistance and verify they are not shorted. A nominal resistance for a low current device should be in the range of 1 to 2 ohms.

At the Pad

At the launch pad, begin by placing your rocket on the pad/rail, and raising the rocket to the vertical (launch) position. Do not install the igniter at this time.

Before you arm the altimeter, have bystanders remove themselves to a safe distance where they will not be injured, should the ejection charges fire prematurely.

Turn on the arming switch for the altimeter, and listen for the startup sequence. The altimeter startup sequence is as follows :

1. 5 second long beep (init mode)
2. 10 second baro history init time (silence)
3. Settings beep (when enabled) or POST fault code beep (if a fault, see *POST fault codes*)
4. 10 second launch commit test time (silence)
5. Launch Detect mode (continuity beeps)
   a. A long beep indicates no continuity on any event terminal.
   b. One short beep indicates continuity on only the drogue terminal.
   c. Two short beeps indicate continuity on only the main terminal.
   d. Three short beeps indicate continuity on the main and drogue terminals.

Assuming the altimeter beeps out the expected continuity status, your altimeter is ready for launch. At this point, you should install the igniter, connect the igniter leads, and leave the area.

Should there be a need to remove the rocket from the pad, or otherwise change its position, begin by disconnecting and removing the igniter. Then, turn off the arming switch for the altimeter, and wait a minimum of 10 seconds after the altimeter stops beeping before moving the rocket.

Analyzing Your Flight

After your flight, the altimeter will beep/flash out your peak altitude using a "per digit" method. For example, let's say your rocket flew to a peak altitude of 2,340 feet. You'd hear the following beep sequence:

beep-beep (2), short pause

beep-beep-beep (3), short pause

beep-beep-beep-beep (4), short pause

beeeeeeeeeeeeeeeep (0), short pause

Short low tone beep (end of audio value report)

Long pause (beeping will repeat)

The altimeter will continue to beep as described until powered off. There are additional flight data items you can enable to beep after each flight (see the "Audio Options" setting in the Advanced Operation section).

Operating Tips for Success

- Always pre-test your altimeter as COMPLETELY as possible prior to every flight. This includes a test of the inputs, outputs, and baro system. These tests can be performed using the diagnostics capability of the RRC3 (see the Advanced Operation section).

- Always pre-test your batteries before each flight and ensure they have adequate power capacity for the anticipated worst case flight profile, including unplanned "on-the-pad" waiting time.

- Always pre-measure your deployment charge initiators. Measure them for a nominal resistance and verify they are not shorted.

- Proper port-sizing creates ideal equilibrium rates. Ensure that your porting is compliant with the recommended sizing. Improperly sized porting or other leaks in the electronics bay can create parasitic pressure effects, impacting equilibrium rates and reliable recovery.

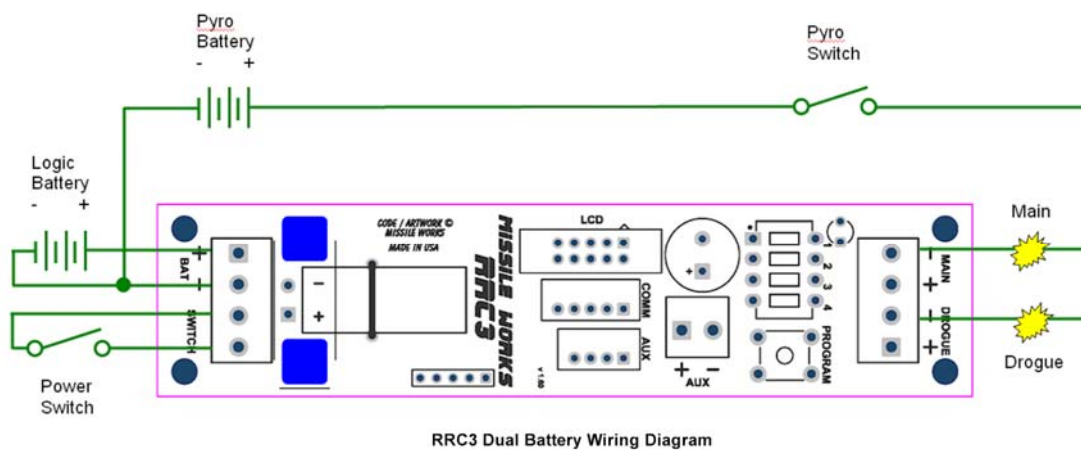## Advanced Features and Operation

The RRC3 provides a number of advanced features and operations while still maintaining and providing the basics of simple and reliable dual event recovery and peak altitude determination. These advanced features are easily accessible, but do not interfere or get in the way of the basic functions that the RRC3 provides.

Dual Battery Wiring

The RRC3 is designed to fly using 9V alkaline batteries in tandem with low current ematches for the drogue and main deployment charges. Should your application require higher current for output events, or your operating at lower battery voltages you might consider using a dual battery wiring setup. This method isolates the RRC3 Logic Battery power from the Drogue/Main Deployment charge power, thus eliminating any potential voltage brown-out scenarios during event activation. The logic battery must comply with the 3.5VDC to 10VDC rating as mentioned in the specs; however your pyro battery may be any voltage up to an absolute maximum of 30VDC.

It is also recommended when using this dual battery operation to first activate the RRC3 Logic Switch, and after verification of a successful boot, then activate the Pyro Switch.

When using dual batteries, use the following wiring diagram as a guide.

RRC3 Dual Battery Wiring Diagram

RRC3 Operational Modes

The RRC3-mini has several distinct modes throughout the course of its operation during flight and recovery. These modes of operation are identified by the function of the piezo and the LED, and the specific phase of flight.

Power Up and Pre-Launch Modes

Power-up Initialization Mode
When power is first applied to the unit, it will provide a continuous 5-second beep to indicate it has been switched on. During this 5-second time period, the RRC3 is looking for a tap of the "Program" button (invoking the DIP Switch Operations Mode) The LED will remain on continuously during the Power-up Initialization Mode.

Baro History Initialization Mode
After the Power-up Initialization mode, the unit goes through a 10-second baro initialization start-up delay. The LED will flash on and off every 2 seconds while in this mode. This delay period allows barometric stabilization and establishes an initial barometric history. The RRC3 also looks for a "Host Connection" message from a host PC computer (attempting to connect in Host or Simulation Modes). These operations are covered in subsequent mDACS User Manual.

POST Mode (Power On Self Test)
Once a barometric history is established, the RRC3 performs several POST checks to validate the integrity of all sensors and to check the current ambient environmental conditions (pressure and temperature).

If there are any detected system warnings or faults, or conditions that fall outside of specified ranges, the altimeter enters a POST Fault Code loop, where it repeatedly reports the specific fault that it encountered. The RRC3 is unable to fly until the fault or warning is corrected.

POST Fault Codes are preceded by a very distinct warning tone (7 very quick low beeps), followed by the beeping and flashing of the specific fault code.

The following lists all POST Fault Code conditions:

POST Fault Code	Description
1	User invoked Settings Default to Factory Settings warning
2	LCD Terminal Fault / LCD is attached and a DIP Switch is ON
3	Barometric sensor Fault / No communication reply
4	Barometric sensor Fault / Prom CRC Mismatch
5	Barometric pressure Fault / Pressure < 10 mbar or > 1200 mbar
6	Temperature Fault / Temperature < -40 deg. C or > 85 deg. C
7	Low Battery Lockout Fault / Battery < Low Voltage Lockout Level
8	Ambient Barometric Fault / Unstable conditions during Launch Commit Test

POST Code Notes:
- Code 1 is beeped/flashed whenever the user performs a Factory Default Operation.
- Code 2 is beeped flashed if you connect the LCD Terminal with a DIP Switch in the ON position.
- Codes 3 thru 6 indicate a hardware fault. Contact Missile Works for warranty or service details.
- Code 7 indicates the battery is at/ below the specified Low Voltage Lockout. Replace your battery.
- Code 8 indicates that ambient baro conditions are unstable for the currently programmed Arming Altitude. Either raise the Arming Altitude setting, or consider flying in more stable conditions.

Audio Options Report Mode
If you have enabled any of the Pre-Launch Audio options of the RRC3, they will be beeped/flashed at this stage of operations. These audio options include beeping/flashing of battery voltage and Deployment modes. (see the following "Base Settings" section if the manual for more details).

Launch Commit Test
The Launch Commit Test is a 10 second test operation that is a "trial run" of the Launch Detect Mode, applying the currently programmed Arming Altitude against ambient conditions. Should ambient conditions be such that a Launch Detect condition is valid during this test period, the RRC3 will invoke a POST Code 8 condition (see above). During the Launch Commit Test, the LED flashes on and off at a 1 second rate.

Launch Detect Mode
When all previous modes are complete, the unit transitions into Launch Detect Mode. The piezo and the LED will beep/flash to indicate the continuity status of the drogue and main output terminals every 5 seconds as follows:

Long Beep/Flash	**No continuity on Drogue or Main**
1 Short Beep	**Continuity on Drogue only**
2 Short Beeps	**Continuity on Main only**
3 Short Beeps	**Continuity on Drogue and Main**

The RRC3 monitors the barometric sensor for a change in altitude as specified by the current Arming Altitude setting to determine the launch of the rocket. As soon the the current altitude exceeds the Arming Altitude, the RRC3 is activated and Launch Detect is declared.

In-Flight Operational Modes

Apogee Detection Mode
While the RRC3 is actively sampling the barometric sensor to determine apogee and subsequent Drogue Event, both the LED and Piezo will be OFF. When the unit determines that apogee has occurred (by reaching a displacement velocity of 0 ft per second) it will initiate the Drogue Event. The Main Event may also activate at apogee based upon the configuration of the Deployment Mode setting (see the following "Base Settings" section if the manual for more details).

Main Detection Mode
After the RRC3 has detected apogee, it will transition to the Main Detection Mode. The unit will continue to sample barometric pressure during the descent phase of the flight until it reaches the designated Main Altitude setting.

Landing Detection Mode
Once the Main Event has occurred, the RRC3 starts monitoring for a Landing Event. The Landing Event occurs when current velocity > -3 ft. per second for a minimum of 2 seconds.

Post-Flight Operational Mode

After Landing Detection, the RRC3 will report the peak altitude it measured during flight. The piezo and the LED will continuously report the peak altitude by beeping/flashing out the individual digits of the measurement. Depending on the peak altitude, the unit will chirp out 3, 4, 5, or 6 digits.   Should you have enabled any additional Post Flight Audio Options (Peak velocity and/or Time to Apogee), they will beeped/flashed here as well. The RRC3 will continue to beep/flash this data until powered off, and repeat the cycle every 10 seconds.

Base Settings

The RRC3 "**Base Settings"** are a collection of settings and controls that provide all the basic functions of the altimeter.   The following list defines the **Base Settings** of the RRC3:

Arming Altitude   *Range: 10 to 30 (100 ft. to 300 ft.) / Default: 30*
This setting establishes the minimum AGL altitude (in feet) required for the altimeter to arm itself for flight operations and to commence the with drogue chute and main chute recovery controls.   The setting is entered in 10 ft. increments.

Main Deployment Altitude   *Range: 3 to 30 (300 ft. to 3000 ft.) / Default: 5*
This setting defines the AGL altitude (in feet) at which the main deployment event is activated during the descent phase of the recovery. The main deployment event is always preceded by the drogue deployment event. The setting is entered in 100 ft. increments.

Deployment Mode   *Range: 1 to 3 / Default: 1*
The Deployment Mode setting defines how and when the altimeter activates the drogue and main deployment events during a flight. There are 3 distinct deployment modes:
   1. *Dual Deploy Primary*   Drogue @ Apogee / Main @ Main Deployment Altitude
   2. *Dual Deploy Backup*   Drogue @ Apogee + Drogue Delay / Main @ Deployment Altitude
   3. *Apogee Only*   Drogue @ Apogee / Main @ Apogee + 1 sec

<u>*Audio Options*</u>   ***Range: 1 to 32 / Default: 32***

The Audio Options setting controls how the onboard piezo/beeper is utilized throughout flight operations. Aside from the drogue or main activation, activating the piezo it is the single-most battery intensive task the altimeter performs. The setting is specified in a binary-based value according to the following table:

Beep Battery Voltage (X.X volts) Pre-Launch	Setting Value + 1
Beep Deployment Mode and Main Altitude Pre-Launch	Setting Value + 2
Enable Pad Power Saver Mode (disable continuity beeps)	Setting Value + 4
Beep Peak Flight Velocity Post-Flight	Setting Value + 8
Beep Time to Apogee (seconds) Post-Flight	Setting Value + 16
Disable all Audio Options	Setting Value + 32

For example, if you wanted to beep the Pre-Launch Battery Voltage (+1) and in addition, employ the use of the Pad Power Saver Mode (+4), you would set the Audio Options setting to (5).

All of the audio option settings are basically self-explanatory; the exception however is the Pad Power Saver Mode.   If this option is enabled, the continuity beeping you hear initially in Launch Detect Mode will stop after 5 minutes. In place of continuity beeping, the altimeter will emit 1 short "beep" every 15 seconds to indicate it is armed and in launch detect mode, saving a lot of battery power for your inevitable pad wait time and subsequent flight.

<u>*Audio / LCD / Telemetry Units*</u>   ***Range: 1 to 4 / Default: 1***

The Units setting determines how the RRC3 will report all the flight performance values. This setting applies to all forms of data reporting (the audio "beeping", the data displayed on the optional LCD terminal, and the values transmitted in flight via the telemetry capability). Choose a setting that is most appropriate for you as follows:

1. Imperial Units (feet, deg F) / Velocity (feet per second / fps)
2. Metric Units (meters, deg C) / Velocity (Kilometers per hour / KPH)
3. Imperial Units (feet, deg F) / Velocity (Miles per hour /MPH)
4. Metric Units (meters, deg C) / Velocity (meters per second /mps)

<u>*Low Voltage Lockout Level*</u>   ***Range: 2 to 9 / Default: 2***

This setting will validate the RRC3 battery voltage is above a minimum voltage level that's appropriate for your battery system. A setting of (2) disables this lockout feature. If this lockout feature is enabled, and the battery voltage is at or below the specified setting, the unit will not arm itself for flight, and instead activate the POST fault code report mode (see the *POST fault codes*)

<u>*Piezo Tone*</u>   ***Range: 2 to 12 / Default: 12***

This setting determines the frequency the piezo "beeper" will operate at. The lowest setting will result in a higher frequency (6.25 KHz), and the highest setting results in the lowest frequency (1.04 KHz). Use this when multiple electronics are onboard your rocket to distinguish the beeping of one unit from another, or to adjust the tone to a frequency that you can hear.

Drogue Delay   **Range: 1 to 30 / Default: 1**

The Drogue Delay is used whenever you have selected a Deployment Mode setting of _Dual Deploy Backup._   In all other cases this settings is not used. Whenever the RRC3 is designated in a backup role when using redundant altimeter systems, you can delay the RRC3 Drogue event using this setting. Should this delay setting be set for a long period, and the RRC3 determines the Main Event requires activation; the RRC3 will also override the Drogue Delay timer and activate the Drogue Event. The setting is entered in seconds.

DIP switch and pushbutton operations

Setting the RRC3 via DIP switch and pushbutton

Access to all the **Base Settings** is made available via the RRC3 DIP switch and pushbutton interface. The value of all these settings can be verified or reconfigured at any time without the use of the optional LCD Terminal or mDACS PC Software and USB Interface module.

In addition to providing access to all these settings, the DIP switch and pushbutton interface can also provide access to the altimeter resident **Flight Log** data and an interactive **Test Mode** that can validate basic operational integrity of the RRC3 (these are covered in the subsequent manual section). DIP Switch 4 determines this basic selection of Settings access, or Flight Log/Test Mode access.

To start a setting session, ensure the RRC3 is powered off, and that it has a battery and power switch attached and read. **Also ensure the DIP switch 4 is in the OFF position.**

Apply power to the RRC3 by activating the power switch. You should hear the start of the 5 second "init" tone. At any point during this 5 second tone, tap the **PROGRAM** button. The beeper and LED should go out, and the unit will begin its Base Settings operation.

The position of DIP Switches 1 thru 3 determines which of the 8 **Base Settings** that you want to verify, or re-program. The Base Settings operation follows a simple process flow:

1. The RRC3 reads the position of DIP Switches.

2. The RRC3 beeps/flashes the current value of the associated setting.

3. The RRC3 pauses for 5 seconds, and then repeats Step 1.

You can change DIP Switches 1 thru 3 at any time to select a new setting for verification. Using this process, you can validate the values of all 8 **Base Settings**. The DIP switch / Settings positions are:

SW1	SW2	SW3	
OFF	OFF	OFF	Arming Altitude
ON	OFF	OFF	Main Deployment Altitude
OFF	ON	OFF	Deployment Mode
ON	ON	OFF	Audio Options
OFF	OFF	ON	Audio /LCD / Telemetry Units
ON	OFF	ON	Low Voltage Lockout / Alarm Level
OFF	ON	ON	Piezo Tone
ON	ON	ON	Drogue Delay

Step 3 of the above process flow is what we'll refer to as the *"Programming Pause"*. If you want to re-program the setting you currently have selected, you would tap in a new value during this pause time. Let's say you wanted to re-program the Main Altitude setting from the default of 500' to 1000'.

Here are the steps you'd perform:

- Select the Main Altitude Setting via DIP Switch (1 ON / 2 OFF / 3 OFF)

- Verify the current setting value of 5 via beep/flash

- During the "Programming Pause", tap the Program pushbutton 10 times

- The RRC3 should provide a double-beep "acknowledge tone" (new setting is saved)

- Verify the NEW setting value of 10 via beep/flash (10 x 100' = 1000')

Done... Programming complete!

Repeat the sequence again should you want to change it to something else, or select a new setting via DIP switch to verify or change. When you're done, simply power off the RRC3. It's now ready to fly with the newly programmed settings.

Accessing the RRC3 Flight Log via DIP switch and pushbutton

As mentioned in the previous section, the DIP switch and pushbutton interface can also provide access to the altimeter resident **Flight Log** data*.*

To start a Flight Log session, ensure the RRC3 is powered off, and that it has a battery and power switch attached and ready. ***Also ensure the DIP switch 4 is in the ON position.***

Apply power to the RRC3 by activating the power switch. You should hear the start of the 5 second "init" tone. At any point during this 5 second tone, tap the **PROGRAM** button. The beeper and LED should go out, and the unit will begin its Flight Log/Diagnostic operation.

The position of DIP Switches 1 thru 3 determines which of the 6 **Flight Log** items that you want to review. The Flight Log/Diagnostic operation follows a simple process flow:

1. The RRC3 reads the position of DIP Switches.

2. The RRC3 beeps/flashes the value of the associated Flight Log/Diagnostic item(s).

3. The RRC3 pauses for 5 seconds, and then repeats Step 1.

You can change DIP Switches 1 thru 3 at any time to select a new item for review. Using this process, you can review/select all 6 **Flight Log** items. The **Flight Log** DIP switch positions are:

SW1	SW2	SW3	
OFF	OFF	OFF	Peak Altitude AGL
ON	OFF	OFF	Peak Velocity
OFF	ON	OFF	Time to Apogee
ON	ON	OFF	Total Descent Time

OFF	**OFF**	**ON**	Drogue Descent Rate Average
ON	**OFF**	**ON**	Main Descent Rate Average

The RRC3 Flight Log data always contains the data from the last flight. Each new flight overwrites the prior flight information. The items in the Flight Log are all beeped/flashed in the appropriate "units" as set by the *Audio / LCD / Telemetry Units* setting as described in the previous **Base Settings** section.

RRC3 Diagnostics and Testing via DIP switch and pushbutton

There are 2 Diagnostic Modes available that the RRC3 supports while in the **Flight Log** DIP Switch mode. Start in the same manner described in the above section. Set the DIP switches as follows:

SW1	SW2	SW3	
OFF	**ON**	**ON**	Diagnostic / Baro Millibars, Temperature, Firmware version
ON	**ON**	**ON**	Diagnostic / Continuity Inputs & All Outputs Test

The Baro/Temperature diagnostic will read the ambient baro and temperature data directly from the onboard sensor, and then beep/flash accordingly. Temperature is beeped/flashed in the appropriate "units" as set by the *Audio / LCD / Telemetry Units* setting as described in the previous **Base Settings** section. Lastly, this diagnostic wraps up by beeping the current RRC3 firmware build version. It takes the form of X.x, allowing you validate the active build you are running. Use this Diagnostic to quickly validate and test the operational integrity of the barometric sensor system.

The Continuity Inputs diagnostic will read the status of the Drogue, Main, and Auxiliary and then beep/flash the input status accordingly. This test mimics the same continuity status beeping/flashing while in Launch Detect Mode:

Long Beep/Flash	**No continuity on Drogue, Main, or Aux**
1 Short Beep	**Continuity on Drogue only**
2 Short Beeps	**Continuity on Main only**
3 Short Beeps	**Continuity on Drogue and Main only**
4 Short Beeps	**Continuity on Auxiliary only**
5 Short Beeps	**Continuity on Drogue and Auxiliary only**
6 Short Beeps	**Continuity on Main and Auxiliary only**
7 Short Beeps	**Continuity on Drogue, Main, and Auxiliary**

At any point during this diagnostic, if you tap the "Program" button, you will simultaneously activate all 3 outputs (Drogue, Main, and Auxiliary) for the standard 1 second activation time used by the Flight controls.

IMPORTANT: ALWAYS USE EXTREME CAUTION and ensure that you have NO LIVE PYRO CHARGES attached to RRC3 when activating this Output test operation.

Advanced Settings

In addition to the 8 **Base Settings** mentioned in the previous manual section, the RRC3 provides a collection of **Advanced Settings** that control the operation of In-Flight Telemetry, and the Auxiliary Output which can be used for a host of extended control operations.

It should be noted that access to all of these settings is accomplished by use of the optional plug-in LCD Terminal accessory, or by use of the USB Interface module and mDACS PC Software application only. These settings are unavailable through the DIP Switch interface. Usage of the LCD and mDACS interfaces are covered in their respective User Manuals.

Flight Telemetry and Settings

The RRC3 provides the ability to stream live telemetry data via the onboard 5-pin Comm Port. The update rate and content of this data stream are configurable for many different applications, including data downlinking, data logging, or digital control of other onboard avionics devices. The data stream is output at user programmable intervals from the primary UART of the RRC3 mCU in a serial packet format as follows:

- 9600 BPS Asynchronous

- 8 Data bits

- No Parity bit

- 1 Stop bit

All data items in the stream are in an ASCII format are individually comma delimited, and each packet is terminated via a standard Carriage Return character (0Dh).

Data Controls

This setting enables the telemetry stream feature of the RRC3. Set this according to the specific requirements for your data stream:

LCD Setting Value	Setting Description
0	**No Telemetry / Disabled**
1	**Telemetry Pre-Launch @ 0.5 sec packet update rate**
2	**Telemetry Pre-Launch @ 1.0 sec packet update rate**
3	**Telemetry Post-Launch @ 0.5 sec packet update rate**
4	**Telemetry Post-Launch @ 1.0 sec packet update rate**

Data Items

This setting controls which data items will be included in the telemetry stream. Set this according to the specific data items your application requires. The following table describes the packet order precedence, formats, and associated binary-based values of all the available data items:
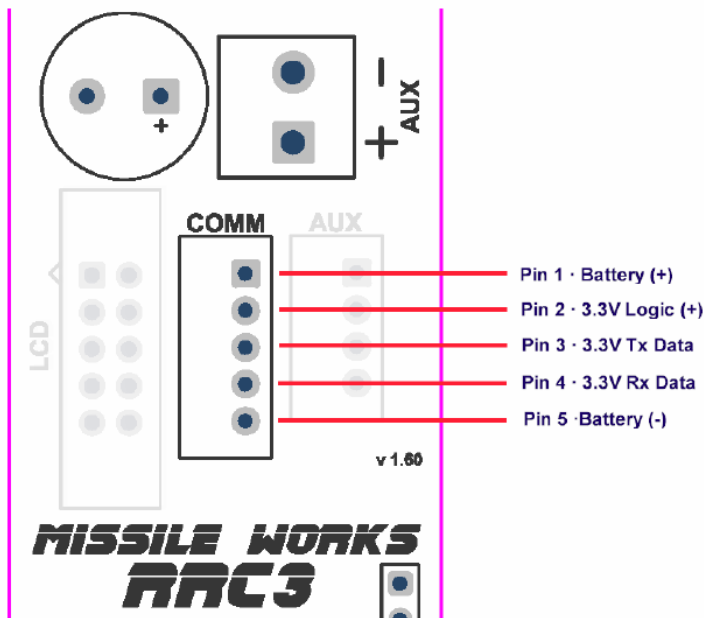
Order	Item	Format (max characters)	LCD Value
1	Timestamp	XXXX.X seconds	Setting Value + 1
2	AGL Altitude	+/- XXXXX (feet / meters)	Setting Value + 2
3	Velocity	+/- XXXX (fps / mps / MPH / KPH)	Setting Value + 4
4	Temperature	+/- XXX (deg F / deg C)	Setting Value + 8
5	Events (v1.5x)	--- / DMA / dma (Event Status Only)	Setting Value + 16
5	Events (v1.6x)	??? / dma / DMA (Continuity and Event Status)	Setting Value + 16
6	Battery Voltage*	X.X volts	Setting Value + 32

* v1.60 Firmware Only

- Altitude, Velocity, and Temperature items are scaled and formatted according to the *Audio / LCD / Telemetry Units* setting.

- Even when some Data Items are omitted from the data stream, the Data Item Order precedence still remains as specified.

- Events are streamed using the "-" character prior to the activation of the event, use an uppercase character while the event is ACTIVE, and use a lowercase character post-activation.

Comm Port Pinout
The RRC3 Comm Port is reserved for connection with the USB-IO, the BTMM Module, or a "tether connection' to an RTx/GPS system. Here's the Comm socket diagram if you're interested in connecting in your own project:

Aux Output Control Settings

The Aux Output Control Settings provide an extremely flexible and capable collection of control options, allowing users to create a custom control sequence independent of the standard drogue and main functions performed by the RRC3.

These settings provide a framework that allows you to design an output "control sequence" via the definition of a "serialized flow" of operations. With one exception, all Aux control sequences have a "trigger event" that initiates the control sequence. When this trigger event is valid/true, optional secondary and tertiary controls or conditionals are evaluated for validity as well.

Access to the Aux Output Control Settings is only available via the optional plug-in LCD Terminal accessory, or by use of the USB Interface module and mDACS PC Software application.

Aux Output Control Sequence (OCS)
The **OCS** (**O**utput **C**ontrol **S**equence) setting is what defines the serialized control sequence used by the RRC3. It also serves as a master enable/disable feature, meaning that regardless of secondary and tertiary settings that may be defined, when the OCS is set to "Disabled", the entire OCS operation is disabled. The OCS settings are as follows:

LCD Setting Value	Setting Description
0	Disabled - OCS and Aux Controls are inactive
1	LED Sync - Syncs the Aux Output with the LED
2	Event Only - Aux is activated by trigger event
3	Event -> Timer - Aux is active via trigger and timer
4	Event -> Loop Comparator - Aux is conditional using trigger and comparator
5	Event -> Timer -> Loop Comparator - Aux requires all three conditionals
6	Event -> Loop Comparator -> Timer - Aux requires all three conditionals
7	Event -> 1-Shot Comparator - Aux is conditional using trigger and comparator
8	Event -> Timer -> 1-Shot Comparator - Aux requires all three conditionals
9	Event -> 1-Shot Comparator -> Timer - Aux requires all three conditionals

LED Sync

Use this OCS setting if you want to drive an external LED, Light, Buzzer, Beeper, Transmitter or similar device. Any time the onboard LED is on, so is the Aux Output.

Event Only

This setting is the most basic of all Aux OCS operations. It functions very simply... when the Trigger Event is TRUE, the Aux Output is activated.

Event -> Timer

This Aux OCS setting combines the Trigger Event with an ensuing timer operation. The timer starts immediately upon activation of the Trigger Event. When the timer interval expires, the Aux Output is activated.

Event -> Loop Comparator

This Aux OCS setting combines the Trigger Event with an ensuing Loop Comparator operation. Once the Trigger Event is activated, the Comparator is then evaluated for validity continuously as long as the trigger event remains valid. If the comparator result is valid, then the Aux Output is activated.

Event -> Timer -> Loop Comparator

This Aux OCS setting combines the Trigger Event with an ensuing timer, and after expiration thereof, it begins a Loop Comparator operation. The timer starts immediately upon activation of the Trigger Event. When the timer interval expires, the Comparator is then evaluated continuously for validity as long as the trigger event remains valid. If the comparator result is valid, then the Aux Output is activated.

Event -> Loop Comparator -> Timer

This Aux OCS setting combines the Trigger Event with an ensuing Loop Comparator, and after validation thereof, a timer operation begins. While the Trigger Event is active, the Comparator is evaluated continuously for validity. The timer starts immediately upon validity of the Comparator. When the timer interval expires, the Aux Output is activated.

Event -> 1-Shot Comparator

This Aux OCS setting combines the Trigger Event with an ensuing 1-Shot Comparator operation. Once the Trigger Event is activated, the Comparator is evaluated for validity only one time. If the comparator result is valid, then the Aux Output is activated.

Event -> Timer -> 1-Shot Comparator

This Aux OCS setting combines the Trigger Event with an ensuing timer, and after expiration thereof, it evaluates the 1-Shot Comparator operation. The timer starts immediately upon activation of the Trigger Event. When the timer interval expires, the Comparator is evaluated for validity just one time. If the comparator result is valid, then the Aux Output is activated.

Event -> 1-Shot Comparator -> Timer

This Aux OCS setting combines the Trigger Event with an ensuing 1-Shot Comparator, and after validation thereof, a timer operation begins. When the Trigger Event becomes active, the Comparator is evaluated only one time for validity. The timer starts immediately upon validity of the Comparator. When the timer interval expires, the Aux Output is activated.

<u>Auxiliary Trigger Event</u>

With the exception of the LED Sync operation, the trigger event is what initiates any Aux Output Control Sequence. The trigger event represents the specific phase of the RRC3 Flight that you want to apply the control sequence to. When that phase of the flight is reached, the Trigger Event is satisfied and the ensuing control sequence can be evaluated. The Trigger Events are as follows:

LCD Setting Value	Setting Description
0	Disabled - No trigger event is defined
1	Launch - Altitude > Arming Altitude and unit has not reached apogee
2	Apogee - Apogee was detected and Altitude > Main Altitude
3	Main - Main was deployed and unit has not landed
4	Landing - Unit has landed

<u>Auxiliary Comparator Operation</u>

Whenever the Comparator is required by the active Aux OCS, an appropriate Comparator Operation setting is required as well. The Comparator Operation defines the specific **comparison test** made by the altimeter. By creating comparisons against the current *Velocity* or *Altitude*, you can create a failsafe permissive or minimum/maximum limit test as part of your Aux OCS.

Altitude is always evaluated as the current "AGL Altitude", and is always expressed in your Aux OCS as a positive value.

Velocity is the current Velocity as calculated by the RRC3. During the *Ascent phase* of your flight will always be a **positive value**, but during the *Descent phase*, Velocity will always be **negative value**.

IMPORTANT: The Ascent Phase of a flight is <u>after the Launch Detect Event and prior to the Apogee Event.</u> The Descent Phase of a flight is <u>after the Apogee Event and prior to the Landing Event.</u>

The Comparator Operations are defined as follows:

LCD Setting Value	Setting Description
0	Disabled - No comparator operation is defined
1	Alt. <= ACV x 100 - Compare AGL Altitude for <= ACV x 100
2	Alt. >= ACV x 100 - Compare AGL Altitude for >= ACV x 100
3	Vel. <= ACV x 100 - Compare Velocity for <= ACV x 100
4	Vel. >= ACV x 100 - Compare Velocity for >= ACV x 100

Auxiliary Comparator Value (ACV)

Just like the Comparator Operation setting, whenever the Comparator is required by the active Aux OCS, an appropriate Auxiliary Comparator Value (ACV) setting is required as well. The ACV establishes the specific **value** used by the altimeter in the aforementioned *Comparator Operation*.

IMPORTANT: The ACV is always expressed as a multiple of 100 (i.e. a setting of 5 = a value of 500)

IMPORTANT: A negative ACV is ONLY APPLICABLE to VELOCITY comparisons. The ACV has an adjustment range of -10 thru 999.

Auxiliary Timer Interval

Whenever the Timer is required by the active Aux OCS, an appropriate Timer Interval setting is required as well. This interval setting establishes the duration of the Aux OCS Timer.

IMPORTANT: The Timer Interval is always expressed in tenths of seconds (i.e. a setting of 10 = a timer interval of 1 second). The Timer Interval has an adjustment range of 0 through 999.

Auxiliary Output Control Value

The Output Control Value determines how the Aux Output functions once it has been activated by a successful Aux OCS operation. There are 3 distinct functions that this setting can establish:

Latched Output *- Once activated, the Aux Output will be maintained ON in a Latched-On state until a subsequent power off of the RRC3.*

One-Shot Output *- The Aux Output will activate one-time with a duration of 1 second. This operation is identical to both the drogue and main outputs when they activate.*

Repeat Output *- When initially activated, the output will behave like the "One-Shot" (on for 1 second, then off again), however it will delay for a specified interval and "Repeat" its activation cycle again. It repeats this cycle until a subsequent power off.*

The following table lists the Output Control Value settings:

LCD Setting Value	Setting Description
0	Latched Output
1	One-Shot Output
2-100	Repeat Output / Repeat Interval = *Setting Value - 1*

Auxiliary Output Control Examples

The following examples illustrate some basic applications using the Aux Output controls

External Status LED

You can wire up an external LED/Resistor to the Aux Terminals of the RRC3 for a visible status indicator for pre-launch status and post-launch data.

Aux Output Control Sequence (OCS)	*LED Sync*
Auxiliary Trigger Event	*n/a*
Auxiliary Comparator Operation	*n/a*
Auxiliary Comparator Value (ACV)	*n/a*
Auxiliary Timer Interval	*n/a*
Auxiliary Output Control Value	*n/a*

Launch Activated Device

Let's say you are night launching and wanted to activate a secondary collection of lights or LED's once the rocket is in flight. You can wire up external LED's or lights to the Aux Terminals of the RRC3 for launch activated event. This example illustrates a continuously activated set of LED's.

Aux Output Control Sequence (OCS)	*Event Only*
Auxiliary Trigger Event	*Launch*
Auxiliary Comparator Operation	*n/a*
Auxiliary Comparator Value (ACV)	*n/a*
Auxiliary Timer Interval	*n/a*
Auxiliary Output Control Value	*0 (Latching)*

Simple Timed Staging or Airstart Event

The Aux Output can ignite an upper stage sustainer or air-started motors using simple timed operation after the Launch Event trigger. Keep in mind the Launch Event triggers occurs when the rocket altitude is above the Arming Altitude. Calculate a Timer Interval by adding your first motor anticipated burn time plus the coast time you desire before the staging or airstart event. Timer intervals are express in 1/10th second values... so for 3 seconds, use a value of 30.

Aux Output Control Sequence (OCS)	*Event -> Timer*
Auxiliary Trigger Event	*Launch*
Auxiliary Comparator Operation	*n/a*
Auxiliary Comparator Value (ACV)	*n/a*
Auxiliary Timer Interval	*30 (3.0 seconds)*
Auxiliary Output Control Value	*1 (1-Shot)*

Advanced Timed Staging or Airstart Event with Altitude Permissive

This example provides the same timing setup from the previous example, but adds a minimum altitude requirement comparative step to ensure a safe minimum altitude has been reached by the first motor burn portion of the flight. The comparator is checked once, and if the minimum altitude has not been reached, then no Aux Event output will be initiated. For this example we'll require a 2000 ft. AGL minimum altitude. Remember that all Comparator Values are **x100**, so for a 2000 ft. minimum we'll use a value of 20.

Aux Output Control Sequence (OCS)	*Event -> Timer -> 1-Shot Compare*
Auxiliary Trigger Event	*Launch*
Auxiliary Comparator Operation	*Alt => ACV x 100*
Auxiliary Comparator Value (ACV)	*20 (2000 ft)*
Auxiliary Timer Interval	*30 (3.0 seconds)*
Auxiliary Output Control Value	*1 (1-Shot)*

Redundant Drogue Event or Post Apogee Payload Deployment

You can activate a redundant pyro event as a backup for your drogue, or activate or deploy a payload after the apogee of your flight has been reached.   Timer intervals are express in 1/10th second values... so for our 5 second example, we'll use a value of 50.

Aux Output Control Sequence (OCS)	*Event -> Timer*
Auxiliary Trigger Event	*Apogee*
Auxiliary Comparator Operation	*n/a*
Auxiliary Comparator Value (ACV)	*n/a*
Auxiliary Timer Interval	*50 (5.0 seconds)*
Auxiliary Output Control Value	*1 (1-Shot)*

Elevation Based Payload Deployment or Main Backup Event

The RRC3 can actively monitor altitude after the Apogee or the Main event, and activate the Aux Output when a specific descent altitude level has been reached. We'll illustrate a backup Main Event using an assumed 1500 ft AGL Main event , and a backup altitude of 1000 ft AGL.

Aux Output Control Sequence (OCS)	*Event -> Loop Comparator*
Auxiliary Trigger Event	*Main*
Auxiliary Comparator Operation	*Alt <= ACV x 100*
Auxiliary Comparator Value (ACV)	*10 (1000 ft)*
Auxiliary Timer Interval	*n/a*
Auxiliary Output Control Value	*1 (1-Shot)*

Landing Locator Beacon

This example allows you to operate a loud piezo or horn with a "pulsed" beep once the rocket has touched down to assist you in location and recovery operations. The Aux Output will activate the horn for 1 second, pause 5 seconds, then repeat. Recall that the repeat interval of the Aux Output is the Aux Output Control Value - 1, so for a 5 second repeat, we use a value of 6.

Aux Output Control Sequence (OCS)	*Event Only*
Auxiliary Trigger Event	*Landing*
Auxiliary Comparator Operation	*n/a*
Auxiliary Comparator Value (ACV)	*n/a*
Auxiliary Timer Interval	*n/a*
Auxiliary Output Control Value	*6 (Repeat 5 seconds)*

RRC3 Operational and Calculatory Reference Section

This section of the manual covers all the underlying operations and calculation methods employed by the RRC3.

Onboard Flash Data Storage Methods

All pressure data captured by the RRC3 is stored at 20 Hz. While the rocket sits on the pad, it continuously updates the "floor" (or launch) altitude using a running average method.

Once the altimeter has reached its "Arming Altitude" (ie. rocket is launched), it will write a 1 second (20 sample) pre-launch ring buffer to flash memory to capture its pre-launch pressure data.

Temperature Data and Battery Voltage Data is recorded to flash memory at 1 Hz rates. These are instantaneous 1 Hz snapshots. The exception to this snapshot sampling method is applied to the Battery Voltage during the Drogue and Main events. The RRC3 performs a 20 Hz "low voltage" sample during the duration of these events and records this low voltage value. Because the sampling is asynchronous to the 20Hz baro data and event overlay, there may be some offset in timing when observing the low voltage value in relation to a given event.

Pressure Altitude Conversion

The RRC3 and the mDACS software both employ the NOAA "Pressure Altitude" calculation method to convert air pressure to an equivalent altitude. The formula is as follows:

$$h_{alt} = \left(1 - \left(\frac{P_{sta}}{1013.25}\right)^{0.190284}\right) \times 145366.45$$

The web reference can be found here:
http://www.srh.noaa.gov/images/epz/wxcalc/pressureAltitude.pdf

mDACS Geopotential Altitude Conversion

If you have accurate temperature for your ambient launch conditions and for your apogee temperatures and you know accurate ambient launch humidity conditions, you can apply the same Geopotential Altitude calculus used by NOAA radiosondes. The temperature data is interpolated linearly from launch to apogee and back down, and the humidity is applied as a constant throughout all the calculations. The Geopotential references can be in the Federal Meteorological Handbook No. 3, Appendix D.

The web reference can be found here:
http://www.ofcm.gov/fmh3/pdf/12-app-d.pdf

mDACS Flight Simulator Pressure Conversion

When the Flight Simulator runs, it feeds a 20 Hz stream of pressure data to the RRC3 in lieu of using the onboard pressure sensor. The simulation altitude to pressure conversion uses the NOAA Station Pressure calculation using a standard 29.92 in Hg sea-level reference (*Pa)* as shown in the following formula:

$$P_{stn} = P_a \times \left(\frac{(288 - 0.0065 \times h_m)}{288}\right)^{5.2561}$$

The web reference can be found here:
http://www.srh.noaa.gov/images/epz/wxcalc/stationPressure.pdf

Pressure and Velocity Displacement Processing

The RRC3 applies multiple filtering stages to the pressure data it collects in order to determine an equivalent displacement velocity. Pressure data oversampling is first performed by the pressure sensor using a 2048 sample average to derive a single pressure reading. This oversampled pressure data is then collected at a 50 Hz rate, then averaged again to derive a 20 Hz sample.   The 20 Hz pressure is then run thru a recursive 21 element FIR filter kernel to produce the 20 Hz velocity data.

To make the altimeter mach immune, additional velocity data discrimination processing is performed to ensure that anomalous velocity changes are ignored. Typically these pressure artifacts are most pronounced during velocity transitions from sonic to sub-sonic speeds.

Product Warranty

Missile Works Corporation has exercised reasonable care in the design and manufacture of this product and warrants the original purchaser that the RRC3 is free of defects and that it will operate at a satisfactory level of performance for a period of one year from the original date of purchase. If the system fails to operate as specified, then return the unit (or units) within the warranty period for repair or replacement (at our discretion). The system must be returned by the original purchaser, and be free of modification or any other physical damage which renders the system inoperable. Upon repair of replacement of the unit, Missile Works Corporation will return the unit postage-paid to the original purchaser.

Product Disclaimer and Limit of Liability

Because the use and application of this equipment are beyond our control, the purchaser or user agrees to hold harmless Missile Works Corporation and their agents from any and all claims, demands, actions, debts, liabilities, judgments, costs, and attorney fees arising out of, claimed on account of, or in any manner predicated upon loss or damage to property of, or injuries to or the death of any and all persons arising out of the use this equipment. Due to the nature of electronic devices, and the application and environments for those devices, the possibility of failure can never be totally ruled out. It is the responsibility of the purchaser or user of this equipment to properly test and simulate the actual conditions under which the device is intended to be used to ensure the highest degree of reliability and success.