Public Missiles, Ltd.

Co-Pilot Dual-Deployment Recovery Altimeter

System Overview

The Public Missiles Ltd. Co-Pilot altimeter was developed exclusively for PML by Missile Works Corp., and was designed specifically for PML's CPR3000 Recovery System (though it can also be used in other applications as well, such as scratch-built deployment systems). The Co-Pilot provides two stage barometrically-controlled (pressure-sensing) deployment of rocket recovery systems and equipment. Using the Co-Pilot altimeter and CPR3000 technology, a small drogue or streamer is deployed at apogee allowing for a fast but controlled descent. At a user-selectable lower altitude, the altimeter fires a second charge to deploy the main chute allowing for a soft landing. This system allows a high-altitude flight to be returned much closer to the launch area than if the main chute were deployed at apogee.

The Co-Pilot is a very rugged and reliable unit in both design and construction. The Co-Pilot uses a standard 9 volt alkaline battery, and has clearly-marked terminals for connecting the On/Off switch and the Drogue and Main deployment charges to help prevent misconnection. The Co-Pilot is also clearly labeled "Fore" (toward nosecone) and "Aft" (toward fins) to aid in proper mounting.

Specifications

Operational Range	0-25000 ft. MSL
Arming Mode	Barometric
Minimum Altitude for Arming	300 ft. AGL
Main Deployment Ranges	800, 600, 400 or 200 ft. AGL
Altitude Reporting Accuracy	? 3% (for flights at least 3k AGL; ? 5% for low flights up to ~2k AGL)
Battery	Onboard 9V alkaline
Nominal Battery Load	15ma
Test Current	80 ?a
Firing Current	1.25 amps for 1 sec.
Dimensions	1.38" W x 5.0" L x ~0.8" H
Weight	3.4 oz. w/battery

MSL = Mean Sea Level; AGL = Above Ground Level; ?a = microamps; ma = milliamps

Handling Precautions ✍

— The Co-Pilot altimeter (as with many electronic devices) is sensitive to damage from ESD (Electro-Static Discharge) and should always be handled in a properly grounded environment. ESD damage is not covered under warranty.

— Never directly handle the Co-Pilot when it is powered ON and connected to live pyrotechnic charges as this may cause premature detonation of the charges.

-- Always connect the negative (-) connection first when connecting deployment charges. The (-) terminal, for both the Drogue and Main deployment connections, is the terminal closest to the FORE end of the circuit board.

— Always allow the Co-Pilot and the battery to adjust to ambient temperature conditions prior to connecting, arming and flying.

— Avoid exposure of a powered ON Co-Pilot to high intensity light (including direct sunlight), heat, cold, wind, or other extreme environmental conditions.

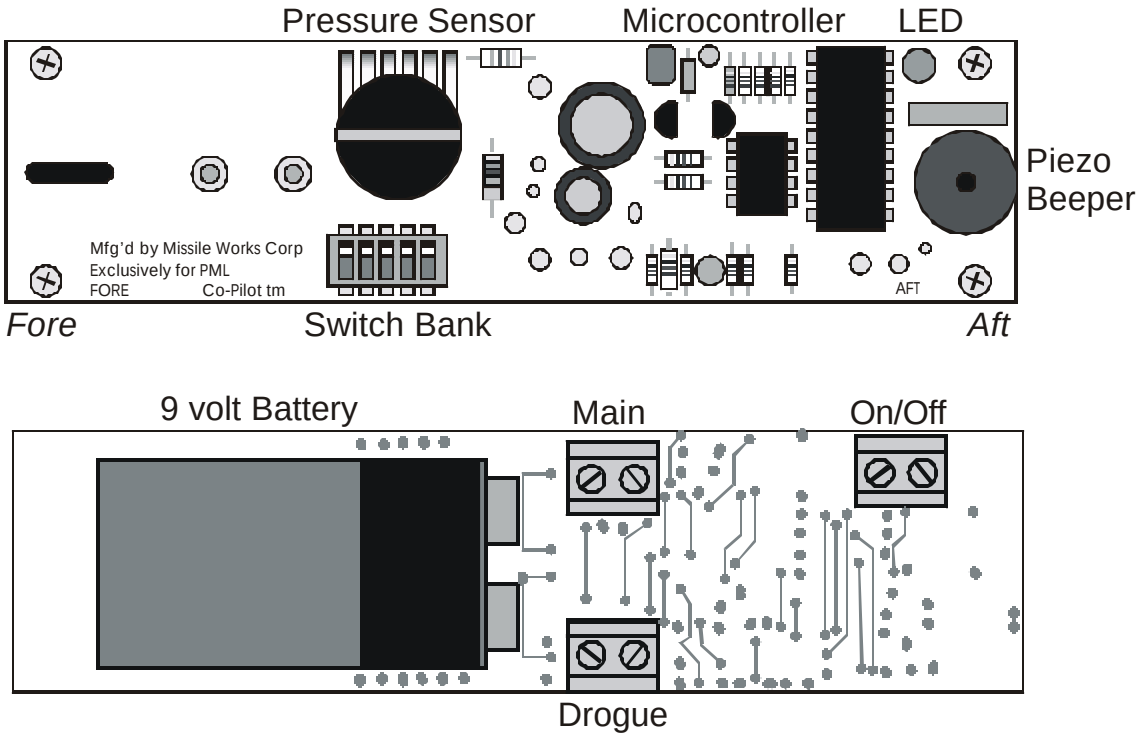
— Always prepare your rocket and recovery system components with the Co-Pilot powered off.

— Never cycle the power switch off, then immediately back on. Always allow the switch to remain OFF for at least 10 seconds prior to restoring power. This will allow the electronics to reset and properly power on again.

Operational Overview

Figure 1 depicts the general component layout of the PML Co-Pilot. The Co-Pilot is designed for several different modes of operation. The bank of switches located on the circuit board is used for selection of these modes.

Figure 1 - General Component Layout of the PML Co-Pilot



The switches are labeled 1 through 5. The ON/OFF position of the switches is also labeled, with an arrow on the switch pack itself pointing in the ON direction. The following table describes the switch functions and the corresponding modes of operation.

Table 1 - Switch Positions and Function

IMPORTANT – The Mach Delay (Switch 3 & 4) and Range (Switch 5) settings MUST be made prior to powering up the Co-Pilot. These switch positions are read at power up ONLY. Always set the switch positions prior to turning the Co-Pilot on.

	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
ON	Main deploys at either 800 or 600 ft. above initial launch elevation based on Switch 5 setting.	Redundant apogee deployment operation (Main and Drogue both fire at apogee. This switch ON overrides the settings of Switches 1 and 5)	4 seconds of delay time is added to the mach delay timer	8 seconds of delay time is added to the mach delay timer	Low-range Main deployment altitudes are selected (600 ft. if Switch 1 is ON, 200 ft. if Switch 1 is OFF)
OFF	Main deploys at either 400 or 200 ft. above initial launch elevation based on Switch 5 setting.	Standard two stage deployment operation	0 seconds of delay is added to the mach delay timer	0 seconds of delay is added to the mach delay timer	High-range Main deployment altitudes are selected (800 ft. if Switch 1 is ON, 400 ft. if Switch 1 is OFF)

Normal CPR3000 Switch Settings

The following settings are recommended for most CPR3000 non-Mach flights. (See the section *Mach Delay Timer* below for Mach and near-Mach flights.)

	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
ON	Main deployment at choice of 800 or 600 ft. (choose via Switch 5)	OFF	OFF	OFF	Main deploy at 600 ft. if Switch 1 is ON, 200 ft. if Switch 1 is OFF
OFF	Main deployment at choice of 400 or 200 ft. (choose via Switch 5)				Main deploy at 800 ft. if Switch 1 is ON, 400 ft. if Switch 1 is OFF

Since all CPR flights will leave Switch 2 in the OFF position, and most will leave Switches 3 and 4 in the OFF position, here's a handy table to show switch positions for setting the Main Deployment altitude.

IMPORTANT – The Mach Delay (Switch 3 & 4) and Range (Switch 5) settings MUST be made prior to powering up the Co-Pilot. These switch positions are read at power up ONLY. Always set the switch positions prior to turning the Co-Pilot on.

Main Deployment Altitude	Switch 1	Switch 5
800 feet	ON	OFF
600 feet	ON	ON
400 feet	OFF	OFF
200 feet	OFF	ON

Standard Two-Stage/CPR3000 Deployment

Two-stage recovery of high power rockets is the standard mode of recovery used in CPR3000 systems as previously described in the "System Overview" section. Standard two-stage deployment is as follows:

- Initial launch, boost and coast phases of flight
- Apogee of flight detected, lower airframe separation and drogue chute or streamer deployed
- Rapid, controlled descent phase to pre-programmed main chute deployment level
- Nosecone/payload section separation, main parachute deployment and touchdown

This mode is selected by placing Switch 2 in the OFF position.

Single-Stage / Redundant Apogee Deployment

Though it is not used for CPR3000 flights, the Co-Pilot can operate in a redundant mode wherein both ejection charges can be fired at apogee. This can be useful for a non-CPR-rocket flight to help ensure redundancy of main chute deployment. If for some reason the Apogee charge does not fire or does not fully eject the parachute/streamer, the Main charge deployment can act as a backup. Single-stage deployment operation is as follows:

- Initial launch, boost, and coast phases of flight
- Apogee of flight detected, Drogue output fires, nearly immediately followed by the Main output firing
- Main parachute/streamer deployed
- Slow descent and touchdown

As noted, this mode is NOT used for CPR3000 flights, but the information is provided here in case you choose to use your Co-Pilot in a non-CPR rocket in which this mode may be useful. This mode is selected by placing Switch 2 in the ON position.

Mach Delay Timer

For extremely high-performance rocket flights approaching or exceeding the speed of sound (Mach), the Co-Pilot can be configured to employ a time delay beginning just after lift-off is detected. (Lift-off is detected by the pressure change of the rocket travelling from 0 to 300 feet AGL). This time delay prevents the possibility of premature apogee detection caused by the high/low pressure effects present along the rocket airframe during transition into and out of Mach. Simulation software such as RockSim or wRASP should be used to determine what portion of the flight might be in or near Mach such that a proper delay time can be chosen.

During the time delay, all pressure samples from the sensor are ignored so the pressure changes of traveling through Mach will not falsely trigger the apogee charge. After the expiration of the time delay, normal barometric sampling resumes. The Co-Pilot can be

programmed for 4 seconds delay (Switch 3 ON/Switch 4 OFF), 8 seconds delay (Switch 3 OFF/Switch 4 ON), or 12 seconds delay (Switch 3 ON/Switch 4 ON).

Be very careful in selecting Mach delay times, since during the Mach delay time pressure sampling is suspended. In the event of a motor failure or other failure which causes the rocket not to achieve the expected altitude, the Co-Pilot cannot "save" the rocket during either the 4, 8 or 12 seconds the rocket may be falling to earth. This is because the Co-Pilot will not sense the pressure increase of falling because it is in the delay mode. The rocket may fall back and impact the ground if a failure happens too close to the ground for the Mach delay time to expire. It is recommended to use the Mach Delay at velocities of 0.8 Mach and above.

Modes of Operation

The Co-Pilot has several distinct modes in its normal operation. The piezoelectric beeper and the status LED indicator identify these modes of operation.

Power-Up and Initialization Mode

After initially powering up the Co-Pilot, it goes through a 15-second initialization and start-up delay. The LED flashes at a fast rate of 5 times per second, and there is no sound from the beeper. This start-up delay allows stabilization of the electronics and establishes an initial launch site pressure level reading (which the Co-Pilot then bases all other pressure changes on; the Co-Pilot "zeroes" itself to the current pressure level of the launch site).

Pre-Launch Mode and Continuity Check Reporting

After the 15-second power up and initialization delay, the Co-Pilot goes into the Pre-Launch Mode. The LED will flash at a slow 2-second rate, and the beeper will indicate the continuity of the ejection charges as follows:

- 0 Beeps — No continuity on either channel
- 1 Beep — Continuity on Drogue deployment system
- 2 Beeps — Continuity on Main deployment system
- 3 Beeps — Continuity on both Drogue and Main deployment system

The Pre-Launch Mode is the mode when the Co-Pilot is "ready to fly". The Co-Pilot also monitors the barometric sensor for a change of 300 feet in elevation to determine the launch of the rocket. After this change is sensed, the Co-Pilot transitions into Mach Delay Mode (if selected) or Apogee Detection Mode.

Mach Delay Mode

When either Switch 3 or Switch 4 is in the ON position and the Co-Pilot has detected launch, the Co-Pilot will enter the Mach Delay Mode. The LED flashes again at its fast rate of 5 times per second, and there is no sound from the beeper. After the expiration of the mach delay (if selected), the Co-Pilot transitions into Apogee Detect Mode.

Apogee Detect Mode

At this point, the rocket has detected launch and is in flight, and any Mach Delay Time has expired. The LED continues to flash at its fast rate of 5 times per second. The beeper will beep at a fast rate of ½ second. During this mode the Co-Pilot is sampling for apogee (indicated by an increase in pressure as the rocket begins falling back to earth just after reaching apogee). When this pressure increase is detected, the Co-Pilot transitions into Deployment Mode.

Deployment Mode

Now that the Co-Pilot has detected apogee, it will fire the Drogue output. The LED will continue to flash at its fast rate of 5 times per second with no output from the beeper. With the Co-Pilot set to operate in standard dual deployment mode, it will continue to sample barometric pressure until it is at the user-selected altitude above the initial launch elevation before firing the Main output. (If the Co-Pilot is operating in Redundant Apogee Mode, as it may be in a non-CPR rocket flight, it will fire the Drogue output immediately followed by the Main output.) After the Co-Pilot has fired both output channels, whether in the normal fashion of Drogue then later Main, or both nearly at the same time, it transitions into Report Mode.

Report Mode

After the Main output has fired, the Co-Pilot will report the peak altitude it measured during flight. The LED will continue to flash at its fast rate of 5 times per second. The beeper will continuously report the peak altitude by beeping out the individual digits of the measurement. Depending upon the peak altitude, the Co-Pilot will annunciate 3, 4, or 5 digits.

For example, let's say the rocket flew to a peak altitude of 1302 feet. The Co-Pilot would beep as follows:

Beep (1)...pause
Beep, Beep, Beep (3)…pause
Beeeeeeeeeeep (0; a long beep means zero)… pause
Beep, Beep (2)…long pause indicating end of report, and then repeat the report

The altitude reporting repeats continuously until the Co-Pilot is turned off.

Test Mode Operation and Diagnostics

The Co-Pilot can also be placed into a Test Mode to verify the basic integrity of the Co-Pilot, and also to ground test e-matches, igniters, ejection charges, or recovery system designs. To place the Co-Pilot into a test mode, toggle Switch 1 or Switch 2 from either Off to On or On to Off right after the power up during the 15-second initialization period.

- Toggling Switch 1 will set the Co-Pilot into Input Test Mode.
- Toggling Switch 2 will set the Co-Pilot into Output Test Mode

The Co-Pilot will continue to operate in the test mode selected until it is powered off.

IMPORTANT: After selecting a test mode, you must power off the Co-Pilot prior to flight or additional testing.

Input Test Mode

After toggling Switch 1 immediately after power up, the Co-Pilot will enter the Input Test Mode. This mode verifies the integrity of all the inputs to the microprocessor. The inputs include the 5 switches and both the Drogue and Main output circuits. Whenever an input is in the ON position, the Co-Pilot will beep out a digit to indicate operational integrity of the input (see Table 2). The test mode scans the inputs starting with the lowest value first (Switch 1) and beeps as shown in the table below. Exercise only one input at a time; e.g. test switch 1, then turn it off and test switch 2, etc. Do not toggle switch one off, then to on and leave it on. The lowest numbered input that's left in the ON position will be the one that is tested regardless of other switch settings.

Table 2 - Input Test Mode Beep Indications

1 Beep	Switch 1 in the ON position	5 Beeps	Switch 5 in the ON position
2 Beeps	Switch 2 in the ON position	6 Beeps	Drogue circuit continuity
3 Beeps	Switch 3 in the ON position	7 Beeps	Main circuit continuity
4 Beeps	Switch 4 in the ON position		

Output Test Mode

After toggling Switch 2 immediately after power up, the Co-Pilot will enter the Output Test Mode. This mode can be used to test the integrity of both outputs (Drogue and Main) and to also ground-test your pyrotechnic e-match, igniter, flashbulb, ejection charge, or to ground test deployment of your entire recovery system. The test mode begins by sounding the beeper at a fast rate of 5 beeps per second. After 10 seconds of countdown, the Co-Pilot will fire the Drogue output. This is followed immediately by firing the Main output (this functions identically to the deployment firing sequence used in the Redundant Apogee Mode).

IMPORTANT: Always exercise caution when using live pyrotechnic charges in the output test mode. Ensure the charges are not on or around flammable materials, will not discharge onto or near flammable materials, and that the charges are secured against movement when charge ignition occurs. Also wear safety glasses and protective gloves at all times.

Another useful accessory for testing the outputs is a pair of 12-volt DC panel lamps; these can be purchased locally at stores such as Radio Shack. The lamps will allow you to observe the proper operation of the outputs without the use of pyrotechnic devices. Connect the lamps across the terminals of the Drogue and/or Main output just as you would connect an e-match or other deployment ignition device.

Barometric Limit Alarm

The Co-Pilot also features a Barometric Limit Alarm. The continuous sounding of the beeper easily identifies this alarm mode. While the Co-Pilot is in the pre-launch mode it tests the barometric sensor reading for basic integrity. If the reading is below 0' MSL or above 14000' MSL the alarm will sound. This extreme reading indicates a failed sensor (unless of course you're attempting to launch from those base elevations; if that is the case you cannot do so as the Co-Pilot will not operate).

IMPORTANT: Do not fly the Co-Pilot if it activates the Barometric Limit Alarm as the alarm indicates either a faulty sensor or the launch site conditions are "out of range" of the Co-Pilot's operation.

Wiring Considerations

Onboard Battery Connections

The Co-Pilot is designed to be operated with a standard 9-volt alkaline battery. Always purchase and use name-brand alkaline batteries. 9-volt NiCad batteries may also be used, but the voltage of 9-volt NiCads can range from 7.2 to 8.4 volts. A higher voltage NiCad is more desirable, as 7.2 volts is on the very edge of acceptable voltage to properly operate the Co-Pilot.

IMPORTANT: Always load test your battery prior to flight to ensure adequate power for reliable operation and ignition of the ejection charges. Even a new battery should be load tested, as occasionally a new battery is bad "fresh out of the box".

To load test a battery, you will need a DC multimeter capable of DC amp measurement with a 10-amp capability. (A new 9-volt battery can easily source in excess of 5 amps.) Briefly connect the meter leads across the battery terminals to measure the DC current capacity. If the measurement is close to or drops below 2 amps, do not use the battery. Some batteries have built in testers, but it is still recommended that a meter be used for testing.

The battery clip hardware is designed to hold the battery tightly. The best method is to first push the battery inside the clip without connecting the battery terminals (see Figure 2). Once the battery is clipped into place, push the battery forward into the circuit board terminals. Next bolt on the battery end clip hardware included with your Co-Pilot (#4 screw, two #4 nuts, washer & lock washer) as shown in Figure 3. Secure the end clip firmly against the battery.

Figure 2 - 9 Volt Battery Insertion (Side View)

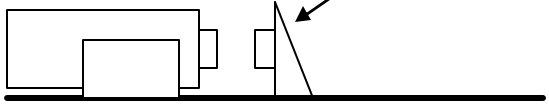
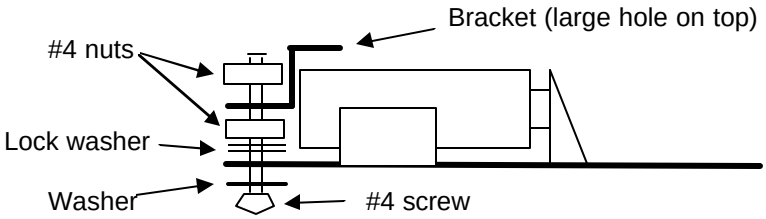


Figure 3 - Battery End Clip Placement (Side View)



External Battery Connections

Though the Co-Pilot is intended to operate with an onboard 9-volt battery, the user may elect to power the Co-Pilot with an external battery source. The voltage requirement for this battery source is 7.5 to 9 volts. ***DO NOT EXCEED 9 VOLTS.*** A standard 9-volt battery clip with wire leads easily mates to the onboard 9-volt battery clip.

Note: When connecting an offboard battery using a 9-volt battery clip, reverse the wire leads to maintain the correct polarity. Check the battery for which terminal is positive and which is negative, and make sure to connect your external battery correctly to the + and – battery terminals on the Co-Pilot.

The user must also adequately size the current capacity of the battery system. Nominal load during operation prior to and after output firing is about 15 ma. During output firing, the Co-Pilot requires nearly 2 amps.

IMPORTANT: Inadequate sizing of an external battery system will damage or cause the Co-Pilot to malfunction. Always pre-test your external battery system design prior to launch.

E-matches and Ejection Charges

The topic of e-matches and ejection charges is often overlooked and not given a proper evaluation. The ejection charge is as critical a component as the electronics. Improper selection or application of e-matches can result in failure of the recovery system and total loss of the rocket. It is foolhardy to attempt to save money and "scrimp" on an ejection charge ignition device considering the hundreds of dollars invested in the electronic-based rocket, the altimeter, the motor casing, and the motor reload itself. The cost of a quality ignition device (usually between one and two dollars each) for each ejection charge is minimal compared to the overall investment, yet the failure of an ignition device can cause destruction of the entire rocket. The message is clear: buy good-quality ejection ignition devices!

- IMPORTANT: Always ground test the type of e-match you'll be using under actual flight conditions prior to committing to flight.
- Improper selection of an e-match will result in a malfunction. Always use an e-match that is suited for the firing conditions of the Co-Pilot (e.g., do not use a match with very low current or very high current requirements).
- Always check your e-match, igniter, or flash bulb devices for continuity and proper resistance prior to using them under testing or actual flight conditions.
- PML recommends that all flashbulbs and electric matches have their electrical wires twisted together until just before installation in the rocket system. This may help prevent accidental ignition of the device due to static discharge.

Selecting an Adequate Electric Match for Deployment Charge Ignition

The Co-Pilot has been tested and flown with several commercially available e-matches. It has also been successfully tested and flown with AG-1 flashbulbs. When selecting an e-match supplier other than those in the table below, refer to the "Specifications" section for the typical test current and firing current of the Co-Pilot. Provide that information to the e-match supplier for them to assist you in selecting the right product. Refer to Table 3 for some known-compatible commercial e-matches for the Co-Pilot.

Table 3 - Recommended Electric Matches

Model	Resistance	Test Current	Firing Current	Wire Color
Daveyfire 28B	1.6 ? 0.3 ohms	20 ma (0.020 amp) max	370 ma (0.37 amps) min	White
Daveyfire 28BR	1.6 ? 0.3 ohms	20 ma (0.020 amp) max	370 ma (0.37 amps) min	Orange
Daveyfire 28F	1.6 ? 0.3 ohms	20 ma (0.020 amp) max	1.00 amp min	Black
Blacksky HiRMI Standard	~2.0 ohms	40 ma (0.040 amp) max	1.00 amp min	Orange
Blacksky HiRMI Sensitive	~2.0 ohms	10 ma (0.010 amp) max	400 ma (0.4 amp) min	Yellow
Oxral (Luna-Tech)	2 ohms (nominal)	25 ma (0.025 amp) max	500 ma (0.5 amp) min	Red/Blue

Launch Day

It's best to prepare your rocket carefully and not to bypass any critical steps. The following list is a guideline of the necessary steps you should take in the preparation of your Co-Pilot. Also follow the directions given for your CPR3000 rocket kit.

At the Prep Table

? Load test the battery
? Check continuity and resistance of the ignition devices (e-matches, flashbulbs, etc.)
? Install e-matches/flashbulbs into CPR3000 system following CPR3000 instructions.
? Make final wiring connections to the ejection charges. Connect the (-) terminal first; the (-) terminal is closest to the FORE end.
? Arm the electronics and verify ejection charge continuity; turn Co-Pilot OFF after continuity check
? Prepare and pack the recovery components (parachutes, streamers, etc.)
? Put on safety glasses and protective gloves.
? Add BP as recommended in your CPR3000 instructions
? Install Co-Pilot/CPR3000 altimeter bay assembly into rocket
? Assemble the rocket and check all deployment coupling junctions ensuring a snug and adequate fit
? Prepare and load the rocket motor

At the Pad

? Place the rocket on the launch rod or rail
? Insert the igniter in your rocket motor
? Arm the electronics and re-verify ejection charge continuity through the beep tones
? You're ready to launch!

Product Warranty

Missile Works Corporation has exercised reasonable care in the design and manufacture of this product and warrants the original purchaser that the Co-Pilot altimeter is free of defects and that 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, contact sales@publicmissiles.com or telephone 810-327-1710 9-5pm EST Mon.- Fri. within the warranty period for repair or replacement. PML will discuss your claim with you and direct you as to how to proceed, up to and including returning the Co-Pilot to Missile Works for warranty repair. PML MUST PRE-AUTHORIZE YOUR WARRANTY CLAIM; DO NOT SEND THE CO-PILOT TO MISSILE WORKS WITHOUT PML AUTHORIZATION OR IT WILL BE RETURNED TO YOU UNREPAIRED. The Co-Pilot must be returned by the original purchaser, and be free of modification or any other physical damage which renders the system inoperable. Upon repair or replacement of the Co-Pilot, Missile Works Corporation will return the Co-Pilot postage paid to the original purchaser. For repairs after the Co-Pilot is out of the warranty period, contact Missile Works Corporation directly. (303) 823-9222 or www.missileworks.com

Mail Address:
Missile Works Corporation
PO Box 1725
Lyons CO 80540

Service & Repair Address:
Missile Works Corporation
10343 Federal Blvd. Unit J #184
Westminster CO 80260

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 Public Missiles, Ltd. and their agents from any and all claims, demands, actions, debts, liabilities, judgements, 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.

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