

MLB

Bat Version 3 User Manual



WARRANTY

The MLB Company guarantees this uncrewed aerial vehicle (UAV) to be free from defects in both material and workmanship at the date of purchase. The warranty does not cover any component parts damaged by use or modification. **In no case shall MLB's liability exceed the purchase cost of this system.** Further, MLB reserves the right to change or modify this warranty without notice.

In that MLB has no control over the final assembly or material used for final assembly, no liability shall be assumed or accepted for any damage resulting from the use by the user of the final user-assembled product. By the act of operating the user-assembled product, the user accepts all resulting liability.

If the buyer is not prepared to accept the liability associated with the use of this product, the buyer is advised to return this system immediately in new and unused condition to MLB.

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INTRODUCTION

The MLB Bat UAV is a low cost aerial sensor platform that is convenient to deploy and operate. It can be launched by hand or with a catapult, and the groundstation provides an intuitive interface for defining a flight plan or airborne re-tasking with a series of waypoints. In flight, the aircraft transmits telemetry and video to the ground station allowing a single operator to monitor the flight and identify points of interest. A stabilized, 3-axis, geo-referenced camera provides real time video surveillance, which is also recorded on the ground station for post-flight analysis. While the aircraft is capable of fully autonomous launch and recovery, a competent radio control pilot is essential for safe operations.

While every effort has been made to ensure safe and reliable operation, there are potential dangers associated with operating the Bat UAV. On the ground, the propeller and catapult can cause injury to operators, and loss of control while flying can lead to injury and damage to persons and property. Bystanders should be kept well clear of the airplane while it is running. Use the system with due care!

A statistical survey of current UAV operations has shown that they have a significantly greater chance of crashing than manned aircraft. MLB has attempted to make the Bat as reliable and easy to operate as possible, but it is the operator's responsibility to operate the system properly. Exercising caution, using sound judgment, and adhering to the procedures outlined in this manual will give the best chance of extending the life of the Bat.

SYSTEM COMPONENTS

Bat Version 3 aircraft

The groundstation components are stowed in the black Pelican case, and consist of the following items:

- Laptop computer
- Video deck (Digital 8 format)
- Video receiver
- Video to USB device with cabling
- Video Antenna
- Tracking antenna system with tripod
- Modem
- Radio control transmitter
- Power cables for video receiver and modem
- Serial cable for modem
- Data/Power cable for tracking antenna with serial/USB adapter
- Coaxial video cable
- 12V Battery

A field box contains components to assist with fueling the aircraft and starting the engine. Items include:

- Electric starter
- Fuel pump
- Fuel container

SYSTEM OVERVIEW

The drawing in Figure 1 gives a basic overview of the system's communication structure.

- 1) The Bat UAV, with a self-contained flight computer capable of flying aircraft with only a GPS signal
- 2) 72 MHz R/C transmitter used for manual modes only; can be disabled with 900 MHz data system
- 3) 900 MHz 2-way modem for flight data and in-flight re-tasking; 10 km range with omnidirectional antenna
- 4) PC laptop computer with flight data, moving map display of UAV, and graphic user interface for mission planning and updating
- 5) 2.4 GHz real-time video downlink; 10 km range with 12 dBi directional antenna

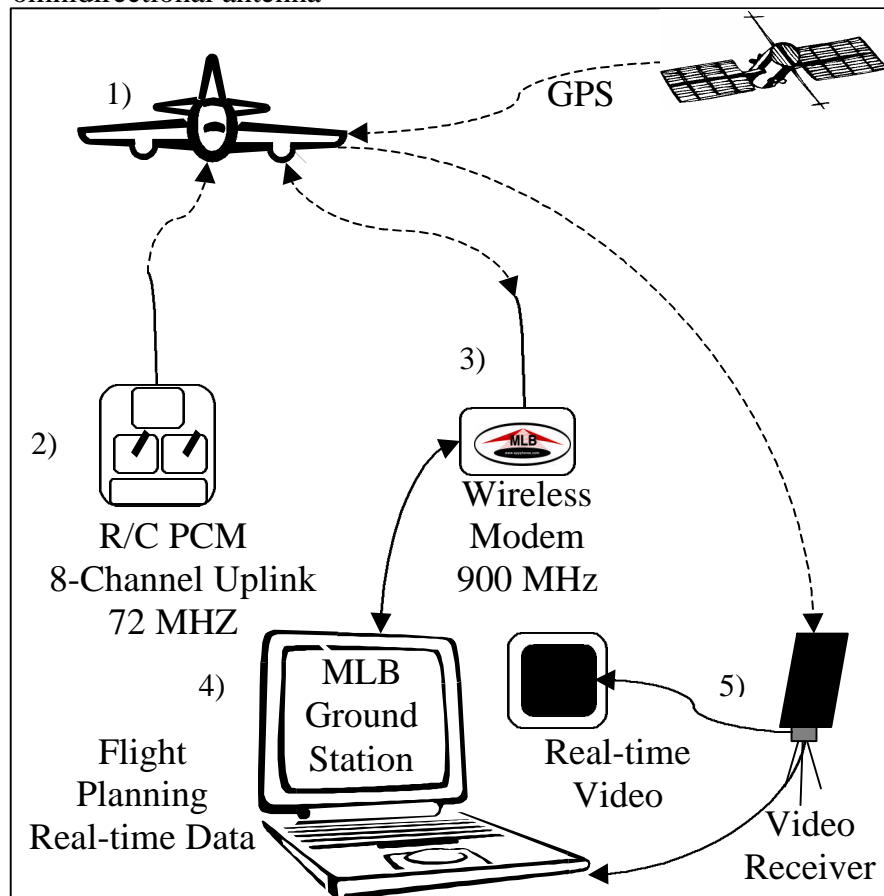


Figure 1. System diagram

HARDWARE IN-DEPTH PROCEDURES

This section provides detailed information on how to perform specific tasks related to the Bat UAV hardware. Detailed procedures for using the MLB Groundstation software are provided in the next section. These sections are not a set of operating instructions. A specific set of sequential procedures for operating the Bat is provided in the OPERATING INSTRUCTIONS section.

Fuselage

This subsection contains information on the nose assembly, airspeed probe, flight computer, power switch, serial port, and access hatch. The lightweight airframe is rigid and very durable due to its fiberglass, carbon fiber, and Kevlar composite construction. Fuselage repairs or modifications should be done by MLB.

1) Nose Assembly

The nose assembly is a removable pod that can be changed to meet a variety of payload needs. Figure 2 shows the nose with a gimbaled, 3-axis turret that contains wide and narrow angle color video cameras. An infrared camera can also be included with the video cameras. Alternatively, the nose assembly can carry a fixed video camera and a special agricultural imaging system. Along with the cameras, the video transmitter and its antenna are part of the nose assembly. Other custom payloads can be integrated into the nose.

To inspect the turret for proper operation, apply a gentle torque by hand to slowly rotate the turret ball. Check freedom and range of motion about all axes. There should be small, even resistance from the servos, but no binding or blockage. If movement is restricted, do not attempt to force it; rather, find the cause of the problem before proceeding. As with any servo-actuated surface, care must be taken when moving. Moving a servo by hand is OK if done slowly and the servo does not bind, but rapid movement of the servo's output shaft or use of excessive force can damage the internal gears. Inspection of the turret for proper operation must be conducted prior to turning on the aircraft. Once the system has been turned on and initialized, the servos cannot be moved.

Prior to each flight:

- Check that the nose assembly is securely mounted to the fuselage.
- Check the turret for proper function.
 - A visual inspection and movement over a small range of motion should suffice in most cases.
 - A full check of the turret's range of motion only needs to be conducted if there is a possibility it was damaged on a prior flight or in transport.
- Check that all camera lenses are clean.



Figure 2. Nose assembly and airspeed probe

2) Airspeed Probe

The airspeed probe is mounted just aft of the nose cone on the left side of the fuselage and extends forward to the front of the nose. To obtain proper airspeed readings the probe needs to be clear of obstruction and properly fitted to the mount, as depicted in Figure 2. Any blockage in the probe can have serious consequences for autonomous flight.

Blockage can cause an erroneous measurement of the airspeed. In almost all cases, the airspeed will read much lower than the true airspeed and the aircraft will dive into the ground trying to increase the airspeed reading. In normal autonomous flight, the flight computer will compensate for a low airspeed by pitching the nose down and then increasing the throttle to compensate for the loss of altitude. If corrective action is not taken immediately, the aircraft will quickly enter a full-power dive, with disastrous consequences

In an autonomous launch, this would occur a couple seconds after launch. In a manual launch, the aircraft would begin to dive when the R/C transmitter is set to autonomous mode. To avoid crashing in either case, revert to manual mode immediately and land the plane.

- Mount the airspeed probe by sliding it into its mounting bracket.
 - The shorter portion of the airspeed probe slides into the mounting bracket.
 - Ensure that about half of the small rubber tubing slides over the larger tube of the mounting bracket.

ALWAYS check that the airspeed probe is clear before flying.

- Inspection with probe mounted on aircraft
 - Look into the probe and check that the rubber tubing at the back of the probe is visible.
- Inspection with probe removed from aircraft
 - Remove the probe by pulling it forward while holding the mounting bracket. The front portion of the tube will slide out where it is attached with the small piece of rubber tubing.
 - Look through the probe to ensure it is clear.

If blockage is evident:

- Remove the probe from its mount, clear any debris, and remount the probe.
- Check that the airspeed system is working properly.
 - Turn on the aircraft and execute the start-up procedure.
 - When the aircraft is ready for launch, gently blow into the airspeed probe and check that the airspeed increases on the groundstation display.

Tip: On the ground station, select “Airspeed” on the plot display drop-down box. A history of the airspeed will then be displayed, so the changes over time can be seen.
 - If the test does not show an increased airspeed on the ground station, there may be additional blockage, or the airspeed sensor may have been damaged at the time the probe was plugged.

A more comprehensive ground test of the airspeed measuring system is also feasible:

- Turn on the flight computer, load a flight plan, select manual launch and complete the Prepare for Launch sequence (up to but not including engine start).
- Turn on the R/C transmitter, switch to autonomous mode, and gently blow into the airspeed probe.
- If everything is working properly, the elevators should deflect upward and a moderate airspeed should be displayed on the ground station.
- Immediately switch back to manual mode. If continuing with the launch sequence, be sure that the transmitter is set back to manual mode.

3) Power Switch

The power switch, shown in Figure 3, is located behind the nose assembly on the left side of the fuselage. It activates the flight computer, video system, data modem, and ignition system.

- For Power On, the switch is toward the back of the plane (direction of the launch g forces and airstream).
- For Power Off, the switch is forward.
- The locking safety latch is rotated into position to ensure the power switch cannot be accidentally turned on.



Figure 3. Power switch and serial port

4) Serial Port

The serial port, located on the left side of the fuselage next to the power switch, can be used for two-way communication between the aircraft and the ground station without the 900 MHz RF modems.

- When the serial cable is connected to the aircraft, the other end should be connected directly to the groundstation laptop computer's serial port.
- The groundstation-aircraft data link will function exactly as it does with the wireless modems when using a serial cable connection.

5) Access Hatch

The access hatch is located on the top of the fuselage. The hatch provides access to the battery lead for recharging and a view of the fuel tank to inspect its level. This is also how the flight computer and associated electronics are accessed. However, except for battery charging and fuel level inspection, this area should only be accessed by MLB

To Open Hatch:

- Remove screw at rear of hatch (shown in Figure 4).
- Raise the back of the hatch while sliding it back until tab at front end is free (Figure 5).

To Close Hatch:

- Hold back end of hatch slightly elevated and slide tab under opening at front of hatch.
- Lower back end of hatch so that the screw hole aligns with the fixed nut.
- Insert screw snugly, but do not over tighten and strip screw.



Figure 4. Access hatch screw

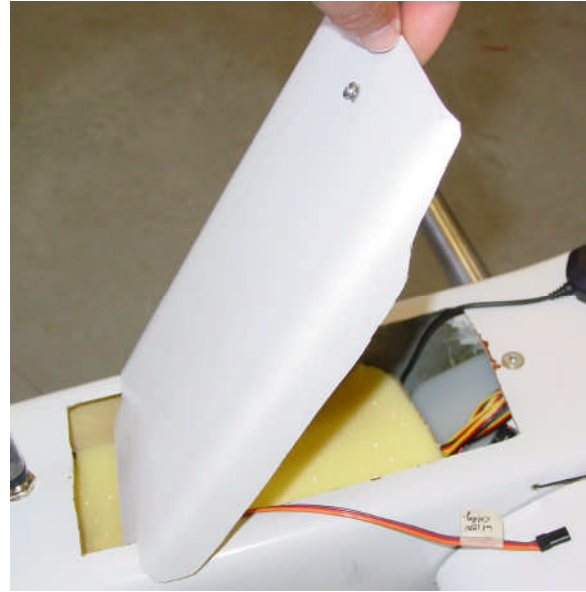


Figure 5. Access hatch open

Tail Section

The Bat's tail is a composite structure with aluminum booms connecting it to the fuselage. The inverted V tail configuration combines the horizontal stabilizer and elevator functions with the vertical stabilizer and rudder. As an elevator, the control surfaces move synchronously, both moving up or down together. As a rudder, the control surfaces move asynchronously. Right rudder command causes the left tail surface to move down and the right surface to move up. The tail section, with or without the booms, can be removed for shipping. This takes a few minutes and requires tools, so the tail is not normally removed for day to day operations

1) Tail Surfaces Removal & Attachment

- Detach the R/C antenna (long thin wire) from the tail surface.
- Unscrew and remove the bolts that are located along the tail booms near the tail surface (see Figure 6).
- Disconnect the servo leads along the tail booms.
- Pulling evenly on both booms, slide the rear section of the booms out of the forward sections. Be sure that both side move equally to keep the slide joints from binding.
- To keep from losing any hardware, insert the bolts back into their holes and loosely attach the nuts.



Figure 6. Tail boom & servo connections

- Reattachment of the tail surfaces is simply the reverse process of removing the tail.
 - Be careful to ensure that the servo connectors are properly and securely connected.
 - Remember to reattach the R/C antenna (Figure 8).

2) Tail Boom Removal & Attachment

- Detach the R/C antenna (long thin wire) from the tail surface.
- The tail surfaces can be removed or left attached for this process.
- Support the tail surface so that it cannot fall as the attaching bolts are removed.
- Remove the bolts that affix the tail booms to the fuselage (2 bolts per side).
- Carefully move the tail boom assembly a few inches out and back from the fuselage to expose the servo wires where they exit the fuselage (see Figure 7).
- Pull the servo wires from the fuselage so that the connectors are accessible.
- Unplug the servo connectors.
- Remove the tail boom assembly.
- Reattach the tail boom assembly by first connecting the servo wires.
 - Be careful to ensure that the servo connectors are properly and securely connected.
 - Push the servo connectors back into the fuselage.
 - Place the servo boom assembly into place, ensuring the servo wires are properly routed and not pinched.
- Bolt the assembly onto the fuselage (snug the bolts but do not over-tighten).
- Reattach the R/C antenna to the rubber band and string with a simple knot.
- The rubber band is used to tension the antenna and it should be slightly shorter than the string when fully stretched.
- The string is a backup. If the rubber band fails, the antenna will not enter the propeller.

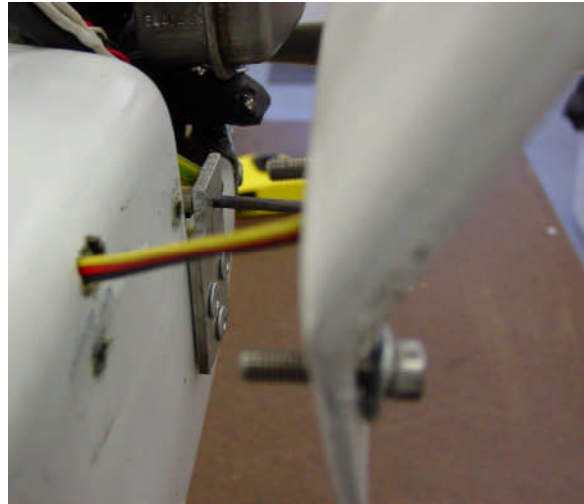


Figure 7. Tail pylon & servo lead

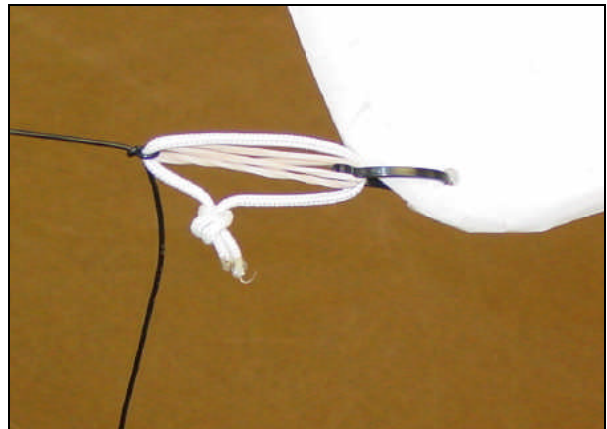


Figure 8. R/C antenna tail attachment

3) Tail Inspection

- Gently move the elevators/rudders (with the power off) to check that the control surfaces, servo, and linkage move freely. If the control surface is at full deflection, the angle between the linkage and the servo might make it difficult to move the servo via the control surface. If this is the case, do not force it to move. Instead, grasp the servo lever and gently rotate the servo toward its center position.
- Inspect the servo, linkage, and associated attachments for any loose or damaged parts.
- Check the elevator/rudder hinge lines for tears.
- Check the servo wire connections along the tail boom.
- Check the tail boom connection near the tail surface.
- Check the tail boom to the fuselage connection.

Wings

For ease of transportation and storage, the Bat's wings are simple to remove and reattach. Constructed of composite materials including Kevlar, carbon fiber, and fiberglass, the wings are very light yet rigid, strong and durable.

1) To Attach Wings

- First, note the position of the snap button on the bottom of the aluminum wing spar that extends from the fuselage (Figure 9).
- With one hand, hold the wing by its leading edge near the wing root (thumb on top and fingers underneath), and use the other hand to support the wing tip.
- Align the aluminum spar on the fuselage with the spar tube at the wing root and slide the wing onto the spar up to the snap button.
- Using a finger on the hand that is holding the wing's leading edge, depress the snap button (Figure 10) and slide the wing a few inches farther onto the spar, but stop before the trailing edge alignment pin hits the wing.
- Attach the servo wire connectors for the flaps and ailerons.
 - o Read the wiring labels and be sure to attach the appropriate connectors.
 - o A wrong connection will cause the plane to crash.
- Slide the servo connectors into the wing and be sure all wiring goes into the fuselage or the wing once the wing is fully attached. Figure 11 shows the servo

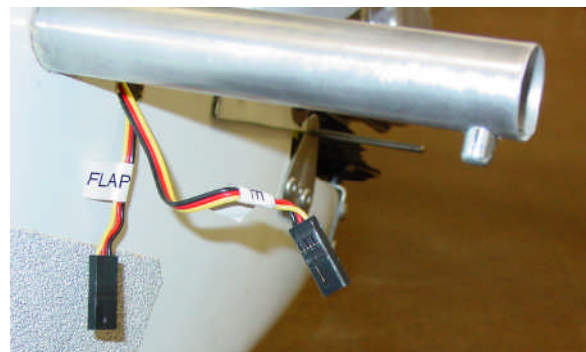


Figure 9. Wing spar and snap button

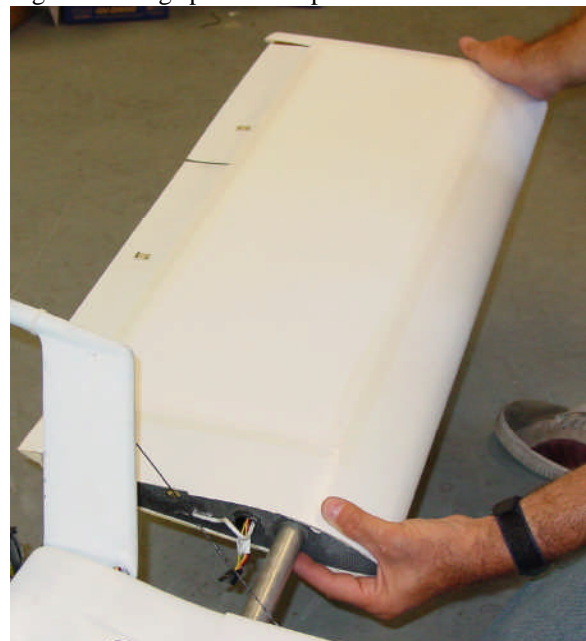


Figure 10. Attaching wing

connectors and wiring being inserted into the wing root.

- o Poorly routed wires can keep the wing from properly attaching and a pinched wire could be damaged and cause a failure.
- Adjust the wing so that the trailing edge alignment pin inserts into its hole in the wing root.
- Continue sliding the wing onto the spar until the wing root touches the fuselage.
 - o Listen for the sound of the snap button locking into place and check with a finger that it is locked. Figure 12 shows the snap button locked in place.

The procedure is identical for both wing halves.

2) To Detach Wings

- With one hand hold the wing by its leading edge near the wing root (thumb on top and fingers underneath), and use the other hand to hold the fuselage.
- Depress the snap button on the underside of the wing with a finger on the hand that is holding the wing.
- Pulling outward from the fuselage in the direction of the wing tip, slide wing out a few inches.
- Detach the servo connectors.
- Remove the wing the rest of the way from the aluminum spar.

3) Wing inspection

There are a few key points that should be checked prior to every flight. A more thorough inspection should be performed at regular intervals.

Prior to every flight & for each wing:

- Ailerons are the outboard movable surface.
- Flaps are the inboard movable surface.
- Gently move the aileron (with the power off) to check that the aileron, servo, and linkage move freely. If the aileron is at full deflection, the angle between the linkage and the servo might make it difficult to move the servo with the aileron. If this is the case, do not force the

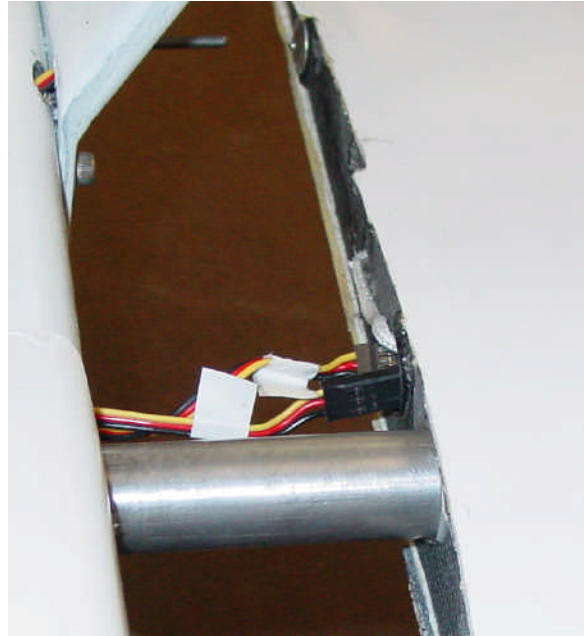


Figure 11. Servo connectors partially inserted into wing



Figure 12. Wing spar snap-button locked in place

aileron to move. Instead grasp the servo lever and gently rotate the servo toward its center position.

- Inspect the servo, linkage, and associated attachments for any loose or damaged parts.
- Check the aileron hinge line for tears.
- Repeat this process for the flap, but note that it only moves from neutral to down.
- Inspect the upper and lower surfaces for skin damage.
- Grasp the wing near the tip at about $\frac{1}{4}$ cord, gently lift upward and check that the wing does not bend or kink.

Propulsion

The propulsion system includes the propeller, fuel system, and engine.

1) Propeller

The propeller is an APC 14x10 regular propeller. Although the aircraft is a pusher configuration, the engine runs in reverse so that a regular propeller, rather than a pusher propeller, can be used. While the aircraft will operate with a slightly worn propeller, this practice is not recommended by manufacturers as a worn or damaged propeller increases the potential of serious injury to operators and bystanders. A damaged propeller can cause excessive vibration and may fly apart during use.

- Check the propeller for damage prior to each flight.
- Check that the propeller is tightly mounted.

2) Fuel System

The fuel system consists of a tank, fuel lines, vent line, and fuel filling port. Figure 13 shows the vent and fuel lines exiting the rear of the fuselage. The vent line is on the right side of the image. The fuel line attaches to the filling port and to the bottom of the carburetor. Attached to the top of the filling port is a refueling line.

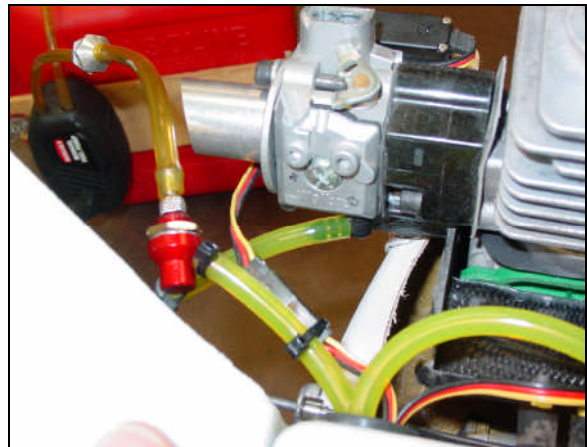


Figure 13. Fuel, vent, and filler lines

A full tank of fuel yields a duration of approximately 6 hours when flown at 35 mph at sea level. For shorter duration flights the aircraft can be flown with less than a full tank, which will save weight and increase performance. Fuel starvation is an avoidable and foolish reason to lose an aircraft, so be sure to have enough fuel for the mission and monitor the fuel level during flight. Furthermore, use good judgment to evaluate the fuel level (e.g. if the aircraft was launched with a half tank and 2 hours later the gauge is still reading above $\frac{1}{4}$ there may be an error in the gauge).

- Fuel tank capacity is 52 fl oz.
- Fuel is unleaded gasoline (87 or higher octane) mixed with high quality 2-stroke motor oil using a 40:1 gas:oil ratio.

- MLB uses oils from motorcycle dealers (i.e. Honda HP-2, Klotz, etc.), but any 2-stroke oil is acceptable.
- To fuel the aircraft:
 - Attach fuel filler probe to filler port.
 - Pump fuel and observe fuel line to verify that fuel is going into the aircraft.
 - For a full tank, continue pumping until a small amount of fuel spills from vent line, indicating the fuel tank is full.
 - If less than a full tank is desired, remove the access hatch and observe the fuel level in the tank. Also, confirm the fuel level on the ground station once the system is up and running.
- To de-fuel the aircraft:
 - Attach fuel filler probe to filler port.
 - Keep the aircraft level (as it sits on its landing gear).
 - Reverse the pump and draw fuel from the aircraft until the pump sucks air.
- Prior to flight inspect the fuel lines
 - Check the fuel lines for any damage.

Check that the fuel lines are properly attached to the carburetor and both sides of the filler port.

3) Engine

The Bat uses a modified 2-stroke engine originally designed for weed trimmers. The carburetor, muffler, and ignition system are considered part of the engine. It requires little maintenance and is easy to operate. All components should be kept clean and the spark plug should be replaced at regular intervals. The engine and carburetor have been adjusted by the factory, and should not need changing.

- Replace spark plug every 100 flight hours.
- Replace the engine every 500 flight hours.

Starting

- The R/C transmitter is required for running the engine.
- Ensure that the propeller is clear of the ground.
- Turn the R/C transmitter on, and set the throttle stick to idle and the trim to full.
- Check that the starter is rotating in the proper direction (clockwise as viewed from the rear of the plane).
 - Reversed leads on the starter battery will cause the starter to turn backwards.
- Hold the plane firmly with one hand and apply electric starter until the engine starts.
 - If the plane is on the catapult and it is cocked, the plane is secure and does not need to be held with a hand.
- Allow the engine to warm up for about 1 minute.
- Check engine performance.
 - Secure the aircraft.
 - Slowly increase and decrease the throttle a few times to ensure that the engine is warm.
 - From idle, quickly advance the throttle to full. The engine should spool up to full throttle without hesitating and emit a high-pitched tone.
 - Peak RPM should reach at least 7,700, which can be checked on the ground station.
 - Idle RPM should be no lower than 4000.
- If any of these tests fail, the carburetor needs to be tuned.

Tuning

- Carburetor tuning is most effectively done with the engine running. For greater safety, adjustments can be made with the engine off and then restarted to test for proper tuning.
- If the engine is running, approach the aircraft from the front and stand straddling the fuselage so that the wing leading edges are pressing against the operators legs, as shown in Figure 14.
- The carburetor has two needle valves. The needle closest to the engine crankcase is the low speed needle. It affects the mixture for throttle settings below 6000 RPM.

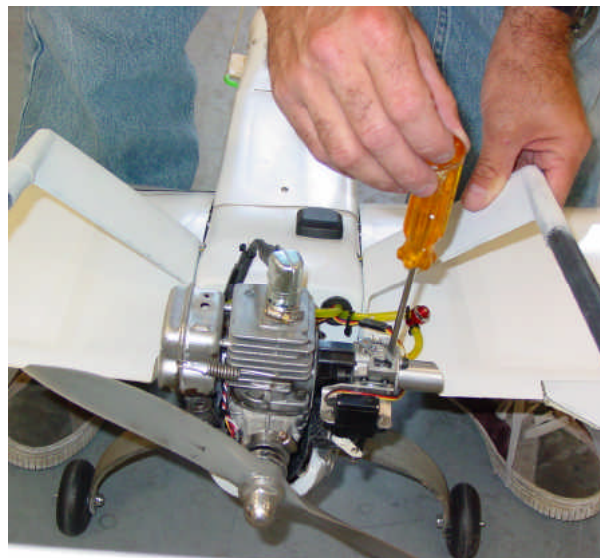


Figure 14. Needle valve adjustment

- The outer needle is the high-speed mixture and affects operation above 6000 RPM.
- Use a small flat-bladed screwdriver to adjust the needle valves.
- A change of 1/8 turn is significant for each of the needle valves, so adjustments should be made carefully.
- Turning the needle counterclockwise richens the mixture; turning clockwise will lean it.
- Tune the high-speed needle by setting the throttle to full and adjusting the needle for maximum RPM. Do not set the needle any leaner after achieving max RPM.
- Tune the low speed needle for smooth idling, and a quick transition to full RPM when the throttle is opened.
- Good initial setting for the needles are:
 - Low Needle 1 1/8 turns open
 - High Needle 1 1/2 turns open
- If the low speed needle is not set properly, the engine may die during long periods of idling (e.g. descents).
- If the high-speed needle is not set properly, the engine will not produce full power and will reduce the aircraft's climb performance.

MLB recommends that you do not change these settings without first consulting MLB.

Flight Computer

The FC-2 flight computer is the heart of the autonomous system. It communicates with the GroundStation operator software, receives signals from the R/C transmitter, stores waypoint information, and monitors GPS signals and internal sensors to maintain aircraft stability and to navigate. The FC-2 is located in a black, carbon-fiber box in the forward section of the fuselage. The flight computer and its associated internal electronics and wiring should not be accessed or inspected by the operator. Moving any of the internal components could damage them, disconnect wires, or cause other problems that may result in a failure.

Turning on the main power switch on the left side of the plane turns on the flight computer along with all of the other aircraft systems.

Caution: Turning on the FC-2 power enables the ignition system, and the engine can be started.

1) Aircraft Control

The most crucial role of the flight computer is to fly the plane. Sensors in the FC-2 provide data to determine the aircraft's inertial state and position. In conjunction with control algorithms, the flight computer uses this information to manipulate the servos for aircraft stability, to execute maneuvers, and to navigate. Even when the aircraft is operated in manual mode, the flight computer is still active. All of the up-linked R/C commands are first processed by the flight computer before they are fed to the servos. This provides stability augmentation and makes the Bat easier to fly than most non-stabilized R/C aircraft.

2) Data Link

Two-way communication between the FC-2 and the ground station is over the 900 MHz modem. After the initial start up sequence has been completed, this communication link is not essential to maintain flight. The aircraft can operate independent of the groundstation, so there is no immediate problem if communication is lost or the ground station fails. However, the two-way link is required to re-task the aircraft and receive flight status updates.

3) R/C Receiver

Signals from the pilot's R/C transmitter are decoded by the R/C receiver and passed to the flight computer. The receiver is the small foam-wrapped box attached to the FC-2 via a gray cable. The receiver's antenna is the thin black wire that extends out the left side of the aircraft and back to the tip of the tail. If this antenna is damaged, the range of the R/C system is reduced; this may result in loss of control of the aircraft. The FC-2 provides power for the R/C receiver, so the receiver is on when the flight computer is on. If the 72 MHz R/C link is lost in manual mode, the aircraft will revert to autonomous mode and begin flying the currently stored flight plan (starting with waypoint 0).

- The R/C antenna cable should be checked for damage (such as kinked or worn wires) prior to every flight.
- The antenna should never be subject to strain, and the external portion should be inspected for damage prior to every flight.
 - Look for nicks, color changes, or thinning of the plastic coating, especially where it exits the fuselage.

4) GPS

A reliable GPS signal is essential to the aircraft's navigation and autonomous operation. The flight computer uses GPS positioning to maintain its track between waypoints and to establish when it has reached a waypoint. In the event of a brief loss of the GPS signal, the Bat will continue flying its course. If the GPS signal is lost for more than 10 seconds, the aircraft heads directly for the home location. If the GPS signal is reacquired, the aircraft will resume waypoint navigation heading to the same waypoint it was heading to prior to the loss of GPS. Without GPS guidance, the aircraft has limited navigational accuracy.

- GPS is used only for autonomous navigation, so the plane can still be flown manually in the event of a loss of GPS.

Occasionally the GPS receiver requires an inordinately long time to acquire its position during startup. This occurs when the receiver fails to initialize properly and must restart its acquisition process.

- If the GPS is slow to acquire, the operator can wait for it to eventually acquire, or
- Turn off the aircraft avionics and ground station modem, wait a minute, and redo the aircraft startup procedure from the beginning.
- If the GPS still fails to acquire it may be damaged, or there may be some external cause for poor GPS signal.

Since the GPS antenna is mounted externally, the antenna and its cable are susceptible to damage. Strong electrical shocks, impacts, or strain on the cable can cause damage. Problems of this nature will normally be detected during start up, and a NO SAT or other GPS warning will indefinitely be displayed on the Groundstation. However, intermittent problems due to a damaged antenna or wiring may not be apparent until the aircraft is airborne.

- If damage is suspected or the GPS fails to acquire DO NOT FLY autonomously until the problem is rectified. Contact MLB immediately to troubleshoot GPS problems of this nature.

Video System

Live video is provided by a one-way link from the aircraft to the ground station. The system consists of cameras and a transmitter on the aircraft, while the ground station has a tracking antenna, a digital video tape deck video receiver, and a USB video adapter.

1) Video Cameras & Transmitter

The airborne video system is housed in the nose section of the aircraft. Two color CCD cameras (charged-couple-device) provide wide angle and telephoto images. A video switch, controlled by the flight computer, selects the image that is transmitted to the ground station. The transmitter operates in the 2.4 GHz band with a power output of 800 mWatt and broadcasts via the stubby dipole antenna mounted on the aircraft's nose section. The main power switch on the left side of the plane turns on the aircraft's video system along with all of the other systems.

Caution: The Video transmitter should never be powered without an antenna attached.

2) Tracking Antenna

At the ground station, the tracking antenna is used to capture the video signal. This system consists of a flat plate antenna, tracking mechanism, tripod, and associated cables – all of which are stowed in the ground station case below the tray.

- As with the servo-controlled components of the aircraft, the tracking antenna gimbals should be moved slowly and cautiously. Do not force them beyond their range of motion.

The tracking system points the antenna relative to a known orientation; therefore, proper initial alignment is essential for accurate tracking. The flat panel antenna has a 34-degree beam width, which translates to only 17 degrees on either side of center. It is therefore imperative that the antenna be oriented as accurately as possible. This is especially important at maximum range.

To set up the antenna:

- Erect the tracking antenna tripod.
- Orient the tripod so that the arrow on the tracking assembly (see Figure 15) is pointed to GEOGRAPHIC North.
 - If using a magnetic compass to find north, declination must be accounted for. See the section on declination correction for additional information.
- Next, attach the flat plate antenna to the tripod head (see Figure 16).
- Viewed from behind, the release lever is on the right hand side and points forward when clamped. The release lever locking pin is located beneath the lever and points forward when locked.
- Check that the release lever is in the open position (pointed to right).
 - If the release lever is in the clamped position and will not move, check that the locking pin is unlocked
- As depicted in Figure 16, hold the antenna in a slightly tilted position and butt the left edge of the attaching bracket up against the left edge of tracking head's top surface.
- Push the right side of the attaching bracket down to snap the release lever closed.
- Press the release lever forward to ensure that it is snugly clamped.

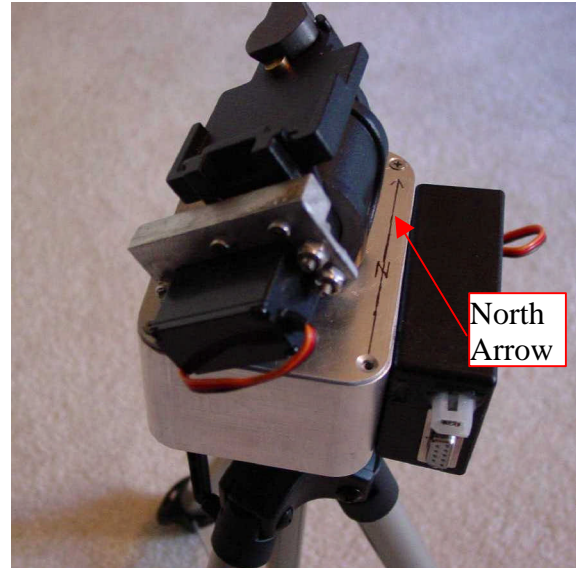


Figure 15. Arrow for orienting the tripod

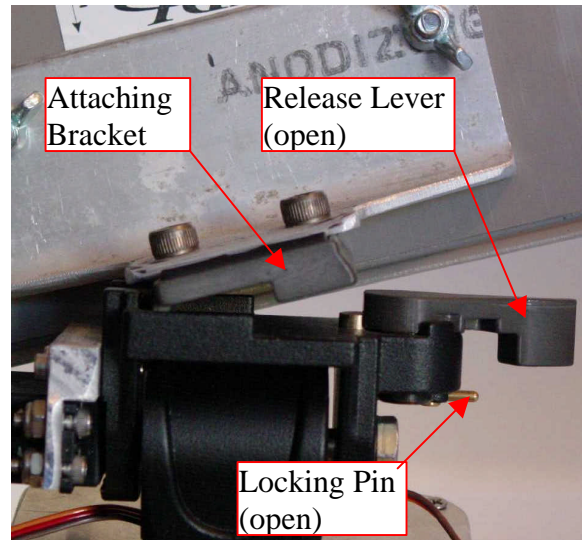


Figure 16. Attaching the antenna to the head of the tracking system.

After the antenna has been set up, the communication/power and coaxial cables need to be connected. While the antenna system has reverse polarity protection, it may still be damaged by an inappropriate connection. Be sure that positive and negative leads of the ground station battery are properly attached prior to connecting or turning on the antenna, modem or receiver.

At the antenna:

- Connect the coaxial cable to the antenna. The larger connector fits on the antenna and the smaller end attaches to the video receiver.
 - Manually rotate the antenna to face south and then attach the antenna cable, at its marked point, to the Velcro strap on the tripod leg. This will minimize wrapping the antenna cable around the tripod while the antenna is tracking so that the servos do not become overloaded.

- Connect the data/power cable (male DB-9 connector) to the tracking antenna's black box.

At the ground station:

- Connect the coaxial cable to the video receiver in the ground station case.
- Check that the antenna data cable is plugged into the USB/Serial adapter.
- Plug the USB/Serial adapter device into the laptop's USB port (be sure that the computer has booted up before making this connection).
- Plug the power connector into its receptacle behind the laptop.

Designate an antenna COM port for the tracking antenna to receive data from the ground station,

- From the Groundstation software pull-down menu, select *Serial Ports*, point to *Antenna Out on*, and then appropriate COM port.
 - If the antenna does not respond, try choosing a different COM port.
 - Proper operation of the antenna can be tested by using the pull-down menu to select *Antenna*, clicking on *Test Antenna*, and then entering values for antenna azimuth and elevation.
 - To close the antenna test window use the pull-down menu to select *Antenna*, and click on *Stop Testing Antenna*.

Notes on USB/Serial Adapter:

- Wait to plug the USB connector into the computer until after the computer has booted up.
- If the USB cable is removed while a COM port is selected for the antenna, a fault can occur.
- To remove the USB cable from the computer, either exit the Groundstation software or (while the ground station is open) deselect the antenna COM port.
 - From the pull-down menu select *Serial Port*, point to *Antenna Out on*, and then click *None*.
- If the USB connector is accidentally removed while a COM output is selected for the antenna, a pop-up window may appear asking the operator to remove the device.
 - Answer "Yes" to remove device. This will slow the system down briefly, but the computer should not shutdown. The computer may crash if the device is not removed.

3) Video Receiver

The video receiver is the white box mounted to the inside of the ground station's lid. It must be set to the same channel as the video transmitter to receive data, marked on the aircraft's video antenna mount. The receiver can be turned on/off independently, but the ground station's Modem/Receiver switch also controls the receiver. Figure 17 shows the power switch on the side of the receiver (indicated by the finger), the channel selector button on top of the receiver, and the channel indicator LED (showing channel 2 selected).



Figure 17. Receiver power & channel switches

- The receiver is not protected from reverse polarity, so be sure that positive and negative leads of the ground station battery are properly attached prior to connecting the modem or receiver.
- Check that the receiver power cable is plugged into the back of the receiver, and that the power connector is attached to its receptacle behind the laptop.
- Check that the power switch on the receiver is on.
- Channels are selected sequentially with the push button, and the current channel is indicated with a red LED.
- The aircraft's transmitter channel is written on the aircraft's antenna mount (Figure 18).
- If the receiver does not lock up while on the ground, the receiver may be swamped by too strong of a signal. Try cupping a hand over the aircraft's video antenna to reduce the signal strength.

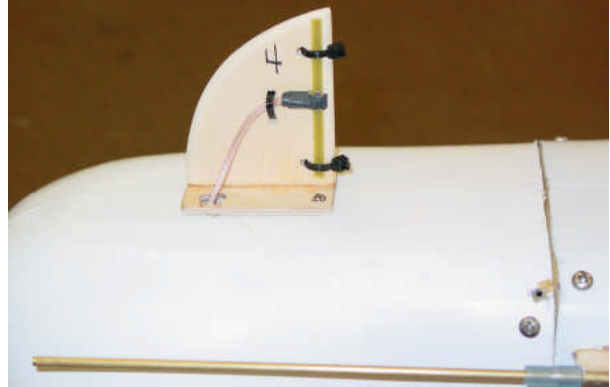


Figure 18. Video transmitter antenna & channel number

4) Video Deck

Output cables from the video receiver lead to the Video Deck that is located next to the laptop. Only the yellow RCA video plug needs to be connected to the deck's **Video In** jack. To conserve the Video Deck's battery, power can remain off until performing the video and telemetry check. For further information, refer to the manufacturer's manual.

- Turn the power on at the upper right side of the Deck's control panel.
- Remember to cue the tape to the point where recording is to begin.
- Simultaneously press the two buttons labeled **REC** to initiate recording. Be sure the red recoding light illuminates.

5) USB Video Adapter

In addition to watching live video on the video deck, a live image can also be displayed on the laptop using the USB digital video adapter. Connecting this device is required only to show video on the laptop. It does not impact the ground station's functions in any other way and does not need to be connected.

To watch live video on the ground station computer:

- Use the Y-adapter cable to connect both the USB digital video device and the video deck to the video receiver.
- Connect the USB digital video adapter to one of the laptop's USB ports.
- Select – **Show Video** – from the Video/Plot dropdown box.
 - Be sure that everything is hooked up and a video signal is present prior to selecting – **Show Video** – or the ground station computer may hang.

Data Modem

Two-way communication between the aircraft and the ground station is facilitated with the 900 MHz modem. The ground station modem is the small black box with the whip antenna. It is mounted with Velcro to the inside of the ground station's lid. To establish proper communication with the aircraft, the modem must be powered up AFTER the aircraft has been turned on. The modem's radio signals can interfere with the video antenna so they should be kept a few feet (5-10) apart during operations.

- The modem is not protected from reverse polarity, so be sure that positive and negative leads of the ground station battery are properly attached prior to connecting on the modem or receiver.
- Place the modem on the ground beside the Pelican™ case and erect the whip antenna.
 - Raising the modem several inches to a few feet off the ground will improve long-range communication.
- Ensure that the modem is at least 5 feet from the video antenna.
- Connect the modem to the laptop with the serial cable.
- Connect the modem power cable to the modem.
- Check that power connector is attached to its receptacle behind the laptop.
- Turn the modem on with the Modem/Receiver power switch shortly after the aircraft has been turned on and wait for its lights to stop flashing (5-10 seconds) before initiating any communication.

Radio Control Transmitter

Although the JR Pro R/C transmitter has an extensive set of programming features that are used to enhance the operation of normal R/C models, they should be left at the factory settings for use with MLB autonomous aircraft. All of the necessary features are set in the flight computer, and adjustments to the transmitter will interfere with these settings, potentially leading to unexpected failures. Maintaining the factory settings reduces the chance of transmitters being improperly set up, and should the transmitter's memory be erased, the default setting will be correct.

Use of the transmitter for MLB aircraft is limited to the two joysticks and the trim slider switches. The joysticks are configured as they are for conventional R/C Airplanes:

- Left stick, left-right controls rudder
- Left stick, up-down controls throttle
- Right stick, left-right controls ailerons
- Right stick, up-down controls elevator
- The trim slider switches are used to set the control surfaces so that in manual mode the plane will fly straight and level with minimal displacement of the joysticks
 - The factory trim setting (neutral) is appropriate for roll, pitch and yaw. The throttle trim should be kept at the top of its range so that the engine will not inadvertently stall when switching from autonomous to manual mode (Figure 19).
 - On the ground, the engine can be killed by pulling both the throttle stick and its trim to the bottom of their ranges.

- The accessory switch labeled “Gear” at the top left of the transmitter is for selecting Manual/Autonomous mode.
- When the lever is pushed away from the operator, the airplane is in Manual mode.
- The transmitter must be in Manual mode for the joysticks and trim switches to be functional.

To test the R/C system:

- Perform the normal aircraft startup procedure and turn the transmitter on.
- Select manual mode on the transmitter.
- Move each joystick one direction at a time and check that the aircraft controls respond appropriately:
 - Throttle stick forward should fully open the carburetor venturi.
 - Rudder stick right the left tail surface should deflect down and the right surface up.
 - Elevator stick back and both tail surface should move up.
 - Aileron stick right and the right aileron should move up, while the left aileron moves down.
- Range test the system:
 - Leave the transmitter antenna down and begin moving one of the joysticks (e.g. elevator).
 - Walk away from the aircraft and observe that the control surface continues to respond to the joystick’s movement without hesitation or erratic behavior.
 - The R/C system should function properly out to 100ft.



Figure 19. Throttle trim

Payload

Additional payloads can be added to the Bat UAV’s standard equipment, and the nose section can be exchanged for a variety of custom payloads. Depending on desired endurance, the Bat can carry up to 5 pounds of payload. Any integration or addition of payload should be conducted by MLB. The following information is provided for reference only, and it in no way implies that this work should be conducted by anyone other than MLB personnel.

Additional payloads must not cause the aircraft to exceed its gross takeoff weight, and they must be securely fixed inside the fuselage so that they do not interfere with any of the aircraft’s systems or alter its center of gravity (CG). Ensuring that the payload cannot move is essential. A shifting load can alter the aircraft’s CG, resulting in instabilities or causing damage to essential equipment that could cause a system failure. A loose item in the fuselage could damage fuel lines, disconnect wiring, or impact the flight computer, any of which could result in a complete aircraft failure.

- The aircraft’s maximum gross takeoff weight is 19 lb.
- The aircraft’s stall speed will increase and the rate of climb will decrease with additional payload. Be sure to operate the Bat in a more conservative manner at higher weights.
- Heavier objects need to be held in place with tie wraps or other strong binding.

- The wing's main spar provides a secure attachment point.
- Lighter objects may be held in place with double sided adhesive, or secured inside a foam package that fits snugly into the fuselage.

The aircraft's CG is marked on the side of the fuselage slightly below and behind the wings leading edge. The aircraft needs to balance within ½ inch of its CG marking regardless of fuel level.

To balance the plane:

- Empty the fuel tank.
- Place the cargo in its desired location.
- Find the CG by balancing the plane on one fingertip under each wing root (be sure that both fingers are located in the same longitudinal position).
- The balance point should be located ahead of the CG mark, but within ½ inch.
- Move the cargo as needed to achieve the proper balance.
- Fill the fuel tank and find the new balance point. It will have shifted aft.
- If the aircraft balances within the allotted ½ inch from the CG, it is safe to fly.
- If not, adjust the cargo and recheck the balance points with the fuel tank empty and full.
- Ensure that the payload is located along the aircraft's centerline so that the lateral balance is not disturbed.

Electronic equipment can interfere with the aircraft's systems. Prior to flying with additional electronic equipment, perform a range test as outlined in the section on R/C Transmitter and a bench test of the other systems. Performing a bench test is not 100% conclusive and requires some judgment from the operator. A good practice is to first perform the tests without the additional payload, to establish a base line, and then repeat the test with the additional equipment installed.

- Bench testing should be done outdoors or in an area that will not hamper GPS reception.
- Perform the "prepare for launch" sequence so that the plane is ready to fly.
- Turn on the R/C transmitter.
- In manual mode, check that the servos respond correctly to all pilot inputs.
- Test for adequate R/C range by checking that the servos respond smoothly and promptly when the R/C transmitter is 100' away and its antenna is collapsed.
- Leave the throttle at a low setting and switch to autonomous mode. The throttle servo should immediately move to a high setting.
- Gently blow into the airspeed probe and the elevators should deflect upward. (Sucking on the tube should have the reverse effect.)
- Roll the plane from side to side; the ailerons should move to counter the aircraft's rolling motion.
- Yaw the plane from side to side; the ailerons and rudders should move to counter the aircraft's yawing motion.
- Return the transmitter to manual mode.
- On the ground station, check that video reception is clear.
- Check that good telemetry is being received.
 - The ground station should ping regularly.

- Airspeed, ground speed, heading, and other status indicators should have appropriate values.

Use the pull-down menu to select a variety of plots and confirm that they represent any activity that was performed during the test procedure.

Batteries & Power Regulator

Charging the aircraft and ground station batteries require a 120 V AC supply that may not be available in the field, so advanced preparation is essential. The following six different batteries need to be charged prior to flying:

- 1) Aircraft battery
- 2) Laptop
- 3) Video Deck
- 4) R/C transmitter
- 5) Ground station gel cell
- 6) Engine starter

1) Aircraft

The aircraft's electrical power is supplied by a single 14.4 V Lithium-Ion battery and a power distribution system that provides regulated power to three separate electrical systems.

Electrical Systems:

- | | |
|------------------------|-----------------|
| 1) FC-2 | 7.0 V regulated |
| 2) Servos and Ignition | 5.0 V regulated |
| 3) Video and Modem | 5.0 V regulated |

The Lithium-Ion battery requires at least 3 hours to charge. The charger does not have any status indicators, but it will shut off automatically when the battery is fully charged. Ideally, the battery should be left on charge overnight to allow the charger to shut-off at full charge. If less time is available, the battery should be left on the charger for a minimum of three continuous hours. At peak charge, the battery will indicate close to 16 V and the voltage will drop proportional to the state of charge; however, below 14 V, the battery will begin to lose power very quickly. Once the battery voltage drops close to 14 V, flight operations should be discontinued as soon as possible.

In addition to making sure the battery does not drop below 14 volts during flight operation, care must be taken to never allow the battery to discharge below 10 V; the Lithium-ion batteries will be permanently damaged if their voltage is allowed to drop below 10 V. Most devices that use Lithium-ion batteries (i.e. cell phones) employ automatic shutdown circuitry to protect the battery from a low voltage condition; however, to protect against an accidental in-flight shutdown, the Bat onboard battery does not have such circuitry. Therefore, the operator must ensure that the battery is never allowed to drop below 10 volts. If the battery is ever discharged below 10 volts, it must be replaced.

Summary:

- A fully charged aircraft battery indicates close to 16 volts.
- Land the aircraft immediately if the battery voltage drops below 14 V.
- The aircraft battery must be discarded and replaced if it ever drops below 10 V.
- The safety lock on the power switch should be used when transporting the aircraft or when the power is switched off for extended periods (>15 minutes).

To charge the aircraft battery:

- Open the access hatch and locate the wire labeled 14.4 V Li-ion (see Figure 20).
- Attach the lead from the wall plug charger.
- The charger has no status indicators, so a minimum of 3 hours of uninterrupted charging is required to ensure a full charge.
- A fully charged aircraft battery will indicate close to 16 volts on the ground station.

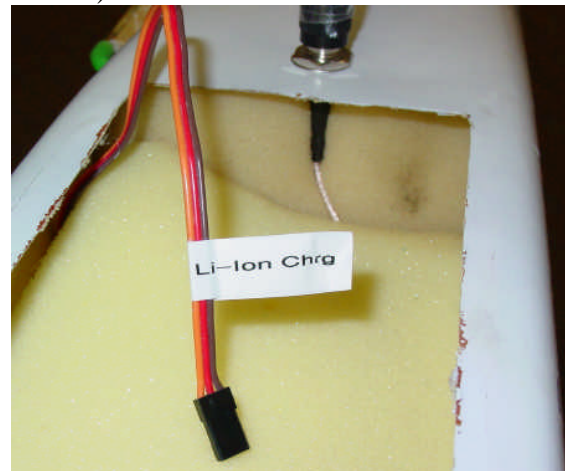


Figure 20. Battery charge lead

2) Ground Station

Charge the five ground station batteries according to the following specifications.

- | | |
|------------------------------------|------------------------------|
| 1) Laptop | manufacturers specifications |
| 2) Video Deck | manufacturers specifications |
| 3) R/C transmitter | manufacturers specifications |
| 4) 12 volt ground station gel cell | 4-12 hour trickle charge |
| 5) 12 volt engine starter | 4-12 hour trickle charge |

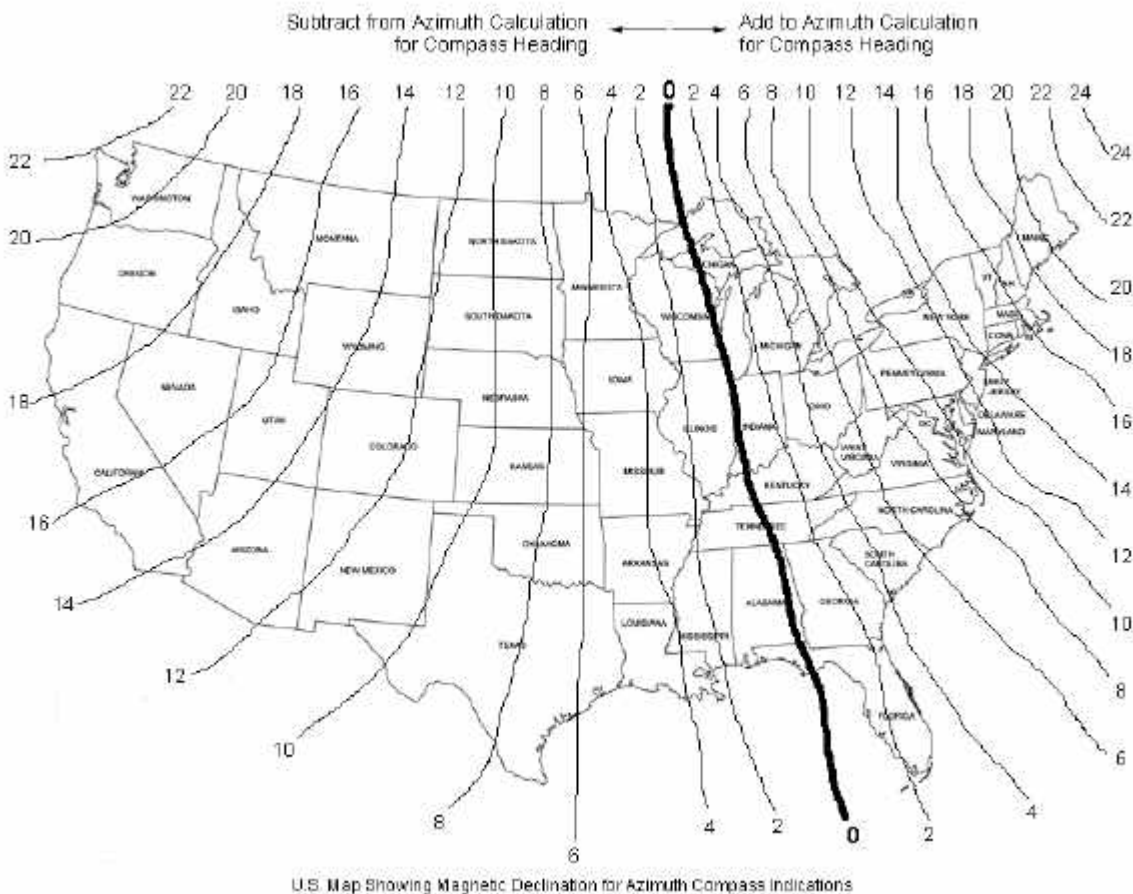
Note for first time use:

A different R/C transmitter may have been used during this aircraft's flight testing or operator training, so be sure to follow the manufacturer's instructions for first time charging of the R/C transmitter.

Declination Corrections

Declination compensates for the difference between the Earth's magnetic and geographic North Poles. To determine the appropriate magnetic bearing for a desired geographic direction, add or subtract the local declination value from the geographic direction. West of the zero line, declination is subtracted, while declination is added East of the line. For example, to find geographic North in central Washington State, the desired geographic direction is $0^{\circ}/360^{\circ}$ and the declination is 20° ; therefore a compass bearing of 340° points to geographic North. Pointing the antenna's North arrow to 340° magnetic would provide the proper orientation in central Washington State. In St. Louis, the antenna would be properly oriented when its North arrow is pointed to 358° magnetic, and in Baltimore, Maryland, the correct orientation would be 010° magnetic.

One should note that magnetic declination changes over time, and the most recent information should be obtained to ensure that the correct declination values are used.



SOFTWARE IN-DEPTH PROCEDURES

The MLB Groundstation is a software program that communicates with the Bat UAV for flight planning, pre-launch programming, in-flight re-tasking, and display of live telemetry. The detailed procedures that follow provide in-depth descriptions of all the Groundstation's functions, including adding map files to the map database, creating flight plans, and initializing the aircraft's launch sequence. There are also sections that explain the formats of the flight data files, the flight plan files, and the Groundstation configuration file. At the end of this section, there are tutorials that will help first-time users become acquainted with the system.

The procedures explained here are instructions for performing specific tasks. This is not a set of operating instructions. A specific set of sequential procedures for operating the Bat is provided in the Groundstation section of the OPERATING INSTRUCTIONS.

Overview

The Groundstation's main screen is shown in Figure 21. The left portion of the screen shows the aircraft state and a user-selectable video or data plot. The right side of the screen is the moving map display that shows the aircraft position, waypoints, and flight path. Features of the aircraft state and moving map are outlined beside their respective Figure 22 & Figure 23.

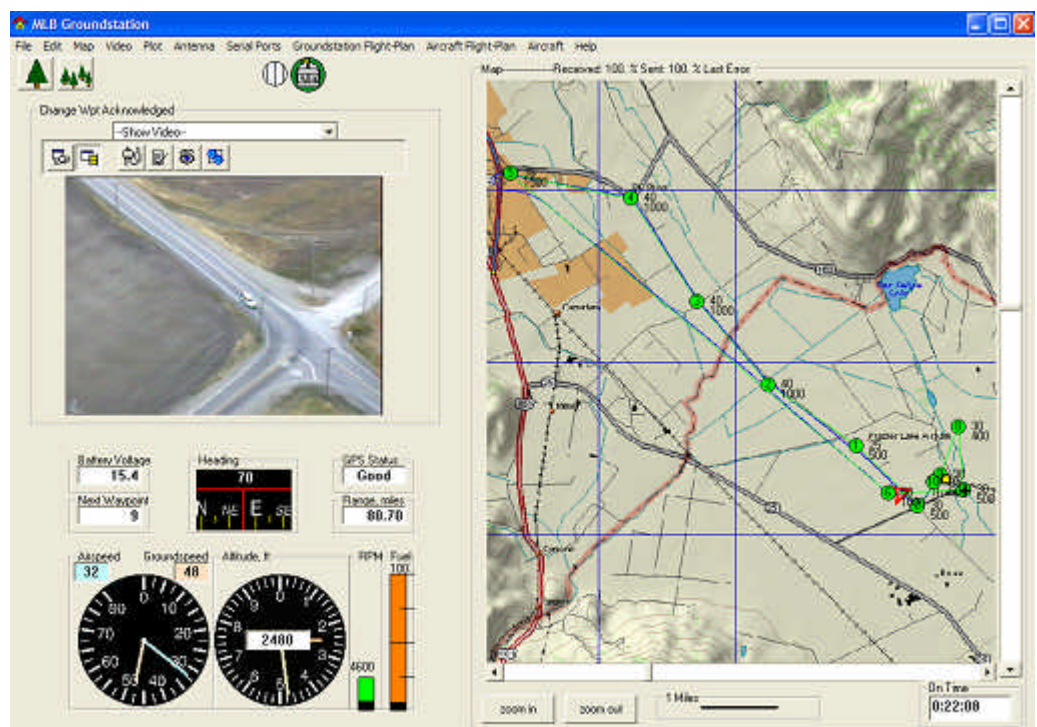


Figure 21. Groundstation main screen

1) Description of aircraft state information

- Camera Zoom controls top the left screen area.
- A telemetry wheel next to the camera zoom control spins and changes color every time a telemetry packet is received from the aircraft.
- The Video/Plot area can show a live video image from the onboard camera or other selectable data plots.
- Battery voltage is displayed to the lower left of the video/plot window.
- The aircraft's state, displayed below the battery voltage, shows that the aircraft is heading toward waypoint 0. This area also will display whether the aircraft is in manual control mode, waiting for launch, climbing out after launch, or circling.
- GPS Status is shown to the lower right of the video/plot window.
- The aircraft's range from the home waypoint is displayed below the GPS Status
- A compass displaying the aircraft's heading graphically and numerically is centered below the video/plot window.
- Airspeed and ground speed are displayed with the blue and brown needles of the left dial gauge, respectively. Both values are also displayed numerically above the gauge.
- Altitude is displayed on the right dial gauge, with the numerical value in the center of the gauge. The short hand shows thousands of feet, the long hand shows hundreds of feet.
- Engine rpm is shown on the bar graph to the right of the altitude gauge.
- The fuel level is shown on the bar graph to the right of the rpm gauge.

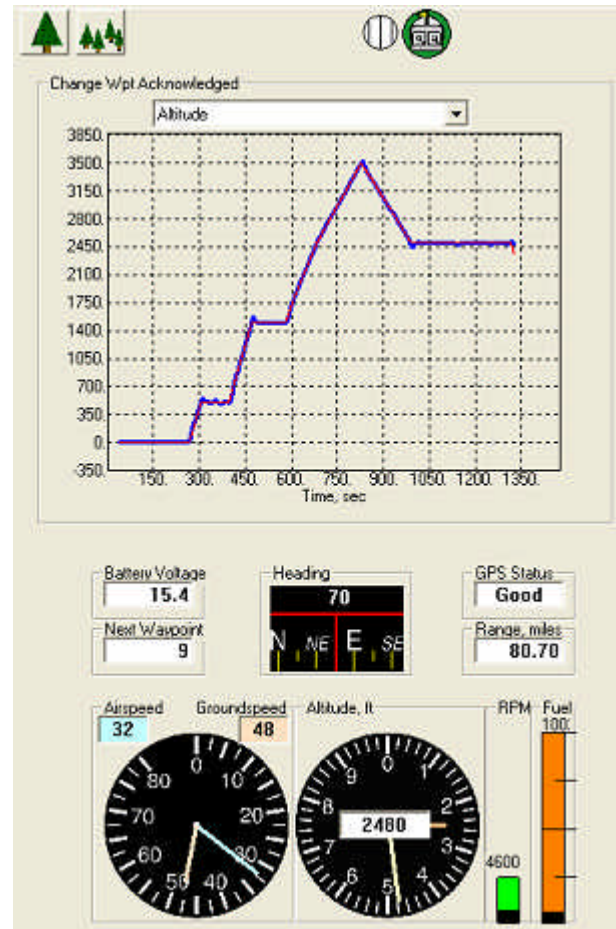


Figure 22. Aircraft State

2) Description of map display

- Circular dots on the map represent waypoints. The dots turn from red to green as the course is confirmed by the aircraft.
- Green lines show the commanded path to be flown.
- Blue lines show the actual path flown.
- The red delta represents the aircraft.
- Scroll bars along the bottom and right side of the map allow the map to be moved in the display area.
- Zoom control buttons, below the bottom scroll bar, show more of the map or increase detail.
- A scale bar to the right of the map zoom controls provides a sizing perspective as the map is zoomed in or out.
- Time since the aircraft's flight computer was initialized is shown at the bottom, far right.

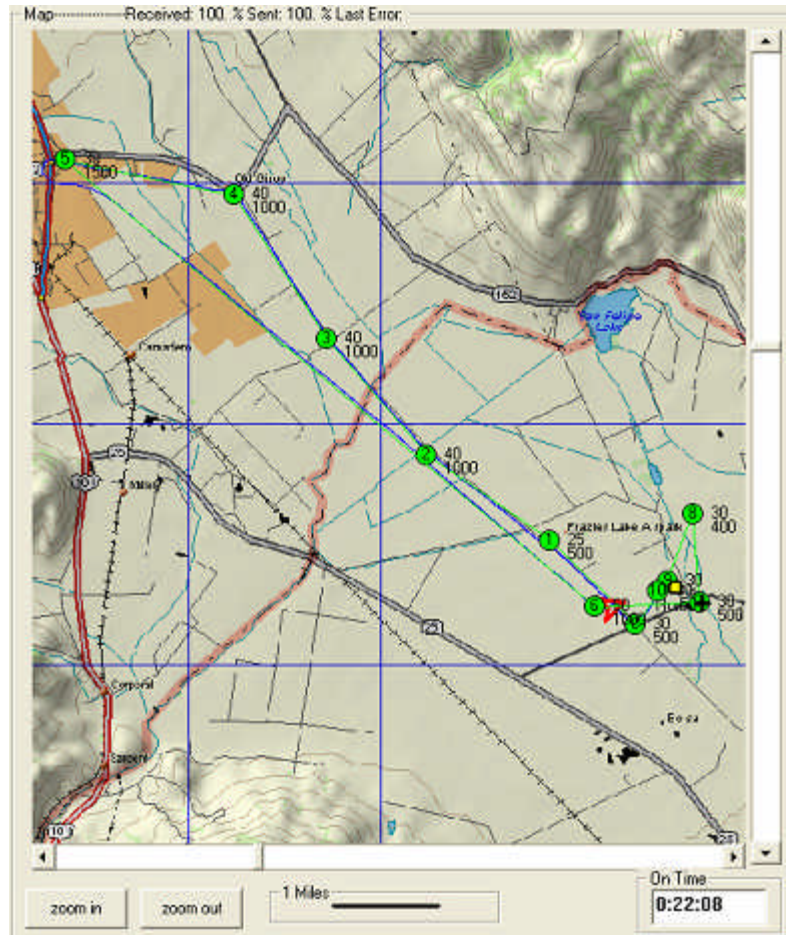


Figure 23. Moving map display

Getting Started

To launch the groundstation software, click the MLB Groundstation shortcut Icon on the taskbar, or from the Windows *Start* button select *Programs* then *MLB Groundstation* and click on the *MLB Groundstation* icon.

Adding & Calibrating Maps

While having a map for the intended area of flight is not essential, a meaningful background is helpful for flight planning and tracking the aircraft's flight path. Once a map has been added, it is kept in the Groundstation's database and will automatically be loaded any time the aircraft flies over that area. When the aircraft flies beyond the boundaries of a map, the groundstation will search its database for a map that covers that geographical area. If no map is found for a given location, a plain gray background will be shown on the map display.

The Groundstation will always open with the default map, which is the first map listed in the database. To change the default map, refer to the "Configuration File" section.

A note of caution when adding or recalibrating a map:

An error made during the map calibration will most likely not be apparent until the map is used for flight planning. If a map jumps unexpectedly, geographic coordinates appear inappropriate, or the map disappears when a waypoint is added that should be on the map, it may be calibrated incorrectly.

1) To Add and Calibrate a Map

An appropriate map image must be available in a graphics format: JPEG, GIF, or Windows Bitmap (BMP). TopoUSA is included with the standard MLB system to provide reasonably accurate map images, but any image, even a hand drawn sketch, saved in the proper format will work. Once a map is added, its area of coverage is automatically computed and added to the database.

- Maps must be rotated so that NORTH IS UP.
- The latitude and longitude of 2 points on the map must be known.
- These two points CANNOT be due N-S or E-W of each other (i.e., they cannot share either the same latitude or longitude).
- Prior to getting started, close and reopen the groundstation program. This will ensure that there are no current flight plans in memory, which can cause problems if proceeding with a new flight plan after the new map is loaded.
- From the groundstation pull-down menu, select *Map* and click on *Add New Map...*
- A *File Open* window will pop up.
- Select the desired map image and click open.
- Click OK in the dialog box when prompted for the coordinates.
- The scroll and zoom functions can be used to accurately identify the known locations.
- Left Click at the 1st known location.
- An *Enter Lat/Lon of Selected Point* window will pop up.
- Enter the coordinates.
- Degrees are in whole numbers (e.g., 37).
- Minutes are decimal numbers (e.g., 121.345) there are no seconds.
- To use decimal degrees instead of degrees and decimal minutes, type the decimal degrees in the degrees box (e.g., 37.123456) and 0 in the minutes box.
- Be sure to select the proper directions *N-S* and *E-W* for the latitude and longitude.
- Click OK.
- Click OK in the dialog box when prompted again for coordinates.
- Left Click at the 2nd known location.
- Enter the coordinates in the *Enter Lat/Lon of Selected Point* window.
- Click OK.
- CHECK THE MAP! Before flying the aircraft using the map, place some waypoints on the calibration points and make sure that the map is properly calibrated.

2) To Recalibrate a Map

- Use the pull-down menu to select *Map* and click on *Calibrate...* and select the map you wish to recalibrate. Repeat the calibration process.

3) To Remove A Map From the Database

- Use the pulldown menu to select *Map* and click on *Delete Map...* and select the map you wish to delete. Click on yes when prompted.
- The map will be removed from the database but the map image will not be deleted.
- Maps can also be deleted from the database by deleting them in the *groundstation.cfg* file. Review the section on the **configuration file** format for more information on how to do this.

4) To Display a Different Map

- Use the pull-down menu to select *Map* and click on *Display Map...* and select the map you wish to display.
- If flight data has been received, the map display will always snap to the map that shows the airplane's location. To look at a map other than that of the flight data, you must delete the flight data by selecting *File* and *Clear Flight Data*.

Creating a Flight Plan

Before the aircraft can be flown autonomously, it must have a valid flight plan. A flight plan consists of a home location and a series of waypoints that are connected by straight lines, which in turn define the aircraft's flight path. The aircraft attempts to position itself along the lines between waypoints rather than just aiming for the next waypoint. These lines, together with the altitudes that define a linear slope between waypoints, create a flight path that resembles a tube through the airspace in which the aircraft will fly. Familiarity with the functions described in the section "Editing Waypoints" is essential to understanding the procedures of creating a new flight plan.

As depicted in Figure 24, a flight path is a continuous course that begins at Waypoint 0 (denoted by the red circle with the 0 inside), proceeds sequentially through all the waypoints, and resumes again at Waypoint 0. Since the home location is not a regular waypoint and is not included in the flight path, a flight plan should always bring the aircraft back close to the home location so that it can land within the operator's supervision. Without this consideration, an aircraft could continue on its course without the operator being able to intervene.

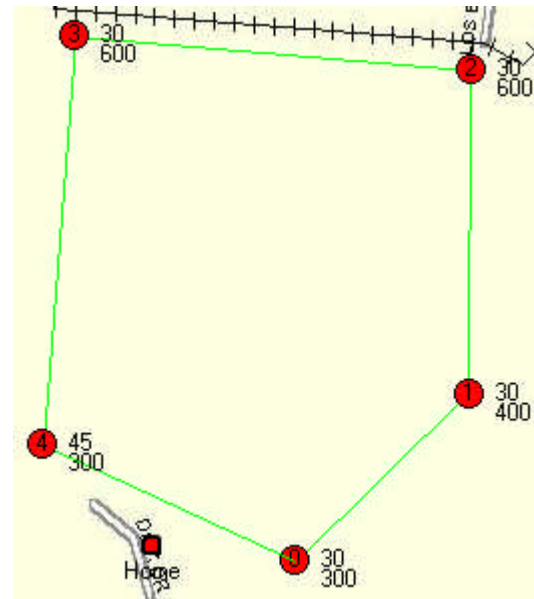


Figure 24. The continuous course of a flight plan

1) Map

- The default map displayed when the groundstation is opened may not be the appropriate map for the flight plan desired.
 - If a map for the appropriate area has already been added, but it is not the current map in the display, the correct map can be opened.
 - From the pull-down menu select *Map*, and click on *Display Map File*. Click on the desired map file.
 - If a map for the intended area of flight has not been loaded, refer to the section on “Adding a Map” before proceeding.

2) Adding Waypoints

- From the pull-down menu select *Groundstation Flight-Plan*, and click on *Add a waypoint*.
 - A Home location and the first waypoint (wpt 0) will be added, and the Edit Waypoint window will pop up.
 - Home is initially placed at the center of the map.
 - wpt 0 is placed a short distance from the Home location.
 - Home is not a regular waypoint, but it has a few special functions.
 - Used to calculate the aircraft’s range, displayed on the aircraft state window.
 - Waypoints can be placed relative to home’s location (altitude designated as 0’).
 - Defines the location for an aircraft Return to Home event (altitude designated as 500’).
 - Used by tracking antenna as the antenna’s location.
- If the desired map is not currently displayed, but it was previously added:
 - Use the *Map File* pull-down, at the bottom of the of the Edit Waypoint window, to choose the desired map.
 - Then, using the Edit Waypoint window, change the current waypoint to Home and repeat the move process.
 - Both Home and wpt 0 are placed at the center of the new map.
 - Drag and drop and/or use the Edit Waypoint window to set the parameters of the Home location and wpt 0.
- Use the *New Waypoint After* & *New Waypoint Before* buttons in Edit Waypoint window to add more waypoints up to a maximum of 99 waypoints (0-98).
 - While adding waypoints, be sure that the correct Altitude, Airspeed, and Position are set, as these are essential to the aircraft’s safety.
- When the flight plan appears to be complete, start at wpt0 and use the *Next Waypoint* button to scroll through the flight plan, checking that each waypoint’s parameters have been set appropriately.
 - Check that the airspeed is never commanded above or below the aircraft’s range.
 - Check that the airspeed is reduced for turns with a heading change greater than 45 deg.
 - Check that altitudes will ensure terrain clearance at and between waypoints.
 - Check that altitude changes between waypoints are within the aircraft’s climb and descent limitations.
 - Check the maximum range to home.
 - Check that the line of sight between the aircraft and ground station is clear to avoid loss of data and video signal.

- Check that the camera operation has been correctly defined for each leg, and that the durations for the circle or cross patterns are correct (the default is 0 seconds).

3) Return To Home Mode

- Enable/Disable Return to Home
 - Upon loss of signal from the R/C transmitter the aircraft can automatically initiate a return to home. This is a safety feature that ensures the operator will always be able to regain manual control during autonomous flight.
 - If the aircraft is intentionally going to be flown beyond the range of the R/C transmitter (~1 mile) or if the R/C transmitter is going to be turned off during the flight, the Return to Home must be disabled.
 - From the pull-down menu, select *Groundstation Flight-Plan* click *Return to Home on Loss of Link* to toggle Return to Home off/on.
 - A check mark beside *Return to Home on Loss of Link* indicates that it is enabled
 - No check mark indicates that it is disabled.
 - The default setting is for Return to Home to be enabled.
- Save the flight plan.
 - From the pull-down menu select *File*, click *Save> Save Flight Plan As...*
 - A *Save As* window will popup displaying the default Flight Plan folder.
 - Any appropriate folder can be selected, but using the default location will make opening and saving files a bit easier.
 - The file extension is irrelevant, but flight plans are text files, so using a “.txt” extension is appropriate.
 - Click *Save*.
- After the flight plan is saved a message box will pop up displaying the distance for the full course, the estimated zero-wind flight time, and the Return to Home status.
 - Review the flight plan summary to ensure it is appropriate, and within the aircrafts limits.
 - If not, be sure to make the necessary changes, and resave the flight plan before proceeding.
 - Click OK.

Editing Waypoints

Waypoints consist of a geographical position, altitude, airspeed, and actions for the aircraft to execute. The *Edit Waypoint* window, shown in Figure 25, is used to edit waypoint parameters. It pops up whenever a new waypoint is added. The *Edit Waypoint* window can also be opened by right clicking on any waypoint.

After changing data in an edit box, all data fields and the map are updated by clicking in a different edit box or by clicking the *Refresh Map* button.

- The *Waypoint* box defines the CURRENT waypoint that is being edited.
- The *Previous Waypoint* and *Next Waypoint* buttons can be used to scroll through the waypoints and the home location.
- The *New Waypoint After* button adds a new waypoint after the current waypoint, and increases, by 1, the number of all subsequent waypoints.
- The *New Waypoint Before* button adds a new waypoint before the current waypoint, and increases, by 1, the number of the current and all subsequent waypoints.
- The *Delete Waypoint* button removes the current waypoint, and decreases, by 1, the number of all subsequent waypoints.
 - Up to 99 waypoints, indexed from 0-98, can be created.
 - The aircraft flies to the waypoints sequentially starting from 0.

The **Edit Waypoint** window contains the following elements:

- Instructions:** Drag waypoint on the map, enter Lat/Lon, or enter distance and bearing relative to the other points. Also enter the altitude and airspeed to maintain while heading for this waypoint, the waypoint action when the waypoint is reached, and the camera action while heading for the waypoint.
- Waypoint:** A box with 'Previous Waypoint' (2), 'Next Waypoint', 'New Waypoint After', 'New Waypoint Before', and 'Delete Waypoint' buttons.
- Waypoint Action:** A dropdown menu set to 'Cross Over' and a 'Duration' field set to 2 min 30 sec.
- Camera Action:** A dropdown menu set to 'Look at Point' and a 'From Wpt' section with 'bearing' (0.000 deg) and 'distance' (0.00 mi) fields.
- Altitude (AGL, ft):** A text field with the value 400.
- Airspeed (mph):** A text field with the value 30.
- Latitude:** Fields for 37 Degrees, 59.847 Minutes, and a direction dropdown set to 'N'.
- Longitude:** Fields for 122 Degrees, 5.680 Minutes, and a direction dropdown set to 'W'.
- Relative Positioning (buttons select relative to what):** Buttons for 'Previous', 'From Home to Wpt 2', and 'Next'.
- Compass Bearing (deg):** A text field with the value -76.6.
- Distance (mi):** A text field with the value 0.194.
- Slope (deg):** A text field with the value 21.33.
- Map File:** A dropdown menu set to 'mikeshouse.jpg'.
- Buttons:** 'Refresh Map' and 'OK'.

Figure 25. Edit waypoint window

1) Waypoint Action

- The *Waypoint Action* box defines what the aircraft will do when it reaches the current waypoint
 - Reaching a waypoint is defined as coming within 260 ft of the waypoint, or flying past the waypoint on the current leg of the course.

- *Fly Through*: The aircraft will continue on to the next waypoint after reaching the current waypoint.
- *Drop*: Optionally equipped aircraft will drop deployable sensors or take still photos at the waypoint while the aircraft continues to fly through to the next waypoint.
- *Circle*: The aircraft will circle the waypoint with a fixed radius for a user-specified duration.
- *Cross Over*: The aircraft will fly in a cross pattern for a selectable duration. It will alternately approach the waypoint from the North, South, East and West to provide a view of all sides of the waypoint.
 - The *Duration* box pops up when either *Circle* and *Cross Over* are selected.
 - Duration is defined from the time the aircraft reaches the waypoint until it departs for the next waypoint.
 - As soon as the time expires, the aircraft will fly from its current location to the next waypoint (using a course leg defined by the center of the circle or cross and the next waypoint).
 - If no time is entered (e.g., 0 min, 0 sec), the aircraft will fly through to the next waypoint.
- *Land Here*: The aircraft will consider this leg part of the final approach before landing.

2) Camera Action

- The *Camera Action* box defines how the camera is aimed while flying from the previous to the current waypoint and while executing the circle or cross pattern. For aircraft without the optional gimballed camera, these parameters have no function.
 - *Fixed to Plane*: The camera's aim point is fixed relative to the aircraft at selectable angles. The camera gimbals are locked so perturbations to the plane are translated to the camera.
 - *Pan*: Selects camera's aim angle to the left or right of the aircraft from -90 to +135 where negative values are left of center, 0 is center, positive values are right of center.
 - *Tilt*: Selects camera's downward aim angle from 0 to -90 where 0 is straight ahead and -90 is straight down.
 - *Look along Course*: The camera's aim point is fixed relative to the course line being flown at a selectable downward looking angle. The camera gimbals actively remove aircraft perturbations at frequencies less than ½ Hz so that the camera continues to look along the course line.
 - *Tilt*: Selects camera's downward aim angle relative to the horizon from 0 to -90 where 0 is straight ahead and -90 is straight down. For example, with the aircraft flying at 500' above ground and tilt set to -45 deg, the camera would be focused 500' ahead of the aircraft.
 - *Look at Point*: The camera's aim point is fixed relative to the current waypoint. The camera gimbals actively remove aircraft perturbations at frequencies less than ½ Hz so that the camera stays fixed on the point.
 - *Bearing*: This is the geographical bearing (0-360 deg) from the current waypoint (waypoint to which the aircraft is flying) to the desired camera aim point.
 - *Distance*: This is the distance (in miles) from the current waypoint to the desired camera aim point.

- If the distance is set to 0 the camera will look at the waypoint. For a distant waypoint the camera will initially be aimed close to the horizon, but as the aircraft approaches the waypoint the camera will continue to tilt down until it is looking directly down as the aircraft flies over the waypoint.

3) Altitude

- The *Altitude* box defines how high (in feet) the aircraft will be at the waypoint.
 - All altitudes are relative to where the plane was initialized, which should be the home location. (The pressure sensor used to estimate altitude is accurate to ± 10 ft over a 1-hour flight.
 - For example, if a waypoint altitude is set to 500', but the terrain at the waypoint's geographic location is 300' higher than the home location, the aircraft will only be 200' above the ground at the waypoint.
 - Conversely, if the waypoint is over a valley and the home location is on a hill the waypoint altitude could be -100' and the aircraft could be well above the terrain
 - When the altitude changes between two waypoints, the aircraft will fly a linear slope between the waypoints.
 - For example, if two waypoints are three miles apart with altitudes of 500' and 800' respectively, the aircraft will be at 700' when it is 1 mile away from the second waypoint.

4) Airspeed

- The *Airspeed* box defines how fast (in mph) the aircraft will fly while approaching the current waypoint.
 - While the aircraft will maintain a constant airspeed on each leg, ground speeds can vary significantly from airspeeds due to wind conditions. The operator is responsible for choosing an airspeed that is appropriate for the wind conditions. The Bat UAV will not navigate properly if it experiences a negative ground speed along its flight path.

5) Waypoint Location

A waypoint's geographical location can be edited in 3 different ways:

- 1) The *Latitude & Longitude* boxes define the specific coordinates of the current waypoint.
 - Degrees are in whole numbers (e.g., 37).
 - Minutes are decimal numbers (e.g., 121.345) there are no seconds.
 - To use decimal degrees instead of degrees and decimal minutes, simply type the decimal degrees in the degrees box (e.g., 37.123445) and 0 in the minutes box.
 - Be sure to select the proper directions *N-S* and *E-W* for the latitude and longitude.
- 2) *Relative Position* box defines a position relative to home or another waypoint.
 - The *Previous & Next* buttons are used to select from which point the current waypoint's relative position will be defined. Use these buttons to scroll through the waypoints and home location.
 - *Compass Bearing*: This is the geographical bearing (0-360 deg) from the point selected to the current waypoint.
 - *Distance*: This is the distance (in miles) from the selected point to the current waypoint.

- *Slope*: This is an optional means of setting the altitude of the current waypoint based on a slope angle from the selected point to the current waypoint.
 - If a slope is specified, the current waypoint's altitude will automatically update to meet the slope.
 - If a slope angle is not entered, this box will automatically update to show a slope calculated from the current waypoint's previously-entered altitude.
 - For example, if the selected point is waypoint 1 and the current waypoint is 3, a negative slope will cause waypoint 3's altitude to be less than waypoint 1's altitude
 - The relative position method is useful for setting up landing approaches and checking climb gradients.
 - Note: the altitude of home is 0 when slope is calculated using this function.

3) A waypoint can be graphically placed by dragging it on the map with the left mouse button

Notes on waypoint location:

- Changing information in any of the 3 ways causes the information to be updated in the other locations (e.g. clicking on the map will change the data in the lat/lon boxes and bearing/distance boxes).
- If a waypoint's position is changed so that it is off the current map, the map will be changed in the map window to show the current waypoint.
- If no map is available, a gray background will be displayed.
- To place the current waypoint on a different map, select the desired map in the *Map File* pull-down menu. The waypoint will be moved to the center of the selected map. Use the *Next Waypoint* or *Previous Waypoint* buttons from the Edit Waypoint window to display the map the other waypoints are on (the map for the current waypoint is always displayed), or use the Display Map menu to display any map.

Using and Editing Existing Flight Plans

After a flight plan has been saved, it can be reused at any time in its present form or as the basis for creating a new flight plan.

- From the pull-down menu, select *File* click *Open > Load Flight Plan*.
 - The Open file window will pop up with the default Flight Plan Folder.
 - Locate the desired flight plan (either in the default folder or in any appropriate folder).
 - Click Open.
 - The selected flight plan with the appropriate map will be displayed.
 - If no map exists in the database for the area of the flight plan, a plain gray background will be used.
- After the flight plan has opened, a message box will pop up displaying the distance for the full course, the estimated zero-wind flight time, and the Return to Home status.
 - Review the flight plan summary to ensure it is appropriate, and within the aircraft's limits.
 - If not, be sure to make the necessary changes and resave the flight plan before proceeding.
- Click OK.
- The flight plan can now be used as is, or it can be modified in any way to create a new flight plan.

- Use the functions described in “Creating a Flight Plan” to modify the flight plan as desired.
- Before saving, sequentially step through all the waypoints to check their parameters.
- Save the new flight plan
 - Review the flight plan summary to ensure it is appropriate and within the aircraft’s limits.
 - If not, be sure to make the necessary changes, and resave the flight plan before proceeding.
- Click OK.

Image Mosaic Flight Plan

An Image Mosaic or Paint Flight Plan is a special type of flight plan used to systematically search or map a designated area. A block of terrain is “painted” with the aircraft’s video camera or other sensors.

Familiarity with the “Creating a Flight Plan” and “Editing Waypoints” sections is essential to understanding the procedures of creating a Paint Flight Plan.

To create a Paint Flight Plan:

- Add and position 4 waypoints that outline the desired area to be painted as depicted in Figure 26.
 - Only the waypoint positions need to be entered.
 - All other necessary parameters will be set later.
 - While placing the waypoints, keep in mind that the aircraft will fly its paint legs parallel to the line between wpt 0 and wpt 1.

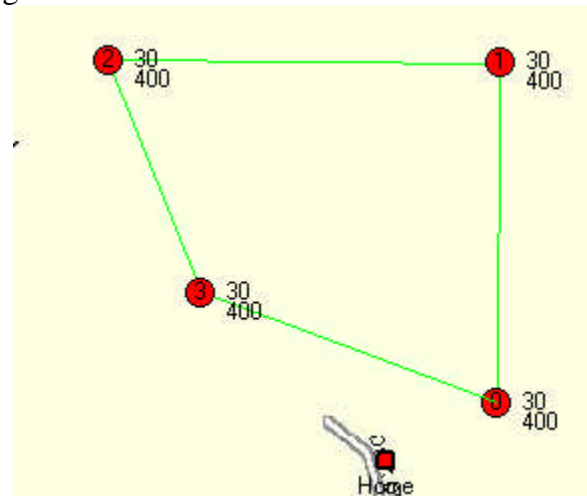


Figure 26. Four-waypoint outline for Paint Plan

- From the pull-down menu select *Groundstation Flight-Plan* and click *Make Paint Pattern*
 - The Paint Path window will pop up with the following parameters:
 - *Turn Cushion*: This is the distance (in miles) that the aircraft will fly beyond the desired area to execute turns and line up for the next run.
 - *Separation*: This is the displacement (in feet) between passes over the area to be painted.
 - *Altitude*: This is the altitude (in feet) above the home location, which will be used for all segments of the flight.
 - *Airspeed*: The aircraft will maintain this airspeed (in mph) for all segments of the flight.
 - The user needs to choose the appropriate values, based on a number of factors including camera, terrain, and weather.
 - Example using the default values in the Paint Path window (0.15 mil, 250 ft, 400 ft, 30 mph for the 4 respective parameters): The time to complete a turn and get on track will be $0.15 \text{ mil} / 30 \text{ mph} \times 3600 \text{ sec/hr} = 18 \text{ seconds}$ (just enough). With a camera viewing angle of 53 deg., the painted area on either side of a path line would be $400 \text{ ft} \times \tan(26.5 \text{ deg}) = 200 \text{ ft}$. With a separation of 250ft, the mid point between paths is at

125 ft, so the margin for error will be 75 ft. Given that there will be another 75 ft margin for the adjacent path, at total of 150 ft will be overlapped if the camera aiming error is 0.

- Enter the appropriate parameters.
- Click OK.
- A series of new waypoints for the aircraft to fly the paint plan will automatically be generated and the original box will be designated with a black line as depicted in Figure 27.
- Enable/Disable Return to Home.
- Save the flight plan.
 - From the pull-down menu, select *Groundstation Flight-Plan* click *Save Flight Plan As...*
- When the message box appears, review the flight plan summary to ensure it is appropriate and within the aircrafts limits.
- If not, be sure to make the necessary changes, and resave the flight plan before proceeding.
- Click OK.

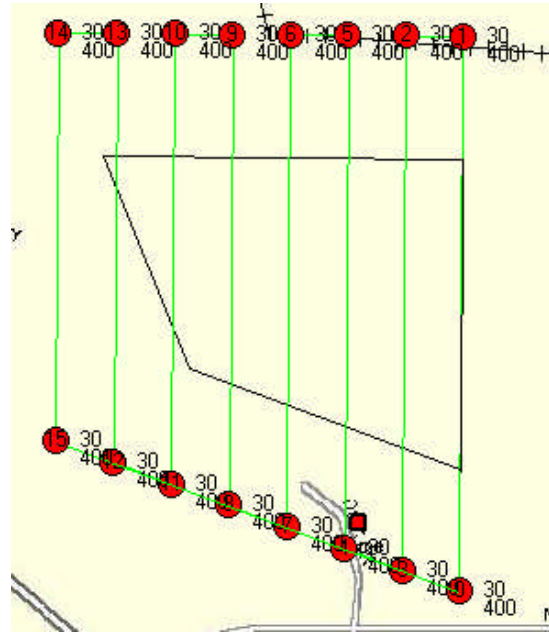


Figure 27. Automatically generated waypoints overlaying originally selected area

Initializing the Aircraft

Prior to launching the aircraft, it must be initialized and a flight plan must be uploaded. During the initialization process, a number of checks need to be performed by the operator to ensure the aircraft's safety. The MLB flight control system uses many components not specifically designed for aerospace applications to produce small yet very capable aircraft at a relatively low cost. These components infrequently initialize in such a way that merely hinder a terrestrial system but could result in complete loss of an aircraft. A quick visual scan of the initialization window will ensure that this does not happen.

- If previous flight data is still being displayed, use the *File... Clear Flight Data* menu to erase this data.
- Clearing previous flight plan information is not necessary.
- The initialization process should not be started until the aircraft preflight procedures have been completed and it is otherwise ready for launch. Refer to the section on "Aircraft Preparation" for the proper preflight procedures.
- Begin by loading an existing flight plan or creating a new one. Refer to the section on "Creating a Flight Plan".
 - If a new flight plan is created, don't forget to save it before proceeding.
- Initiate the launch sequence.
- From the pull-down menu select *Aircraft* and click *Start up*.

- A *Launch Method* dialog box will ask whether the launch will be Autonomous.
 - An autonomous launch requires no pilot involvement. Once the engine is started and the aircraft is ready to go, the R/C transmitter is switched to Autonomous mode, which causes the throttle to automatically advance to full. The flight computer then waits to detect the launch acceleration. Upon detecting the launch, the flight computer initiates a climb out sequence up to 100' prior to initiating normal waypoint navigation to wpt 0.
 - If autonomous launch is selected, the aircraft is launched under manual control, and the R/C transmitter is switched to Autonomous mode after the aircraft is airborne, the flight computer will remain in standby and hold the engine at full throttle while waiting to detect the launch. The plane will eventually crash.
 - An aircraft can be recovered from this scenario by quickly switching the R/C transmitter back to manual mode and landing the aircraft manually.
 - A manual launch requires a pilot to manually fly the aircraft for takeoff. Upon reaching a safe attitude the R/C transmitter can be switched to Autonomous mode and the flight computer will initiate normal waypoint navigation to wpt 0.
 - If manual launch is selected, the flight computer will not initiate the climb out sequence and the aircraft could crash if the R/C transmitter is switched to Autonomous mode prior to launch or too quickly after launch.
 - Select *Yes* for autonomous launch, *No* for manual launch.
 - A *Connect Now* message box (Figure 28) will pop up prompting for the aircraft to be turned on.
 - Turn the aircraft main switch to on.
 - Turn the ground station modem on.
 - Wait until the modem lights stop blinking.
 - Level the aircraft and hold it still for initialization.
 - Click OK.
-
- Figure 28. Connect now message box
- A *Startup* window will pop up with a checklist of the initialization sequence (Figure 29).
 - Red lights indicate that the task has not begun.
 - Yellow lights indicate that the task is being processed, and each turn of the dial represents an exchange of data between the aircraft and groundstation.
 - Green lights indicate that the function has been completed.
 - The *hold still* checklist item indicates that the aircraft's sensors are being zeroed and calibrated, and the aircraft must be still and level for this operation.
 - If the sensors are not calibrated properly, the aircraft may have difficulties during and autonomous launch and the camera aiming will be inaccurate for the entire flight.
 - Place or hold the aircraft on the ground with its wings and fuselage level and ensure that the plane remains still.
 - After all the lights are green
 - Check that the launch method is correct.
 - Check the *Max Altitude* window; this is the maximum altitude, above the ground station, that the aircraft sensors can measure.

- Be sure that the flight plan does not contain any altitudes above the max altitude.
- Check the *Distance from Home* window; this displays how far (in miles) the aircraft is from the flight-plan's home location.
- Assuming home is defined as where the aircraft is, the distance from home should be less than 0.05 miles.
- If the GPS unit acquires satellites before it reaches thermal equilibrium, it may have some position error. The error will be corrected as the circuitry warms up.
- If the distance from home is not reasonable, based on your location, wait a few minutes to see if it improves, or power down the aircraft and restart the initialization process.

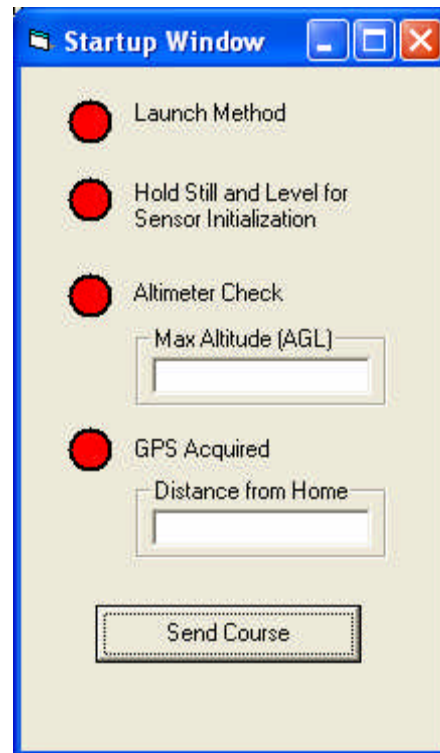


Figure 29. Startup window

Click on *Send Course*

- The Startup message box will close.
- A *Comm* message box will popup, Figure 30, showing the progress of the flight plan being uploaded.
 - Wait for the lights to turn green as the data for each waypoint is uploaded. The waypoints on the map turn green as well.
- The initialization is now complete and the aircraft is ready for launch.
- Prior to launching the plane perform a final check of the system:
 - Check that telemetry is being received.
 - Check that the battery voltage is sufficient for the flight.
 - Check that there is sufficient fuel for the flight.
 - Check that the GPS status is “Good”.
 - Check that the distance from home is appropriate, and that aircraft symbol is in the appropriate position on the map display.

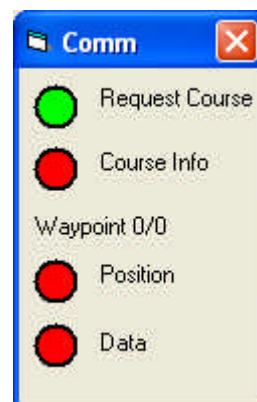


Figure 30. Comm message box

Re-tasking Aircraft

The aircraft may be re-tasked at any time during flight. Individual or multiple waypoints can be edited, the aircraft can be redirected to an out of sequence waypoint, or an entirely new flight plans can be opened. Essentially all of the tools available in creating a flight plan can be used to re-task the aircraft.

While the process of re-tasking the aircraft is quite simple, careful planning is essential to ensure the aircraft's safety. Consideration must be given to how the aircraft will transition to the new course, how much time will be added to the flight plan, and where the aircraft will be at the end of its flight plan. Ensure that a flight plan will always return the aircraft close to the home location at a reasonable altitude. Never assume that a return/landing sequence can be uploaded at a later time. The aircraft does not rely on communication with the Groundstation software to maintain flight or follow a flight plan. This allows the aircraft to continue flying if communication is lost or the ground station crashes, but re-tasking the aircraft may be impossible.

- A flight plan being edited on the Groundstation is not active until it has been sent up to the aircraft, and a confirmation is received from the aircraft that it has a viable flight plan.
 - While changes are being made on the Groundstation, the aircraft continues to fly its old flight plan.
 - Waypoints that have been edited change from green to red. Once the changes have been uploaded and confirmed by the aircraft, the waypoints will revert to green.
- To move individual points, simply drag them to a new location.
- The Waypoint Edit window can be used to change all of the waypoint's parameters and to add or remove waypoints.
- An entirely new flight plan can be opened: from the pull-down menu, select *File* and click *Load Flight Plan...*
- Loading a new flight plan will erase the old flight plan, but the flight data will not be altered.
- Once the flight plan has been edited or loaded into the groundstation, it needs to be uploaded to the aircraft. From the pull-down menu select *Aircraft Flight-Plan* and click *Upload Course to Aircraft*.
 - A Dialog box will pop up prompting for the waypoint at which to begin the new course, unless the plane is being flown manually.
 - Select the desired waypoint number and click OK.
 - A Comm message box will pop up showing the progress of the flight plan being uploaded.
 - Wait for the lights to turn green as the data for each waypoint is uploaded.
- Alternatively, the aircraft can be redirected to any waypoint without editing the course. From the pull-down menu, select *Aircraft Flight-Plan...Go to Waypoint* and click on the desired waypoint number.
 - The aircraft will create a course line directly from its current position to the desired waypoint using the selected waypoint's parameters.
 - The aircraft's altitude will change along a line from the current altitude to attain the altitude of the desired waypoint when it reaches the waypoint.
 - The aircraft will then continue the flight plan from the selected waypoint.

- If Home is selected, the aircraft will proceed to the home location at 30 mph and 500 ft altitude, and orbit at 500' feet until redirected. The altitude will change to 500 ft at the aircraft's fastest rate of climb or descent.

Reviewing the Aircraft's Course

The current flight plan that the aircraft is using can be sent from the aircraft to the groundstation. Reviewing the aircraft's course is useful when the ground station's course is accidentally edited or the user wishes to start fresh after lots of edits. If the groundstation computer hangs or crashes, downloading the aircraft's course will load the current flight plan back into the ground station, once restarted.

To review the aircraft's current flight plan:

- From the pull-down menu select *Groundstation Flight-Plan* and click *Download Course from Aircraft*.

Shut down Aircraft

Aircraft equipped with internal data logging must be shut down from the ground station to ensure that the data memory is not corrupted. Aircraft without data logging may be shut down with the aircraft main power switch at any time after landing.

To shut down the aircraft from the ground station:

- From the pull-down menu select *Aircraft* and click *Shut Down!*.
 - A Confirm Shutdown message box will pop up (Figure 31).
 - Review the Confirm Shutdown checklist.
 - When ready, click *Yes*.

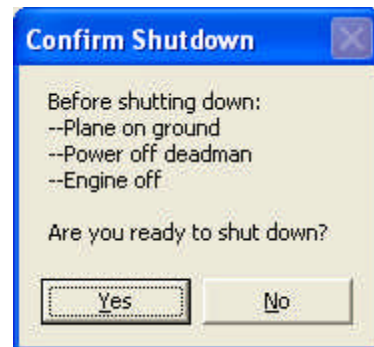


Figure 31. Confirm shutdown

- A text box (Figure 32) will pop up displaying the communication between the aircraft and ground station during the shutdown procedure.
 - When the C:> appears, click Done.

As a safety measure, the aircraft cannot be shut down while the airspeed is reading above 10 mph. If the airspeed measurement has drifted during flight, sucking on the airspeed probe may be necessary to lower the airspeed reading.

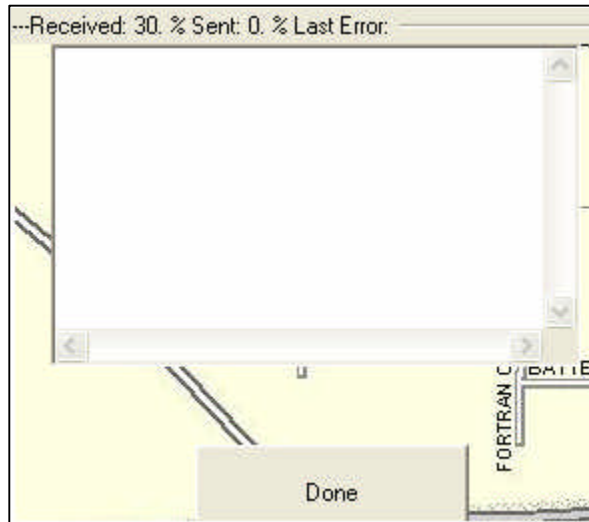


Figure 32. Shutdown text box

Saving and Loading Flight Data

The Flight Data displayed on the groundstation is held in memory. When the groundstation program is closed, this data is automatically saved to a text file named "lastflight.csv" in the directory where the ground station is installed.

- The data can be saved at any time while the program is running.
 - From the pull-down menu select *File* and click *Save> Save Flight Data*.
- The Flight Data can also be loaded back into the groundstation to review a flight.
 - From the pull-down menu select *File* and click *Open> Load Flight Data*.

Flight data format

The flight data is stored in a text file that most spreadsheet programs should recognize as a "comma separated variable" or "CSV" file. Each variable is in its own column, and each column is separated by a comma. The first line lists the names of the variable stored in each column. The variables are the same as those on the list of the plot drop-down box.

Flight Plan Format

The flight plans are simple text files. It is possible to edit them by hand, but not recommended as it is very easy to introduce errors. The following is a line-by-line description of the flight-plan-file:

<i>Line Number</i>	<i>Example</i>	<i>Description</i>
1.	0	0=Return-to-Home Enabled 1=Return-to-Home Disabled
2.	37.4257 -121.96105	Latitude/Longitude of home location (decimal degrees)
3.	4	How many waypoints follow.
4.	0.0 0.25 400 30	Waypoint 0 data: miles East of Home, miles North of Home, altitude in feet, speed in MPH
5.	-.25 .25 400 30	Waypoint 1 data
6.	-.25 0.0 400 30	Waypoint 2 data
7.	0.0 0.0 400 30	Waypoint 3 data
8.	0,0,0,-45,0	Waypoint 0 Modes: Flight Mode, Flight Mode Data, Camera Mode, Camera tilt, Camera pan (fly through, camera fixed at -45 tilt, 0 pan)
9.	3,150,2,-.25,0.25	Waypoint 1 Modes: Cross over 150 seconds, aim camera at waypoint.
10.	2,190,2,-.25, 0.0	Waypoint 2 Modes: Circle 190 Seconds, aim camera at waypoint
11.	1,0,1,-45,0	Waypoint 3 Modes: Drop, look down course line with camera tilt = -45 degrees.

Configuration file format

The configuration file (groundstation.cfg) is used by the program to store information when the code is not running. About the only modifications to it that should be necessary are updating the map database (deleting maps or changing the path to a map).

Line Number	Example	Description
1.	MLB V1.0	File Title
2.	1860,3135,12090,9660	Groundstation window size and location
3.	1	1=Show map, 0=Hide map
4.	235,109,142,60,190	Not Used
5.	2	How many maps in the database
6.	"nasa_ames.bmp",37.398,37.426,-122.059,-122.031	Map 1 data: Name, Min Lat, Max Lat Min Lon, Max Lon
7.	"firstst.jpg",37.409,37.438,-121.974,-121.946	Map 2 data

Notes:

- Usually the map names are the complete path (e.g., "c:\windows\desktop\MLB Groundstation\firstst.jpg")
- The lat/lon numbers have been truncated-- usually much more precision is necessary. These changes were made to the example to enhance readability.
- The first map in the map database list is displayed when the groundstation is started up. To bring your favorite map up by default, move its line to the top of the list.
- Always make a backup copy of groundstation.cfg when editing it, because if there is an error you could have to re-calibrate every map in the database.

Autonomous takeoff procedures

The most important aspect of an autonomous launch is to select “Yes” to “Autonomous Launch” from the “Launch Method” window during groundstation aircraft startup procedure. The operator also needs to set appropriate parameters for the first waypoint (wpt 0) so the aircraft can execute a smooth transition from launch to waypoint navigation.

- Wpt 0 should be a short distance from the launch location ($\frac{1}{4}$ to $\frac{3}{4}$ mile).
- Wpt 0's altitude should be at a reasonable height above the launch location (300 to 500 ft).
- The operator should know exactly where wpt 0 is relative to the launch location, so that proper navigation can be confirmed immediately after launch.

Autonomous landing procedures

An autonomous landing is the same as normal waypoint navigation except that the final waypoints define a slope and an approach direction for landing. A final approach waypoint is set so that the aircraft's landing direction will be from that point to the desired landing site. The aircraft is capable of flying an 8 degree glide slope (in still air conditions), so an appropriate altitude and distance from the approach waypoint to the landing point needs to be chosen. Consideration must be given for wind conditions, landing field geometry, and approach path obstructions. Also, the final approach leg should be at least $\frac{1}{4}$ mile long, so that the aircraft has plenty of time to correct for transient errors incurred at the final turn and to establish itself on the proper flight path. Additional distance should be provided if the turn to final is greater than 45 degree of heading change.

For example, a final approach waypoint altitude of 400 ft would require an approach distance of 2846 ft or just over $\frac{1}{2}$ mile (i.e. $400' / \tan(8 \text{ deg}) = 2846'$. $2846' / (5280 \text{ ft/mile}) = 0.54 \text{ miles}$). However, if a 50' high power line crosses the approach path ~500 feet from the desired touchdown point, this would be a risky approach (i.e., $500' * \tan(8 \text{ deg}) = 70'$). If the aircraft flew the trajectory perfectly, the aircraft would have only a 20 ft safety margin to clear the power line.

To perform an autonomous landing:

- Set an appropriate final approach waypoint.
 - Maximum glide slope of 8 degrees
 - Minimum distance $\frac{1}{4}$ miles
 - Speed 30 mph
- Set a waypoint at the desired landing point.
 - Speed 30 mph
 - Altitude 1 foot below ground level
 - If the landing is not at the home location, be sure to accurately know the elevation difference of the two locations.
- Set an additional waypoint a short distance 100' beyond the desired landing point to ensure that the aircraft will continue to descend and land if it overshoots the landing waypoint.
 - Speed 30mph
 - Altitude well below ground level (50')

Voice Error Messages

The Groundstation monitors many of the parameters the aircraft transmits, and will give audible warnings if certain thresholds are reached. If these warnings do not seem appropriate for your particular operations, un-check the *Aircraft...Sound Warnings* menu.

Tutorial 1 (Creating a flight plan)

This tutorial can be completed without the aircraft or any additional equipment other than the laptop computer. It is a systematic example of how to create a flight plan that uses a broad range of the system functions. For more detail on the features introduced here refer to the previous sections.

1) Getting started

After booting up the laptop computer, start the MLB Groundstation station software by double-clicking on the Groundstation icon located on the desktop or on the taskbar.

2) Add a Map

- Open the directory C:\MLB Files\Maps\ and copy the file firstst.jpg. Paste it into the same directory and rename it firstst1.jpg.
- From the Groundstation's pull-down menu, select *Map* and click on *Add New Map...*
- From the list of maps in the "Open" window select *firstst1.jpg* and click open.
- Click OK in the dialog box.
- Left Click at the intersection of Disk Dr and Nordeck Pkwy (this is approximately in the center of the map).
- In the Latitude box, type 37 Degrees, and 25.360 minutes *N*.
- In the Longitude box, type 121 Degrees, and 57.619 minutes *W*.
- Be sure the to select the proper directions (*N & W*)
- Click OK.
- Click OK in the dialog box.
- Use the scroll bar on the right side of the map to show more of the map's upper section.
- Left Click at the intersection of the railway tracks and Los Esteros Rd.
- In the Latitude box, type 37 Degrees, and 25.864 minutes *N*.
- In the Longitude box, type 121 Degrees, and 57.721 minutes *W*.
- Be sure the to select the proper directions (*N & W*).
- Click OK

Alternately, you may use the lat/lon grid lines shown on the map to calibrate it. The lines are labeled along the top and left edges.

3) Create a Flight Plan

A flight plan consists of a series of waypoints that determine the aircraft's path. Each waypoint defines an airspeed, altitude, and camera setting.

If an error was made during the map calibration, it may not be apparent until a waypoint is added. If the map jumps significantly or disappears completely when the first waypoint is added, delete the map or recalibrate it.

To create the first waypoint:

- From the pull-down menu select *Groundstation Flight-Plan*, and click on *Add a waypoint*
- The home location and a waypoint will be placed on the map and the Edit Waypoint window will pop up, displaying the waypoint's parameters.
- If the Edit Waypoint window is accidentally closed, reopen it by right clicking the waypoint icon on the map.
- Progressing from the top down in the Edit Waypoint window:
 - The Waypoint box will show 0.
 - Skip past the Add/Delete Waypoint buttons.
 - In the Waypoint Action box, select *Fly Through* (default).
 - When the aircraft reaches this point, it will continue on to the next waypoint.
 - In the Camera Action box select *Fixed to Plane*, 0 Pan Deg, -45 Tilt Deg.
 - The camera will be locked to the aircraft looking straight ahead and down 45 degrees.
 - In the Altitude and Airspeed boxes, type 400, and 30.
 - The aircraft will reach waypoint 0 at 400 ft above the launch altitude with an airspeed of 30 mph.
 - Click OK to close the Waypoint Edit window.
 - Move Waypoint 0 to an interesting position.
 - In the map area left click the Waypoint 0 icon and drag it a short distance west of its location.

Now create a second waypoint that the aircraft will orbit for 5 minutes:

- From the pull-down menu, select *Groundstation Flight-Plan*, and click on *Add a waypoint*.
- In the Edit Waypoint window be sure that Waypoint 1 is selected; if not, click on Previous Waypoint or Next Waypoint to scroll through the waypoints.
- In the Waypoint Action box, select *Circle*.
- Notice that a circle has been drawn around Waypoint 1.
- Click in the Duration box and type 5 min.
- In the Camera Action box, select *Look at point*.
- In the bearing box, type 0; in the distance box, type 0.
- The Camera will look at Waypoint 1 while the aircraft flies towards the waypoint and while it orbits it.
- In the Altitude and Airspeed boxes, type 500 and 30, respectively.
- In the Latitude boxes, type 37 Degrees, 25.864 Minutes N.
- In the Longitude boxes, type 121 Degrees, 57.721 Minutes W.
- Click Refresh Map.
- Waypoint 1 with its circle will move to the railroad crossing at Los Esteros Rd. (if the map was calibrated properly).

Now create a third waypoint close to home:

- In the Waypoint box, be sure 1 is displayed
- Click on New Waypoint After.

- In the Waypoint box, click Previous Waypoint to move back to Waypoint 2.
- Leave all parameters at their defaults.
- Skip down to the Relative Position box.
- Use the Previous or Next buttons to scroll to “From Home to Wpt 2”.
- In the Compass Bearing box, type 90.
- In the Distance box, type 0.1.
- Click OK.

Save the Flight Plan:

On the main menu select *File*, and click on *Save > Save Flight Plan As...*

Flight Plan Synopsis:

After takeoff, the aircraft will climb to wpt 0 at 30 mph with its camera locked to the aircraft heading and looking 45 deg below the horizon.

After reaching wpt 0, the aircraft will continue flying at 30 mph and begin a slow climb to reach wpt 1 at 500 ft. The camera will look towards Waypoint 1.

Upon reaching wpt 1, the plane will begin its orbit for 5 minutes. The camera will automatically switch from looking along the course line to focusing on wpt 1.

After 5 minutes of orbiting, the aircraft will head to wpt 2 at 30 mph while slowly descending back to 400 ft. The camera will be locked to the aircraft heading and looking 45 degrees below the horizon.

After reaching wpt 2, the aircraft will head for wpt 0 and repeat the pattern.

Home is not a regular waypoint for a flight pattern.

Things to try:

Put waypoints on the map gridlines to check the map's calibration.

Delete the map when you're done, since it is already in the database under a different name.

OPERATING INSTRUCTIONS

This section provides a concise summary of everything that needs to be done to ensure successful flights. Anyone conducting flight operations with the Bat UAV should be very familiar with this section of the manual. If you are unsure of how to perform any of the procedures listed here, refer to the sections on **HARDWARE** and **SOFTWARE IN-DEPTH PROCEDURES**.

Advanced Preparation

Charge Batteries

Aircraft:

- 1) 14.4 volt Li-ion minimum 3 hours

Ground Station:

- | | |
|----------------------------|--------------------------|
| 1) Laptop | per manufacturers specs |
| 2) Video Deck | per manufacturers specs |
| 3) R/C transmitter | per manufacturers specs |
| 4) Ground station gel cell | 4-12 hour trickle charge |
| 5) Engine starter | 4-12 hour trickle charge |

Mix Fuel (enough for planned missions)

Check Video Deck

Ensure that the video deck contains a tape for recording, and cue the tape to an appropriate starting point.

Prepare Flight Plan

A flight plan can be created in the field; however, completing some or all of the work prior to departing for field operations will reduce the onsite workload where time is often short. If possible:

- 1) Load and calibrate appropriate maps.
- 2) Enter Latitude/Longitude coordinates of home location.
- 3) Enter waypoint locations.

Flight Operations

Prior to setting out the equipment, assess the location's feasibility for flight operations. The Bat requires a relatively level area of at least 100 m by 50 m. The 100 m orientation must be aligned with the wind, and cannot be obstructed by buildings, hills or trees that will interfere with the launch departure or landing approach. Additionally, no obstructions may block the line of sight from the aircraft to the ground station during flight operations. Once a location that is suitable for the current conditions has been selected, choose an appropriate place to set up. The ground station should be located at a safe distance from the landing area (at least 50 ft) with no vehicles or obstructions between the ground station and the takeoff/landing areas. The objective is to provide the operator with easy access to the takeoff/landing areas and clear visibility of the aircraft while maintaining a safe distance.

Flight operations start with the setup of the ground station and the airplane. A good practice that helps to ensure that nothing is omitted during the ground station and aircraft setup is to conduct each of these operations separately. Finish the aircraft setup prior to setting up the ground station, or visa versa, or have different people be responsible for each of these tasks. Once the preflight aircraft checks have been completed and the ground station is ready, the startup and launch sequence can be initiated.

1) Airplane Setup

- Attach the wings
 - o Hold the wing by its leading edge near the wing root (thumb on top and fingers underneath), and use the other hand to support the wing tip.
 - o Slide the wing partially onto the main spar.
 - o Attach the servo wire connectors for the flaps and ailerons ensuring that all wiring goes into the wing or fuselage.
 - o Check that the trailing edge alignment pin inserts into its hole in the wing root.
 - o Listen for the sound of the snap button locking into place and check with a finger to ensure that it is locked.
- Fuel the aircraft.
- Check airspeed probe. Ensure that it is properly mounted, and look through it to confirm that it is unobstructed.

Pre-flight Inspection

Once the aircraft has been fully assembled, perform a thorough inspection to confirm that nothing has been omitted.

- Check that the power switch is in the off position.
- Check that all 4 antennas are mounted securely and have no visible damage.
- Check that both wings are locked into place, and that they are not visibly damaged.
- Check that the aileron and flap surfaces move easily, and that the servos and linkages are OK.
- Check that the tail surfaces are not damaged.
- Check the elevator/rudders for movement, and that the servos and linkages are OK.
- Check that the engine, propeller, spinner, and muffler are all mounted securely.
- Check that the carburetor venturi is clean.
- Check that all fuel and vent lines are securely attached to their proper connections.
- Check that the throttle servo and linkage are OK.
- Check that the airspeed probe is CLEAR and securely mounted.
- Confirm that there is sufficient fuel for the flight. If the fuel tank was not filled to its overflow point, open the access hatch and visually inspect the fuel level.

Only after all of the checks are completed should the aircraft be turned on for the startup procedure.

2) Ground Station

- Open the Pelican™ case and remove the following items from their storage space: (Be sure none of the cables are pinched when lowering the shelf.)
 - o R/C transmitter

- Tracking antenna head with tripod
- Flat plate antenna
- Cables: serial, coaxial, data/power
- Open the laptop & video deck and initiate computer boot-up.
- Assemble the antenna and attach cables to the video receiver, power, and USB Port.
- Secure video cable to tripod.
- Place the modem outside the Pelican™ case (away from the video antenna) and attach the serial and power cables.
- Connect the modem serial data cable to the computer.
- Connect power cable to the video receiver.
- If using the live video display on the laptop, connect the USB video adapter to the video receiver and to the laptop.
- Start the ground station code on the laptop (click the *MLB Groundstation* icon on the taskbar).
- From the *File* menu select *Load Flight Plan* (assuming that a flight plan was written ahead of time), or create a new flight plan as explained in the SOFTWARE IN-DEPTH PROCEDURES.
- Review the flight plan and click *OK* when ready.
- From the pull down menu select *Aircraft* and click on *Startup*.
- Select appropriate launch method (autonomous or manual).
- Turn on the aircraft.
- Turn on the Modem/Receiver power switch at the ground station.
 - Wait for the modem to initialize (5-10 seconds).
- Ensure that the aircraft is level (as it sits on its landing gear).
- Click *OK* in “Connect Now” dialog box.
- Wait for the column of lights to turn green in “Startup Window”.
- Verify that the flight plan does not include any altitudes higher than the maximum allowable.
- Verify that the distance to home is no greater than 0.05 miles, or the appropriate distance if the aircraft is not at the home location.
- Click on “Send Course” button.

Video and Telemetry Check

- Check that the video receiver is set to proper channel.
- Turn on the video tape deck and check that the tape is cued.
- Check that video is being received. The tape deck should show a picture from the aircraft’s camera.
- Check that telemetry is being received. The laptop should ping at 1 Hz, the telemetry status wheel should rotate, and the aircraft’s state should update (compass heading, airspeed, altitude, etc).

3) Takeoff

If there is any doubt whether the engine is properly tuned, start the engine on the ground, adjust the needle valves, and stop the engine prior to mounting the aircraft on the catapult.

Catapult

- Mount the aircraft on the catapult tray.
 - A small amount of bungee tension helps during the mounting process.
 - Check that the aircraft's launching pins are BOTH properly locked to the catapult tray.
- Check the release pin is securely fastened in place.
- Tension the catapult bungee appropriately:
 - 100% fully loaded aircraft with no wind, or at high altitudes
 - 90% fully loaded aircraft with moderate wind
 - 80% lightly loaded aircraft with moderate wind
- Check that the tensioning cords are properly aligned on all its pulleys.

Engine Start

- Check that the Auto/Manual (gear) switch, on the R/C transmitter, is in the manual position (flipped away from the operator).
- Turn on the R/C transmitter.
- Set the throttle stick to idle (down) and the throttle trim to full (up).
- Start the engine with electric starter.
- Warm up engine. Run the engine at a high setting until it runs smoothly and then cycle the throttle until the engine runs smoothly at full throttle.
- Check the engine max RPM on the ground station display (should be 7,700 rpm or higher).

Launch

- Check wind direction, and do a final survey of the takeoff area.
- Perform a final status check at the groundstation.
 - Check for telemetry.
 - Check battery voltage is greater than 14.5 volts.
 - Check that airspeed is greater than 0.
 - Check that groundspeed is 0.
 - Check that the distance to home and location of the airplane icon on the map display are accurate.
 - Check aircraft status is Manual.
 - Check GPS status.
Do NOT fly if the GPS status is not "Good".
- Start recording video.
- Turn the video antenna tracking system power switch on.

Autonomous Launch

- Switch the R/C transmitter to autonomous mode.
- Wait for the engine to reach full RPM and confirm that it sounds good.
- Launch the aircraft and check that it executes a proper climb out.

Manual Launch

- Verify that R/C transmitter is in manual mode.
- Advance the throttle to full.
- Wait for the engine to reach full RPM and confirm that it sounds good.

- Launch and manually fly the aircraft.

Transition to Autonomous Flight

- Verify at the groundstation that all of the aircraft's systems are functioning.
- Once the aircraft is above 200 ft. and clear of all obstructions switch the R/C transmitter to autonomous mode.
- The aircraft can be returned to home by moving both the throttle stick and trim to the idle position.

4) Landing

Autonomous Landing

- Create and landing approach path into the wind.
- Set a designated landing waypoint at the desired touchdown point.
- Set an additional waypoint beyond and below the landing waypoint.

Manual Landing

- Allow the aircraft to fly autonomously to a point where the pilot can comfortably take control.
- Set the throttle stick to center and trim to full.
- Switch to manual control and land the plane.

5) Post-flight Operations

Ground station

- Execute aircraft shutdown.
- Stop video recording and switch off tape deck.
- Switch off the R/C transmitter and collapse the antenna (so it does not get damaged).
- Switch off power to the video antenna tracking system.
- Switch off Modem/Receiver power.
- If conducting further flight operations be sure to go through all of the procedures and checks starting with loading a flight plan.
- Shut down laptop.
- Detach cables and stow components in the Pelican™ case
- Ensure that cables are not pinched when the lid of the case is closed.

Aircraft

- Shut off flight computer.
- Perform a post-flight inspection of the aircraft to check for damage.
- If conducting further flight operations, be sure to go through all of the procedures and checks starting with the preflight inspection.
- Remove remaining fuel from aircraft.
- Remove wings.

SPECIFICATIONS

Uses	Short range surveillance and remote sensing
Powerplant	1.4 cubic inch (23cc) 2-stroke engine
Fuel	Gasoline & oil mixture 40:1
Wingspan	72 inches
Gross weight	19.0 lbs (maximum)
Payload	5.0 lbs
Speed	25 to 50 mph
Duration	6 hours
Altitude (maximum operating)	9000 feet
Range	6.0 mile radius (telemetry limited); 200 mile range (fuel limit)
Sensor	Color CCD video cameras with 53 & 17 deg FOV on 3 axis stabilized gimbaled mount; Optional infrared video, high resolution still camera, and special agricultural camera available
Data Link	900 MHz 2-way data comm (800 mw); 2.4 GHz video downlink (800 mw)
Launch	Autonomous car-top catapult launcher or hand launch
Recovery	Automatic return-to-base with manual recovery or autonomous GPS landing
Guidance	GPS waypoint navigation with autonomous launch and landing Aircraft navigates a specified flight path using GPS guidance. Altitude and airspeed are specified for each course leg.
Ground Station	PC laptop with moving-map and flight data displays is used to monitor the flight and store data. Video receiving and recording of color video from onboard camera.
Radio Control Uplink	72 Mhz R/C 8 channel PCM uplink for manual control increases ability to launch and land in confined areas.
Support equipment	Tracking antenna for 2.4GHz system, omni-directional antenna for 900MHz system, power supplies, engine starter, fuel container, and shipping cases all included in standard system.
Training and Support	Initial ground and flight training provided at MLB facilities as part of standard system. Additional support (flight operations, on-site flight training, and repair) area available.
Warranty	Warranty against manufacturer defects for 30 days after delivery.

CHECK LISTS

Advanced Preparation

Charge Batteries

- aircraft main
- laptop
- video deck
- ground station 12 volt pack
- R/C radio uplink transmitter
- electric starter

Set up Maps and Missions

- load map for area of operation
- ensure proper map calibration
- create and save flight plan
- ensure terrain and obstacle clearance
- limit climb and descent rates to ± 800 fpm
- limit speed to <50 mph IAS
- limit turns to <40 mph IAS
- limit mission duration to <5 hour
- limit mission radius <6 miles

Flight Operations

Survey Launch Area

- ensure takeoff and landing areas large enough and clear of obstructions
- 100 X 100 yard landing area, 350 yards to 50 ft obstacle
- check wind direction & speed for launch and landing
- ensure wind and gusts < 30 mph or don't fly

Aircraft Set-Up

- fuel aircraft
- attach wings
 - ensure servo wires are appropriately connected
 - check snap buttons are locked in place
- deployed modem antenna
- attach tracking beacon
- check airspeed probe for blockage

Catapult Set-up

- unfold catapult
- lock elevation
- ensure catapult securely mounted on roof racks
- ensure ropes & pulleys properly routed and clear
- lock release-pin

Ground Station Set-Up

- boot laptop
- set-up tracking antenna
 - check orientation is pointed to geographic North
 - attach data/power cable to antenna, power supply and laptop
 - attach coaxial cable to antenna and receiver
 - face antenna south and attach cable to tripod leg
- set-up modem
 - attach power cable to modem and power supply
 - attach data cable to modem and laptop
- set-up video receiver
 - check that the power cable is connected
 - check that the video cable is connected from receiver to video deck
- if viewing video on laptop set up USB video adapter
 - connect video adapter to video receiver
 - connect video adapter to laptop's USB port
- start ground station code
- load proper course into ground station
- turn on video deck
 - ensure video tape cued

Preflight Aircraft

- ensure aircraft fueled
- visually inspect fuel level from inside access hatch if necessary
- check fuel lines unobstructed & properly attached
- check engine and muffler secure
- check propeller for damage and securely mounted
- check control surfaces for solid feel and free movement
- check camera turret for solid feel and free movement
- check camera lens clear
- check all antennas properly installed/deployed
 - video
 - modem
 - radio
 - tracking beacon
- CHECK AIRSPEED PROBE CLEAR
- prime engine

Preflight Ground Station

- check appropriate course is loaded
- wpt0 should be in launch direction at $\frac{1}{4}$ - $\frac{3}{4}$ mile out
- check appropriate launch mode selected
- momentarily switch R/C transmitter to autonomous mode and check flight status
- “launch” for autonomous launch
- “wpt 0” for manual launch
- check GPS status
- check distance from home
- check battery level
- check fuel level

Pre-launch Checks

- check engine is warmed-up
- check data link status
- check GPS status
- check distance from home
- check airspeed/groundspeed
- start video recoding
- turn on antenna power switch

FLIGHT TRAINING

This is a set of checklist-style instructions to be used by a team of operators for flight training. The main difference between these instructions and the previous set of checklists is that the tasks are distinctly separated for the different operators, and some comments are added to provide sequencing among the operators.

These instructions are set up for three operators, but the last two categories can be combined into a single operator's tasks.

- 1) Ground station
- 2) Aircraft
- 3) Catapult

Ground Station Operator

Ground Station Set-Up & Operation

Unpack

- R/C transmitter
- Modem
- Antenna
- Cables

Boot laptop

Connect modem

Connect & align antenna

Connect video deck

Start MLB Groundstation software

Initialize antenna port

Open existing flight plan or create new flight plan

Wait for aircraft operator to complete preflight preparation

Have aircraft operator switch on aircraft

Switch on modem/receiver power

Initialize aircraft

Switch on video deck

Give go ahead for R/C operator to test controls mount & start aircraft

Wait for catapult operator to start aircraft

Do final check that all systems are OK

Switch on video antenna automatic tracking system power

Start video recording

Give go ahead to launch aircraft

Closely monitor aircraft data on climb-out

Monitor aircraft & video during flight

Prior to commencing landing approach

Check that autopilot is unlocked

Check that R/C operator is ready

Closely monitor aircraft on descent to landing approach & on final approach

Aircraft & R/C Operator

Aircraft Set-Up

- Attach wings
- Fuel aircraft
- Deploy modem antenna
- Attach tracking beacon

Aircraft Preflight

- Check fuel line securely attached
- Check carburetor clean
- Check engine and muffler securely mounted
- Check rudder/elevator controls
- Check wings locked & aileron controls
- Check all antennas secure (4)
- Check camera and lens
- Check airspeed probe for blockage
- Check landing gear
- Prime engine
- Inform ground station operator that the aircraft is ready

Wait for ground station operator to prepare flight plan

- Turn aircraft on when requested by ground station operator

Wait for ground station operator to finish initializing aircraft

- When cleared by ground station operator
- Turn on R/C transmitter and test for proper control surface movements
- Give go-ahead for catapult operator to mount aircraft

Start & Launch Aircraft

- Check takeoff and landing areas large enough and clear of obstructions
- Check wind direction & speed for launch and landing
- Ensure wind and gusts < 30 mph or don't fly

Wait for catapult operator to mount aircraft, load catapult & and get ready to start engine

- Set throttle for starting ($\frac{1}{4}$)

Catapult operator applies starter

- Allow engine to warm up and perform full rpm Check

Wait for ground station operator to do final check of all system

- When cleared by ground station operator, clear catapult operator to unlock pin
- Switch to autonomous mode and advance throttle to full
- When engine is at full rpm and ready, clear catapult operator to launch
- Monitor aircraft on takeoff and climb out; be prepared to take manual control
- Turn off R/C transmitter

Landing and Post Flight

Check that transmitter is in autonomous mode & throttle is full

Turn on R/C transmitter and remind ground station operator to unlock autopilot

After landing, cut engine

Set throttle and trim to low, switch to manual

Catapult Operator

Catapult Set-up

- Remove cover
- Unfold rail
- Remove support block
- Lock elevation
- Check catapult securely mounted on roof racks
- Check condition of rope and routing on pulleys
- Check condition of bungee
- Check condition/function of sled & tray
- Check release-pin properly placed and locked
- Assemble starting equipment
- Check wind direction & speed for launch
- Set catapult into wind
- Check that takeoff area is large enough and clear of obstructions

Load Aircraft

Wait for R/C operator to finish ground-testing controls

- When cleared by R/C operator, mount aircraft on catapult
- Check aircraft pins properly engaged in tray
- Tension bungee
- Re-check that ropes are properly routed on pulleys
- Inform R/C operator that the aircraft is ready to start

Start & Launch Aircraft

R/C operator

Set throttle for starting ($\frac{1}{4}$)

When cleared by R/C operator, apply electric starter

- Press starter firmly against nose cone, squeeze contact switch

R/C operator

Warm up engine and perform full rpm check

Wait for ground station operator to do final check of all system

When cleared by ground station operator, clear catapult operator to unlock pin

When cleared by R/C operator, unlock release pin (DO NOT RELEASE PIN)

R/C operator

Switch to autonomous mode and advance throttle to full

Clear catapult operator to launch

When cleared by R/C operator release launch pin

Post launch

- Reset or repack catapult

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