

Operation Manual

Team Six: Autonomous Unmanned Aerial Vehicle

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Initial Setup

The overall project consists of many individual systems unified onto a projectile, and then launched into the air. Because of the inherent dangers of projectile flight, several precautions must be observed prior to a test flight.

Remote Control (RC) Transmitter/Receiver

The system uses a Futaba T6J 6-channel transmitter to control the aircraft. It is strongly recommended that all members involved in the flight of the aircraft, read and *understand* the transmitter's manual. The transmitter must be configured to the aircraft that it will be controlling. Do not assume that the person who used the transmitter last has left the controller in a valid state. There are various settings for different types of engines (electric, nitro), different aircraft frames (fixed-wing, v-tail), including different aerial platforms all together (plane, heli). If these are misconfigured, there is a high chance for failure.

Read through the transmitter manual, and configure the controller with the appropriate settings for the aircraft, and the person who will be piloting the aircraft. Because these settings vary from pilot to pilot, the only settings which will be listed are the settings which apply to the Telemaster (regardless of pilot) with an electric motor.

Set or confirm the settings (see transmitter instruction manual for reference) for:

1. Flight parameters (PARA)
 - a. TYPE = ACRO
 - b. MODE = S-FH
 - c. TCUT = ESC
 - d. BF/S = ON
2. Dual rate switches (D/R)
 - a. Set according to pilot
3. Servo trim
 - a. Verify correct according to aircraft frame
 - b. See page 35 for different servo trim settings if they need to be changed
4. Flaperon (FLPR)
 - a. ON

This is not an inclusive list. Reference the controller manual for the rest of the settings, along with how they affect the flight of the aircraft.

Autopilot Software

The ArduPilot Mega 2.5 (APM) is supported by the Mission Planner tool which is available on the hardware's support page at www.ardupilot.com. Mission Planner must be installed in order to program the APM. It is strongly suggested that a laptop computer be brought to all flights, with Mission Planner installed and [preferably] with maps pre-fetched (unless there is internet access at the site). Go to the

Commented [RJ1]: Greg, do you want to add the specific measurements we set the throws to? i.e. 25mm, 30mm, etc..?

site mentioned above, download and installed the software, then connect the APM to verify that the hardware is operational, and there are no communication issues.

It is strongly suggested that the initial configuration wizard be run in order to appropriately calibrate the APM for flight. This involves choosing the correct firmware, calibrating the compass, accelerometers, and remote controller. The calibration should not have to be run after every firmware load, however be sure that the calibration is valid *after* reloading the APM firmware (i.e. switching from hardware-in-loop tests to actual flight).

The specific requirements for calibrating the APM are found both, in the software and on the support pages (online) for the APM.

Pre-Flight

Before starting your mission, there are essential tasks that must be completed to guarantee a safe and successful flight. Those tasks include both mechanical aspects and electrical/computer aspects.

Mechanical Components

Before flying the Senior Telemaster plus it is first imperative to check that all of the mechanical components of the plane are functioning correctly. This ensures that there will not be any in-flight surprises that could result in a crash. Before anything can be checked, the wings of the plane, the batteries, the autopilot, the GPS, and the telemetry must first be installed. The positions for all components besides the wings have Velcro, so installation just involves attaching the Velcro on the back of each component with the Velcro on the plane. The wings are fairly straightforward; first insert the left wing and run the servo cables through the fuselage to connect to the receiver, and then insert the right wing onto the structure of the left wing, again running the servo cables through the center of the fuselage. Once the wings are installed and the servo cables are connected in their appropriate location (see Electrical Component section), the first thing to check is that all of the servo motors that control the elevators, ailerons, rudder, airdrop, and flaps are functioning correctly. This process involves using the remote control to manually move each component while on the ground. In the event that a motor is not functioning properly, the operator should first check to verify that the servo cable is properly connected to the transmitter inside the plane. If it is plugged in correctly and still not functioning, the servo motor should then be tested by itself. This can be done by moving the servo cable to a location on the transmitter that is verified to work. If after this the servo still does not work, it is time to replace it with a functional servo. Assuming that all of the servos work and that the plane controls are functioning correctly, the next step is to check that the “throw” values are set correctly. The throw values refer to how far each control (ailerons, rudder, elevator) moves under maximum extension. The specific throws for the Senior Telemaster Plus are as follows:

- Ailerons – 25mm up, 20mm down
- Elevator - 20mm up and down
- Rudder – 35mm left and right.

These can be adjusted via the “control throw” settings on the remote control. The remote control manual should be referenced for further detailed instruction.

Following checking the servos, the center of gravity of the plane must be checked to ensure that the plane will fly level. To do this, there are two spots marked on the body of the plane, almost directly underneath the middle of the wings. Once the spots are located two members of the team should lift the plane from exactly those points. If the plane stays horizontal (or tilts forward slightly) the center of gravity is correct. If the plane tilts extremely forwards or backwards, the weight distribution of the plane must be changed, and this is best accomplished by moving the batteries fore or aft in their Velcro until the plane stays horizontal.

Once the above checks are complete it is time to load the airdrop. This can be done by opening the airdrop doors via the servo motors, and then slowly closing them while holding the air drop device in a location that will allow the closing doors to pick it up. The camera can then be installed and turned on at this point.

Electrical Components

Batteries

Lithium Polymer Battery (LiPo)

The first electrical component you need ready are the batteries. The main batteries used for powering the motor are a pair of **Venom 50C 6S 5Ah 22.2V Li-Po batteries** and the auxiliary batteries used for powering the rest of the electronics are NiMH batteries. While charging the NiMH batteries is quite simple and straight forward, charging the Li-Po batteries requires more attention. Li-Po batteries **MUST** be charged using a balance charger, such as the **V6AC Balance Charger**. This programmable charger is very easy to use right out of the box. The instructions for charging a Li-Po are as follows:

1. **Power on the charger** - It has a broken internal AC inverter, therefore it must be powered on by an external DC source. Make sure the DC source meets the performance requirements laid out in the charger's operating manual (input voltage: 11-18V, current draw 0.1-5.0A).
2. **Set the proper parameters in the charger** - LiPo Balance Charging mode, 22.2V(6S), and max charging current of 1C = 5A. Keep in mind that setting the output current too high relative to the DC source's input current will stop the charging sequence.
3. **Connect the battery with the charger** – Connect the main (+) and (-) leads of the battery to the corresponding output ports of the charger and connect the **6-pin** balancing lead to the balancing port of the charger. Note that LiPo batteries with different series cell configuration (such as 4S or 3S) require a balance port adapter.
4. **Start charging** – During the charging process the charger will display various parameters in real time: Battery type, charging mode, current output, voltage reading, time taken, time remaining, etc.
 - a. In the event of an error the charger also beeps and displays an error message. Detailed troubleshooting instructions can be found in the charger operating manual.
5. **Remove all connections and power off the charger once charging has finished**

Nickel-Metal Hydride Battery (NiMH)

The NiMH batteries are recommended to be charged using the **Prophet Sport** charger. The procedure is simple:

1. **Power on the charger** – Simply plug in the power cable to an outlet.
2. **Plug in the battery** – NiMH batteries do not have a balancing cable but simply the main (+) and (-) leads
3. **Start charging** – Press the red start button!
4. **Remove all connections and power off the charger once charging has finished**

Setting up and mounting the Electronics

Proper setup and placement of all electronic components is extremely crucial. Failure to do so can result in unbalanced weight distribution, component failures and even personal injuries. The instructions are as follows:

1. **Setup the autopilot module** – Some of the autopilot setup procedures such as the ones requiring wired USB connection are recommended to be performed before mounting any of the components. The placement of all components have been strategically planned for proper weight distribution and smooth operation and therefore does not accommodate for external wiring or accessing the autopilot directly.
2. **Connect all servo extension cables** – As the servos are placed in various places on the plane, proper extension cables must be installed in order to reach the autopilot(autonomous flight) or the receiver(manual flight) in the component bay in the front. As these cables run across the whole length of the plane, make sure they do not interfere with the placement of other components. *Always double check all cable labels as it is easy to mix them up.*
 - List of all servos: left & right aileron, left & right flap, elevator, rudder, and pair of airdrop servos.
3. **Mount the Li-Po batteries** – It is recommended that the batteries are mounted before any of the other components but after the extension cables due to its large weight and size. Make sure the Velcro strips on the batteries line up with the corresponding Velcro strips on the fuselage and ensure firm contact.
4. **Mount the camera and video transmitter** - asdf
5. **Connect all servos and external modules to the autopilot** – ALL electrical
6. **Mount the rest of the components** – asdf

Autopilot

Firmware

The ArduPilot Mega 2.5 (APM) is capable of piloting multi-copters, fixed-wing aircraft, and land vehicles, all in real life or in simulators. Because of the wide range of applications, the APM must have the appropriate firmware installed prior to mission planning.

1. **Insure that Mission Planner is installed and that the APM is calibrated (see Autopilot Software).**
2. **Connect the APM unit to the computer with Mission Planner installed via a micro-USB cable.**
3. **Click on “Connect” at the top right of the frame in Mission Planner.**



Figure 1 – Connecting the APM to Mission Planner

- a. The APM module should be communicating with the software now. If not, see the supporting webpages for troubleshooting. The most likely candidates for error are an incorrect baud rate, or an incorrect serial port.

4. **Click on the “Initial Setup” tab, and then select “Install Firmware”**



5. **Install the firmware** – the tool suite includes different firmware for different purposes. Be sure to install the correct firmware which is appropriate for the actions that you will be performing.
 - a. The most common choices will be the Aircraft firmware, or the Hardware-in-Loop (HIL) simulator firmware.

Hardware

Ensure that the following supporting hardware are all mounted properly, and connected to the autopilot. See the following pictures for a visual reference. Images taken from the APM support website (Instructions → First Time Setup → Assembly).

1. **GPS Unit**
2. **Telemetry**
3. **All input/output servo connections**
4. **Any other supporting hardware not covered in this manual**
 - a. This could include airspeed sensors, barometers, an external compass and more.

CONNECT TO CORRESPONDING CHANNELS OF RC RECEIVER

- ROLL / AILERON 1
- PITCH / ELEVATOR 2
- THROTTLE 3
- YAW / RUDDER 4
- AUX 1 (OPTIONAL) 5
- AUX 2 (OPTIONAL) 6
- AUX 3 (OPTIONAL) 7
- *AUX 4 (MODE SWITCH) 8

*CONNECT CH 8 (MODE SWITCH) TO ANY AVAILABLE CHANNEL ON RC RECEIVER

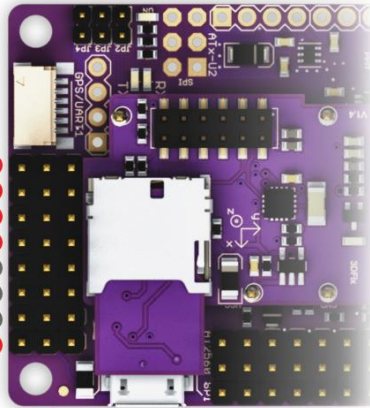


Figure 2 - Servo connections for the APM

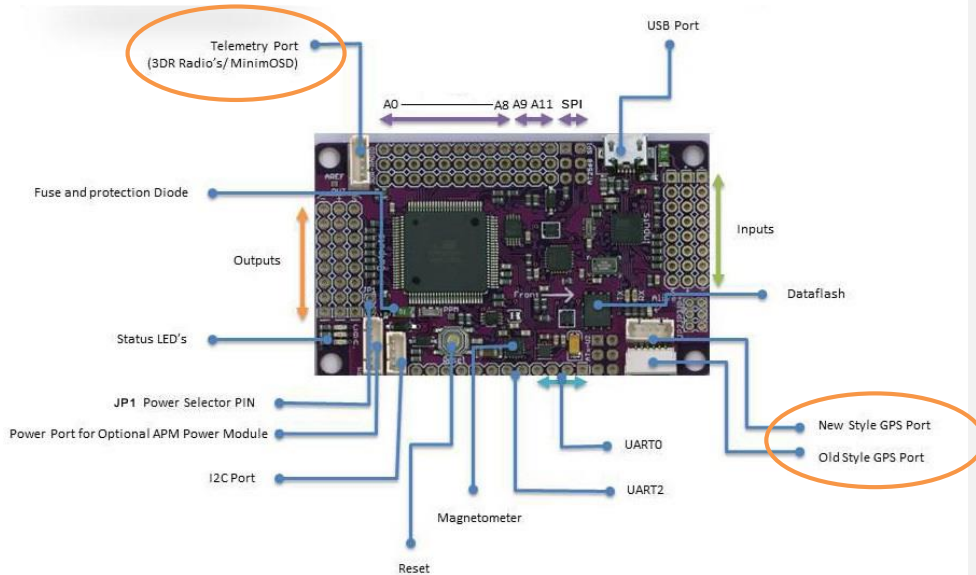


Figure 3 - GPS and telemetry ports for the APM

Mission Planning

The Mission Planner tool suite is capable of a wide range of flight operations. It is capable of creating new custom flight operations which can be deployed for the APM for versatility not included with the standard ArduPilot operations. Because of the vast complexity of the tool, the scope of this manual will only cover trivial mission planning which includes following a set of waypoints, then returning to the

launch. For further information about more complex operations, see the support pages for the Mission Planner tool suite at www.dev.ardupilot.com.

1. **Start Mission Planner** – ensure that the APM module is nearby. To upload new waypoints to the APM unit, you must either connect the APM to the computer with Mission Planner installed, or connect the receiver for the 3DR telemetry device to the computer with Mission Planner installed. For the latter, you will also have to supply external power for the APM unit.
2. **Connect to the ArduPilot Mega** – with the APM setup in one of the configurations in the previous step, click the “Connect” button on the top right hand corner of the Mission Planner tool.
3. **Navigate to the Flight Plan tab** – the flight plan tab is where the user will program all of the waypoints for the APM. Upon rendering the tab, the screen should look similar to the following figure.

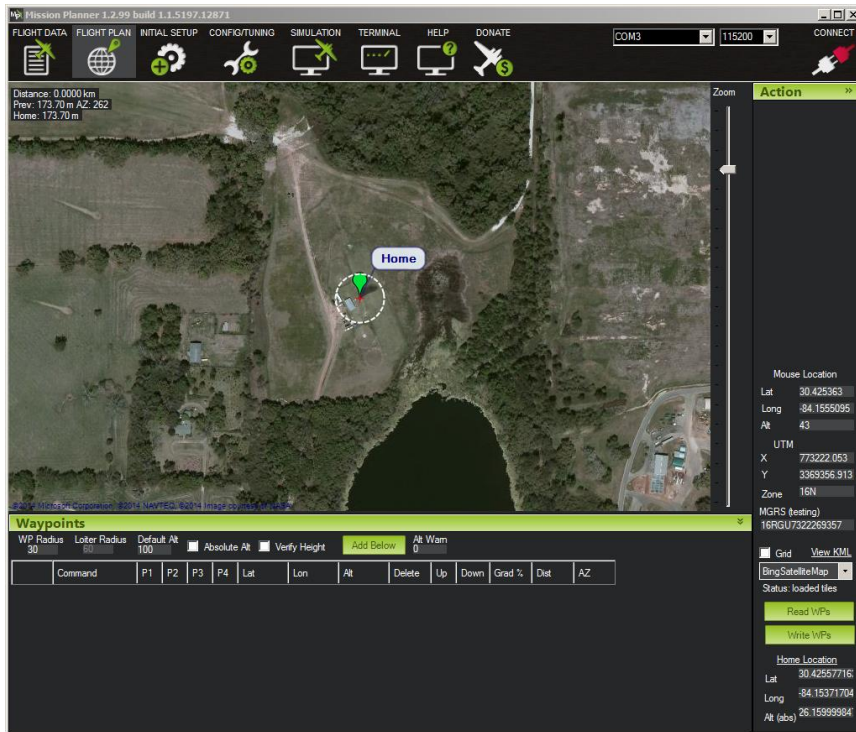


Figure 4 - Mission Planner - Flight Plan user interface

4. **Create your mission** – on the map, navigate to the point where your aircraft will launch from. Right click on the map to plot the first waypoint. A new flag will appear, and a new row will be added at the bottom of the screen corresponding to the new waypoint.

- a. As previously mentioned, the tool allows users to program the aircraft to perform special functions. Clicking on the dropdown tab for the corresponding waypoint will open a series of preprogrammed operations. See the supporting web page for further explanation for each function.
- b. An example mission will look like the following figure when complete.

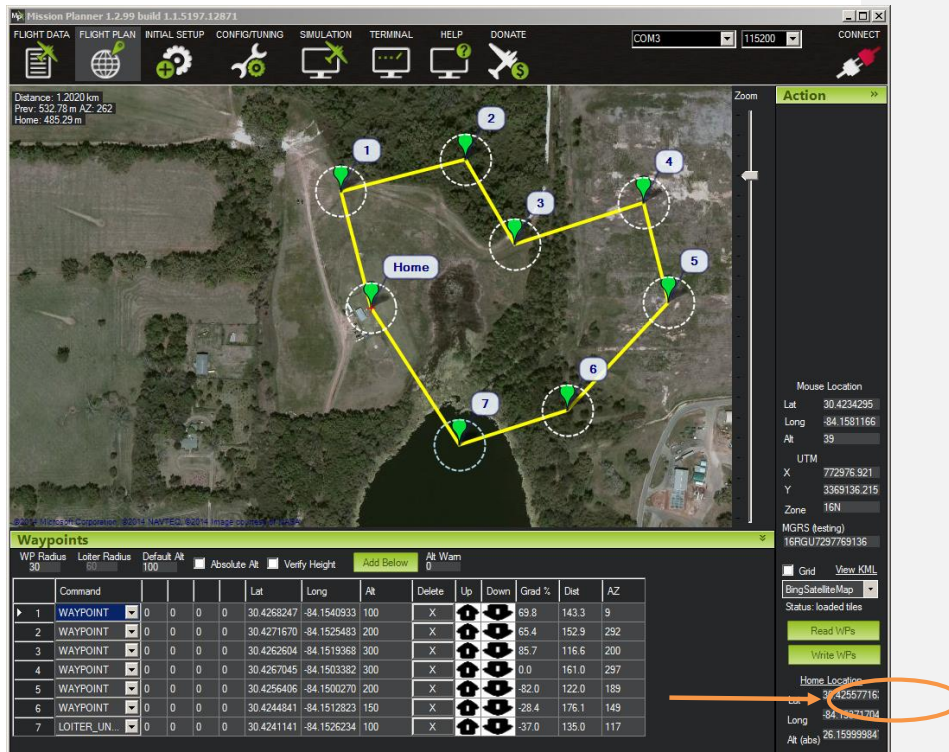


Figure 5 - An example mission programmed in Mission Planner

5. **Write waypoints to the APM** – click on the button in the bottom right corner of the Flight Plan tab (see previous figure for reference). This will send your flight plan to the connect APM unit. It is a good idea to then delete the waypoints in the tab, then click on Read WPs to verify that the flight plan was saved in the APM successfully. After you are satisfied with your mission, disconnect the unit from Mission Planner by clicking “Disconnect” in the top right of the screen.

Flight

In flight operation varies rapidly depending on whether or not the plane is to be flown in Autonomous mode, manual mode, or a combination of the two. The ArduPilot Mega 2.5 (APM) is capable of various

different modes of flight. Currently, the APM is programmed with two modes controlled by the ch. 5 switch on the remote control. In the down position, the aircraft is in manual mode; in the up position, the aircraft will be set to autonomous mode (Auto).

IMPORTANT – Ensure that the transmitter is in “Manual” (ch. 5 switch is down) when applying power to the system. If the switch is set to Auto, the aircraft will attempt to find its first waypoint. This means that the aircraft will apply power to the throttle unexpectedly and can harm/damage anything which is in the way of the propellers.

Manual

In the manual flight mode the plane is entirely controlled by the remote control. An experienced R/C pilot should be at the control if this mode is to be used. The pilot should fly a stable, sweeping flight path over the entire search area, paying attention to the time of flight. The flight time should be above 20 minutes but no more than 40 minutes. While the pilot is flying the search pattern, an operator should be on the computer watching the camera feed for targets. When a target is located, the GPS coordinate of the target, as well as the alpha numeric, orientation of the target, color, and shape of the target should be recorded. After the target area has been searched and all targets have been recorded, the next task to complete would be the air-drop. The air-drop target coordinates should be known, so the pilot must fly to the target coordinates after coordinating with the computer operator. The elevation of the plane and the horizontal velocity should be input into the appropriate Matlab code to determine when the drop must take place so that the target will be hit. Following this task, the pilot should bring the plane in for landing.

Autonomous

When the pilot is ready, he/she can switch the aircraft into Auto. The aircraft will then begin to move towards its first waypoint regardless of its current position (including on the ground!). When Auto is engaged, the pilot will lose control of the throttle and elevators (pitch), however the APM will engage a setting called Stick Mixing. This allows the pilot to make small corrections to the roll.

The flight plan will be created such that the pilot should never have to touch the controls once the aircraft has left the ground. The APM will take the aircraft to the preprogrammed waypoints, capturing video along the way. Using the connected 3DR telemetry radio, the user on the ground station can remotely tell the APM to fly to a specific destination.

Post-Flight

Once flight is complete it is time to shut down everything and prepare for storage. The first step of this process is to disconnect all of the electrical connections- starting with the power to the propeller. The propeller spins at very high speed, and it is very important that it be unplugged before any other work is done on the plane to avoid bodily injury. After all of the electrical connections have been unplugged, the GPS and telemetry devices must be removed and properly stored so that they are no lost or damaged in transport. The wings should then be removed, starting with the right side, then followed by

the left side. When the wings are stored and transported they should not be placed with weight on the servo motors. Care must be taken so that the servos will not be damaged during transport.

The charge of the batteries should be checked at this point. With Lithium-Polymer batteries it is very important that they are not stored fully depleted.

Image Analysis

There several options to autonomously detect the geometric shapes and alphanumeric digits that are required for this project. One choice is using MATLAB's built-in Image Processing Toolbox. This option would scan the image for any pattern that resembled a geometric shape or alphanumeric digit. The pattern is compared against a library that needs to be created and filled with examples of the before mentioned shapes or digits. The drawback to using this option is if the image does not display the shape or digit exactly as you have it loaded in the library, it will not recognize it.

Another choice to consider is a neural network. This can be created using MATLAB's Neural Networking Toolbox. The benefit of this method is it will cover the scaling and rotation problem that arises from other methods. The drawback to this option is the amount of time to create the network could be very long. Additionally, the program may take an obscene amount of time to "learn" the shapes and digits that you are trying to recognize.

There are also several open source programs that are available that will handle the image processing portion of this project. Examples of these programs are TINA (<http://www.tina-vision.net/>) and OpenCV (<http://opencv.org/>).