Kestrel Autopilot System

Autonomous Autopilot and Ground Control
for Small Unmanned Aerial Vehicles

UAV Flight Guide

Version 1.8

10/27/08

PROCERUS
TECHNOLOGIES

Introduction

The Unicorn platform is and inexpensive and durable air vehicle for UAV research and development. Coupled with the Kestrel Autopilot and Virtual Cockpit, it has proven to be a reliable test platform as well as an effective end user training tool.

While not intended for novice users, this guide is designed to provide step-by-step instruction for UAV and ground operations specific to the delta wing platform, the Kestrel Autopilot, and Virtual Cockpit ground control software when delivered by Procerus as a ready-to-fly UAV system. It assumes a certain level of experience and familiarity with terms and does not replace a working knowledge of the Kestrel Users Guide. It also assumes the air vehicle and associated components are flight worthy. When purchased from Procerus, Unicorn specific default values are set (ex: take off speed) and should not be changed until you become familiar with the system overall.

Equipment Checklist

- Laptop (battery charged)
- Virtual Cockpit ground control software properly installed
- Game pad controller

- Aircraft (with all onboard equipment in place and functioning properly)
- UAV Lithium polymer Batteries (charged)

- Commbox with antenna (charged) with power cord (optional)
- Serial cable (optional USB adapter if needed)

- Video Equipment (battery charged), cables, tripod antenna / receiver.
  (DV deck, video capture card, or TV as desired for video viewing & recording)

- Repair kit / tools (props, tape, etc.)

- Pre-flight checklist

- RC transmitter (primarily used for tuning and safety purposes)
  RC experience required.
- RC trainer cable (transmitter to Commbox connection)

** Laptop, mini DV deck, RC transmitter not supplied. Video receiver / antenna optional.*

Virtual Cockpit Main Window

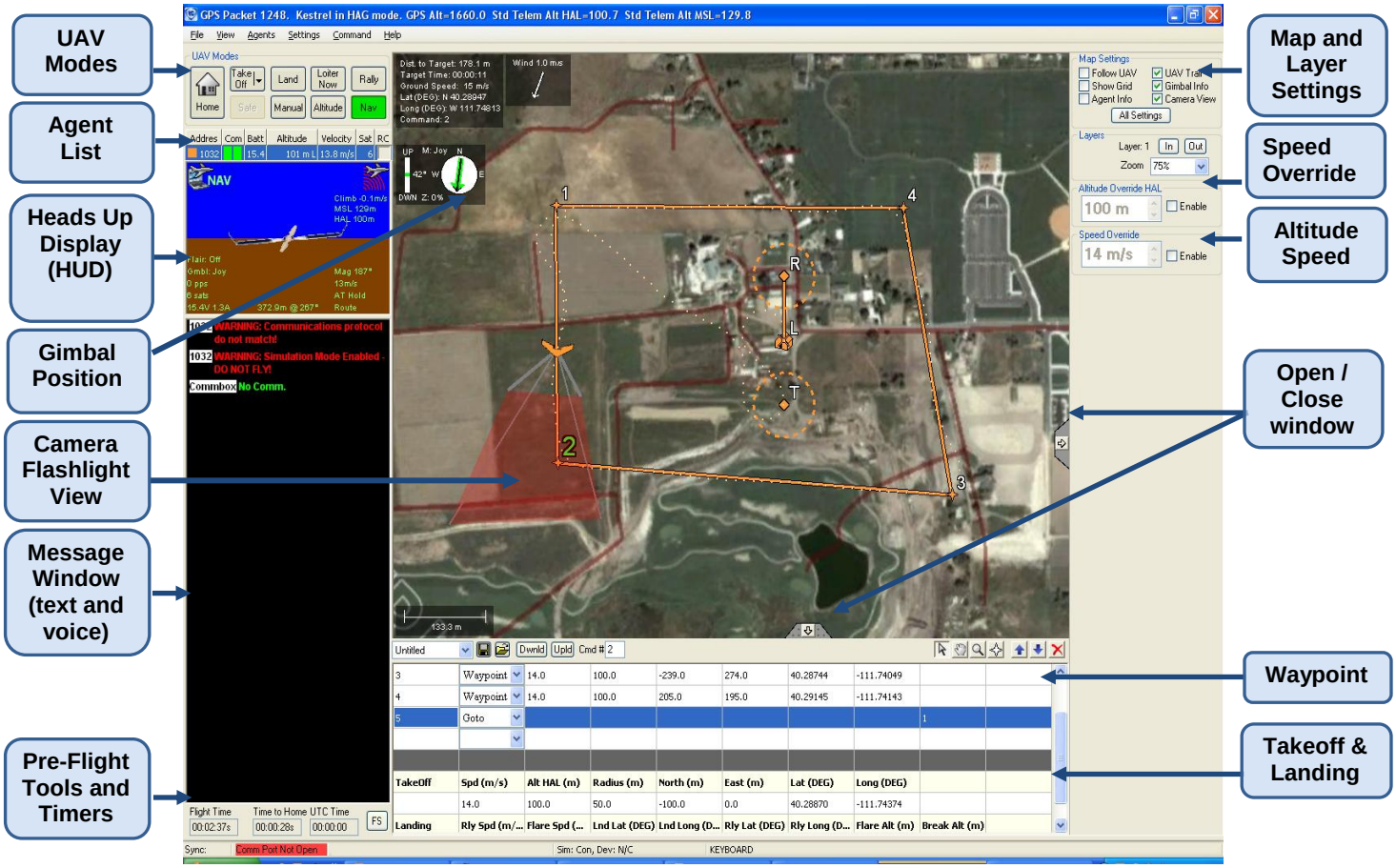

Figure 1 Virtual Cockpit Main Screen

When preparing the Virtual Cockpit (VC) and UAV for flight, your screen should look much like the VC main window above which shows the necessary settings and conditions prior to launch.

This guide discusses:

- Before You Fly
  - System Setup
  - System Check

- Flight Plan and use of Virtual Cockpit
  - VC Modes (Home, Take offs, Land, Loiter, Rally, Manual, Altitude, Nav)
  - Agent List (Address, Comm, Batt, Alt, Vel, Sat, RC checkbox)
  - Heads Up Display (flight info, current mode = Manual, comm strong)
  - Message Window (Commbox)
  - Pre-flight buttons (Zero pressure, Check sensors, verify Failsafes)
  - Map area (Flight plan, Rally and Landing points uploaded)
  - Flight plan setup (4 Waypoints, Take off point and Rally and Land points)
  - Launch and Recovery

Pre-flight Check

Prior to each flight it is important to conduct a pre-flight of the UAV and ground control station. A printed copy of the Kestrel pre-flight checklist should have been included with the Kestrel Autopilot system. An electronic copy of the checklist is also available online at http://www.procerusuav.com/developer.php. This guide will explain the steps of the pre-flight checklist in detail.

GROUND STATION PRE-FLIGHT

1. Hardware setup

1. Boot up laptop
2. Attach antenna to Commbox
3. Verify that the video receiver antenna is pointer toward the mission area
4. Attach serial cable to laptop and Commbox
5. Attach optional GPS receiver to the Commbox
6. Attach USB gamepad to laptop

The Commbox connects to the laptop using a standard RS232 serial cable. An "RS232 to USB" adapter may be necessary if your laptop does not support RS232 connections.

2. Power on the Commbox

Power up the Commbox and verify that the wireless modem is functioning correctly. An LED strobe will occur (a sequential flash of the LEDs).

3. Launch the Virtual Cockpit (VC)

Running the VC for the first time will automatically add agent 1032 by default (you can enter name/color). You may change this in the VC on the Agents pull down menu. ("Agents → Edit Agent List") In order to communicate with an agent, the agent address in the VC must match the agent address stored on the autopilot. To change autopilot address, see Users Guide Chapter 7.

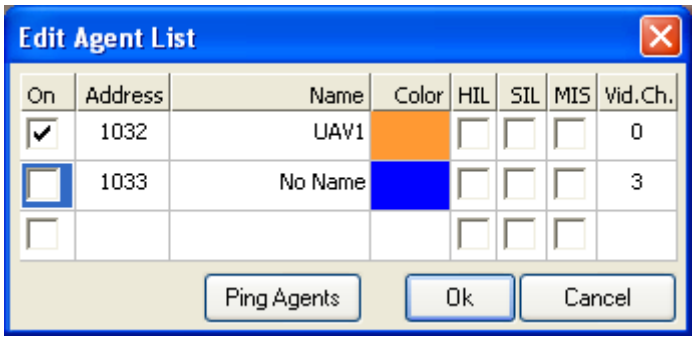

Figure 2 Edit agent list

4. Open Serial Port

The Virtual Cockpit will automatically open the last serial port used by default. If not correct, select the right port from "Settings → Comm and Registry". (or F7). The serial port will open automatically upon selection.

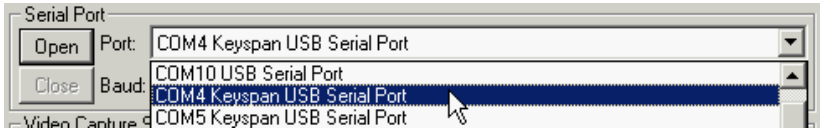

Figure 3 Serial port selection

5. Check Commbox Voltage

Commbox voltage is displayed in the Message Window, which should be a minimum 10V prior to flight, (if not, plug in external power). If voltage drops below 9V land the airplane immediately.

Table 1 - Commbox v1.1 LEDs

LED Label	Description
VC	Virtual Cockpit communication
RC	RC transmitter communication
MODEM	Autopilot communication
BATTERY	Battery Status
POWER	On/Off state

Figure 4 Commbox status in VC message window

Table 2 Commbox Battery LED color code

Battery LED Condition	Battery Status
Solid Green	Charged
Amber	Charging
Blink Green & Red	Low Voltage
Fast Blink Red	Critical Voltage

Note: Communication is improved by elevating the Commbox antenna up off the ground, (4-5 feet or higher).

AIRCRAFT PRE-FLIGHT

6. Disconnect the Motor

For safety purposes, turn the motor on/off switch to OFF.

7. Check UAV External Structure

Ensure that all control surfaces can move freely. Check the airframe to make sure that nothing is loose or broken.

8. Check Propeller Assembly

Check props and hubs for damage or fatigue. Ensure that prop is tightly fastened to the motor shaft. Damaged or loose props can cause excessive vibration and even break apart, which can damage the aircraft and harm operators.

9. Check UAV Center of Gravity

Ensure the aircraft is properly balanced. Hold the aircraft up using a fingertip at the center of gravity (CG) location on each wing, checking to ensure that the aircraft maintains a level position. Next hold the aircraft up by the prop shaft and one finger on the centerline of the fuselage opposite the motor and ensure that the aircraft balances in a level position. If the aircraft does not balance correctly, shift the location of the batteries or add ballast weights to move the CG to the correct location.

It is important to balance the aircraft so that the CG is very close to the correct location for the airframe. An incorrect CG will make the aircraft unstable during flight and could create hazardous conditions.

AUTOPILOT PRE-FLIGHT

10. Power on Airplane

Plug in airplane batteries. The amber power LED on the Kestrel Autopilot will light up. The servos should also be powered up at this time.

11. Verify Communication

The wireless communications link should be established on power up. This is indicated by the comm symbol (small airplane with red waves) in top right corner of the Virtual Cockpit HUD. The red waves in the HUD will disappear when communication is lost. Also, users may look at the Agent Status List shown in Figure 6. The Comm. columns show two communications bar graphs. The graph to the right represents the Virtual Cockpit's packet reception statistics. Make sure the bar graph remains near full. The bar graph to the left is the autopilots received signal strength indicator. Not all autopilot modems are equipped with this capability, thus it may not be displayed.

Figure 5 Comm. Status in the Heads-Up-Display (HUD)

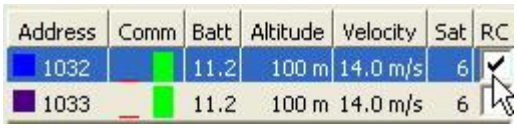

Figure 6 Comm Status in Agent List shows as a bar graph over time

12. Verify Wireless Range

Periodic range checks may be appropriate to verify proper function of the wireless communications link. While on the ground, and with the Commbox antenna in its normal vertical position, move the UAV a minimum of 60 to 100 meters away from the Commbox, verifying communications remain strong as noted in the VC. Wireless range of the UAV in the air tends to be six to ten times greater than range on the ground.

13. Verify Airplane Battery Voltage

Connect airplane batteries verifying that the battery voltages are sufficient (11V +) for flight by observing the battery indicator in the Virtual Cockpit. The UAV battery voltages are visible in the Agent Status List and in the HUD (see Figures 7 and 8). **Note:** If flying multiple UAVs, only the selected agent status is displayed in the HUD. Click on Agent Address to select the desired Agent.

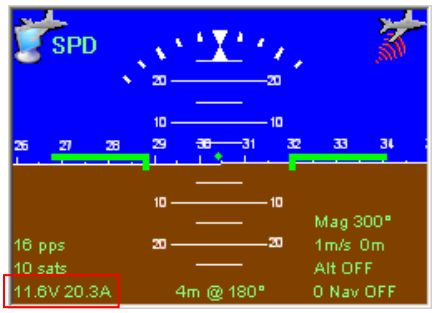

Figure 7 Battery Status in HUD

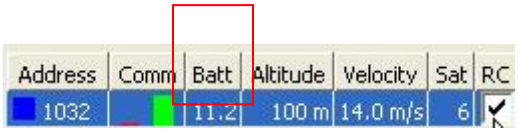

Figure 8 Battery status in Agent Status List

Warning: Use only battery sets that are of the same charge. (Connecting batteries of different charge levels can damage batteries or cause unsafe conditions). Do not allow the battery voltage to drop below 9.5V on 3-cell Lithium

Polymer battery packs. If this occurs, land the plane immediately. See Failsafes for Low and Critically Low settings, (see Figure 14 below).

14. Verify GPS Lock

Verify that the GPS has acquired satellite lock. This usually requires reception from four or more satellites. The number of satellites detected is displayed in both the Agent Status list and in the HUD (Figures 9 and 10). The UAV will only appear in the correct location on the map after GPS lock is acquired. (displayed as a wing-shaped icon)

Figure 9 Satellites in Agent List

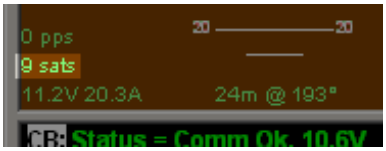

Figure 10 Satellites in HUD

The number of satellites displayed in the HUD will be green with satellite lock, yellow without satellite lock, and red with the text “NO GPS COMM” when the GPS is NOT detected.

Warning: If at least 5 satellites are not detected - DO NOT FLY.

15. Enter Starting Altitude (MSL)

Depending on whether terrain elevation data is loaded into the Virtual Cockpit for the initial UAV GPS lock position, users may see Figure 11 as a pop up window. Select the source for the altitude information from the three different radio buttons and press the OK button.

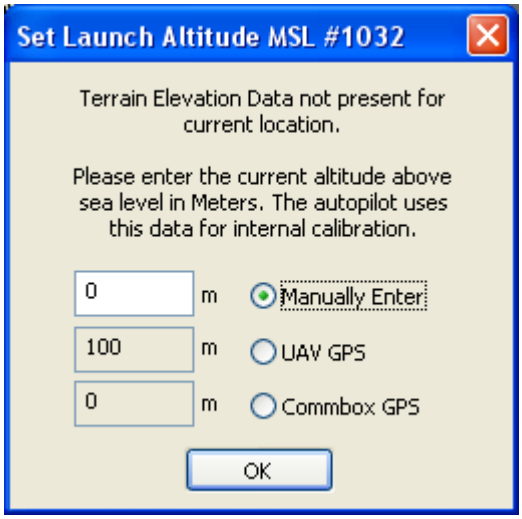

Figure 11 Set Launch Altitude window

16. Verify Manual Mode

Make sure the current UAV mode is Manual Mode (Figure 12). You can check this by making sure the Manual button is currently green. If it is not, click the Manual button now. If you want to assure that the motor will not fire under any circumstances, whether in RC or Autopilot control, then place the UAV in "Safe" mode by clicking "Safe".

Figure 12 UAV Modes with Manual selected

Manual Mode allows users to operate the UAV in a semi-autonomous fashion. In this mode the autopilot maintains a constant airspeed by pitching up and down. Users have full control over the UAV's roll and throttle using the gamepad. Figure 13A and 13B details the gamepad button layout while in Manual mode. A more thorough description of the different UAV Modes can be found at the end of this document and in Chapter 5 of the Kestrel Users Guide.

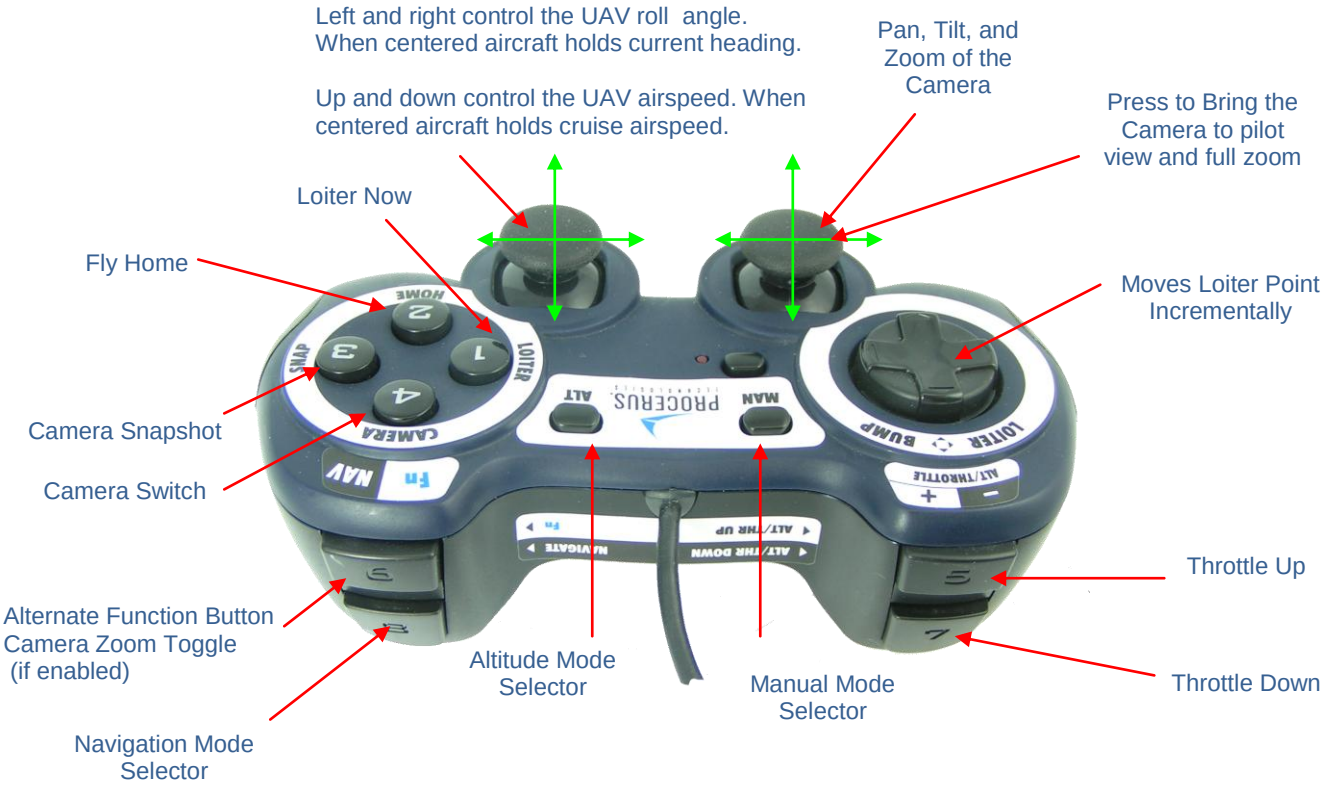

Figure 13 Manual Mode front view

The following sections briefly describe some simple adjustments that can be made to the autopilot if outfitting the autopilot into a different airframe. For those who have

purchased an entire Kestrel system with UAV included these steps will already be completed at the factory. A more thorough integration procedure is described in the Integrators Guide.

Installation Step

Servo mixing

"Servo Mixing" is a UAV parameter used to mix servo output necessary for control of different airframe types. Servo mixing can be configured in the Autopilot Config Menu under "Servo Settings->Mixing". Check the appropriate checkbox for mixing and press the Upload Config button. Note: This requires an Update Flash if the user wishes to retain the settings after powering down. (never update Flash while UAV is in the air)

Installation Step

Control Effort Direction

Disconnect the motor. Select Manual mode using the UAV Modes buttons. Check that the control effort is in the correct direction. This can be done by tipping the airframe and observing the control surface deflections or by selecting the "Use Desired" checkbox in the PID Values settings screen (F5 – PID Values) and typing in desired roll and pitch angles while observing the control surface deflection. To correct reversed control effort, the sign may be switched on the servo scalars in the Servo Window of the Virtual Cockpit.

Trim the UAV

This step is only necessary if the UAV has not been flown before or has been altered due to a hard landing. In most causes the Auto Trim feature built into the Kestrel autopilot is more than sufficient. This can be enabled through the Agent Config window under "Auto Trims->Use Auto Trim" checkbox. If users would like to manually trim the aircraft, follow the steps below that use an RC transmitter discussed in Appendix A.

Adjust the servo trims until the bottom surface of both the control surface and adjacent wing are parallel. This can be done either by holding the servo sticks in the correct position, by moving the trim tabs, or by entering in different **servo bias** values in the Servo Window of the Virtual Cockpit

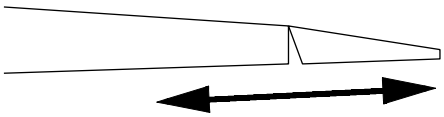

Figure 14 - Parallel Bottom Surfaces for trim.

Go to the Servo Window (F5 – Servos) and press "Upload Trims" to transfer the current trim settings to the autopilot while the UAV is trimmed. If you re-adjust the stick positions after hitting Upload Trims, press "Zero Sticks". The Zero Sticks button tells the Commbox that the RC transmitter sticks are centered. Be sure to Update Flash prior to autopilot power down to retain these settings. Trimming the UAV during flight may be necessary but must be done while flying in Manual mode (where UAV stability is not augmented by the autopilot).

17. Verify Proper Attitude in HUD

Verify in the Virtual Cockpit HUD that the airplane attitude is measured correctly by tipping and holding the UAV for 3 seconds at 45° roll (left / right) and then at 45° pitch angles. (up / down). **Note:** If the attitude spins or does not appear to respond, contact Procerus Technologies as your autopilot may need to be re-temperature compensated.

SENSORS AND FAILSAFES

Figure 14 Pre-flight buttons

Important: perform these steps before each flight..!!

18. Zero Pressure

Ensure no wind is blowing on the Pitot tube or over the autopilot. Press “Zero Press.” to zero the current altitude and airspeed of the autopilot. This step is necessary because barometric conditions can change and we want to avoid false readings.

19. Set GPS Home Position

Upon gaining GPS lock, the Home position is set. You may reset the Home position by pressing the GPS Home button which sets Home at the current UAV position. Verify that the GPS has acquired satellite lock. The home position is displayed on the map.

20. Check Sensors

Use the “Check Sensors” button to verify that all sensors are within appropriate limits. Make sure the airplane is level and not moving, and that the Pitot tube is not pressurized by wind or objects, when the Check Sensors button is pressed. This is further described in Section 4.2.6 of the User’s Manual.

21. Verify Failsafes

Press “FS” to open the autopilot **F**ailsafes **S**etup window. The autopilot failsafes handle various failure conditions; Loss of Communications, Loss of GPS, and Low Battery conditions, and are set by default for the Unicorn with 3 cell lithium polymer (Lipo) batteries.

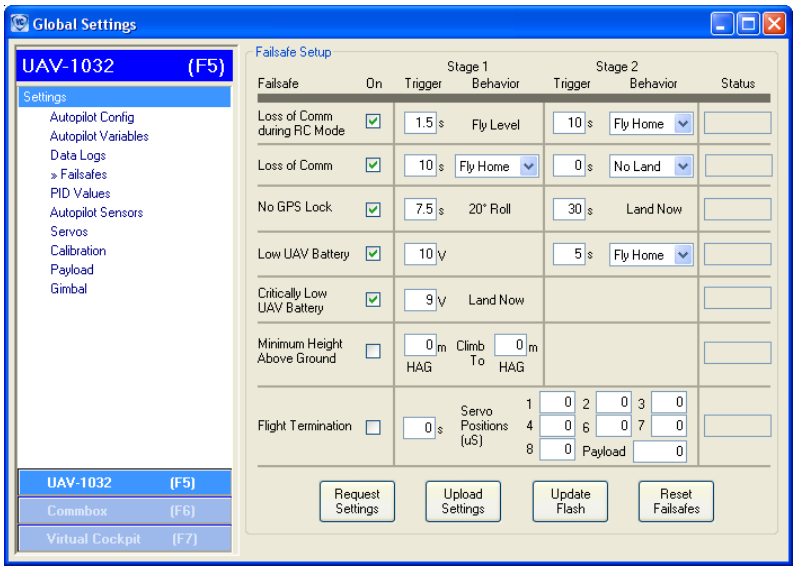

Figure 15 Failsafes window

Failsafe Stages

Select the On checkbox to enable the failsafe. Failsafes may have one or two stages. Each stage has a trigger condition and a behavior. The trigger condition specifies how the failsafe stage is entered and the behavior describes the action if triggered. The Request Settings and Upload Settings buttons are used to retrieve and update the autopilot failsafe settings. Reset Failsafes sets all failsafes to their non-triggered states; although some failsafes such as Loss of Comm. will reset themselves when reacquiring communications.

If you have made a change to the failsafe settings click the Update Flash button to write the values to autopilot memory. Never update Flash during flight..!!

Prepare Flight Plan

This section will outline the preparation required for an automatic takeoff, navigation of a flight plan, and automatic landing.

22. Create or Load Flight Plan

A flight plan may be created by adding individual waypoints. Pre-saved flight plans may also be loaded from file. To add waypoints to the flight plan, right click over the map and select a waypoint under Insert Commands.

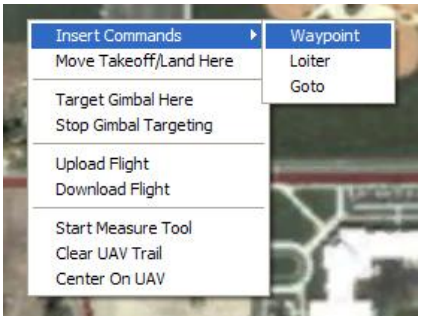

Figure 16 Add Waypoint Using Map

Flight plans may be loaded and saved either by using the load and save options under the File drop-down menu or by using the load/save buttons above the Flight Plan (see Figure 17). The default waypoint parameters are recommended for first time use. The waypoint types (Flight Plan items) are described in the following table.

Note: Prior to getting GPS lock, the icon representing the UAV and Home location will not appear on your map area. (See Figure 1)

However, you can set up your flight plan, Takeoff waypoint, and Rally and Land points. If those points do not appear on your map area, select "Move Takeoff/Land here" as noted in the Figure 16 above. You can set up your entire flight plan and landing sequence prior to getting GPS lock. You can also save your flight plan(s) for use when you arrive at your flight location.

Table 3 – Waypoint Types

Name	Description
Waypoint	Fly to Waypoint
Loiter	Orbit Waypoint
Goto	Causes flight plan to execute (jump to) a specific waypoint.

Warning: Be careful when adjusting the commanded airspeed on waypoints. Commanding the UAV to fly an airspeed that is too slow may cause the UAV to stall. For Unicorn or Zagi platforms, do not go below 14 meters per second.

1. **Editing the Waypoints**

   As waypoints are added to the Flight Plan, waypoint parameters like altitude and airspeed (default values set) may be edited. Waypoint properties may be edited by either double clicking on the waypoint on the map or by using the Flight Plan list. To reveal the Flight Plan, click the tab at the bottom, center of the map.

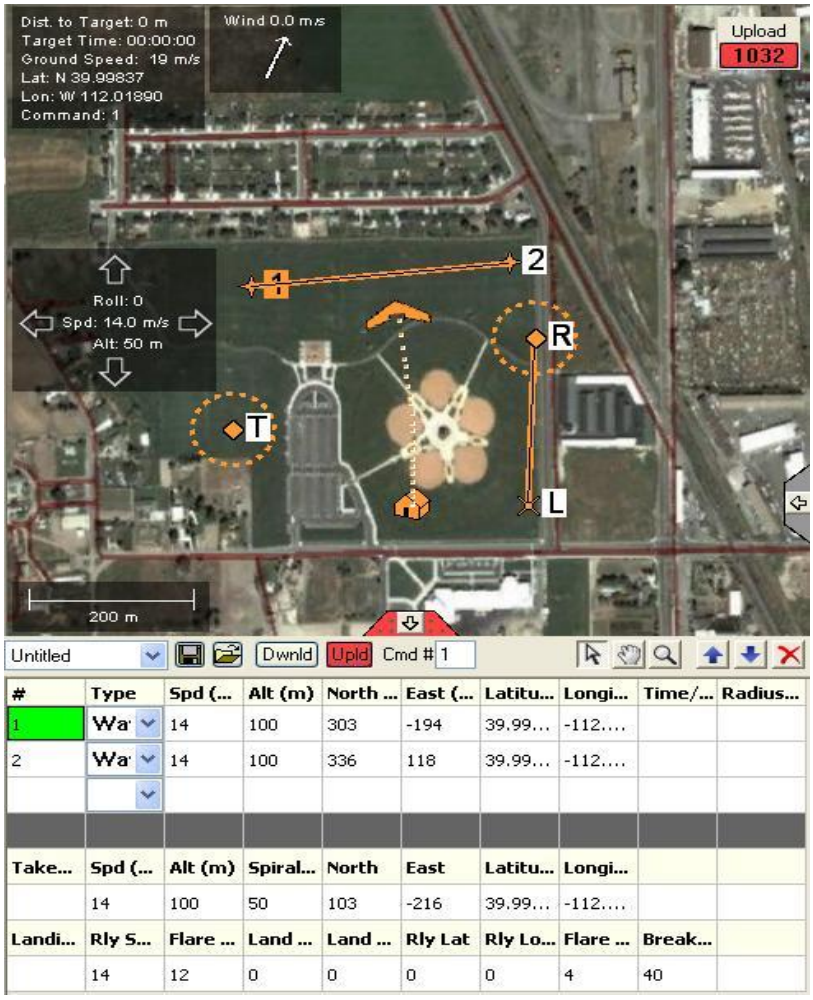

Figure 17 Editing a Flight Plan Waypoint in the Flight Plan list

2. **Upload the Flight Plan**

Upload the Flight Plan is easily accomplished by pressing the red button (displays agent number on the red button) that appears in the top right corner of the map area. This indicates the flight plan is different from that on the autopilot and must be uploaded.

You can also upload the flight plan by either pressing the Upld button or right clicking on the map and selecting "Upload Flight" (see Figure 17). This transfers the Flight Plan to the autopilot. The Upload button will turn red when the Flight Plan in the VC is different than that on the autopilot, thus requiring an upload of the Flight Plan. It changes to yellow when uploading and returns to normal button color when completed.

3. **Current Flight Plan Item**

The current waypoint is highlighted on the map and is listed in the Flight Plan tool bar. You may choose to fly to any waypoint at anytime by right clicking on the waypoint on the map and selecting "Set As Current Command" or by changing Cmd # 1 to the desired waypoint number. The UAV will then proceed to that waypoint.

Figure 18 Takeoff modes

4. **Takeoff and Landing Points**

Takeoff and Landing Points are considered separate from the NAV waypoints but are uploaded to the autopilot as part of the Flight Plan. There are 3 different Takeoff modes; the default being Takeoff to Waypoint. (climbs to desired altitude around Takeoff point and remains there until the users selects one of the autonomous or pilot-in-the-loop modes.

The Takeoff Waypoint is used for the Takeoff Waypoint Mode. In this mode the UAV flies to the uploaded waypoint while it is climbing. Once reaching the takeoff waypoint the UAV will circle indefinitely while climbing to the takeoff altitude and remain there. Users have to manually change the UAV Mode to command the airplane out of the loiter. (example; switch to autonomous navigation mode by selecting the "Nav" button)

The Virtual Cockpit default values (Altitude, Manual) are recommended for the Unicorn airframe for Takeoff, Rally and Land waypoints but may be changed per your air vehicle considerations and characteristics. UAV Modes are described in Appendix B.

Landing consists of a Rally point and a Landing point. (See Figure 1) Send the UAV to land by selecting "Land" (see Figure 12). The UAV will fly to the Rally point at the current altitude, descend at the Rally Velocity and Descent Rate while circling about the Rally waypoint until arriving at the Rally Break Height (Figure 17 shows a Break Height of 40 meters). The UAV will then "break out" and follow the glide slope down to the Landing point. The UAV will gradually transition from the Rally Velocity to the Flare Velocity while following the glide slope. Near the Land point the UAV will hold a 0° roll and turn OFF the throttle.

Note: The landing glide slope is determined by the distance between the Rally and Land waypoints and Altitude of the Rally point end height. A recommended ratio is less than 0.40 for Rally Break Height over distance between Rally and Land waypoints (for the Unicorn platform, a distance of 150 to 200 meters between Rally and Land waypoints is suggested).

Pre-Launch Check This section assumes all of the prior steps of the Flight Guide have been followed. The steps presented in this section are for preparation prior to launching the UAV.

23. Verify GPS Lock

The number of satellites indicator will turn green and report at least 3 satellites when GPS lock is attained. Recommended minimum number of satellites prior to takeoff is 5. GPS lock is essential for waypoint navigation and failsafe function. (See Figure 1, Agent List)

24. Verify Sensor Calibration

Check each of the following sensors to verify they are within the specified acceptable ranges. If the airspeed or altitude are outside of the acceptable ranges (Table 4), press Zero Press. If this does not bring the airspeed or altitude within acceptable ranges, press the Check Sensors button to verify all sensors are operating properly.

Figure 19 Pre-flight buttons

Table 3 Acceptable Sensor Ranges

Sensor	Acceptable Range
Airspeed	0 ±2.5 m/sec while still, > 10 m/sec with finger pressure over end of pitot tube.
Altitude	0 ±5 m at home altitude
Attitude	0 ±8° roll and pitch with UAV level by sight

25. Verify Wireless Range

Periodic range checks may be appropriate to verify proper function of the wireless communications link. While on the ground, and with the Commbox antenna in its normal vertical position, move the UAV a minimum of 60 to 100 meters away from the Commbox while maintaining line of site, verifying communications remain strong as noted in the VC. Wireless range of the UAV in the air tends to be six to ten times greater than range on the ground.

26. Verify Manual Mode

Make sure the current UAV mode is Manual Mode (Figure 19). You can check this by making sure the Manual button is currently green. If it is not, press the Manual button now.

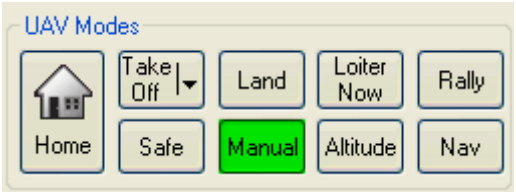

Figure 20 UAV Modes with Manual selected

27. Verify Feedback Control

With the propeller clear of hands, enable the motor switch and increase the throttle using the gamepad's shoulder buttons (Figure 13B). The motor should spin up. Observe the control surface deflections while tipping the UAV in different directions (left/right, up/down). The control surfaces will attempt to control the UAV as it is currently commanded. While in Manual Mode, the UAV will try to maintain a 0° roll if the gamepad's right stick is NOT moved by the user.

Take Off

1. Check Throttle

Carefully hold the UAV so that the propeller is clear of obstructions. Put the motor switch in the "On" position. Put the UAV into take off mode and verify that throttle increases to the Takeoff Throttle setting and the UAV moves the control surfaces to attempt to maintain takeoff pitch. Check the UAV battery voltage while the motor is running to ensure that the voltage does not drop to critically low levels. Shut off the motor by putting the UAV in Manual or Safe mode and put the motor switch in the "Off" position.

2. Launch the UAV

Holding the airplane by the throw holes (Unicorn wing style with prop in back), switch the UAV Mode to Take Off Waypoint. The autopilot will take over in auto Takeoff mode and increase the throttle to the specified Takeoff Throttle setting. The autopilot will control the UAV to fly towards the Takeoff waypoint and circle upward around that point during the climb out stage. Users must switch to Nav Mode after the Takeoff cycle has completed. (or Altitude or Manual Modes for pilot-in-the-loop operation)

Caution: We recommend using a glove when launching these aircraft due to the spinning prop being in the back of the airplane. When you select "Takeoff", the prop will spin up. Be ready with your fingers in the throw holes and your body in a position to throw the aircraft prior to selecting Takeoff. It's best if a second person operates the Virtual Cockpit.

** Give the plane a strong overhand throw, straight forward, without twisting your hand (avoid throwing like you might throw a football) AND, importantly, continue to follow through so your hand proceeds through the forward motion, with your hand moving "down and away" from the spinning prop.

Recommended throw angle for a Unicorn or Zagi style UAV is 35° above level. Takeoff Modes are described in Appendix B.

See the launch demonstration videos on the Virtual Cockpit installation CD ROM.

LANDING

This section assumes all of the prior steps of the Flight Guide have been followed. The steps presented in this section are for preparation prior to landing of the UAV.

1. Place Rally and Land Waypoints

Move Land waypoint (labeled "L" on the map) to the desired landing location. Move the Rally waypoint (labeled "R" on the map) to a location about 200 meters away from the Land waypoint and in the direction from which you would like the UAV to approach the Land waypoint. Preferably you'll want to land into the wind if possible.

Waypoints can be moved by clicking and dragging them on the map or by typing in new coordinates in the waypoint list. Be sure that both the landing area and landing flight paths are open and clear of obstacles. Be sure to upload changes to your flight plan.

2. Switch to Land Mode

Put the UAV into Land mode by pressing the Land button.

3. Assist the Landing

If needed, you can help the autopilot avoid obstacles by using the gamepad. Assistance is most effect for obstacle avoidance and flaring the UAV if needed immediately prior to touch-down.

4. Disable the Motor

Turn OFF the UAV motor switch (near the motor) when the UAV has landed. Placing the UAV in Safe Mode provides an additional layer of safety, by preventing the motor from firing in RC or Autopilot control. These measures will help to ensure operator safety.

5. Unplug the Batteries

Turn OFF the UAV by unplugging the batteries.

Follow safe usage guidelines when using Lithium Polymer batteries.

See www.procerus**uav**.com/documents/LiPolyUsage.pdf for safety information.

Appendix A
RC Radio Use for Development Purposes

During development and tuning of the autopilot, it may be necessary to take full control of the autopilot, and therefore, the UAV. For safety reasons you may feel it necessary to have an RC radio in the loop so you can take over the UAV manually as desired.

An RC transmitter may be connected to the Commbox which controls the servos directly, bypassing autopilot control. This is called RC Mode and it is enabled via channel 5 on the RC transmitter.

The RC transmitter is connected to the Commbox through the buddy trainer cable. This can be seen in Figure 20. The following section will cover proper RC transmitter setup.

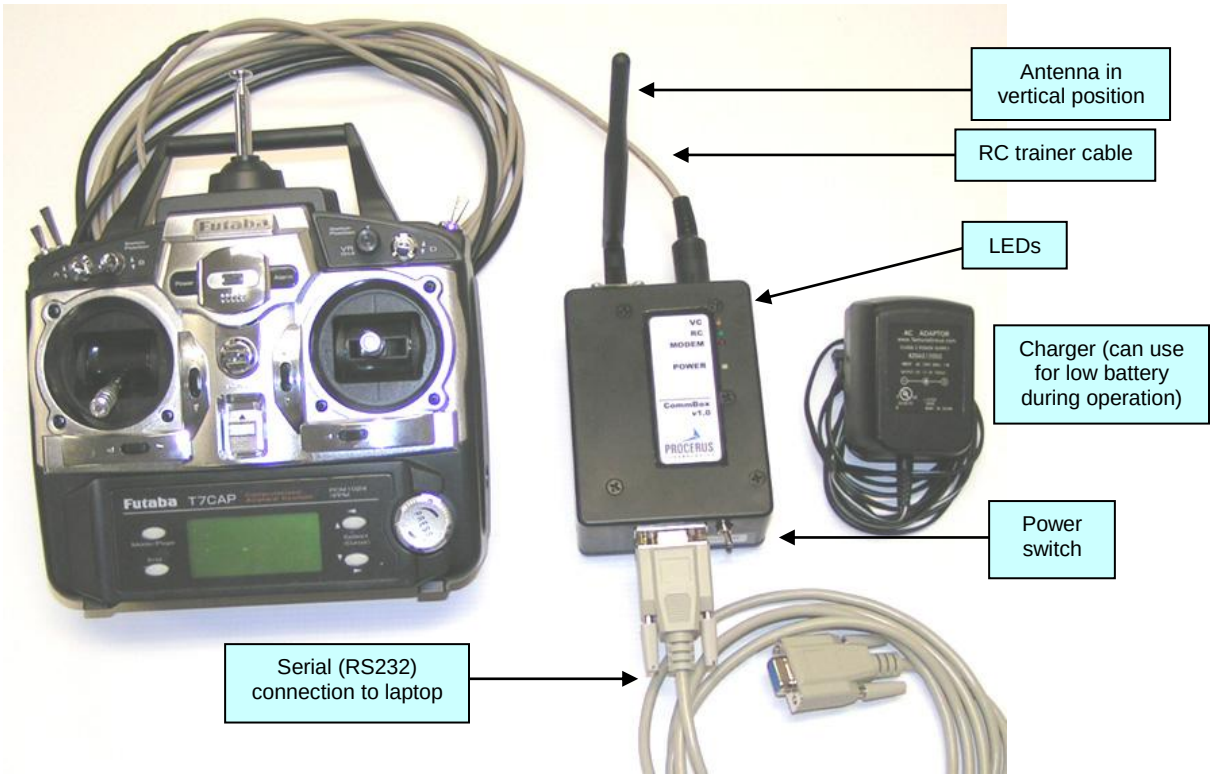

Figure 21 RC Transmitter, Commbox, antenna and cables, DC adapter

RC Transmitter Preparation

Select the RC check box in Agent List in Virtual Cockpit (See Figure 1). If using multiple agents (more than 1 UAV) select the checkbox for the agent number you wish to control. Ensure RC channel 5 switch is in RC Mode position.

1. Transmitter

Any Futaba or Hitec RC Transmitter with 5 or more channels may be used to manually fly the UAV or to assist autopilot control such as during takeoff, landing and for remote throttle enable/disable for aircraft that may require the throttle off during launch.

2. Program RC Transmitter

Ensure that servo mixing is disabled on the RC transmitter. All servo mixing occurs in the autopilot. Ensure that Transmitter is in PPM mode (NOT PCM). The default settings for transmitter model memories are typically correct for use with the Kestrel Autopilot but be sure to check for proper control surface deflection prior to flight.

3. Zero the Trim Tabs

Set the trim tabs or sliders of each channel to the zero or center position. This step is recommended to allow for most trim ranges as may be needed.

4. Connect to Commbox Using Trainer Cable

The RC transmitter signal is captured by the Commbox using a standard trainer cable. This cable plugs into the trainer cable port on the RC transmitter and the 6-pin connector on the Commbox.

5. Strain Relieve Trainer Cable

Strain relieve the trainer cable to the back of the RC transmitter by using the WM-2A self-adhesive cable mount to prevent damage to the trainer cable connector and to prevent the cable from being inadvertently unplugged from the transmitter box during flight.

Figure 22

Figure 23 Trainer cable strain relieved to the back of RC Transmitter.

6. Remove Transmitter Crystal

Be sure to remove the RC transmitter crystal or RF module. This will increase transmitter battery life and will eliminate possible interference with RC airplane hobbyists close by.

7. Dual Rate Settings

If your transmitter supports dual rates, you may set these as desired. (ex. 100% / 50%)

8. Verify RC Signal

Power On the RC transmitter and verify that the RC signal is being received by the Commbox. The LED labeled “RC” will flash to indicate reception of signal.

Use the channel 5 switch on the RC transmitter to toggle the autopilot into RC Mode. RC Mode disables the autopilot’s autonomous modes and gives the user “dampened” RC control of the UAV using the RC transmitter, effectively “slowing down” the dynamics of the UAV. Turning ON RC Mode turns OFF autopilot control and vice versa. RC Mode On is indicated when all of the UAV Mode buttons are grayed out

Figure 24 RC Mode ON

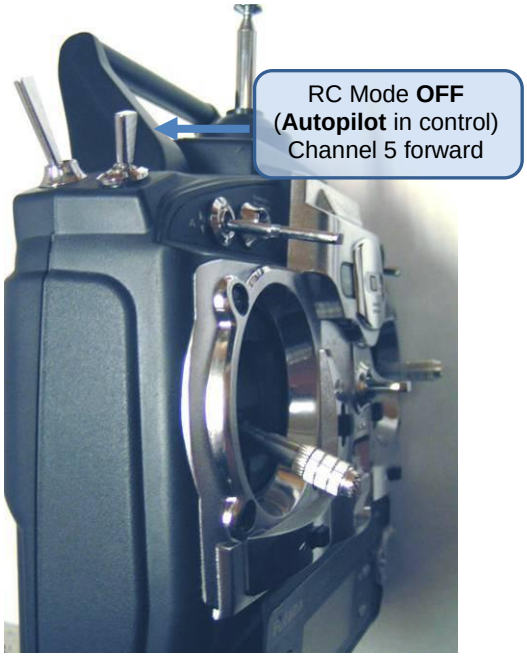

Figure 25 RC Mode OFF

Figure 26 RC Mode ON (Mode buttons grayed-out)

Figure 27 Mode Off

Appendix B

UAV Mode Descriptions (Table 4.7 in Users Guide)

UAV Mode	Description
Takeoff	The button has two different click points that are separated by a dividing line. When clicked to the left of the dividing line the takeoff mode is set to **Takeoff Waypoint**. When depressed to the right of the dividing line a separate menu is displayed allowing for different takeoff commands. The command is not sent to the autopilot until a second click on the menu is performed. ▪ *Takeoff Waypoint:* Fixed throttle at % of full throttle specified by **takeoff throttle**. Stage 0 holds a fixed roll and pitch. Stage 1 flies to waypoint specified on Virtual Cockpit map. While in flight towards the waypoint, the user can adjust the path using the gamepad controller, influencing roll and speed. When reaching the loiter circle the airplane will continue in the loiter indefinitely until instructed otherwise. ▪ *Takeoff Spiral:* Fixed throttle at % of full throttle specified by **takeoff throttle**. Stage 1 holds a fixed roll and pitch. Roll is held at zero, pitch is held at **takeoff pitch**. Stage 2 climbs while orbiting about launch point at **Orbit Radius** until **takeoff transition altitude** is reached, then switches the UAV Mode to Navigation Mode (NAV Mode - flies waypoints) ▪ *Takeoff Joystick:* Fixed throttle at % of full throttle specified by **takeoff throttle**. Stage 0 holds a fixed roll and pitch. Stage 1 switches to climb mode while continuing to hold roll angle commanded by joystick/gamepad. Stage 2 ends when aircraft reaches the altitude specified in the takeoff waypoint. The UAV then switches to Alt Mode.
Land	Flies to rally point at current altitude, descends while orbiting rally point until reaching rally point **Break Height**. Follows glide slope from rally break height down to land **Flare Height**. During the glide slope the user can change the path and airspeed using the gamepad. Airspeed transitions from **rally velocity** to **flare velocity** while on glide slope. Motor is shutoff once UAV reaches landing point.
Loiter	Orbits about a location and altitude at **cruise airspeed**. Depending on UAV configurations the orbit location can be centered about the onboard cameras center field of view. The orbit radius can also be configured to be a default loiter radius or an optimal loiter radius for maximum camera on target visibility. For more information on this mode see Chapter 5, Using the UAV Modes.
Home	Flies to and orbits about home point at **cruise airspeed** and current altitude. If current altitude is lower than **minimum go home alt,** UAV will climb to **minimum go home alt** while en-route to home point. UAV will stay at current altitude if Low Battery failsafe has triggered.
Rally	Flies to and orbits about **Rally Point** at current altitude and **cruise airspeed**. If current altitude is lower than **minimum go home alt,** UAV will climb to **minimum go home alt** while en-route to rally point.
Manual	Holds commanded roll angle and **cruise airspeed**. Commanded throttle controls altitude. Roll keys are ←, →, and "space". **Cruise airspeed** offset keys are ↑ ↓. Throttle keys are "a" and "s". RC controller may be used to control roll and throttle.
Safe	Prevents the motor/engine from throttling up under any circumstances.
Altitude	Holds commanded altitude and roll angle. Roll keys are ←, →, and "space". Altitude keys are "a" and "s". **Cruise airspeed** offset keys are ↑ and ↓. RC controller may be used to control roll.
Nav	Flies to each waypoint in Flight Plan according to waypoint parameters.
RC Mode (all other	Autopilot disables low-level and high-level control, giving complete stick-to-surface control to the pilot via the RC controller. If desired, the autopilot can be configured to

modes grayed-out)	enable rate damping or higher level control in RC Mode (Roll held at zero degrees for example). When RC Mode is disabled, autopilot resumes in whatever mode it was in before RC Mode was enabled. RC Mode is enabled via the channel 5 switch on RC controller.

Appendix C

Airframe Types Supported

- V-tail
- Elevon
- Rudder, elevator
- Rudder, elevator, aileron
- Rudder, elevator, flapperon
- Elevator, flapperon
- Ruddervator, aileron