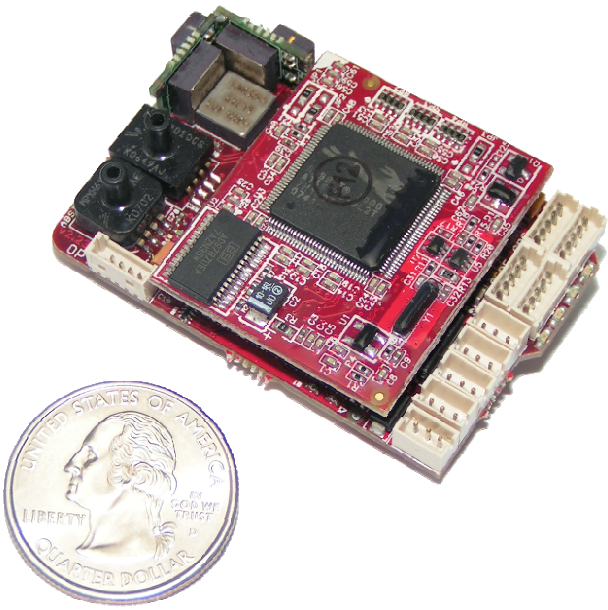
Kestrel Autopilot System

Autonomous Autopilot and Ground Control
For Small Unmanned Aerial Vehicles



Kestrel User Guide

Kestrel Autopilot
(Firmware version MA8.4)
&
Virtual Cockpit 2.6

8/20/08
Document Version 2.1

PROCERUS
TECHNOLOGIES

Recent Changes to This Guide

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PROCERUS TECHNOLOGIES

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1 Introduction

The Kestrel Autopilot (KAP) System provides intelligent, autonomous flight control, GPS waypoint navigation as well as autonomous takeoff, flight, and auto-landing routines for micro / mini unmanned aerial vehicles (UAV). Along with the Virtual Cockpit and Commbox ground station hardware and software control system, it offers a highly effective avionics package for a variety of military and commercial applications.

An external GPS unit is used for inertial navigation and wireless modems for ground station to autopilot communication. The autopilot can guide mini UAVs autonomously and/or receive dynamic user commands through the ground station or RC radio while providing live video feeds to the user. Its sensors are 3-axis rate gyros and accelerometers for attitude estimation, differential and absolute air pressure sensors for airspeed and altitude measurement. It is a small, lightweight, low-cost, low-power solution that provides real-time trajectory generation and tracking and simple intuitive user interfaces.

The Virtual Cockpit ground control software makes “click ’n fly” operation easy while providing powerful mission planning, monitoring, and in-flight adjustment on a notebook computer, allowing the user to interact with the UAV in a variety of different modes that include stick & rudder, altitude-heading-velocity commands, and dynamic waypoint specification, operator-in-the-loop, and other autonomous and semi-autonomous modes.

2 Kestrel Avionics

The autopilot system can be divided into airborne components and ground station components. The airborne components are referred to as the *avionics*. The avionics consist of the autopilot, GPS, Pitot system, and digital modem. Figure 2-1 shows the avionics block diagram.

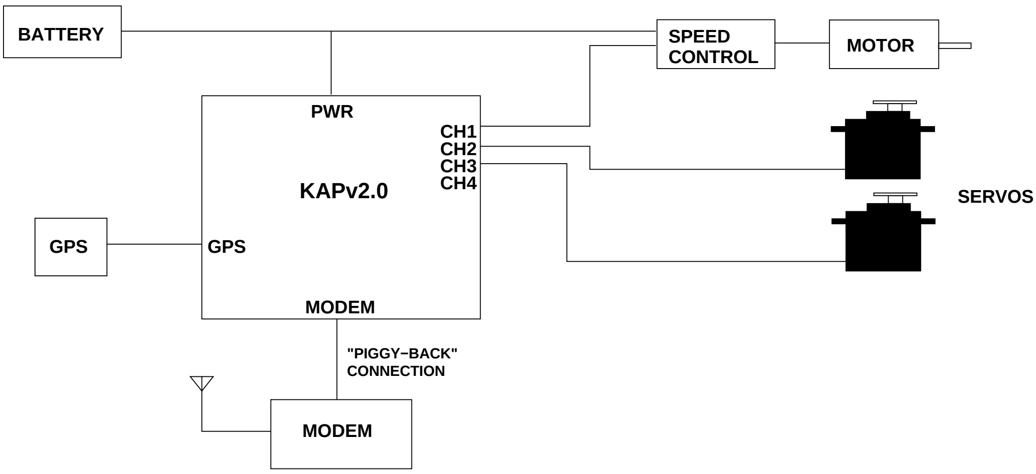


Figure 2-1 Avionics block diagram

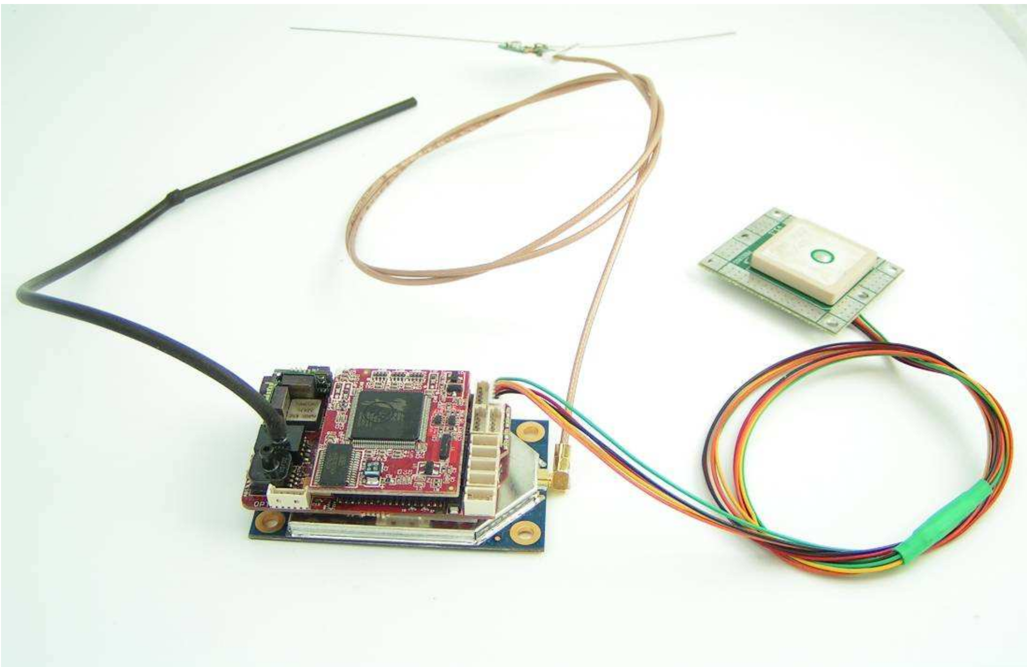


Figure 2-2 Avionics Kestrel 2.23, Maxstream XTend modem, Pitot tube, [UBlox GPS module](), [Procerus Dipole communications antenna]()

2.1 Autopilot

The autopilot is the heart of the Kestrel system. It is powered by an 8-bit 29 MHz processor. The autopilot board contains a suite of sensors used by the autopilot software to measure and estimate the states of the aircraft. The autopilot interfaces directly to the digital communication link which enables it to send real-time status telemetry to the ground station and receive commands in-flight. The GPS plugs into the autopilot board (optional) and provides inertial navigation information to the autopilot. It also has several additional interface ports to support payloads. The autopilot controls the aircraft through four standard RC hobby servos. If more servos are needed, a servo extender board can be used. Figure 2.3 shows the Kestrel autopilot with Maxstream XTend modem attached. Other modems are supported such as Aerocomm (4868 and 4424 for international use), Microhard, and Freewave.

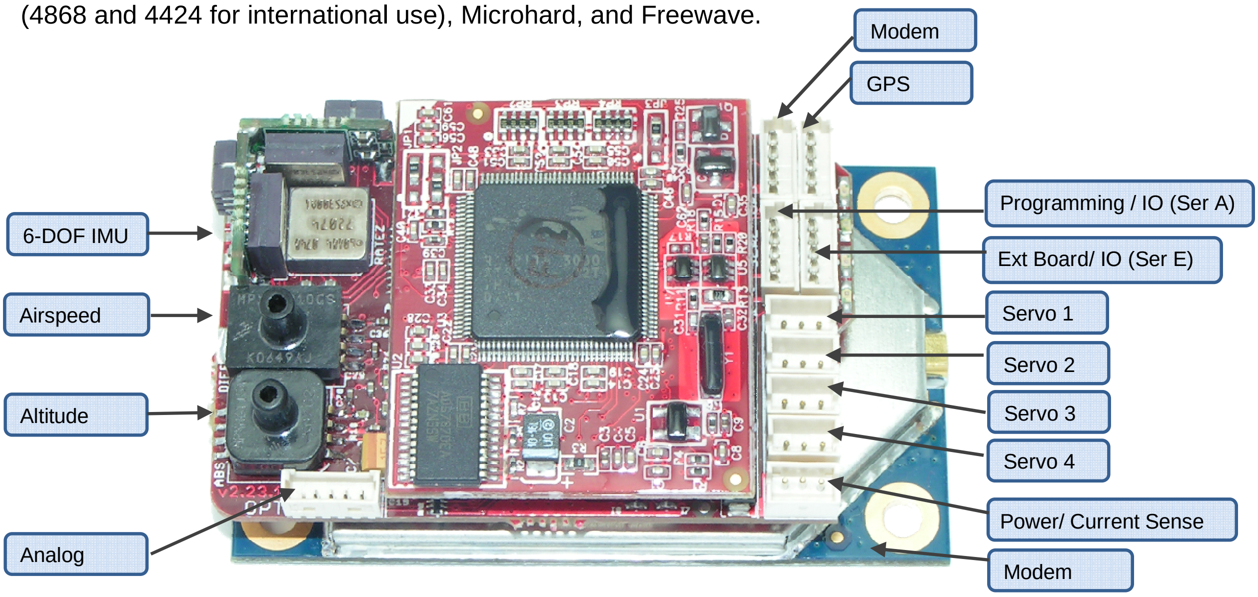


Figure 2-3 Kestrel 2.23 Kestrel Autopilot with Maxstream XTend modem attached

Note: Procerus does not support the Aerocomm AC4490 modem in this release and does not plan to support that particular modem in the future. This is due to reliability issues.

2.1.1 Block Diagram

Figure 2.4 shows the block diagram of the Kestrel 2.x autopilot.

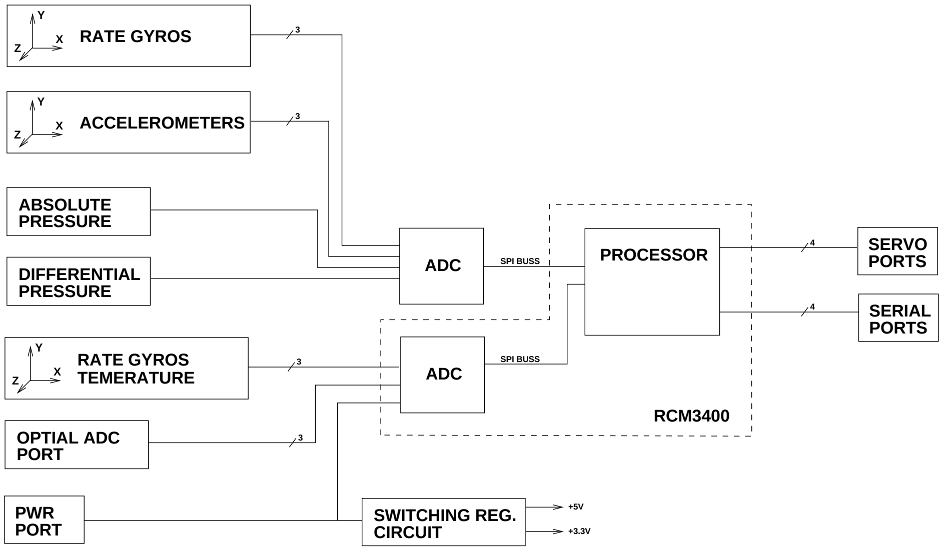


Figure 2-4 Kestrel 2.x block diagram

2.1.2 Port and LED Locations

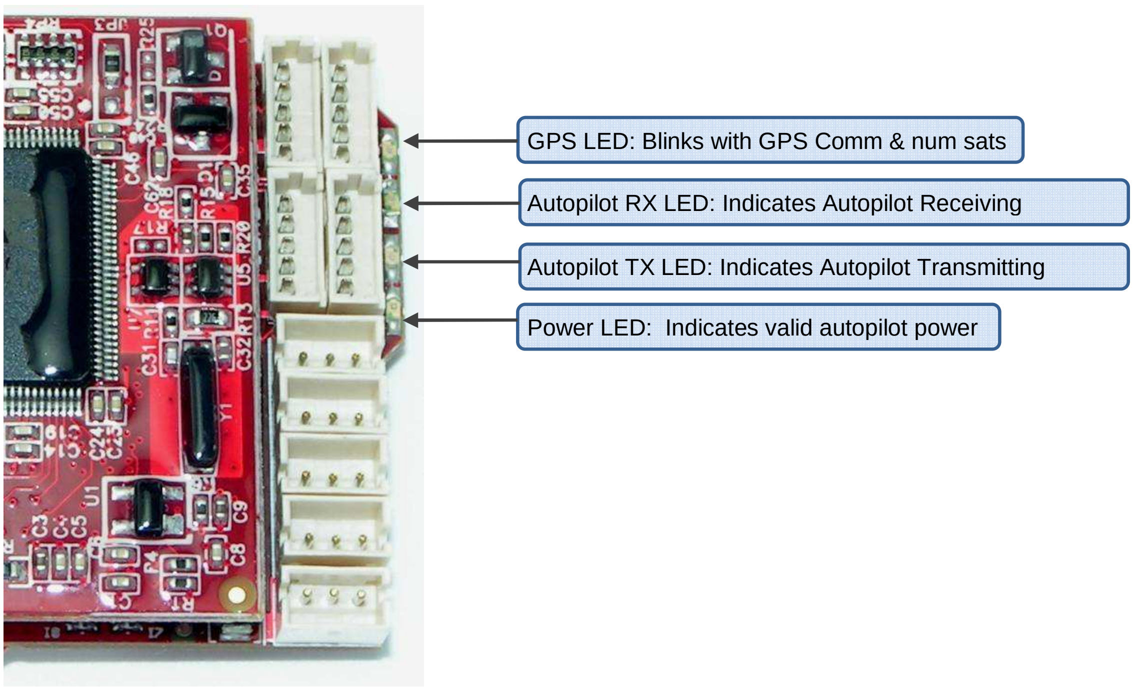


Figure 2-5 LED locations on the Kestrel 2.x autopilot

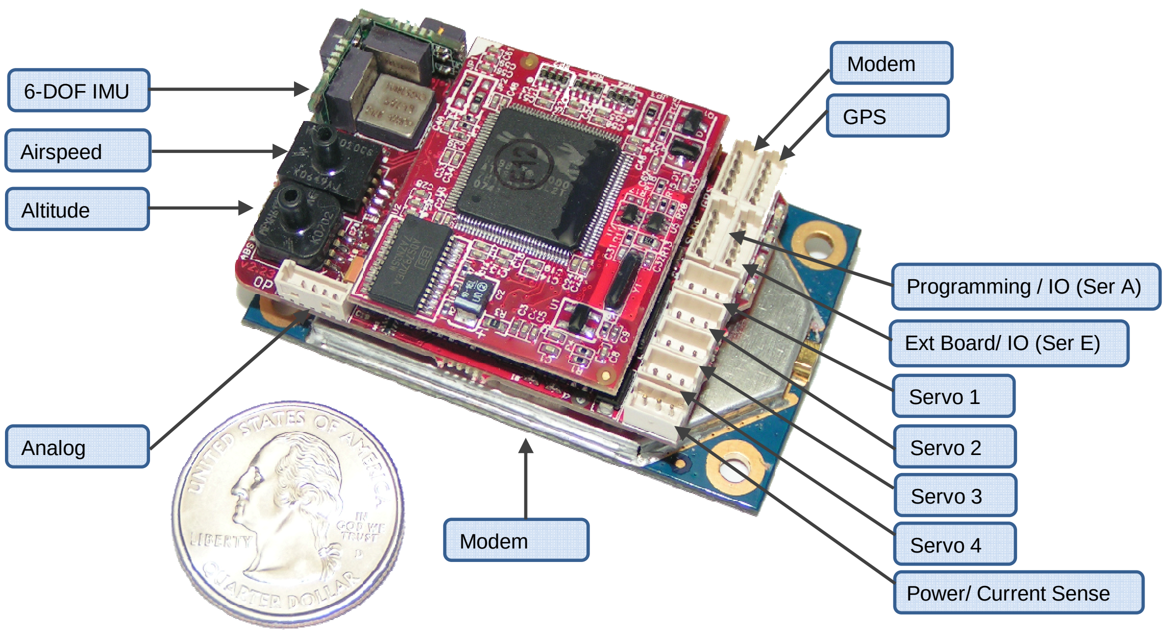


Figure 2-6 Port Locations on Kestrel 2.x

2.1.3 Jumper and Header Locations

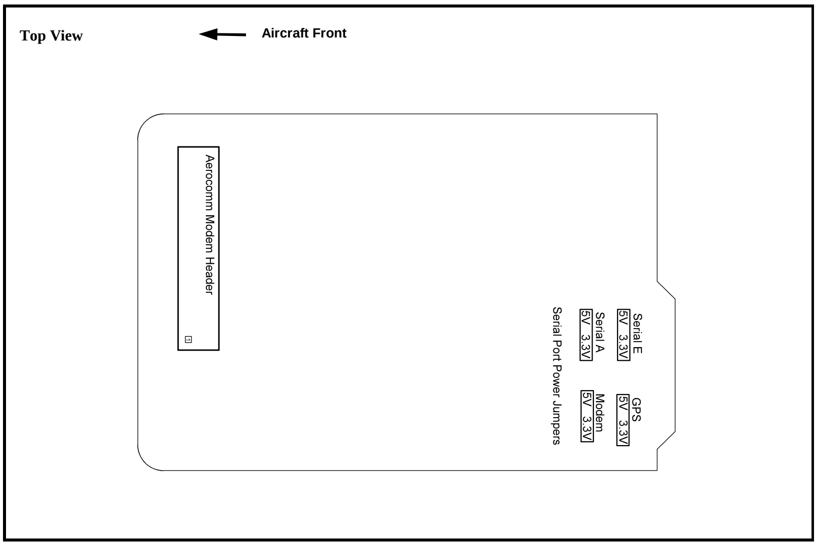


Figure 2-7 Jumper and header locations on the Kestrel 2.x autopilot

2.1.4 Port Functions

The following tables describe the general pin assignments for each port type.

Power Port

Pin	Description
1	GND
2	PWR (6V – 18V)
3	Current Monitor

Servo Ports

Pin	Description
1	PWR
2	GND
3	Signal

Analog Input Port

Pin	Description
1	GND
2	PWR 5V
3	Ch 1
4	Ch 2
5	Ch 3 ** (GND, see note below)

Serial Ports

Pin	Description
1	GND
2	PWR (3.3V or 5V)
3	Autopilot TX
4	Autopilot RX
5	CMD or CLK

*** Attention: For red main board PCB autopilots (V2.23, serial numbers 1550 to 1799), pin 5 is connected to ground.*

Power Port: This port supplies the autopilot power and is typically connected directly to the autopilot or aircraft main battery. The GND and PWR pins connect to the negative and positive battery terminal respectively. The Current Monitor pin is used to detect current draw of the main battery by measuring the voltage drop across a 0.01Ω resistor in series with the battery. This resistor's power rating should be as follows:

RESISTOR POWER > (MAX MOTOR CURRENT)^2 x 0.01 (WATTS)

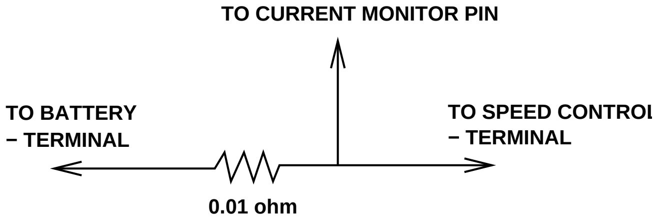


Figure 2-8 Typical Current Monitor Circuit

Optional ADC Ports: Three analog inputs (pins 3-5) on the Optional ADC port allow users to measure 0.01V to 3.29V. Filtered analog 5V is available on pin 2. This pin supplies the autopilot analog sensors so use caution not to introduce noise on this pin.

Serial & I/O Ports: There are 4 serial ports that double as I/O ports. Serial E and Serial A allow users to interface with payload needs. The GPS port is dedicated for the GPS unit. The MODEM port is optional if the modem is not plugged into the modem “piggy-back” header. For each serial port, the autopilot TX and RX lines are found on pins 3 and 4 respectively. All serial ports operate at TTL levels (0V to 3.3V) and can be configured for standard serial, SPI, or I2C communication. Pin 5 on all serial ports serves as a digital I/O. Pins 3 and 4 can be used as digital I/O if not being used for serial communication. Table 2.1 shows the pin assignments (connections to Rabbit 3000 processor) of all serial ports.

Table 2.1 Serial Port Pin Descriptions

Pin	SerA	SerE	GPS	Modem
1	GND	GND	GND	GND
2	PWR (3.3V or 5V)	PWR (3.3V or 5V)	PWR (3.3V or 5V)	PWR (3.3V or 5V)
3	TxA (PC6)	TxE (PG6)	TxD (PC0)	TxF (PG2)
4	RxA (PC7)	RxE (PG7)	RxD (PC1)	RxF (PG3)
5	Reset/Smode	ClkE (PG5)	ClkD (PF0)	TClkF (PG0)

Servo Ports: These ports are configurable for different aircraft types. Servo connections for standard configurations are detailed in the integration manual.

2.2 GPS

The Kestrel system supports three GPS interfaces: Furuno Binary, u-blox binary, and standard NMEA. The autopilot is programmed by default for u-blox Binary protocol in support of the u-blox GPS receivers. The autopilot can be re-configured by the user to use Furuno binary protocol. To use NMEA, a special compiled version of the avionics software is required. This can be obtained by contacting Procerus. The GPS provides position, heading, and velocity information necessary for waypoint navigation.

The Kestrel system combines sensor information with GPS information to provide smooth position and velocity information between GPS samples. For areas where GPS reception may be intermittent, the Kestrel 2.2 autopilot with magnetometer has the ability to navigate using dead reckoning techniques and wind information. This ability is limited and is only designed to be useful during brief GPS outages of 30 seconds or less. The Kestrel also has user-configurable failsafes that address scenarios in which GPS lock becomes unreliable or is lost completely. The autopilot does not require a GPS lock for operator-assisted modes such as Manual or Altitude modes where pilot input is used to steer the aircraft.

2.3 Digital communication link

The Kestrel system is designed to be used with a bi-directional data link. The data link is used to set up and configure the autopilot as well as monitor and re-direct the aircraft in flight. The data link is also designed to send stick position information from the RC transmitter for pilot-in-the-loop operation. This is discussed in more detail in section 3.5.

The standard modem used with the Kestrel autopilot system is the Maxstream Xtend. This modem has a 115K baud interface and over-the-air baud rate and a 1000 mW power output. The Kestrel autopilot supports any digital link with a serial interface baud rate of 115K baud. The RF channel functions are supported with Aerocomm modems. If Maxstream modems are used then RF channel and RSSI functions can also be used. The Aerocomm modem uses a server/client infrastructure that allows several aircraft to be controlled from one ground station. The aircraft can communicate with each other as well as the ground station. Using a ¼-wave dipole on the aircraft and ground station, communication ranges of greater than 10 kilometers can easily be achieved. As of the writing of this document, these modems have been tested out to a range of 10 kilometers in a non-urban environment using a directional antenna with minimal packet loss. Other modems that the Kestrel

To support the control of multiple aircraft from one ground station, each aircraft is assigned a unique 16 bit address. This is known as the Aircraft Address and can be changed by the user if desired. This is detailed in Chapter 6 Multi Agent Control.

Two hardware versions of the Kestrel 2.x series autopilots are in distribution. The two types are easily differentiated by looking at the color of the main PCB (not the microcontroller, but the board underneath all of the sensor components). Autopilots with a green main PCB (2.22 and earlier) are designed with an Aerocomm style header on the back which allows the Aerocomm style modems to be plugged directly into the autopilot. This permits the modem and autopilot to be stacked, reducing wiring complexity and space required for the installation. Autopilots with a red main PCB are designed for direct plug-in of Maxstream modems. To use a modem different from the intended type, an interface board, provided by Procerus, may be used. If desired, the modem may be mounted externally and connected to the autopilot via the external modem header.

2.4 Air data system

The Kestrel autopilot is equipped with differential and absolute pressure sensors for sensing the airspeed and barometric altitude of the aircraft. These sensors are integral for proper aircraft control and care should be taken to ensure proper Pitot tube and autopilot installation. The differential pressure sensor requires a Pitot tube to be mounted on the airframe out of the prop wash. For more information on mounting see the Installation and Configuration Guide.

2.5 External Servo Boards

The Kestrel autopilot is designed to control 4 hobby servos. If additional servos are required, the user may purchase the External Servo Expansion board. The servo board plugs into the autopilot and allows the use of an additional 8 servos. Also available is an External I/O board which provides RPM sensing capability in addition to six extra servo ports. Technical data sheets are available from Procerus detailing the use and installation of both servo expansion boards.

2.6 External Magnetometer Board

The Kestrel 2.2 autopilot has a built-in 2-axis magnetometer. This is useful for providing an absolute heading reference that can be used to navigate during GPS outages or for geo-locating images from an onboard video camera. Because magnetometers are extremely sensitive to interference from “hard iron” and magnetic field producing objects (such as electric motors), it may be desirable to mount the magnetometer external to the autopilot. For this purpose an external, 3-axis magnetometer board can be purchased from Procerus.

3 Ground Station Components

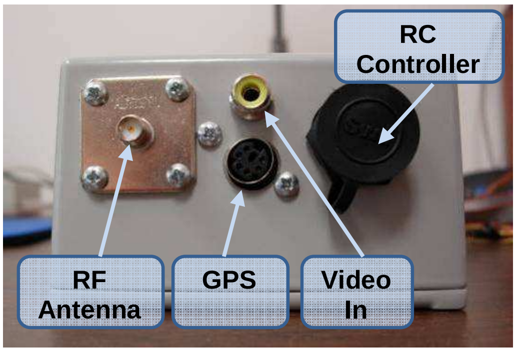
The ground station components consist of the Commbox, a Futaba-compatible RC transmitter, and Virtual Cockpit ground station software. While the RC controller can be used during normal flight, it is only required during development (See Chapter 4 on use of the game pad controller).

3.1 Commbox

The Commbox is the heart of the ground station communications hardware. The ground station has 3 main purposes.

1) To handle communications between the ground station computer and one or more aircraft,
2) To pass the position information from the ground station GPS to the ground station computer,
3) To send RC transmitter stick information to the aircraft for pilot-in-the loop control.

The ground station Commbox consists of the main board, digital modem, and GPS. The main board has an 8-bit CPU that decodes the pulse train from the transmitter into stick positions for controlling the airplane. It also passes data from the digital modem to and from the ground station computer and parses position information from the GPS. It contains a wireless modem used to communicate with the UAV autopilot, an interface for a Futaba-compatible RC transmitter, and a nickel metal battery to power the Commbox. Optionally, the Commbox may include a text overlay device that allows telemetry data to be displayed & recorded over the video itself. (Note the yellow connectors in the picture on the right – call for pricing for this feature).



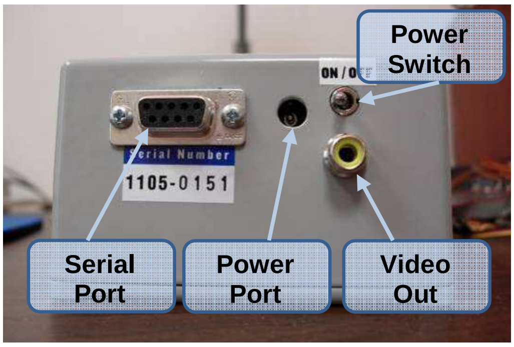


Figure 3-1 Commbox ports and connections

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

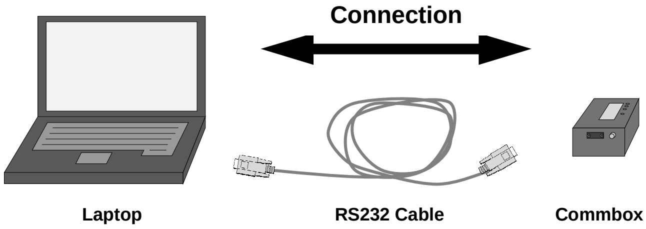


Figure 3-2 Commbox and computer connection

The Commbox power switch is located next to the RS232 port on the Commbox. On power-up, the Commbox verifies that its wireless modem is functioning correctly. If the modem is ready for use, an LED strobe (sequential flash of the LEDs in order) will occur. The LED strobe will not occur when the Commbox is powered on if the modem is not functional or is disconnected. Table 3.1 and Table 3.2 describe the LEDs.

Table 3.1 Commbox LEDS

LED Label	Description
VC	Virtual Cockpit communication
RC	RC transmitter communication
MODEM	Autopilot communication
BATTERY	Charge state
POWER	Power ON / OFF

Table 3.2 Commbox BATTERY LED

Power LED Condition	Battery Status
Green	Charged
Amber	Charging
Green & Red Blinking	Low Battery
Red Blinking	Critically Low

3.2 Video Overlay

The Commbox has the ability to overlay UAV text information on an NTSC video signal. The video signal must be run through the Commbox. For typical use, a cable will be connected to an analog video receiver output and to the Commbox video overlay input (next to the Commbox RF antenna connection). Another video cable will connect the video overlay output (next to the power switch) to a video recorder or capture device. Video In and Video Out are shown in Figure 3-1. Figure 3-3 is a still image taken from video with overlay. If multiple UAVs are being flown from the same ground station, then the video overlay data will correspond to the agent that has the RC check box checked in the Virtual Cockpit.

Figure 3-3 Video Overlay Example

DATE
TIME
Battery Voltage
UAV Mode
MAG Heading
GPS Satellites

Figure 3-4 Top Left Overlay Cluster

GPS Latitude
GPS Longitude
Home Range / Bearing
Altitude / Airspeed
Comm Packets/Second

Figure 3-5 Top Right Overlay Cluster

Figure 3-4 and

Figure 3-5 provide a description of the UAV information that is shown in the video overlay. Distances and speeds such as range to home, altitude, and airspeed are in metric units (meters and meters per second) Angles such as bearing to home and heading are in degrees.

The video overlay option is available from Procerus. It requires that a bob-4 device be installed into the Commbox. Please call for pricing information.

Table 3.3 Overlay Field Description

Overlay Field	Description
DATE	GMT date.
TIME	GMT time.
Battery Voltage	UAV autopilot voltage.
UAV Mode	Current UAV Mode shown as the following three letter acronyms: • MAN – Manual Mode. • ALT – Altitude mode. • TKO – Takeoff. • NAV – Navigating to waypoints.

	• LTR – Loitering about current position. • RLY – Flying to Rally waypoint. • LND – Landing.
MAG Heading	Magnetometer heading in degrees.
# GPS Satellites	The number of GPS satellites.
GPS Latitude & Longitude	Decimal degree global position of UAV.
Home Range / Bearing	The distance and heading from home to the UAV.
Altitude	UAV altitude in meters.
Airspeed	UAV airspeed in meters per second.
Comm Packets/Second	Signal strength indicator, the number of packets per second received.

3.3 Commbox GPS

An external GPS may be purchased from Procerus Technologies and connected to the Commbox for use in identifying the ground station and home position. Figure 3-1 shows the GPS port where the external GPS plugs into the Commbox. The Commbox GPS allows for Convoy Following operations.

3.4 Antenna Pointer

The Commbox can be configured to support a pan/tilt antenna pointer. These are typically used for aiming a directional video antenna to improve video reception. The antenna pointer will aim at the currently selected video agent. As of version 2.0.7 of the Commbox firmware and release version 2.5 of Virtual Cockpit, Procerus supports the Directed Perception PTU-D46-17 pan/tilt antenna pointer system. To use this capability, the Commbox firmware and Virtual Cockpit must be updated to at least the versions mentioned above.

To integrate an antenna pointer into the system, some simple calibration steps are necessary. This is primarily due to the fact that the antenna pointer does not have a heading sensor to determine its orientation. This guide details all the steps for installing the system as well as initialization steps that need to be performed each time the Commbox is rebooted.

3.4.1 Installing the Antenna Pointer

Antenna pointer installation is very simple. First, make sure the Commbox firmware version is greater than 2.0.7. This can be checked by turning the Commbox on, connecting to Virtual Cockpit and selecting **Help > About Virtual Cockpit**. The first time the antenna pointer is used, it is necessary to configure a few special options. To do so, first verify that Commbox communication is functional by looking at the Messages window in Virtual Cockpit. Next to the word Commbox, you should see a temperature and voltage reading.

To control the Directed Perception Pan-Tilt unit, the programming cable coming from the Commbox should be connected to a null-modem adapter on the Pan-tilt controller as pictured in Figure 3-6. The Commbox firmware may be configured to use Serial Port A or Serial Port C, and the appropriate firmware must be installed for this to work properly.

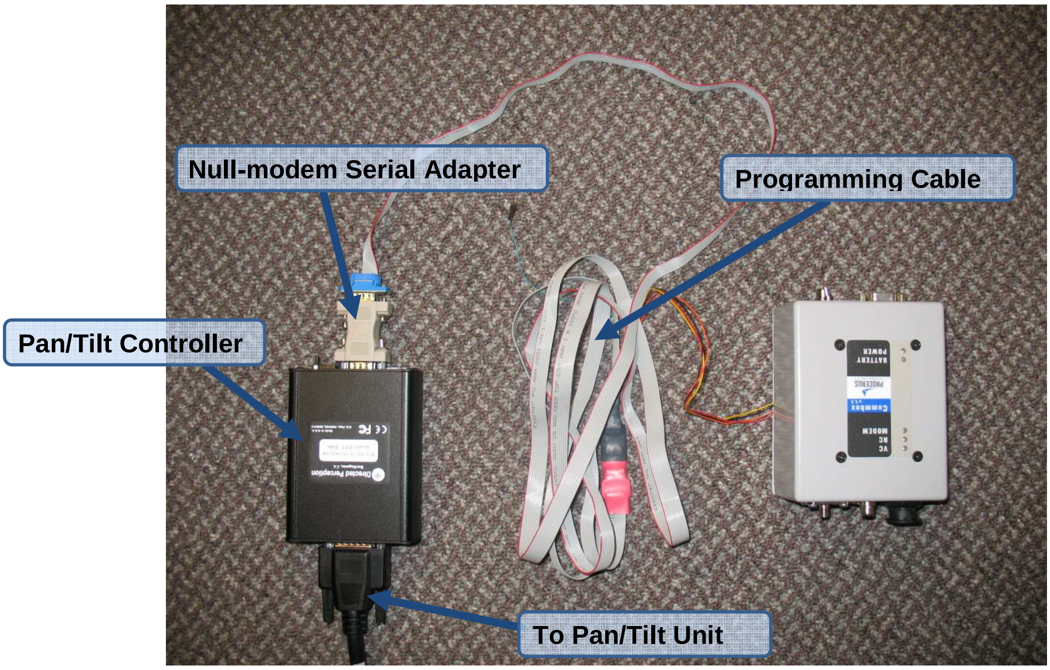


Figure 3-6 Connection from Commbox to Pan/Tilt Antenna Pointer

Click the F6 key to go to the Commbox settings screen. Towards the bottom of the screen, select the checkbox which says Enable Ant Pointer. In the screen above it, several values should download. If they have not downloaded, hit “Request All Values.” Scroll down to the bottom of this list and you should see values for “Antenna Pointer Type”, “Tilt Cal”, and “Test Desired Tilt”. If there is an error in reading these values, this indicates that the Commbox firmware is outdated and needs to be updated.

Once all of the values have downloaded, the combo box labeled “Type” indicates the currently selected antenna pointer type. If it is incorrect, change it to the correct value (PTU-D46 for the Directed Perception controller). Then, update flash. You can now hook up the antenna pointer to the Commbox and turn on power. The pan/tilt unit goes through a startup sequence where it moves to each extreme on the tilt and pan axes and ends at the zero point. The Antenna Pointer Messages screen should now read “D NOT SET”, and a similar message appears in the Virtual Cockpit Messages window. This indicates that the current orientation of the antenna pointer pan axis has not been set. We are now ready to calibrate the antenna pointer.

3.4.2 Antenna Pointer Calibration

Each time the Commbox is rebooted, it is necessary to recalibrate the pan axis. The calibration is stored in non-volatile memory, however, making calibration very simple. Turn on the Antenna Pointer Settings screen by going to **View > Antenna Pointer Settings**. To calibrate the pan axis, navigate to the right-hand pull-out of Virtual Cockpit. The Heading window will be orange before the axis is calibrated. Make sure that the Track checkbox is NOT selected and enter in the angle at which the front of the antenna pointer is currently facing (in degrees from 0-360). (The angle to enter in can be read off of a compass by aligning the compass to face north and reading off the direction that the front of the antenna is facing.) Then, turn the Track checkbox on. The antenna pointer will attempt to point at the selected agent or will go to a zero pan angle if no agents are present. You can continue to fine-adjust the angle until it is correct by turning off the checkbox, entering the current pan orientation, and rechecking the checkbox. If the pan axis does not move, verify that the antenna pointer unit is powered and that the Drive Enable button in the Commbox Settings screen is enabled. When the Commbox is properly calibrated, update flash to save the value.

The tilt axis also needs to be calibrated. This can be done by adjusting the “Tilt Cal” Commbox variable in the Commbox Flash menu (enter angle offsets in radians). To test both the pan and tilt axis, it can be useful to input a desired angle for pan and tilt. To do so, tracking (auto point) must be disabled and drive must be enabled. Then, you can change the “Ant Desired Hdg (rad)” value and the “Test Desired Tilt (rad)” values to test the pan and tilt axes respectively. The tilt calibration value should not need to be changed after the first calibration.

3.5 RC Transmitter

An RC transmitter may be used to manually fly the UAV. The RC transmitter provides stick-to-surface control in any mode. This is useful for pure pilot-in-the-loop manual control, or for influencing the control of the aircraft in any of the autonomous modes. When the RC transmitter is plugged into the Commbox, the stick deflections are sent to the aircraft and summed into the servo commands. This allows the experienced user to maintain direct control of the aircraft while tuning the various PID control loops. Any Futaba or Hitec RC airplane transmitter with 6 or more channels will work.

The RC transmitter is also used to enable or disable RC Mode control and enable the motor in Takeoff Mode. Channel 5 is used for this purpose. When the channel 5 pulse is longer than 1500 μs, the normal autopilot modes are enabled, when the pulse is shorter than 1500 μs, the normal autopilot modes are disabled and RC Mode is enabled.

In RC Mode, the autopilot is controlled using stick to surface commands with the autopilot providing rate feedback to help stabilize the aircraft. The user can turn off the rate feedback in RC Mode if desired. RC Mode is useful for quickly taking control of the aircraft during gain tuning or development. The transmitter is not needed for normal autonomous flight and can be unplugged or turned OFF when not needed. It is advisable, however, to keep the RC radio in the loop for safety purposes.

Figure 3-7 Commbox and RC controller, RS232 cable, power adapter

It is highly recommended that the trainer cable be strain relieved to the back of all RC transmitters by using the WM-2A self-adhesive cable mount, as shown in Figure 3.7, to prevent damage to the trainer cable connector and to prevent the cable from being inadvertently unplugged from the transmitter box during flight. The WM-2A mount is available for free from Procerus Technologies.

Figure 3-8 Trainer cable strain relieved to the back of RC Transmitter

The Virtual Cockpit is a Windows-based ground control software system for the Kestrel autopilot system. The Virtual Cockpit allows the operator to configure, monitor, issue commands to the autopilot and Commbox, upload flight plans, and change waypoints, all while UAVs are in the air. This chapter describes the Virtual Cockpit and its various features, as summarized below.

- Simplified user interfaces
- Multiple Geo-referenced maps
- Terrain Elevation Data
- Easy to use Mode support
- Point and click waypoint editing
- In-flight mission reprogramming and waypoint uploading
- In-flight gain tuning
- Flight plan save / retrieve
- Multi-vehicle support (real-time sensor data and flight information on all vehicles)
- Precision data logging
- User-configurable failsafes
- Video capture and still shots
- Telemetry data playback
- Hardware-In-the-Loop simulation
- Integration screens
- Convoy Following support
- Altitude and airspeed override
- Take off timer for single user operation
- Adjust default waypoint settings for different airplane setups
- Password protection on settings screens
- Units of measure – user selectable: Metric, English, Nautical
- User adjustable gamepad setup
- Quick and easy waypoint upload using waypoint pop up box
- Ability to support an 8^{th} servo channel through the Virtual Cockpit
- All settings are stored in XML to facilitate different Virtual Cockpit setups

3.6 System requirements

- Microsoft Windows XP and Vista
- 128 MB RAM.
- 20 MB free hard drive space.
- DirectX 8 compatible video card with at least 8 MB video RAM.
- DirectX 9.0c April 2006 runtime
- 700 Mhz or faster CPU.
- Video Capture
  - (optional) VCE Pro PCMCIA video capture card for video recording.
  - (optional) WDM streaming capture device (recording not available)
  - (optional) Analog or digital capture device (digital camera, DV deck, etc.)

3.7 Installation

Run setup.exe and follow the onscreen prompts. By default, the Virtual Cockpit will be installed in the C:\Program Files\Procerus Technologies\Virtual Cockpit directory.

3.8 Initial Setup-up

The following sections will take the user through basic initial setup of the virtual cockpit.

3.8.1 Adding agents

The first time the Virtual Cockpit is run after installation, the Virtual Cockpit will insert a default UAV agent of 1032. In order to communicate with an autopilot, the agent address entered in the Virtual Cockpit must match the agent address stored on the autopilot. The address in the Virtual Cockpit may be changed by accessing the Edit Agents List dialog through the Menu Selection **Agents** → **Edit Agent List**. Each autopilot is shipped with a factory default address of 1032. For directions on changing the autopilot's address stored in onboard flash memory consult Multi-Agent Control in Chapter 6. In the Edit Agent List dialog box shown in

Figure 3-9, you may specify the name and color of the UAV but they are not required and are only useful for association of Virtual Cockpit agents with actual UAVs. The HIL, SIL and MIS check boxes are used when adding simulated agents to the Virtual Cockpit as described in Chapter 7. The video channel box is only used when the Commbox is configured for video receiver channel switching.

Figure 3-9 shows the Edit Agent dialog box.

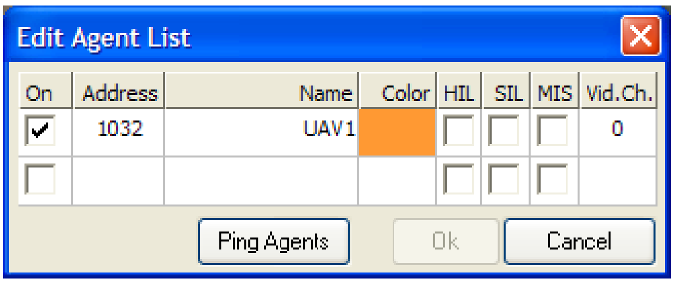


Figure 3-9 Edit Agent dialog box

3.8.2 Opening the serial port

The Virtual Cockpit will automatically open the last serial port used by default. If the default port is not correct, select the appropriate serial port. Serial port settings may be accessed under the Virtual Cockpit **Settings > Comm and XML** drop-down menu, or by pressing **F7**.

A list of the available serial ports will be displayed. This may vary depending on your computer configuration. For example, if using a connected USB to RS232 converter, the serial port may be listed as COM4. Figure 3-10 shows the serial port dialog.

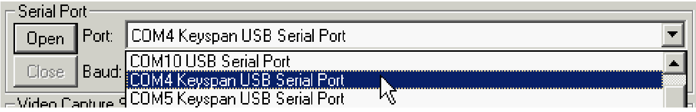


Figure 3-10 Selecting and opening the serial port

If the serial port is available, the serial port will open automatically upon selection from the drop-down list. If the serial port does not open, it is either in use by another program or not functional.

3.8.3 Adding map images

The Virtual Cockpit has the ability to display geo-rectified images in the map display. This greatly aides in flight plan preparation and in monitoring a UAV's location during flight.

To add a geo-rectified image to the map display, select "Map Settings" from the "Settings menu. Press the "Add" button on the dialog that appears to open the Add Map Item dialog. Select "Color Image" from the Map Type drop-down list and then press "Load" to browse to the image file location.

In order to properly geo-locate map images, the Virtual Cockpit uses a world file (.wf) for each image. A world file is a text file which specifies the geographic location of the upper-left corner on an image as well as the resolution, in pixels/meter, along the width and height of the image. When an image is added to the map, the Virtual Cockpit will attempt to automatically load a world file of the same name as the image, with a .wf extension. If no world file is present, the world file parameters can be manually entered into Add Map Item dialog.

The easiest way to generate geo-rectified images and world files is to use the MapMaker utility included with the Virtual Cockpit installation. The MapMaker utility can capture images directly from Google Earth™, or by defining a set of control points it can be used to geo-rectify an aerial image. Refer to the *Map Acquisition Guide* for more information on the MapMaker Utility and obtaining geo-rectified images. More information on the Virtual Cockpit map settings is available in the Virtual Cockpit help file.

3.8.4 Adding terrain data

The Virtual Cockpit uses terrain elevation data in order to calibrate the aircraft's altitude and height above ground. Terrain data in either the NSGS Grid Float or DTED formats can be used. Similar to map images, terrain elevation files are added using the Map Settings dialog.

See the Virtual Cockpit help file for more information on adding terrain elevation files. For information on acquiring terrain elevation data files refer to the *Map Acquisition Guide*.

3.9 Main Window

The main window of the Virtual Cockpit is designed to provide easy access to the most frequently used buttons and status information. Lower level aircraft specific information is accessible through drop-down menus and dialogs. Figure 3-11 shows the Virtual Cockpit main window.

Note: The Virtual Cockpit has a number of buttons that change color to indicate the current state of the Virtual Cockpit and selected UAV.

- If the button color is red, it signals that a change has been made in the Virtual Cockpit but that the button needs to be pressed for the change to take effect.
- If the color of the button is yellow the Virtual Cockpit has sent the corresponding information to the autopilot and is waiting for a response.
- If the button remains yellow for a large amount of time, it is possible that the communication link with the autopilot is poor which may require diagnosis.

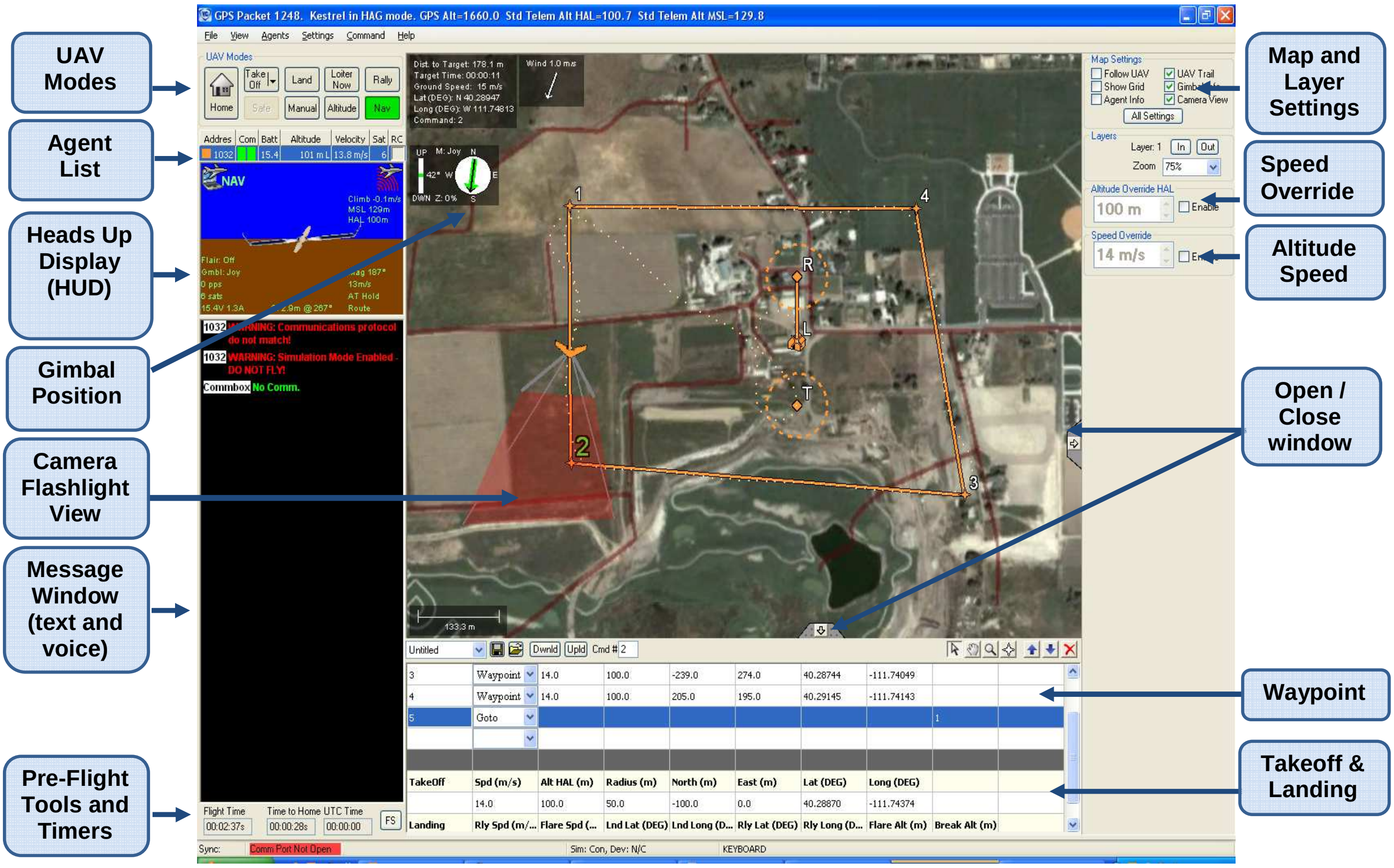


Figure 3-11 Virtual Cockpit main window

3.10 Map & Flight Plan

The Map window is used to monitor the position and navigational status of the UAV and to manage the flight plan. The Map displays the position of all agents and their waypoints. Each agent, and the associated set of waypoints, has a unique color. The information in the flight plan, status, wind, and keyboard control is for the selected agent only. Figure 3-12 shows the map portion of the main Virtual Cockpit window. The map can be customized and configured using the Map Settings window.

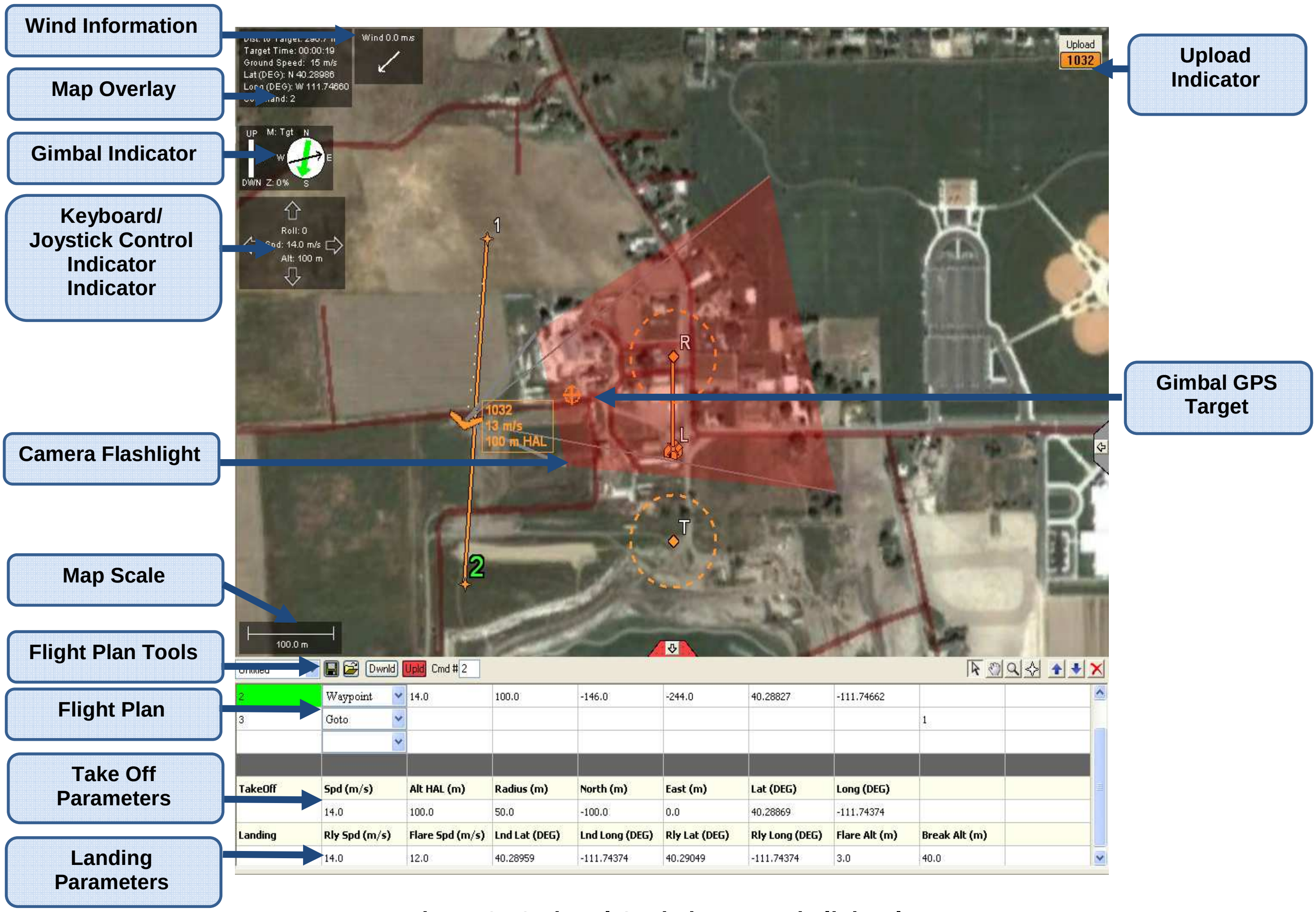


Figure 3-12 Virtual Cockpit Map and Flight Plan

3.10.1 Flight Plan

The Flight Plan list in the map window contains the information about each waypoint or loiter point in the flight plan. There are three types of commands that can be used in a flight plan, listed in Table 3.4. All commands except the **Goto** command have an associated altitude and airspeed. These values can be changed by double-clicking on the waypoint or by editing the value in the Flight Plan window. To enter a command in the flight plan either, right click on the map window and select Insert Commands, or click in a blank row in the flight plan window and select a flight item type from the **Type** dropdown menu. Multiple waypoints can be quickly added by either clicking the add waypoint icon in Flight Plan window and then clicking on the map, or by holding down the CTRL key while clicking on the map.

A group of flight items makes up a *route*. The last item in a route is always a Goto command which tells the UAV which command to jump to in order to restart the route. On the map display a route appears as a set of connected waypoints and loiter points that form a loop. To create a route, add a series of waypoints and loiter points to the map. The Virtual Cockpit will automatically connect these points to form a route. When all of the desired points have been added, right-click on the map and select Insert Commands->Finish Route. This causes the Virtual Cockpit to add a Goto command after the last route item. The Goto command will cause the UAV to return to the first item in the route and then continue executing the route. Once a route has been finished a new route can be added by adding flight items to the map. During flight the UAV will continue to fly its current route until the operator commands it to execute a new route by double-clicking on an item in the desired route in the Flight Plan window.

After the flight plan has been entered, use the **Upload** button in the Flight Plan Tools, or click the Upload Indicator button, or right click on the waypoint and select **Upload Flight**. The flight plan is executed in Nav Mode. All waypoints have an associated legal position given in latitude and longitude. For user convenience, a separate field for relative waypoint placement is given. This position indicates the position of the waypoint relative to home in meters north and east. Note: The position is correct as long as the home point is not moving, such as the case in convoy following.

Table 3.4 Flight plan item types

Name	Description
Waypoint	Fly to waypoint location.
Loiter	Orbit waypoint with specified radius.
Goto	Causes flight plan to execute (jump to) specific command.

3.10.2 Search Areas

The Virtual Cockpit has the ability to define *search areas* in order to make it easier to command a UAV to fly over and image a particular area of interest. To create a search area, either click the add waypoint button in the Flight Plan window, or hold down the CTRL key and then click and drag the mouse in the map window to define the search area. The Virtual Cockpit will place a yellow square over the map to mark the search area. It will also create a series of waypoint commands which direct the aircraft to fly over the entire search area. The algorithm which generates these waypoint commands depends on a number of configurable parameters which are summarized in Table 3.5. Once the waypoints have been created, the user must upload them to the Kestrel Autopilot before the aircraft can fly the route.

Table 3.5 Search area parameters

Parameter	Description
Airspeed	The default waypoint airspeed is used. Set in the “Comm and XML Settings” setup screen.
Altitude	The default waypoint altitude is used. Set in the “Comm and XML Settings” setup screen.
Wind Speed	The latest wind data reported by the Kestrel Autopilot is used unless wind override is turned on (see below).
Wind Direction	The latest wind data reported by the Kestrel Autopilot is used unless wind override is turned on (see below).
Percent Overlap	The amount of overlap between images in successive passes of the search area. Set in the “Comm and XML Settings” setup screen.
Turn Around Time	The number of seconds required for the aircraft to make a 180 degree turn and then achieve steady, level flight again. Set in the “Comm and XML Settings” setup screen.
Camera Azimuth	Current camera azimuth settings as reported by the Kestrel Autopilot.
Camera Elevation	Current camera elevation settings as reported by the Kestrel Autopilot.
Camera HFOV	Camera horizontal field of view (in radians). Set in item P129 on the “Autopilot Variables” setup screen.
Camera VFOV	Camera vertical field of view (in radians). Set in item P129 on the “Autopilot Variables” setup screen.
Max Viewing Angle	Maximum viewing angle (in degrees) from vertical above which image pixels are considered too low-resolution to be useable. Used to determine how far the aircraft must fly during a pass before it has imaged an entire strip of the search area. Set in the “Comm and XML Settings” setup screen.

3.10.2.1 Wind Override

The aircraft is strongly affected by the wind speed and direction at the altitude that it is going to be flying. For this reason, the code the computes the search pattern takes the wind into account. Unfortunately, the wind on the ground rarely matches the wind at the flying altitude. For this reason, a Wind Override has been added to the Virtual Cockpit.

The Wind Override allows the user to tell the Virtual Cockpit what the wind direction and strength is at flying altitude for each agent before the aircraft is launched (perhaps you know it from a previous flight). This allows the VC to compute the search pattern using known wind values at altitude, and results in more accurate coverage of the search area.

To set the Wind Override, right-click on an “empty” area of the map, and choose “wind override” in the popup. Type in the wind direction and speed, and hit the OK button. The wind indicator in the upper left-hand corner of the map will turn red, with the word “OVERRIDE!” displayed to help you remember that wind override is in effect. A “Wind Override On!” message is also displayed in the message window.

To turn the Wind Override off, right-click on an “empty” area of the map and choose “wind override” in the popup again, to uncheck it.

Note that Wind Override will automatically turn off when the aircraft starts reporting valid wind information after takeoff.

If you want to change the current Wind Override setting, turn Wind Override off and then turn in on again, entering in the new values.

3.10.3 Takeoff Parameters

The Takeoff Parameters are the settings used by the autopilot in Takeoff Mode. These settings are uploaded with the flight plan using the **Upload Flight Plan** button. Table 3.6 describes the Takeoff Parameters. Advanced parameters such as the Takeoff Pitch and Takeoff Transition Altitude can be adjusted by the experienced user in the Aircraft Configuration Window.

Table 4.1 describes the Takeoff Mode in more detail.

Table 3.6 Takeoff Parameters

Name	Description
Airspeed	The commanded airspeed during takeoff
Altitude	The altitude at which the UAV will transition to Nav Mode.
Spiral Radius	The radius at which the aircraft will orbit as it climbs.

3.10.4 Landing Parameters

The Landing Parameters are the settings used by the autopilot in Landing and Rally Mode. These settings are uploaded with the flight plan using the **Upload Flight Plan** button. Table 3.7 describes the Landing Parameters. Other parameters such as the rally point radius and descent rate can be adjusted by double-clicking on the Rally Point.

Table 3.7 Landing Parameters

Name	Description
Rally Vel	The commanded airspeed during the fly to and circle down stages of the landing sequence.
Flair Vel	The commanded airspeed during the final glide slope stage of the landing sequence.
Land Lat	The position of the landing point in decimal degrees latitude. This is the point where the aircraft will attempt to touchdown.
Land Long	The position of the landing point in decimal degrees longitude. This is the point where the aircraft will attempt to touchdown.
Rly Lat	The position of the Rally point in decimal degrees latitude. This is the point that the aircraft will fly to in Rally Mode and circle around in landing mode.
Rly Long	The position of the Rally point in decimal degrees longitude. This is the point that the aircraft will fly to in Rally Mode and circle around in landing mode.
Flair Alt	This is the height at which the aircraft will disable the motor.
Break Alt	This is the height at which the aircraft will break out of the spiral descent around the Rally point and enter the glide slope to the landing point.
Radius	This value is only available by double-clicking on the Rally. It is the radius in meters of the spiral descent.
Rate	This value is only available by double-clicking on the Rally point. It is the descent rate used during the spiral descent.
Land Type	The Kestrel Autopilot supports multiple types of landings. By default only the normal rally land is enabled. To enable the other types of landings go to the VC Settings, Comm and XML settings (F7) and activate the check boxes. The supported landing types are listed below.

	- Normal – Rally Land. UAV flies to rally point and circles down to a breakout altitude. The UAV then flies down a glide slope path to the landing point. - Parachute – UAV flies to rally point and descends. It then flies to the pre-computed parachute “pop” point and releases its parachute and cuts engine. The landing point is the approximate location where the UAV will land. - Deep Stall – UAV flies to rally point and descends. It then flies to the pre-computed deep stall “initiatate ‘pop’ point” and deep stalls the UAV. The landing point is the approximate location where the UAV will land.

3.11 Advanced Settings

The Virtual Cockpit contains a number of settings windows to aid in configuring the autopilot, the comm. box and the Virtual Cockpit itself. These settings windows are contained within a Global Settings dialog which can be activated by selecting any of the items from the **Settings** menu. The windows in the Global Settings dialog are grouped into three categories: UAV, Commbox and Virtual Cockpit.

3.11.1 UAV Settings

The UAV group contains windows that allow users to access any of the configurable autopilot parameters. These windows can be accessed at any time by pressing the F5 key. Any changes made to settings in these windows directly affect the autopilot and must usually be uploaded before taking affect.

The UAV Settings windows only display status and configuration information for the UAV currently selected in the Main Window Agent List. For more information on the individual UAV settings windows see the Virtual Cockpit Help file. For information configuring the Kestrel autopilot refer to the *Installation and Configuration Guide*.

3.11.2 Commbox Settings

The Commbox settings windows allow users to see current Commbox status and set any configuration options. These windows can be accessed at any time by pressing the F6 key. For more information on individual Commbox settings windows see the Virtual Cockpit help file. For information on configuring the Commbox refer to the *Installation and Configuration Guide*.

3.11.3 Virtual Cockpit Settings

The Virtual Cockpit settings windows allow users to control the behavior of the Virtual Cockpit. These settings include default values, map display, video settings, keyboard/joystick settings and audio warnings. Pressing the F7 key at any time will display the Virtual Cockpit settings windows. For more information on the individual settings windows refer to the Virtual Cockpit help file.

3.12 Replay Window

The replay window allows the user to debug and watch characteristics of a previous flight in the Virtual Cockpit. The Virtual Cockpit will view the replayed data log as if it were an actual flight so all warnings and failsafe triggers that may have occurred in the replay data log will appear during play back.

When a replay file is loaded, as shown in the next section, a replay agent is added to the agent list. This method allows the Virtual Cockpit to simulate another flight without interfering with agents that are already added to the list and data logging. Also when a replay data log is loaded the Virtual Cockpit will automatically close any open comm port and simulator socket connection. This guarantees that there will be no interference between the replay agent and previously added agents. When the replay window is closed, after the user has finished, the comm port will automatically be reopened by the Virtual Cockpit.

3.12.1 Using the Replay Feature

To open the replay window go to the **View menu->Replay Window**. Figure 3-13 shows the different controls available with the replay window.

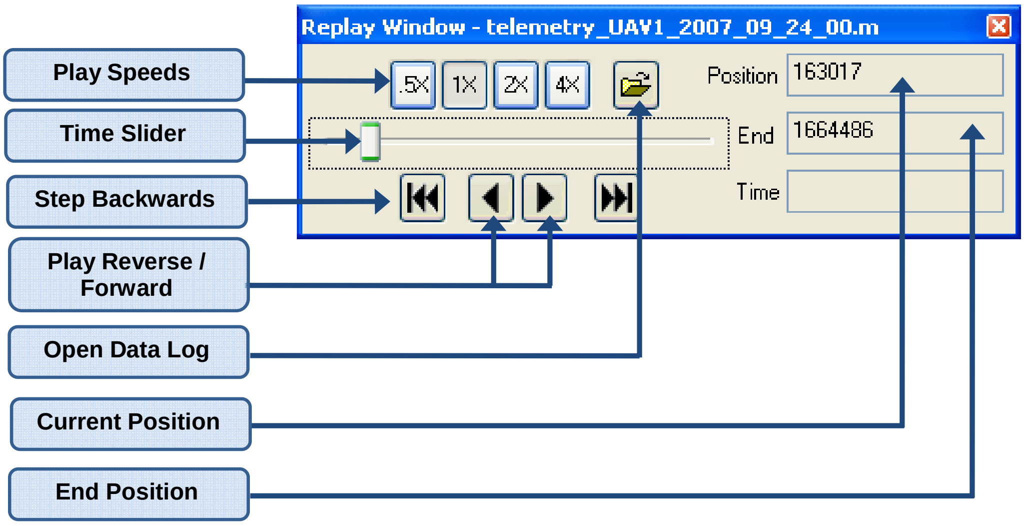


Figure 3-13 Replay Control Window

Click the **Open Data Log** button to browse for the data log that will be replayed.

Note: By default the Virtual Cockpit stores the data logs in the program installation folder under **C:\Program Files \ Virtual Cockpit \ Datalogs** and only Matlab standard telemetry files can be replayed.

After the file is selected, the replay window will verify that the file is valid and will scan through the file looking for the total duration. The total duration is then placed in the End Position, with units in milliseconds.

From here users can press **Play Forward** at .5X, 1X, 2X, and 4X speeds. Pressing the **Play** button again will cause the replay to pause. The user can also reverse play the data log. At any time the slider may be grabbed and moved to a position in the data log. When the user presses the **Close** button in the top right corner of the Replay Window the data log will be closed and the Virtual Cockpit will be reset to its previous settings.

3.13 Viewing video in the Virtual Cockpit

The Virtual Cockpit has a built in Video Window for real-time display and capturing of video from a UAV. The Video Window supports real-time video playing and single image grabbing of any Direct Show WDM streaming device.

To display video in the Video window (F8), the user must select the correct video capture device from the Devices list menu. Next the user must click the Preview button to start real-time video playing in the Video window. To capture a snapshot from the current video stream, the operator can simply click the Snap button on the Video Window or on the Gamepad (see Figure 3-14 and Figure 4-1).

The Virtual Cockpit currently only supports recording with the PCMCIA video capture card "VCE-PRO" provided by Imperx. This capture card provides clear video with less than 50 millisecond latency. Figure 3-14 shows the Video Window used when a VCE-Pro card is inserted before starting the Virtual Cockpit. Figure 3-15 shows the Video Window when using a different capture device that is DirectShow compliant.

Figure 3-14 Video Window with VCE-Pro frame grabber

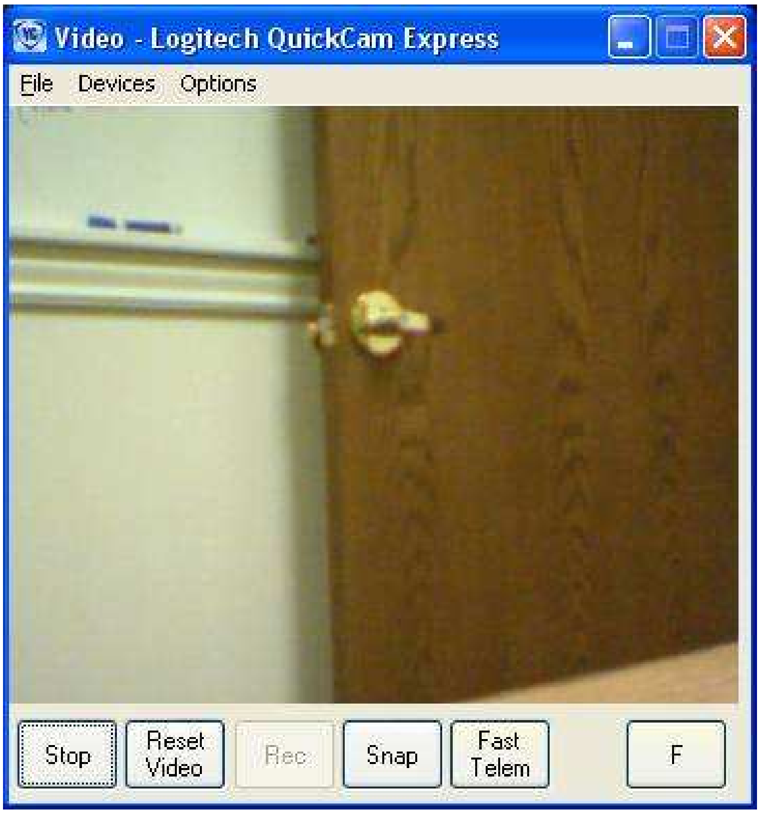


Figure 3-15 Video Window using DirectShow capable capture device

4 Using the UAV Modes

With the introduction of Kestrel autopilot firmware version MA5, the autopilot supports different levels of autonomy which are represented as autopilot Modes. Currently there are 15 different modes supported. The modes allow the user to quickly change autopilot behavior through a single click in the Virtual Cockpit. There is a pilot-in-the-loop mode which gives the user direct control of the aircraft control surfaces via the RC Controller. This mode is used for gain tuning, algorithm development, and cases where manual flight is required. The user can enable rate damping in this mode as an assist to the pilot. This mode is known as *RC Mode*. RC Mode is enabled via the channel 5 switch on the RC controller. In RC Mode, all other modes are disabled.

To fully utilize the available UAV modes a gamepad/joystick is required. The gamepad that is fully supported by the Virtual Cockpit is the Logitech Dual Action Gamepad, and is available from Procerus Technologies or through other suppliers. This chapter will discuss each of the individual UAV modes, giving them thorough explanation along with detailed controller mapping. The only mode that will not be detailed in this chapter is RC Mode, in which case the UAV is controlled completely by the RC controller (stick to surface control).

4.1 Manual Mode

Manual Mode is a semi-autonomous mode in which the control of the aircraft's roll, airspeed, and throttle is given to the ground station operator through the gamepad. The autopilot maintains the command airspeed at all times to prevent the vehicle from stalling. The autopilot also maintains the command roll angles to prevent over banking.

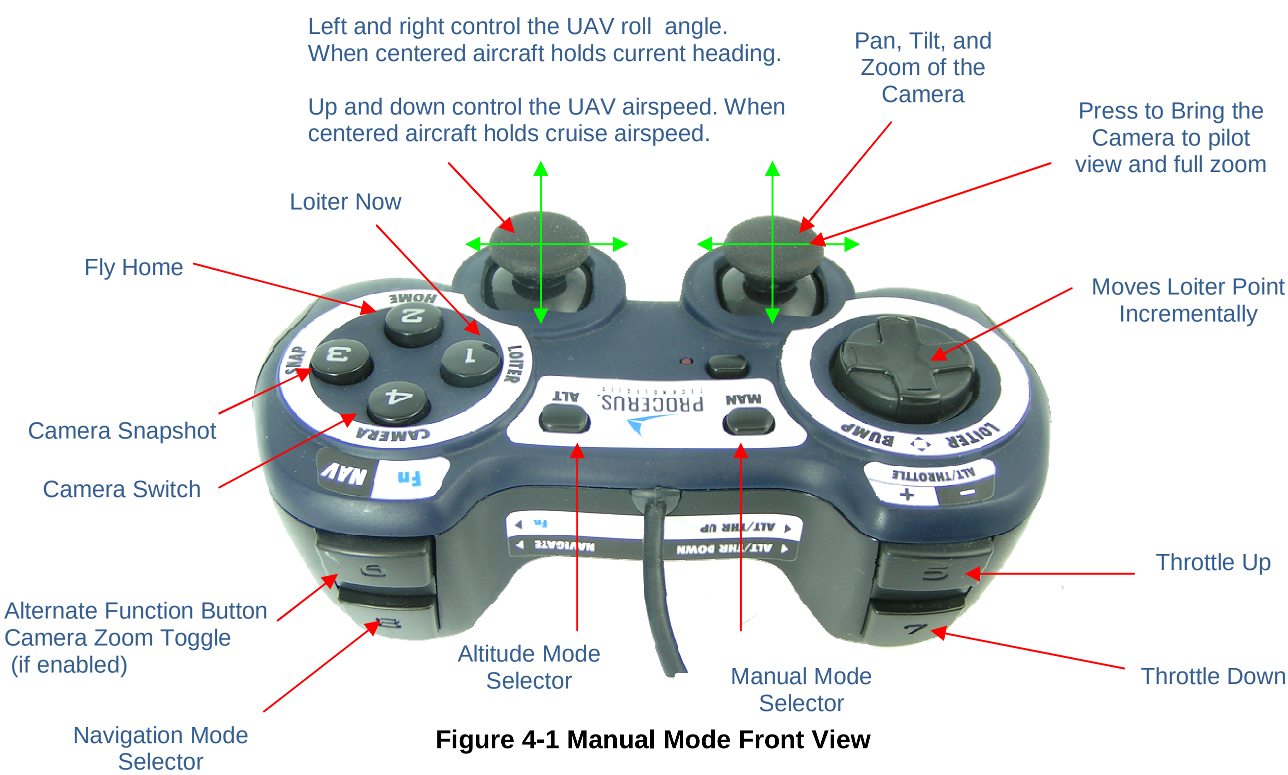


Figure 4-1 Manual Mode Front View

The user is given complete control of the throttle using the gamepad. This mode is useful for manually landing the aircraft or maneuvering in small or obstructed flying fields. Figure 4-1 shows the gamepad controls during Manual Mode operation.

Manual Mode is very useful for when a user wants to manually land a UAV. By controlling the throttle of the aircraft the ground operator can lower the UAV's altitude quickly while guiding it into the land point using roll commands from the right stick. By pressing forward and backward the operator can cause the UAV's airspeed to change and effectively flair the vehicle near touchdown.

4.2 Altitude Mode

Altitude Mode is another semi-autonomous mode that heavily uses the gamepad. In this mode, the operator is in control of the desired altitude and roll angles, while the UAV manages the throttle to maintain the airspeed. In this mode the user does not need to be concerned about maintaining a constant altitude since the autopilot takes care of it. Altitude Mode will be the most used semi-autonomous use among ground station operators.

Figure 4-2 and **Error! Reference source not found.** show the gamepad controls during Altitude Mode operation.

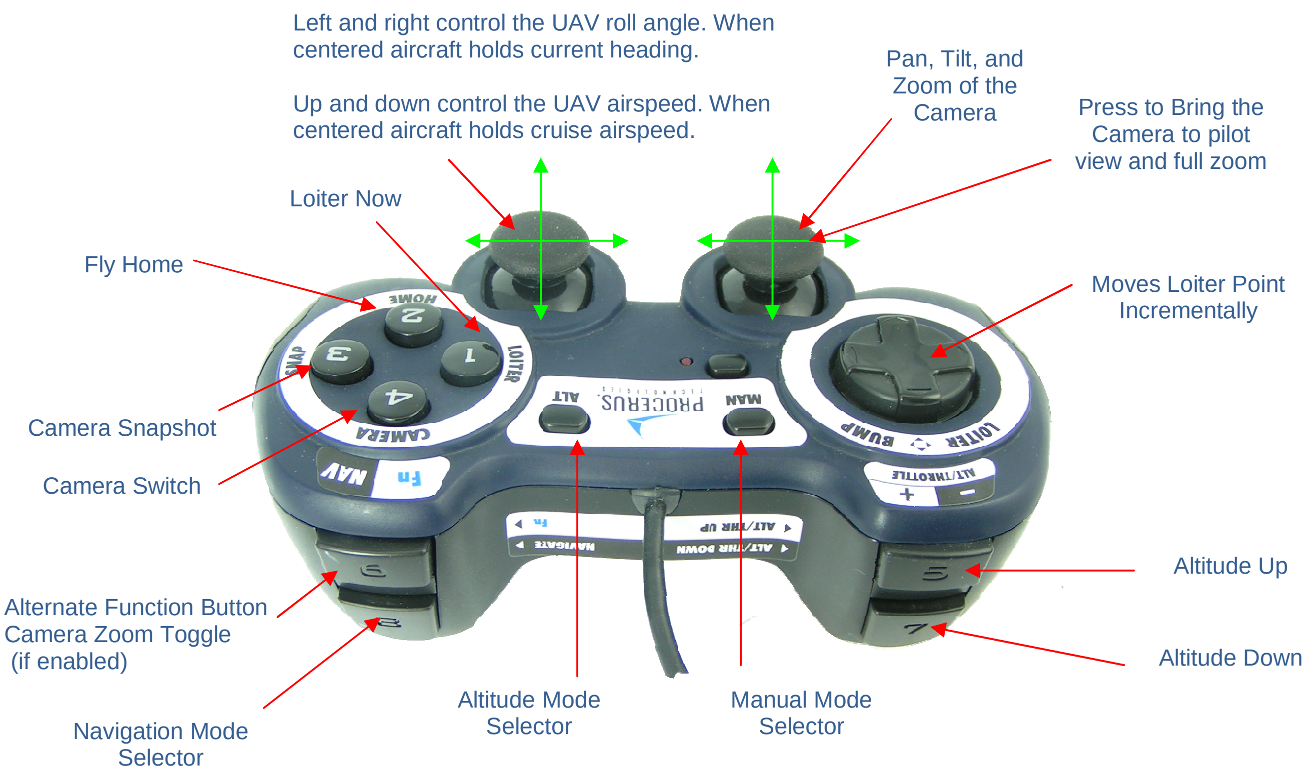


Figure 4-2 Altitude Mode Front View

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4.3 Takeoff Mode

Starting with the Kestrel firmware version MA6, the autopilot has 3 different takeoff modes. The different modes can be command by clicking on the **Takeoff** button on the main Virtual Cockpit screen, and then selecting the desired takeoff mode. A brief description of the 3 different modes is given in

Table 4.1.

Ground station users who do not have additional help in launching may wish to use the Takeoff countdown timer. This allows users to click the **Takeoff** button and wait for a specified period of time before the throttle starts. The last two seconds of the takeoff timer are used to throttle up the propeller to 20% to give the person throwing the airplane a warning. The takeoff countdown time remaining can be seen on the **Takeoff command** button when initiated. Users can enable or disable this feature through the Autopilot Config window from **Mode Configuration->Takeoff Mode->Count Down Timer**.

Table 4.1 Takeoff Mode Descriptions

Mode	Description
Takeoff Spiral	1. The first stage of takeoff causes the UAV to fly a fixed throttle percentage and fixed pitch. During this stage, users can temporarily change the pitch by using the gamepad. Once the UAV reaches a predefined speed or the rotate altitude it transitions to the second stage. 2. During the second stage of takeoff, the UAV loiters around the GPS location that it recorded when it reached the second stage and continues climbing to the desired altitude. 3. Once it reaches the desired altitude specified in the takeoff loiter, it automatically transitions to navigation mode.
Takeoff Waypoint	1. The first stage of takeoff causes the UAV to fly a fixed throttle percentage and fixed pitch. During this stage, users can temporarily change the pitch by using the gamepad. Once the UAV reaches a predefined speed or the rotate altitude it continues to the second stage. 2. During the second stage of takeoff the UAV continues to fly wings level until reaching the takeoff transition altitude. During this stage, users can control the aircraft's roll angle using the right stick on the gamepad. Users may also adjust the airspeed by pushing forward or pulling backwards on the right stick. When the user lets go of the gamepad, the UAV will continue back at the trim airspeed and wings level until reaching the transition altitude. Once the UAV reaches within the orbit radius of the takeoff waypoint, the user will no longer be able to manually control the aircraft. 3. During the third stage of takeoff the UAV flies to the uploaded takeoff loiter location. Users may adjust the airspeed by pushing forward or pulling backwards on the right stick. When the user lets go of the gamepad, the UAV will revert back to the trim airspeed. The UAV will continue to circle at the takeoff loiter indefinitely and maintain the desired altitude until commanded otherwise.
Takeoff Joystick	1. The first stage of takeoff causes the UAV to fly a fixed throttle percentage and fixed pitch. During this stage, users can temporarily change the pitch by using the gamepad. Once the UAV reaches a predefined speed or altitude it continues to the second stage. 2. During the second stage of takeoff, the autopilot maintains a zero roll angle while climbing to the desired altitude in the takeoff waypoint. Users can override the roll angle and airspeed using the right stick on the gamepad. 3. Once the UAV reaches the takeoff altitude, the autopilot transitions to Altitude Mode.

Controls for the gamepad in all takeoff modes are the same as Manual Mode and Altitude Mode with the exception of Throttle Up, Throttle Down, Altitude Up, and Altitude Down.

4.4 Land Mode

Land mode is an automated landing and approach for the Kestrel autopilot system. There are four stages associated with the normal rally land mode described below.

1. When commanded to land, the UAV flies to the previously uploaded Rally point at the current altitude and landing airspeed. Once it reaches within the orbit radius of the Rally point the autopilot transitions to stage 2.

2. During the second stage, the UAV circles downwards while holding an orbit. The descent rate can be adjusted in the Virtual Cockpit by double-clicking the Rally point and editing the appropriate field. When the UAV's altitude reaches the break out height, it maintains that altitude until the airplane's position reaches the backside of the loiter, away from the landing point.
3. The third stage of landing mode is the glide slope approach. During the glide slope approach users can adjust the path of the UAV using the right stick on the gamepad. This is useful for any unanticipated objects in the path. When releasing the joystick, the UAV recalculates its path to the landing point and continues on in a straight line fashion.
4. When the UAV is within 30 meters of the landing point or is underneath the flair height uploaded in the landing point the UAV flairs. The flair commands the UAV to hold a 0 degree roll with no throttle. During the flair the commanded pitch is the last pitch angle recorded before the flair condition triggered.

The gamepad can be used to adjust the flight path during the final approach phase of the landing. The user can control the roll angle and the airspeed. Roll and airspeed control is accomplished using the right stick of the gamepad.

4.5 Loiter Now

Loiter now mode is useful for users who are flying the UAV by camera and spot something that they would like to view for a longer period of time. There are different options for Loiter Now Mode that can be configured through the Agent Config Settings Window. These settings are described in Table 4.2.

Table 4.2 Loiter Now Configuration

Option	Location	Description
Camera Centric Loiter	Agent Config -> Mode Configuration -> Common ->Camera Centric Loiter Now	If enabled, causes the autopilot to check which camera is currently being viewed (side look or forward look). The UAV estimates the GPS location of the center of the field of view (FOV) of the camera and initiates a loiter about that point. The user can use the loiter shift option to fine tune the center of the loiter to place the object of interest in the field of view. If this option is not enabled the autopilot will loiter about the GPS position of the UAV when loiter mode was entered.
Optimal Radius Loiter	Agent Config -> Mode Configuration -> Common ->Optimal Radius Loiter Now	If enabled, causes the autopilot to compute the loiter radius that will maintain an object of interest in the center of the side look camera field of view. If the user changes the altitude using the gamepad or the override pull out menu, the autopilot will re-compute the optimum radius for that altitude. If this option is not enabled the autopilot uses the default loiter radius found in the Agent Config Window.
VC Calculated Optimal Radius Loiter	VC Settings->Comm and XML Settings	If enabled, causes the Virtual Cockpit to compute the loiter radius that will maintain an object of interest in the center of the side look camera field of view. This takes into account terrain elevation data (if loaded). If the user

		changes the altitude using the gamepad or the override pull out menu, the Virtual Cockpit will re-compute the optimum radius for that altitude. If this option is not enabled the autopilot uses the autopilot Optimal Loiter Radius or the autopilot default loiter radius found in the Agent Config Window.

Loiter Now can be command by either clicking on the **Command Mode** button in the Virtual Cockpit, or by pressing the **Loiter Now** button on the gamepad during any UAV Mode. See

Figure 4-3 and **Error! Reference source not found.**.

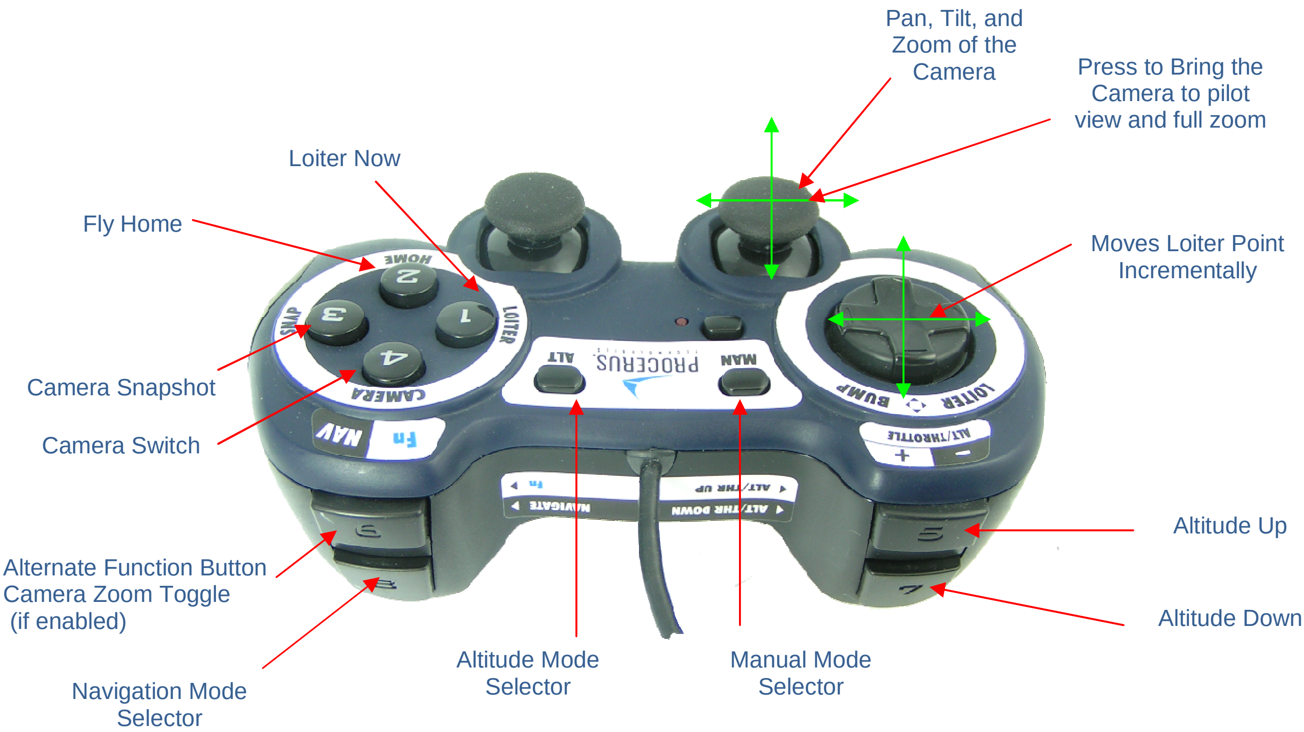

Figure 4-3 All Other Modes Front View

If the UAV is equipped with a side look camera, the ground operator can configure the autopilot to enable both the camera centric loiter and optimal radius loiter settings. This allows a unique feature inherit to the Kestrel autopilot that creates loiter circles that try to maintain the center view of the camera at the instant the Loiter Now command was received. The steps to setup the Loiter Now side look viewer are described below. Follow these steps to maximize the amount of eye on target video.

1. Navigate the airplane using the forward look camera to the general region that the ground operator wishes to view.
2. Switch to the side look camera using either the **A/B** button on the Video Window or press the **Video Switch** button on the gamepad (Figure 4-1 and

3. Figure 4-2).
4. Using the right thumb stick, try to center in the video the object that needs to be continuously viewed.
5. Click the **Loiter Now** button on the Virtual Cockpit or press the **Loiter Now** button on the gamepad. This will create a Loiter Now point on the waypoint map at the estimated GPS location and with an optimal loiter radius given the UAV's current altitude.
6. Allow the UAV to get on the path of the orbit for at least ½ of a lap around the loiter.
7. Depending on when the UAV received the Loiter Now command, the estimated position may not be exact. Users can adjust the position of the Loiter Now circle using the gamepad, as illustrated in Figure 4-4. As the user watches the video and notices that the object of interest is not in the center of the video. Using the direction arrows on the gamepad, the user can push in the direction of object of interest. After clicking the arrow pad, the **Loiter Now** command on the map will change position slightly causing the airplane to readjust itself. Allow the UAV some time to get back on course before readjusting it again.

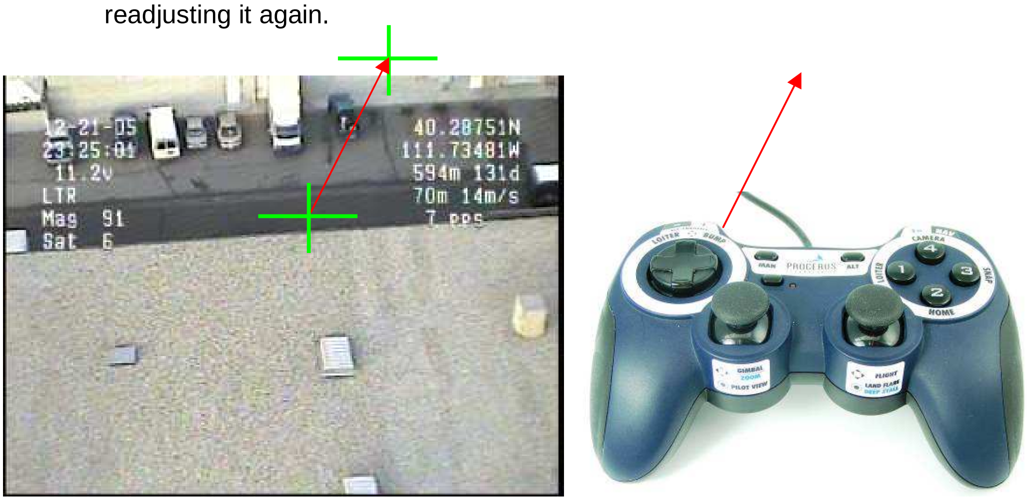

Figure 4-4 Adjusting Loiter Center with Gamepad

4.6 Rally Mode

Rally Mode commands the UAV to fly to the Rally point and loiter. The user can adjust the location of the loiter by moving the Rally point on the map and then uploading the flight plan. The autopilot uses its current altitude and current desired airspeed for the duration of the Rally Mode. This can be overridden using the **Altitude** and **Airspeed Override** controls found in the right-side pullout menu in the Virtual Cockpit map display. Rally Mode is very useful for testing the Rally land location before actually committing to an autonomous landing. The gamepad button mapping can be seen in

Figure 4-3 and **Error! Reference source not found.**.

4.7 Home Mode

Home Mode sends the UAV directly to the location designated as "home." The home location can come from any of these sources: UAV GPS when first acquiring GPS lock, Commbox GPS location if receiver is connected and broadcast flag is enabled, or users manually uploading the home location. Home Mode can be thought of as a safety feature. If at any time the ground operator feels the vehicle is in jeopardy of getting lost, the user can press either the **Home** button on the main Virtual Cockpit window or the **Home** button on the gamepad (see

Figure 4-3 and **Error! Reference source not found.**).

When the Home command is initiated, the UAV will immediately begin flying towards the home location with the airspeed set to the autopilot's configured cruise airspeed. Users can configure a setting on the autopilot that commands the UAV to fly to home with a minimum go home altitude. This is useful for when flying in rugged terrain, urban environments, or forested areas. The enable setting for the minimum go home altitude can be found in the Agent Config Window with this location: Mode Configuration->Home Mode->Use Minimum Home Alt. Above the check box users can set the minimum altitude that UAV will fly to. If the Use Minimum Home Altitude is not checked or the UAV is already above the minimum home altitude, the UAV will use its current altitude when flying to the home location.

4.8 Navigation Mode

Navigation (Nav) Mode is a fully autonomous mode with many built in flexibilities that allow users to make adjustments when needed. Nav mode can be set by clicking on the **Nav** button in the Virtual Cockpit or pressing the **Nav** button on the gamepad (see
Figure 4-3 and **Error! Reference source not found.**).

Nav Mode can only be initiated after a flight plan has been uploaded to the autopilot. If users attempt to place the UAV in Nav Mode before uploading a flight plan, the autopilot will return a Negative Acknowledgement (NACK) and will remain in the previous mode.

When the UAV is in Nav Mode it processes one waypoint command at a time. Users can change the current command being executed by right clicking on the desired waypoint and choosing the **Set As New Command** menu option. They may also enter in the command number manually in the flight list window. A new flight plan may be uploaded to the Autopilot at any time. The Autopilot will wait until the last command has been uploaded before executing the new list; however, the current command *number* does not change, so, for example, if the autopilot was en-route to waypoint 2 it will be en-route to the new waypoint 2 when the new flight list is uploaded.

Users may often find it beneficial to take over the UAV in a semi-autonomous mode such as Altitude Mode when flying a flight plan. When the user returns to Nav Mode by clicking the **Nav** button in the Virtual Cockpit or pressing the **Nav** button on the gamepad, the UAV will return to the last desired waypoint number. Users may also find it necessary to override the waypoint script's altitude and velocity command.

4.9 Convoy Mode

Convoy mode places the UAV into a unique mode that enables the UAV to follow a moving convoy. The center of the convoy or the home position is always the same location as the Commbox. To allow the home position to move, a GPS receiver and antenna is connected to the Commbox through one of its exterior ports. Call Procerus for this Commbox add-on if interested.

Before entering Convoy Mode it is important to properly set up the convoy loiter points. To view the Convoy points on the waypoint map, go to the Commbox Settings screen (F6) and check the "Display Convoy Items on map" check box. Next, locate the home position and the convoy circle on the waypoint map screen. Figure 5.8 shows an example setup.

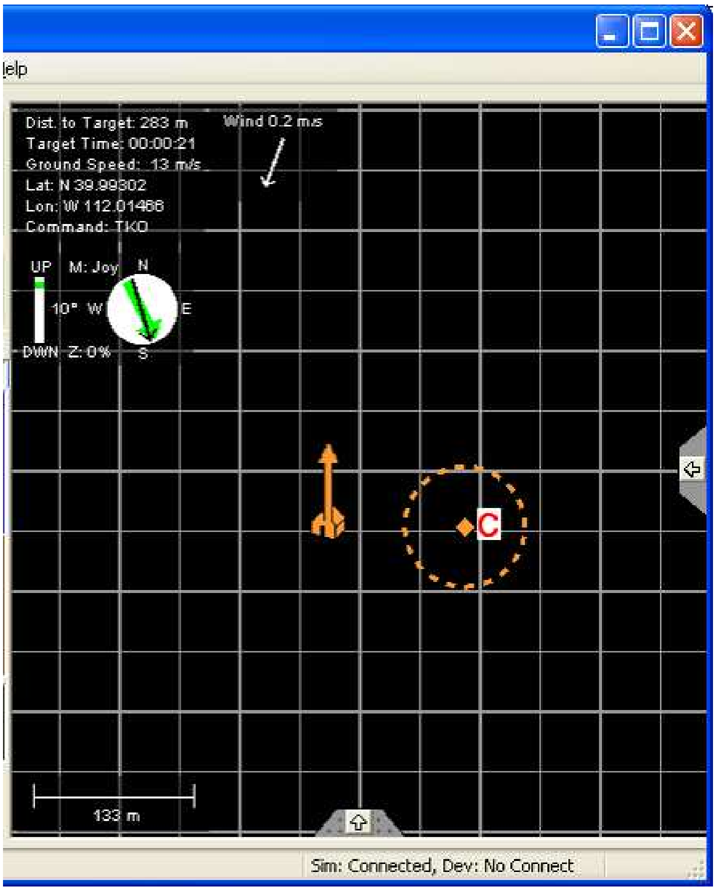

Figure 4-5 Convoy Mode element

The convoy point is different from all other waypoints because of its relative positioning. When setting up the Convoy point "C", adjust the point such that the relative placement of the point and the home location is the same as how the UAV is desired to be placed. For example, if it is desired to have the UAV off to the right side of the convoy, first look at the Convoy heading and place the Convoy point 90 degrees clockwise of the home position at the desired range. Once the Convoy point is configured make sure to upload the waypoint list.

Another thing to know is that when the Convoy slows to a stop the UAV will fly and circle around home until the Convoy begins to move. This makes it so that the UAV is ready to go in case the Convoy turns completely around.

4.10 Targeting Mode

Targeting mode is used in conjunction with Procerus' OnPoint™ Targeting application. It allows for the OnPoint application to easily upload desired Gimbal and Targeting locations to the UAV. Typically the user will have already selected a targeting point in OnPoint before placing the UAV into Targeting mode.

4.11 Deep Stall Mode

If the airframe is capable of holding a high angle of attack trim condition, the Kestrel autopilot can be configured to deep stall the aircraft. In the default mode, there is a single value that first needs to be configured. It is found in the Autopilot Config (F5) screen at: Mode Configuration->Land Mode->Deep Stall Elevator Pos. This is the value to which the elevator will deflect when placed in Deep Stall mode. A negative deflection causes a positive pitch.

Additionally, the autopilot can be commanded to maintain a fixed pitch during the deep stall. For some airframes, this is more effective than maintaining the elevator at a fixed position. To enable fixed pitch deep stall, select the checkbox at the following location in the Autopilot Config screen: Mode Configuration->Land Mode->Fixed Pitch Deep Stall Landing. If fixed pitch deep stall is configured, the appropriate pitch must be set in the Deep Stall Fixed Pitch field below the Fixed Pitch Deep Stall Landing checkbox. Please note that if fixed pitch mode is configured, the deep stall elevator position must still be configured. In fixed pitch mode, the autopilot will attempt to maintain the desired pitch. However, the pitch integrator term is disabled during deep stall, and a non-zero deep stall elevator position will be required to enter a deep stall.

Enable deep stall landings using the Gamepad in the VC by going to Virtual Cockpit (F7) > Manual Control and check the “Enable Deep Stall Btn 11” button.

When the user is ready they may press the Deep Stall Mode button. During deep stall the autopilot can change its heading slowly through the game pad or arrow keys if no game pad is present. Once the autopilot has been tuned properly for Deep Stall Mode, a Deep Stall landing may be attempted.

Figure 4-6 Initiate Deep Stall Mode from the game pad

4.12 Pitch Mode

NOTE: This mode requires experience and caution.

Pitch mode places the autopilot into a game pad state, where the game pad is directly controlling both Pitch and Roll angles. This can become dangerous when the operator commands too high of a pitch angle which can cause the UAV to stall. This gamepad mode most closely mimics an RC controller so it works well for near full control of the UAV through the game pad. Again, caution is advised.

4.13 PID Mode

PID Mode is to be used in conjunction with Manual or Altitude mode when tuning the PID values. Essentially it disables the Virtual Cockpit from sending gamepad control packets in either of the two modes.

4.14 Altitude and Speed Override

The Virtual Cockpit has the ability to override the current desired altitude and airspeed during some UAV Modes. Overriding the desired altitudes and airspeeds is beneficial, for example, when users have uploaded waypoints at a certain altitude and they want to temporarily change the altitude. Instead of having to re-upload the entire waypoint list, operators can click the altitude override checkbox and immediately change the altitude. Table 4.3 lists the different modes that allow altitude and airspeed override commands. When the checkboxes for the overrides are unchecked, the autopilot returns to the previous commanded airspeed or altitude.

Table 4.3 Altitude and Airspeed Overrides

UAV Mode	Altitude	Airspeed
Manual Mode	YES	NO
Altitude Mode	YES	YES
Navigation Mode	YES	YES
Home Mode	YES	YES
Takeoff Mode	NO	NO
Loiter Now Mode	YES	YES
Rally Mode	YES	YES
Land Mode	NO	YES
Convoy Mode	YES	NO
Targeting Mode	YES	YES
Deep Stall Mode	NO	NO
Pitch Mode	NO	NO
PID Mode	N/A	N/A

5 Autopilot Control Structure

The Kestrel autopilot uses a combination of feedback and feed forward controllers for the elevator, aileron, throttle, and rudder control. This chapter details the control loops available on the autopilot. This information is very helpful when tuning the PID loops.

Virtual Cockpit setup and tuning windows

- PID window
- Autopilot Setup window

Control Diagram

- PID Feedback Block
- Feed-Forward Block
- UAV Parameters
- Elevator Control
- Throttle Control
- Aileron
- Altitude Tracker
- Units

5.1 PID Window

The PID window (Figure 5-1) and the Airplane Setup window (Figure 5-2) in the Virtual Cockpit Settings window will be used frequently in this chapter.

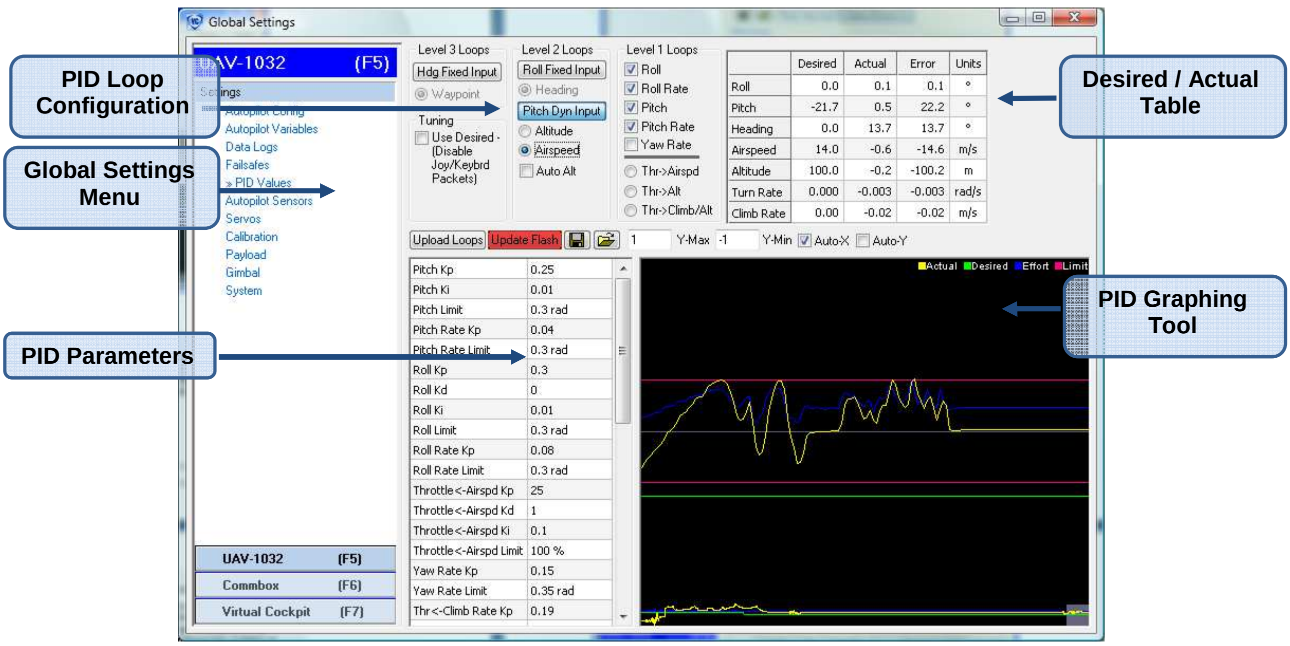

Figure 5-1 PID window

The global settings menu is used to select different views like the PID values and autopilot setup views. The PID loop configuration area is used to enable and disable PID control blocks on the autopilot. The PID Parameters area is a table of the PID gains and limits used for control tuning. The desired / actual table lists the desired and actual roll, pitch, heading, airspeed, altitude, and turn rate of the airplane. The PID graphing tool can assist PID tuning by plotting the control performance (desired, actual, and effort).

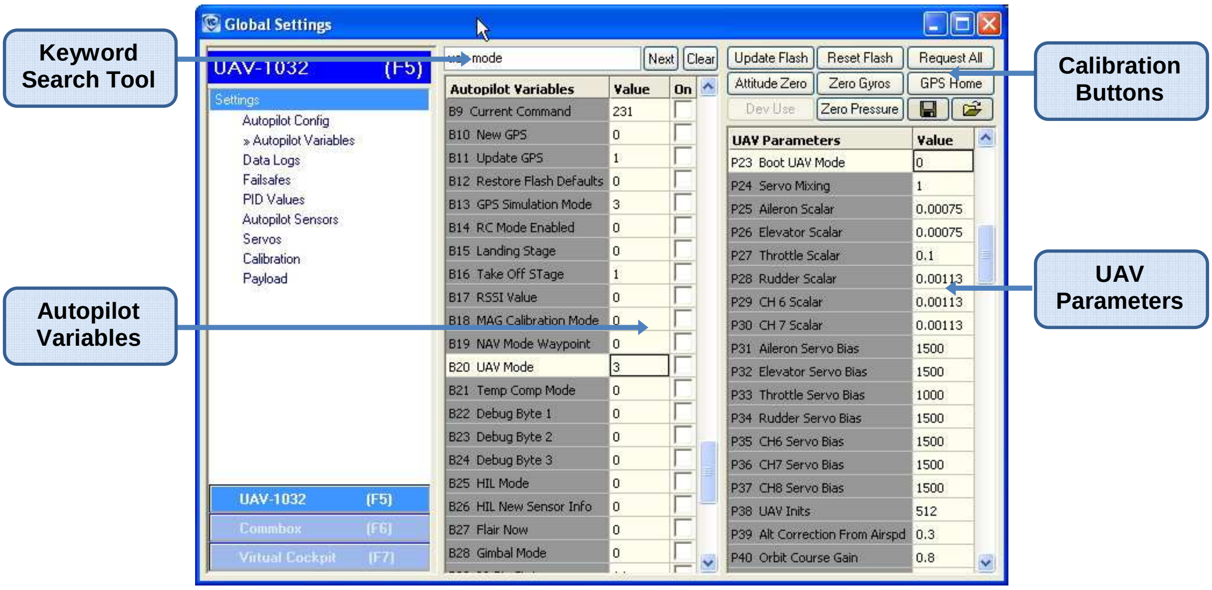

Figure 5-2 Autopilot Setup window

The keyword search tool is used for searching for words in the autopilot variables and the UAV parameters. The keyword search tool is found at the top of the autopilot setup screen. Autopilot Variables lists variables found on the autopilot. Checking the checkbox to the right of the variable causes the Virtual Cockpit to continually refresh the corresponding variable.

The calibration buttons located in the top right corner of the autopilot setup screen are used to;

a. Update the autopilot flash memory
b. Zero the autopilot attitude, to zero the pressure sensors and,
c. Reset the GPS home position.

5.2 Control Diagrams

This section will describe the different control blocks found in the control diagrams. A detailed description of the tuning parameters for each block will be provided. The control diagrams follow the diagram component descriptions.

5.2.1 PID Feedback Block

The Proportional, Integral, Derivative (PID) feedback block is used to remove error in a system. Controller name convention for the Kestrel autopilot follows the pattern where **PID Pitch > Elevator** is the PID controller that uses pitch error to generate elevator control effort. shows the **PID Pitch > Elevator** controller and is an example of the PID block symbol used in this manual.

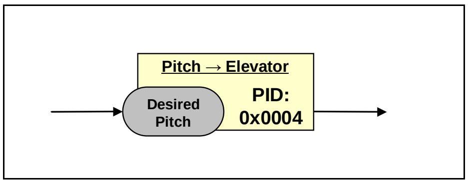

Figure 5-3 Example PID block

To simplify the diagrams, we assume that all control blocks have access to the necessary sensor information. For example, the **Pitch > Elevator** controller shown in Figure 5-3 has access to the actual pitch angle of the airplane. The tunable parameters for the PID block are listed in Table 5.1.

Table 5.1 PID Feedback Block Parameters

Parameter	Description
Kp	Proportional gain
Ki	Integral gain
Kd	Derivative gain
Limit	Saturation limit for control effort

The PID block inputs are desired and actual system values. The system error is the difference in the desired and actual inputs. Proportional, integral, and derivative control efforts are calculated from the system error. The output of the PID block is the sum of values that are proportional, derivative, and integral control efforts. The control gains Kp, Ki, and Kd are used to scale the proportional, integral, and derivative control efforts prior to being summed as the PID block output. The parameter Limit is used to set the saturation limits or maximum and minimum output of the PID block control effort. The parameters for each PID block on the autopilot are listed in the PID tuning view in the Virtual Cockpit settings window.

5.2.2 Feed-Forward Block

The Kestrel autopilot uses Feed-Forward blocks to generate control effort from desired system values. Feed-Forward blocks are designed to improve system performance and reduce the amount of control effort required by PID feedback blocks. The controller name convention for the Kestrel autopilot follows the pattern where **FF Airspeed > Pitch** is the feed-forward controller to that uses airspeed to generate pitch control effort. Figure 5-4 shows the Feed-Forward block used for **FF Airspeed > Pitch** control, and is an example of the Feed-Forward block symbol used in this manual.

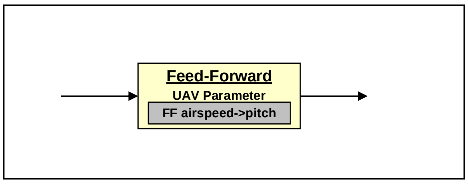

Figure 5-4 Feed Forward block

Typical use of a Feed-Forward block involves setting the PID gains to zero on parallel PID blocks, tuning the Feed-Forward controller until the desired performance is achieved, and then re-tuning the parallel PID (feedback) block gains. The parameters for each Feed-Forward block are listed in the UAV Parameters column under the Autopilot Setup view in the Virtual Cockpit setup window.

5.2.3 UAV Parameters

Variables labeled UAV Parameters are used for signal control and tuning.

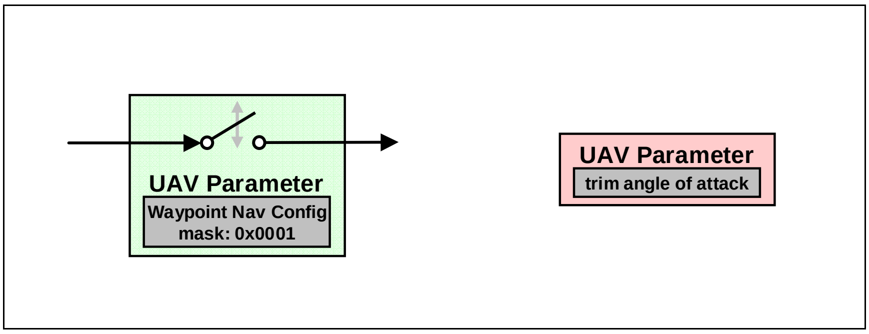

Figure 5-5 UAV Parameter

Figure 5-5 shows example UAV Parameters. In this example, UAV Parameter uses the bit corresponding to the bit mask: 0x0001 to enable signal flow. The example UAV Parameter on the right is the variable that provides a **trim angle of attack**. These UAV Parameters are inter-mixed into the control schemes for elevator, aileron, throttle, and rudder control. Most UAV Parameters are represented in the Autopilot Configuration Window and as such the bits are set by check boxes.

5.2.4 Elevator Control

Elevator control is used for longitudinal and airspeed stability of the aircraft (i.e. pitch rate, pitch, altitude, and airspeed control). Figure 5-6 diagrams the elevator control on the Kestrel autopilot. Notice that both the **Altitude > Pitch** and **Airspeed > Pitch** controllers command a desired pitch, thus, both controllers are never enabled at the same time.

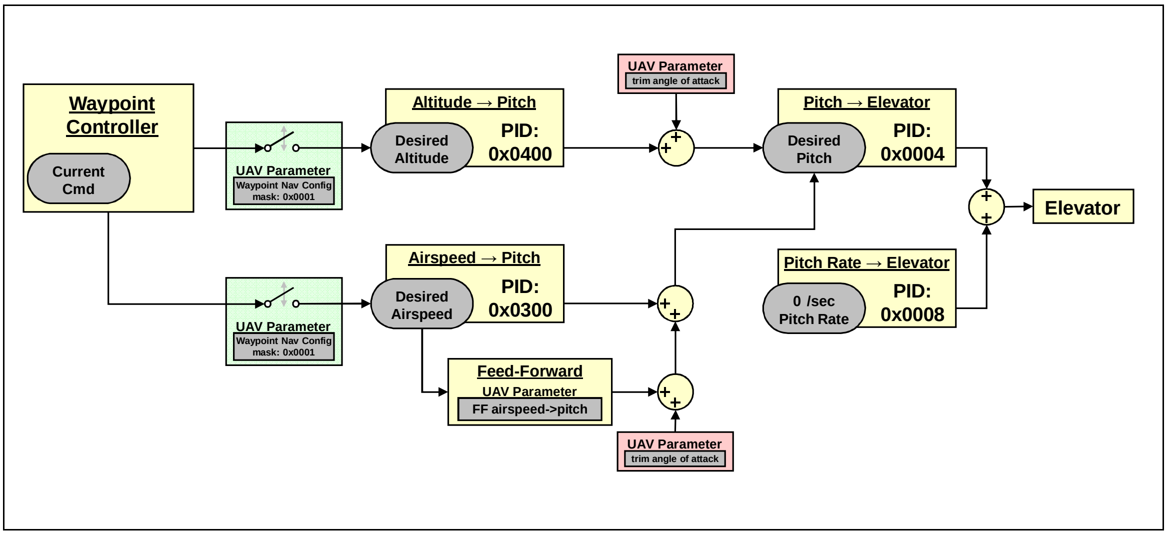

Figure 5-6 Elevator control loop

5.2.5 Throttle Control

The throttle control is used to control airspeed during level flight. The throttle control should be tuned first, as it will be used to control airspeed while other controllers are tuned. Figure 5-7 shows the control diagram for the throttle control. Notice that both the altitude and airspeed controllers command throttle values and, thus, both controllers are never enabled at the same time.

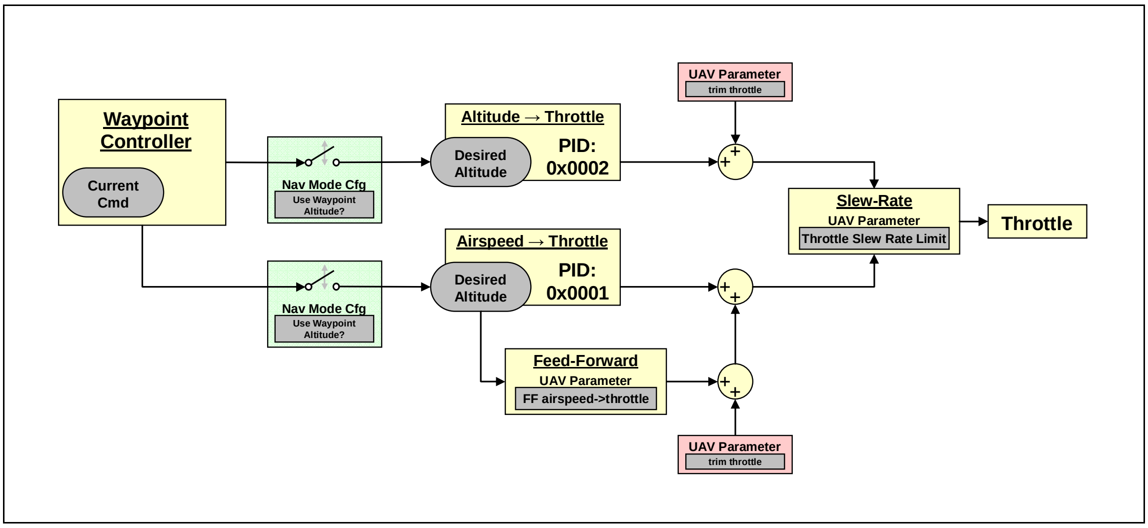

Figure 5-7 Throttle control loop

5.2.6 Aileron & Rudder Control

Aileron control is used for lateral stability of the aircraft (i.e. roll rate, roll, and heading control). Figure 5-8 and Figure 5-9 diagram the aileron control on the Kestrel autopilot.

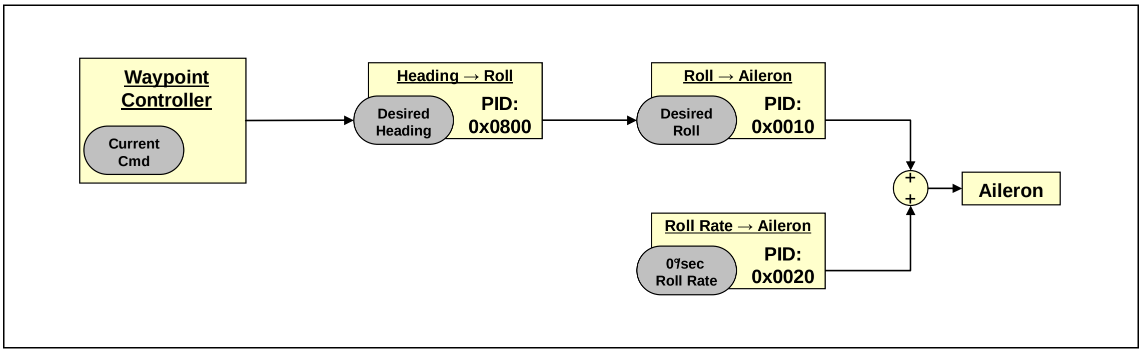

Figure 5-8 Aileron control loop

An alternate aileron control structure is shown in Figure 5-9. This control structure is used for airplanes that use rudder or a v-tail to control roll and heading. If the aircraft has rudder only, the rudder servo is plugged into the aileron channel and the yaw rate controller is connected to the aileron channel. If the aircraft has ailerons and rudder, the yaw rate controller is connected to the rudder and the rudder servo is connected to the rudder channel.

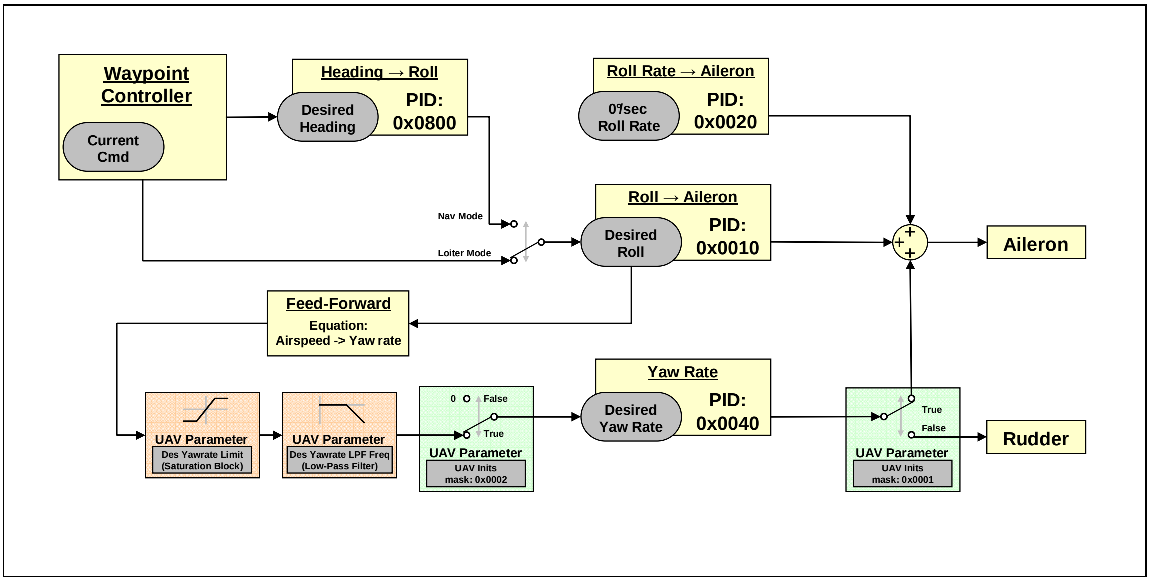

Figure 5-9 Alternate aileron and rudder control

5.2.7 Altitude Tracker

The Altitude Tracker is responsible for controlling altitude in such a way as to climb and descend in an optimal manner and to hold altitudes with precision. The Altitude Tracker uses three different altitude control methods: climb, descent, and altitude hold. A window is used to determine which altitude control method should be used. Altitude hold control is used if the UAV is inside the window. The climb and descent control is used if the UAV is below or above the window, respectively. The altitude window changes size and location depending on location of the UAV. Figure 5-10 shows the baseline Altitude Tracker.

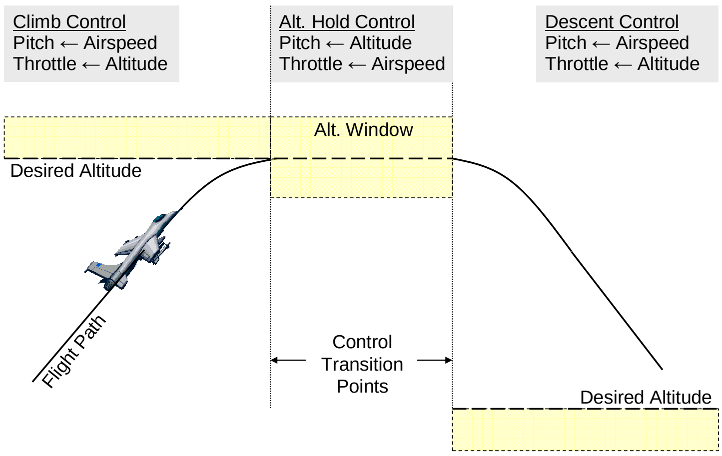

Figure 5-10 Altitude Tracker

The altitude hold control uses pitch control to regulate altitude and throttle control to regulate airspeed. The climb and descent control methods both use pitch control to regulate airspeed and throttle control to regulate altitude.

The theory behind using the throttle from altitude during climb and descent is to gradually transition the aircraft's climb rate to zero upon arrival to the desired altitude. The window size is specified by the UAV Parameter **Alt tracker window**.

5.2.8 Units

Table 5.2 provides the units for the trims and controller gains and limits used on the Kestrel autopilot.

Table 5.2 Gain, Limit, and Trim Units

System	Parameter	Unit
PID Roll Rate→Aileron PID Pitch Rate→Elevator PID Yaw Rate→Elevator PID Heading Rate→Elevator	Kp	rad / (rad/s)
	Ki	rad / rad
	Kd	rad / (rad/s^2)
	Limit	rad
PID Roll→Aileron PID Pitch→Elevator PID Heading→Roll	Kp	rad / rad
	Ki	rad / (rad s)
	Kd	rad / (rad/s)
	Limit	rad
PID Altitude→Pitch	Kp	rad / m
	Ki	rad / (m s)
	Kd	rad / (m/s)
	Limit	rad
PID Airspeed→Pitch	Kp	rad / (m/s)
	Ki	rad / m
	Kd	rad / (m/s^2)
	Limit	rad
PID Airspeed→Throttle	Kp	% / (m/s)
	Ki	% / m
	Kd	% / (m/s^2)
	Limit	%
PID Altitude→Throttle	Kp	% / m
	Ki	% / (m s)
	Kd	% / (m/s)
	Limit	%
UAV Parameters	FF airspeed->pitch	rad / (m/s)
	FF airspeed->throttle	% / (m/s)
	trim throttle	%
	trim airspeed	m/s
	angle of attack	rad

6 Multi-Agent Control

This chapter describes the process of adding and controlling multiple UAVs using the Virtual Cockpit.

6.1 Adding Agents

Agents may be added or removed from the Virtual Cockpit at anytime.

1. **Open Add New Agent Window**
   Select **Agents** → **Edit Agent List** from the drop-down menu. A window will appear, as shown in Figure 6-1.

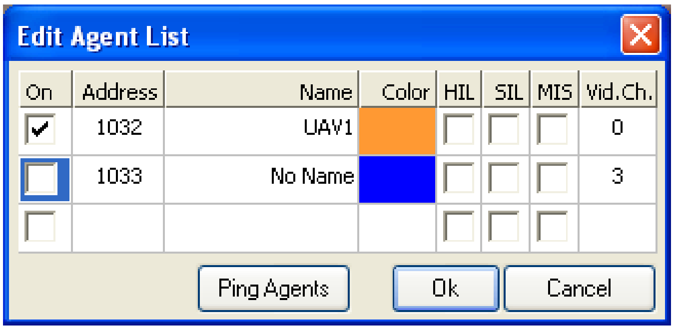

Figure 6-1 Add New Agents Window

2. **Enter Agent Information**
   Enter the new agent's address, name, and color that will be used in the Virtual Cockpit for agent identity. The address entered must match the address of the corresponding autopilot. Check the **On** box next to those agents you wish to control in the Virtual Cockpit.

3. **Press Ok**
   Press the **OK** button to add the new agents into the Virtual Cockpit.

6.2 Agent Status and Control

Agent status is displayed in the same manner as a single, agent with the exception that multiple agents are listed in the Agent List above the Attitude Indicator and each agent's UAV location and waypoints are displayed on the map. To select an agent, click anywhere on the row corresponding to the desired agent. The background will turn blue for the selected agent. Figure 6-2 shows 2 agents with the second agent being selected.

Figure 6-2 Selecting an Agent from the Agent List

Once an agent is selected, the Virtual Cockpit interface will correspond with that agent. This includes all autopilot specific setup screens. For example, the UAV Modes buttons, HUD, Flight Plan, and autopilot setup screens will correspond to the selected agent.

6.3 Changing Agent Address

The Factory default agent address is 1032. The agent address can be changed to any value from 1-9999. The following steps describe the process for changing an agent's address.

Turn On System

Turn on the autopilot and Commbox. Load the Virtual Cockpit with the correct agent number. You should have communications with the aircraft.

Add New Agent With New Address

Use **Edit Agent** to add a second agent. Make the address of the second agent the new address. The user can choose any address between 1 and 2000.

Change Airplane Address

With the first agent selected, open up the UAV settings window (**F5**) and select **Agent Config** on the left side of the window. Expand the Communications section by pressing the "**+**" button. Locate the **Airplane Address** value. Change this value to the desired agent address (within 1 to 2000). Press the **Upload Config** button to make the changes take effect. You will notice that communication with the first agent will stop and the second agent will begin receiving communications from the autopilot.

Warning: Be sure to record the new agent address. The only method of communicating with an agent is by using the correct agent address. If the agent address is lost and you are not able to establish communication with that agent, first try pinging the autopilot (Edit Agents list, Ping Agents). If unable to establish comm., contact Procerus Technologies.

Update Flash on New Agent

You will need to select the new agent by clicking on the new agent in the agent list. The **Update Flash** button will be red because the Airplane Address is stored in flash and to permanently save the new value the button needs to be pressed. Press the **Update Flash** button.

Remove Agent with Old Address

Use the Agent Editor to remove the original agent.

6.4 RC Control of Multiple Agents

Under normal multi-agent flight conditions, an RC controller is not recommended for use. However, certain situations may necessitate using an RC controller, such as new cooperative control algorithms developed using the Developers Kit. For normal multi-agent flight the gamepad is recommended.

The RC check box is located to the right of each agent in the Agent List. The RC check box indicates which agent is receiving the RC controller packets from the Commbox. Only one agent can be controlled with the RC controller at a time. Figure 6-3 shows 2 agents.

Figure 6-3 Selecting Agent for RC Control

Warning: It is strongly recommended that **RC Mode be DISABLED** (channel 5 on your RC controller) while switching RC control of agents. If RC Mode is enabled and the RC check box is unchecked, the autopilot will no longer receive the control packets from the RC transmitter. This will result in a UAV that is not being controlled. Before un-checking RC control on an agent, make sure it is flying autonomously with RC Mode disabled.

Figure 6-4 RC Mode ON

Figure 6-5 RC Mode OFF

7 Hardware-in-the-loop Simulator

The Kestrel Autopilot and the Virtual Cockpit have a built-in ability to simulate a 6 degree of freedom UAV through the use of a 3rd party, open source simulator called *Aviones*. Aviones displays the simulated flight in 3D allowing the user to quickly and easily test flight plans and new software development prior to full outdoor flight.

Aviones uses the idea of loadable code libraries for simulation. Aviones loads two libraries: physics and autopilot.

- The physics library computes how the airplane responds in its natural environment using user-definable airplane coefficients, wind, and 6 degree of freedom models.
- The autopilot library describes the autopilot and how it will respond to its orientation and position in the simulated world.

By using Procerus' proprietary autopilot DLL, Aviones can communicate with the Kestrel Autopilot and replace the autopilot's sensor information with that generated by the physics library. After the Kestrel receives the sensor information it can compute a controller output which is fed back into the physics library.

The Hardware-in-the-Loop (HIL) simulation can be set up two ways. The first method is shown in Figure 7-1. In this method the Virtual Cockpit communicates with the Aviones over a TCP/IP connection. Aviones then passes the data from the Virtual Cockpit to the autopilot over a wire serial connection. The serial cable is connected to the autopilot's modem port. The advantage of this method is that only one serial port is needed. The disadvantage is that the modem needs to be unplugged from the autopilot so that the hard wire serial connection can be used with Aviones.

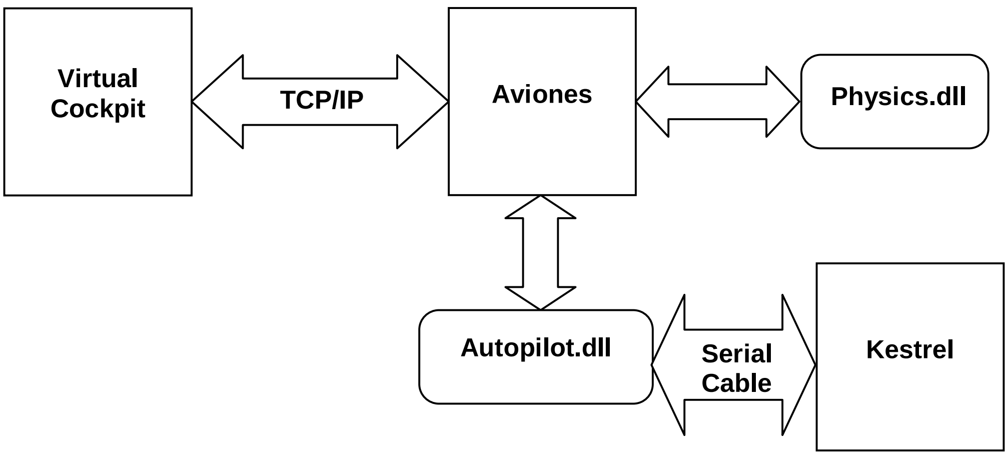

Figure 7-1 Hardware-in-the-Loop setup using TCP/IP connection

To overcome this limitation a second method was developed, shown in Figure 7-2. In this configuration, the autopilot communicates with the Virtual Cockpit over the standard serial modem interface. Aviones communicates with the autopilot over a serial connection. The advantage of this method is that the modem can be left connected to the autopilot (which may be installed in an airplane) and the Virtual Cockpit is not needed (A third party ground station can be used).

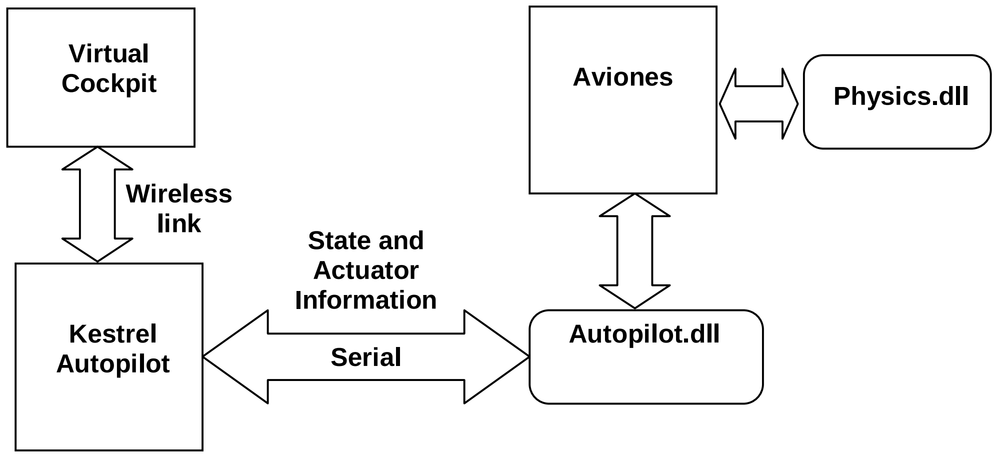

Figure 7-2 Hardware-in-the-Loop setup using serial connection

7.1 Installing Aviones

The folder containing the Aviones simulator is located on the install CD under **d:\Aviones** (where d is the letter of your CD drive). To install Aviones, simply copy the entire folder to your hard drive. Located in this folder is **Aviones.exe** which is the main runtime executable. Along with this are the physics and autopilot libraries.

There are two configuration files:

- physics_params.txt
- autopilot1032_regs.txt.

These files are normal text files that may be edited in a text editor allowing for customization of the Aviones simulator. Note that the autopilot1032_regs.txt file is suffixed with 1032 corresponding to a simulated agent number of 1032. This will be explained more in the next section.

7.2 Running the Simulator

To start the Aviones simulator, double-click the **Aviones.exe** in Windows explorer. The program will open up to a 3D display, similar to Figure 7-3.

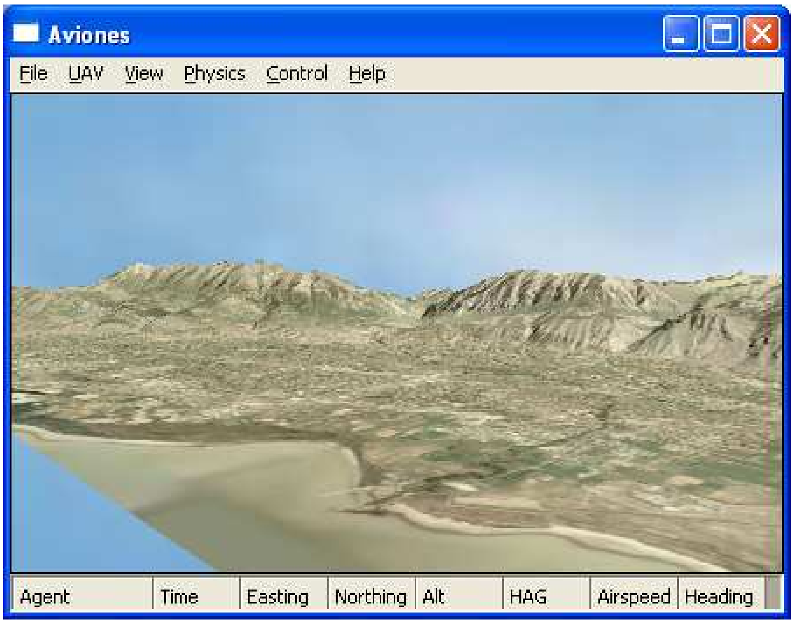

Figure 7-3 Initial view of Aviones Simulator

The next step depends on which method you wish to use to communicate with Aviones. If the autopilot is installed in an airplane with a modem attached, it is better to use the serial link. If the autopilot is on your desk and the modem can easily be removed, the TCP/IP method can be used.

7.2.1 Setting up HIL system using external serial connection

Aviones can be set up to talk directly to the autopilot over a serial cable, as shown in Figure 7-4. The following steps are used to start the HIL simulation using the external serial connection:

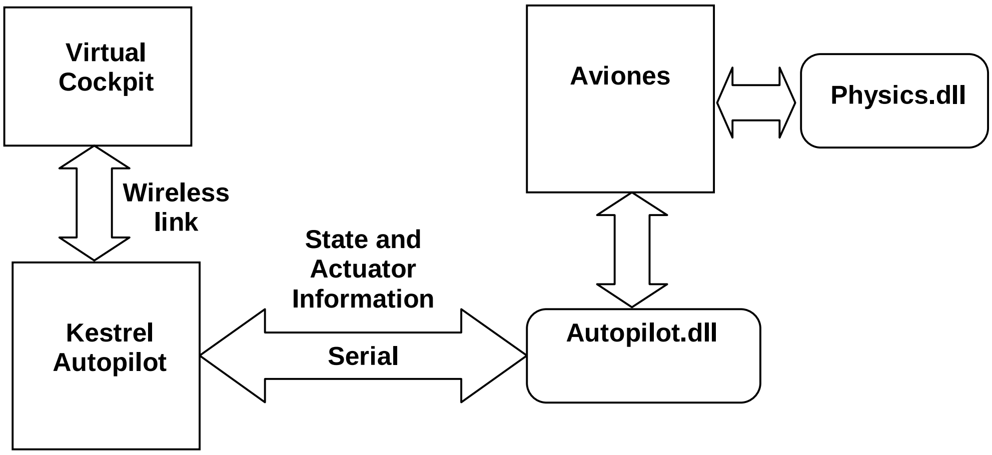

Figure 7-4 Hardware-in-the-Loop setup using serial connection

1. Configure the autopilot to accept HIL information through serial port A. This is done in the Payload configuration screen in the Virtual Cockpit (See Figure 7-5). Under heading **Port A, GPS, and Rudder Signal,** select **Pins 3,4 for Hard ware-In-The-Loop**.

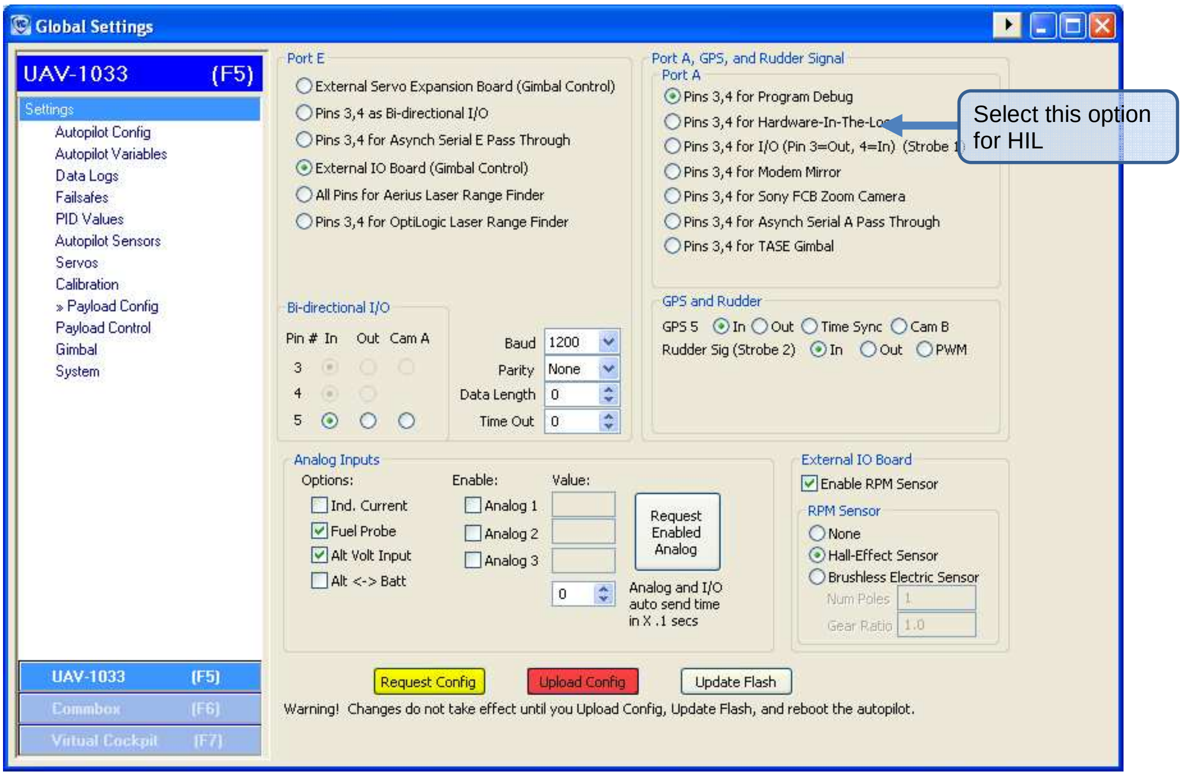

Figure 7-5 Configuring autopilot for HIL over serial A

2. Click **Upload Config**, then **Update Flash**.
3. Click **Request Config** to make sure the airplane received the new setting.
4. Re-boot the autopilot.
5. The next step requires the use of the autopilot programming cable with the 5 wire programming connector. This is provided by Procerus. Plug the 5 wire pig tail in the DIAG connector on the programming cable (see Figure 7-6).

DIAG connector

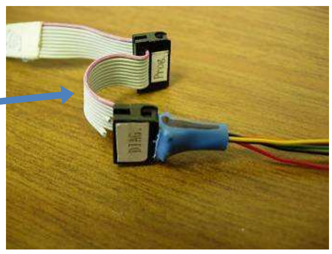

Figure 7-6 Plugging programming pig-tail into DIAG port for use with HIL

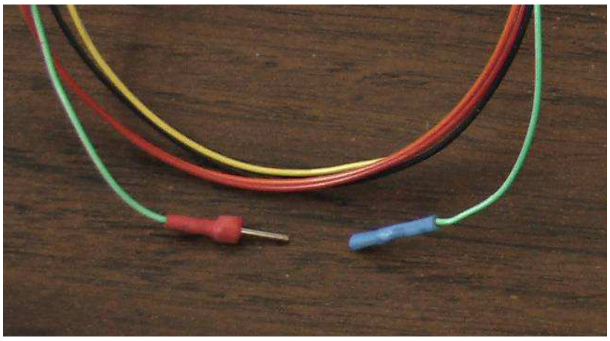

Figure 7-7 Disconnect Programming Enable Connection

6. Plug the 5 pin Molex connector into port A on the autopilot (See Figure 7-7)

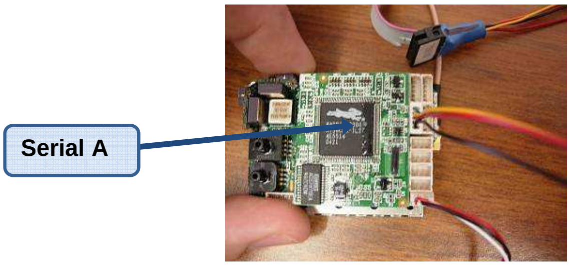

Figure 7-8 Plugging programming pig-tail into serial A on autopilot use with HIL

7. Plug the serial connector on the other end of the programming cable into a free serial port on your computer (You may use a serial to USB converter). Make a note of the serial port number – it will be needed later.
8. Load Aviones.
9. From the UAV menu in Aviones, select **Add new**. This will open another dialog allowing you to change the agent name. You may type a new name in or just click **OK** to add a new agent to Aviones.
10. Under the View menu select **HIL Simulation Control**. This will open up a new dialog box allowing you to configure the simulation session (See Figure 7-9).
11. The first step is to select the correct serial that Aviones will be using to communicate with the autopilot:
    a. Place the cursor in the Serial Port # box.
    b. Delete the value that is currently in the box using the backspace key (The box should turn red)
    c. Enter the serial port number connected to the autopilot (from step seven).
    d. Press **Enter** – The box should turn white and the word "Open" should be displayed in the box to the right (see Figure 7-9).
    e. The serial port is now open.

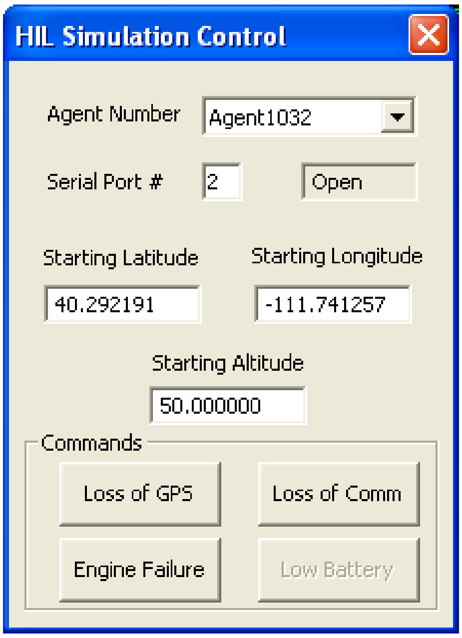

Figure 7-9 Hardware-in-the-Loop Simulation Control Window

12. Set the starting longitude and latitude
13. Set the starting altitude. This is the altitude above the average terrain in the simulation environment.
14. Close the HIL Simulation Control Window.
15. You should now have communications between the Virtual Cockpit and the Autopilot over the normal communications link and communications between Aviones and the autopilot over the serial cable. To verify communication between Aviones and the autopilot, the right-most LED on the autopilot should be blinking rapidly (see Figure 7-10). This indicates that the autopilot is receiving sensor information from Aviones.

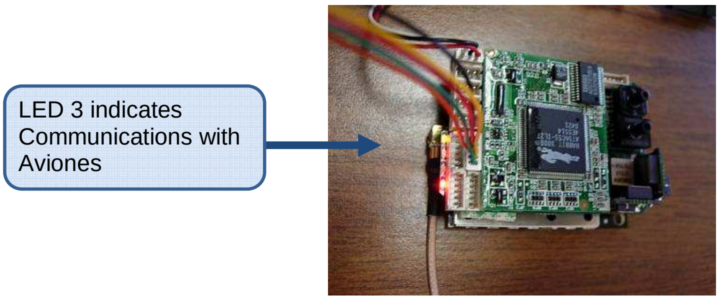

Figure 7-10 LED 3 blinking indicates communications between autopilot and Aviones

16. The next step is to set up and upload a Flight Plan in the Virtual Cockpit.
17. Launch the UAV in Aviones: **UAV pull down menu -> Launch if necessary**.
18. Select **Take Off** mode in the Virtual Cockpit.

7.2.2 Setting up HIL system using TCP/IP connection

The second choice for using Aviones and the Virtual Cockpit is to use the TCP/IP connection to Aviones. In this configuration, the autopilot communicates with Aviones through the Virtual Cockpit. Because high speed state information is passed between the autopilot and Aviones (See Figure 7-11), the wireless link that is normally used to communicate between the Virtual Cockpit and the autopilot cannot be used. The modem must be unplugged and replaced with the serial programming cable provided by Procerus. The communications will pass between Aviones and the autopilot over this cable. The communications that normally go through the wireless link between the Virtual Cockpit and the autopilot will also go through this cable (after going through a TCP/IP link between Aviones and the Virtual Cockpit). The following steps are used to setup the HIL simulation using the TCP/IP interface.

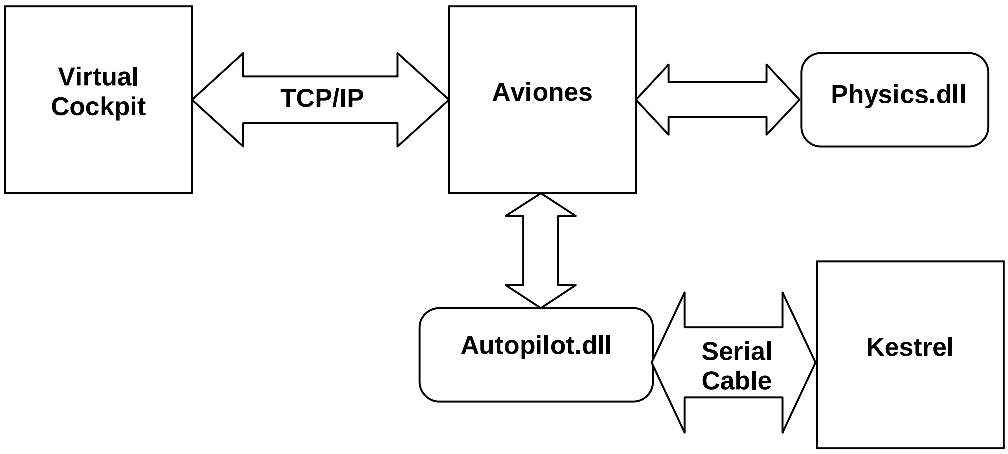

Figure 7-11 Hardware-in-the-Loop setup using TCP/IP connection

1. Remove the modem from the autopilot (either from the back of the autopilot or from the modem plug on the front) (See Figure 7-12). **Note**: Removing the modem is not necessary when using Kestrel Hardware versions 2.23 and above.

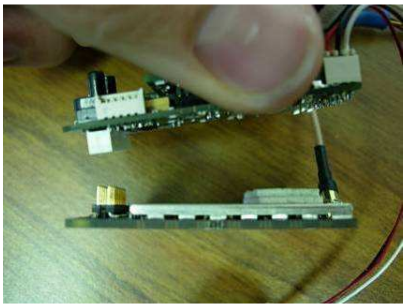

Figure 7-12 Removing modem prior to using TCP/IP connection to Aviones

2. The next step requires the use of the autopilot programming cable with the 5 wire programming connector. This is provided by Procerus. Plug the 5 pin header on the programming cable into the autopilot modem port (see Figure 7-13).

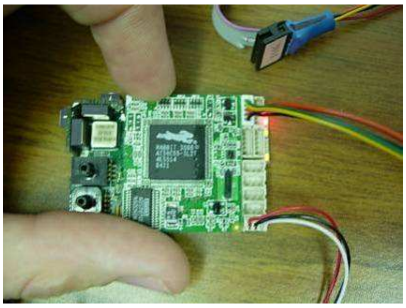

Figure 7-13 Connecting serial cable to the modem port on the Autopilot

3. Plug the other end of the programming cable into a free serial port on the computer that will be running the Virtual Cockpit. Make a note of the serial port number – it will be needed later.
4. Power on the autopilot
5. Load Aviones
6. Load the Virtual Cockpit
7. Open the **Edit Agents** window (This can be found in the **Agent Menu -> Edit Agents**).
8. The right-most column is labeled **HIL** for "Hardware-in-the-Loop." Check this box next to the agent number of the autopilot.
9. Click **OK**
10. A dialog box will pop up (see Figure 7-14) where the IP address of the computer running Aviones may be specified. If Aviones is running on the same computer running the Virtual Cockpit, click the **Loopback** button and press **OK** to connect to Aviones.
    Virtual Cockpit will now attempt to connect to Aviones and add all the agents that were selected and had the HIL checkbox checked.

    Note: If there is a communications port opened on the Virtual Cockpit, the Virtual Cockpit will automatically close this in the event that Aviones needs to open the same comm port. If connected successfully, the Virtual Cockpit will indicate on its status bar and Aviones will have added the Agent to its list on the bottom of the window, as shown in Figure 7-15.

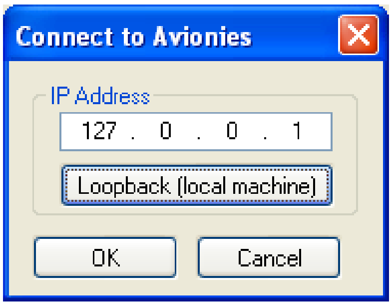

Figure 7-14 Connection window to Aviones

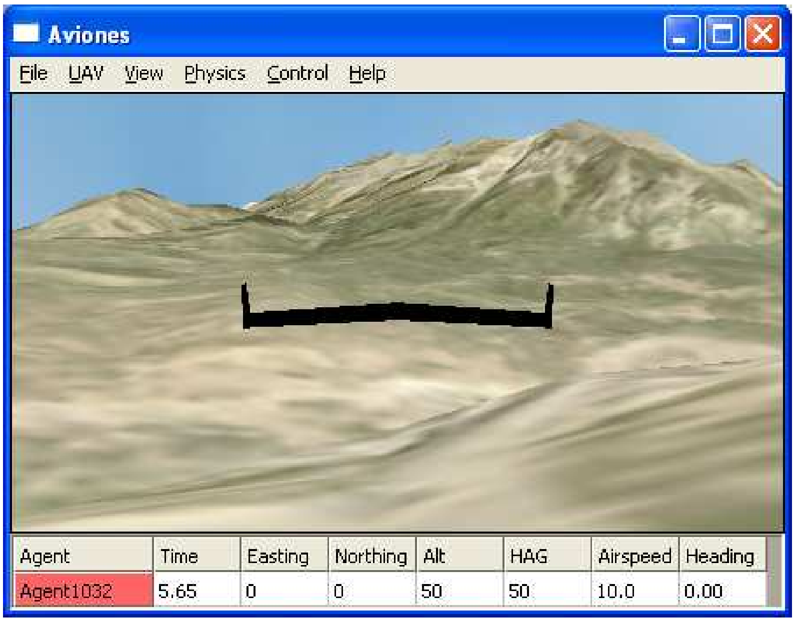

Figure 7-15 Agent added in Aviones.

11. The next step is to make sure that Aviones is setup to talk to the autopilot through the correct comm port. Open up the HIL Simulation Control Dialog through the View Menu->HIL Sim Ctrl. When the dialog is opened it will fill in the current autopilot information that was originally contained in the autopilot1032_regs.txt file. This is shown in Figure 7-8.
   a. Place the cursor in the Serial Port # box.
   b. Delete the value that is currently in the box using the backspace key (The box should turn red)
   c. Enter the serial port number connected to the autopilot (From step three).
   d. Press **Enter** – The box should turn white and the word "Open" should be displayed in the box to the right (see Figure 7-9).
12. With the correct serial port open, data should begin to flow between Aviones, the Virtual Cockpit, and the Autopilot. The Virtual Cockpit should show communications with the autopilot.
13. Start the simulation by placing the UAV in Take Off Mode using the Mode buttons.
14. Launch the UAV in Aviones: **UAV pull down menu -> Launch if necessary**.

There are a number of simulation commands available through the HIL Sim Control window. The following table lists these commands and their associated functions.

Table 7.1 HIL Simulation Commands

Command	Description
Loss of GPS	This command will emulate a loss of GPS satellite lock. If the Loss of GPS failsafe is enabled, the autopilot will take the associated actions.
Loss of Comm	Clicking this button will stop all outgoing autopilot telemetry. This will make the autopilot believe that it has lost communication to the ground station and if enabled, the loss of comm failsafe will trigger. This is not implemented if the direct serial connection between Aviones and the autopilot is used.
Engine Failure	This command stops the autopilot from controlling the throttle in the physics library and commands a constant throttle of zero. Doing so will cause the airplane to lose velocity and eventually lose altitude.
Low Battery	(This feature is not yet available.)

Appendix A

A.1 Description of Autopilot Floating Point Variables

Table A-1 Description of Autopilot Floating Point Variables

Label	Variable Name	R/W	Description	Units	Range
F0	DT	Read Only	Inner loop sample time	Seconds	.02 -> .008
F1	Phi	Read Only	Estimated roll angle used by the low-level control loops	radians	+/- 3.14
F2	Theta	Read Only	Estimated pitch angle used by the low-level control loops	radians	+/- 3.14
F3	Psi	Read Only	Estimated heading(ground track or absolute: see attitude reference) angle used by the low-level control loops	radians	+/- 3.14
F4	Phi Quat	Read Only	Experimental roll angle estimate - not used for control.	Radians	
F5	Theta Quat	Read Only	Experimental pitch angle estimate - not used for control.		
F6	Psi Quat	Read Only	Experimental heading angle estimate - not used for control.		
F7	Psi GPS	Read Only	Estimated ground track heading produced by a complementary filter combining GPS ground track and gyro based heading rate integration. Psi GPS error weight is the gain of the complementary filter		
F8	Psi Mag	Read Only	Estimated heading produced by a complementary filter combining Magnetic heading and gyro based heading rate integration. Psi Mag error weight is the gain of the complementary filter. This is sent to the Virtual Cockpit in the standard telemetry and displayed in the HUD		
F9	True Psi	Read Only	The estimated actual heading, orientation not direction of travel, of the UAV.		
F10	Psi GPS Error Weight	Read Only	Complementary filter gain for Psi GPS. More gain means GPS heading will be used more heavily.	Rad/Rad	>0
F11	Psi Mag Error Weight	Read Only	Complementary filter gain for Psi Mag. More gain means magnetic heading will be used more heavily.	Rad/Rad	>0
F12	Climb Rate	Read Only	The current climb rate of the UAV.	m/s	+/-
F13	GPS East Pos	Read Only	The relative position reported by the GPS in Meters east of the home position.	Meters	+/-
F14	GPS North Pos	Read Only	The relative position reported by the GPS in Meters north of the home position.	Meters	+/-
F15	East estimate	Read Only	The estimated relative position of the aircraft in Meters east of the home position. This position is interpolated between GPS samples.		
F16	North	Read Only	The estimated relative position of the		

Label	Variable Name	R/W	Description	Units	Range
	estimate		aircraft in Meters east of the home position. This position is interpolated between GPS samples.		
F17	GPS Speed	Read Only	The ground speed as reported by the GPS	m/s	>0
F18	Ground Speed estimate	Read Only	The ground speed estimate interpolated between GPS samples.	m/s	>0
F19	GPS heading	Read Only	The ground track heading as reported by the GPS	Rad	+/- 3.14
F20	GPS altitude	Read Only	The altitude above sea level as reported by the GPS	Meters	> 0
F21	GPS lat	Read Only	The latitude as reported by the GPS	Degrees	
F22	GPS lon	Read Only	The longitude as reported by the GPS	Degrees	
F23	Inertial data sim X	Read/Write	The simulated position of the aircraft in meters east of simulated home position. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Meters	
F24	Inertial data sim Y	Read/Write	The simulated position of the aircraft in meters north of simulated home position. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Meters	
F25	Inertial data sim velocity	Read/Write	The simulated ground speed of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	m/s	> 0
F26	Inertial data sim heading	Read/Write	The simulated GPS ground track heading of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Radians	+/- 3.14
F27	Inertial data sim alt	Read/Write	The simulated GPS altitude of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Meters	
F28	Inertial data sim lat	Read/Write	The simulated GPS latitude of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Degrees	
F29	Inertial data sim lon	Read/Write	The simulated GPS longitude of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Degrees	
F30	Inertial data sim GPS home lat	Read/Write	The simulated GPS home position latitude of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Degrees	
F31	Inertial data sim GPS home lon	Read/Write	The simulated GPS home position longitude of the aircraft. Only relevant when the GPS simulator is enabled (see byte GPS simulation mode)	Degrees	
F32	RC over Comm.. PPS	Read Only	The number of RC controller packets received per second from the Commbox	Pkts/sec	0 -> 20
F33	Heading Rate	Read Only	Heading rate of the aircraft as measured by the gyros and attitude estimator	Rad/sec	+/-6.28
F34	Last Comm.. Time	Read Only	Time stamp when last communications was received by autopilot from Commbox or Virtual Cockpit. Used for failsafes.	Seconds	

Label	Variable Name	R/W	Description	Units	Range
F35	Last RC over Comm.. Time	Read Only	Time stamp when last RC controller packet was received by autopilot from Commbox. Used for failsafes.	Seconds	
F36	Last GPS lock. Time	Read Only	Time stamp when last GPS packet with valid GPS lock information was received by autopilot from GPS receiver. Used for failsafes..	Seconds	
F37	Last GPS Comm.. Time	Read Only	Time stamp when last communications was received by autopilot from GPS receiver. Used to determine health of GPS receiver.	Seconds	
F38	Last good battery time.	Read Only	Time stamp when the battery voltage was above low battery threshold. Used for failsafes.	Seconds	
F39	Mag heading Raw	Read Only	Raw magnetic heading as reported by the Magnetometer (if present)	Radians	+/- 3.14
F40	Battery voltage	Read Only	Voltage on autopilot power bus.	Volts	7->18
F41	Battery current	Read Only	Voltage on autopilot current sense input – calibrated in Amps measured across .005 ohm resistor – low side sense.	Amps	
F42	Debug float 1	Read/Write	Debug value used by developers		
F43	Debug float 2	Read/Write	Debug value used by developers		
F44	Debug float 3	Read/Write	Debug value used by developers		
F45	Wind speed	Read/Write	Wind speed estimate	m/s	
F46	Wind heading	Read Only	Wind heading estimate (from heading)	Radians	+/- 3.14
F47	Ground Track heading estimate	Read Only	The estimated ground track heading	Radians	
F48	Estimated crab angle	Read Only	Estimated crab angle based on ground track, airspeed, and wind information	Radians	
F49	Gyro P	Read Only	Roll rate as reported by roll gyro	Rad/Sec	+/-6.28
F50	Gyro Q	Read Only	Pitch rate as reported by pitch gyro	Rad/Sec	+/-6.28
F51	Gyro R	Read Only	Yaw rate as reported by yaw gyro	Rad/Sec	+/-6.28
F52	Ax	Read Only	Acceleration along X (out nose of A/C) as reported by X accelerometer.	M/sec^2	+/- 98
F53	Ay	Read Only	Acceleration along Y (out right wing of A/C) as reported by Y accelerometer.	M/sec^2	+/- 98
F54	Az	Read Only	Acceleration along Z (out bottom of A/C) as reported by Z accelerometer.	M/sec^2	+/- 98
F55	Diff pressure	Read Only	Pressure on the pitot tube as measured by the differential pressure sensor	M/sec	+/- 100
F56	Abs pressure	Read Only	Absolute barometric pressure as measured by the absolute pressure sensor. Calculated in meters above home position (where pressure cal button was pressed)	Meters	-1000 -> 30000 MSL
F57	Mag x	Read Only	Magnetic field in X direction as measured	A/D counts	+/-1500

Label	Variable Name	R/W	Description	Units	Range
			by magnetometer.		
F58	Mag y	Read Only	Magnetic field in Y direction as measured by magnetometer.	A/D counts	+/-1500
F59	AX corrected	Read Only	X acceleration corrected for Coriolis acceleration. Only calculated when Quaternion EKF enabled	M/sec^2	
F60	AY corrected	Read Only	Y acceleration corrected for Coriolis acceleration. Only calculated when Quaternion EKF enabled	M/sec^2	
F61	AZ corrected	Read Only	Z acceleration corrected for Coriolis acceleration. Only calculated when Quaternion EKF enabled	M/sec^2	
F62	Quat Filter gain	Read/Write	Development gain used for Quaternion EKF. Only relevant when EKF is enabled		
F63	Linear gain scalar	Read Only	Gain scheduling variable based on difference between measured airspeed and trim airspeed. The control efforts of inner loop are scaled by this amount.	None	.2 -> 1
F64	Square gain scalar	Read Only	Gain scheduling variable based on the square of the difference between measured airspeed and trim airspeed. Not used	none	.2 -> 1
F65	Nav gain scalar	Read Only	Gain scheduling variable based on the difference between ground speed and airspeed. Used in navigation script.	None	.2->2
F66	Airborne timer	Read Only	Seconds since airborne flag triggered.	Seconds	>0
F67	AVX time	Read Only	Seconds since autopilot boot up	Seconds	>0
F68	Aileron auto trim effort	Read Only	Effort produced by the auto trim algorithm. Not currently used	Rad	
F69	Elevator auto trim effort	Read Only	Effort produced by the auto trim algorithm. Not currently used	Rad	
F70	Aileron servo position	Read Only	Servo position being sent to aileron servo. This is the combination of control efforts and RC transmitter values. This is before any mixing is calculated (ie, aileron verses left elevon).	Rad	
F71	Elevator servo position	Read Only	Servo position being sent to elevator servo. This is the combination of control efforts and RC transmitter values. This is before any mixing is calculated (ie. elevator verses right elevon).	Rad	
F72	Throttle servo position	Read Only	Servo position being sent to the throttle servo. This is the combination of control efforts and RC transmitter values.	Percent (%)	0->100
F73	Rudder servo position	Read Only	Servo position being sent to rudder servo. This is the combination of control efforts and RC transmitter values	Rad	
F74	Calc des yawrate	Read Only	The calculated desired yawrate based on the airspeed and desired roll angle. This value is sent to the yawrate controller if 0x0002 of UAV parameter UAV init is set.	Rad/Sec	
F75	Estimated latitude	Read Only	The estimated latitude of the aircraft. This position is interpolated between GPS	Degrees	

Label	Variable Name	R/W	Description	Units	Range
			samples.		
F76	Estimated Longitude	Read Only	The estimated longitude of the aircraft. This position is interpolated between GPS samples.	Degrees	
F77	GimbalDes Azimuth	Read/Write	The desired heading command of the gimbal. This value is reference from straight out the nose of the aircraft. Positive values are towards right wing.	Rad	+/-pi rad
F78	Gimbal Des Elevation	Read/Write	The desired elevation command of the gimbal. This value is reference from straight out towards horizon. Negative values are down.	Rad	0,-pi
F79	Gimbal Az Pos	Read/Write	The desired heading command of the gimbal. This value is reference from straight out the nose of the aircraft. Positive values are towards right wing.	Rad	+/-pi rad
F80	Gimbal El Position	Read/Write	The desired elevation command of the gimbal. This value is reference from straight out towards horizon. Negative values are down.	Rad	0,-pi
F81	Average Airspeed	Read Only	10 second average of airspeed	m/s	
F82	Airspeed Bias	Read Only	The wind corrected difference between ground speed and indicated airspeed – should be near zero at sea level.	m/s	
F83	Est Diff Pres Scalar	Read Only	The estimated differential pressure scalar – only calculated when airspeed cal is finished.	Kpa/kpa	
F84	Altitude MSL	Read/Write	The Altitude AGL of the aircraft – assumes ground calibration.	Meters	
F85	Take Off Timer	Read Only	Time left before throttle up for take off.	Seconds	
F86	Gimbal Target Lat	Read/Write	The target of the gimbal in degrees latitude	Degrees	
F87	Gimbal Target Lon	Read/Write	The target of the gimbal in degrees longitude	Degrees	
F88	Gimbal Target Alt	Read/Write	The target of the gimbal in meters above launch or meters above sea level (depends on bit 3 of gimbal mode – see Excel spreadsheet)	Meters	
F89	Orbit Phi Bias	Read	The estimated attitude estimation error in loiters	Radians	
F89	Nav Phi Bias	Read	The estimated attitude estimation error in level flight.	Radians	
F91	Terrain Elevation	Read	The height of terrain below the UAV as received by the terrain elevation packets (packet 31) sent by the ground station	Meters	
F92	Mag Z	Read	The raw output of the z-axis of the magnetometer (if present)	A/D units	
F93	Height Above Terrain	Read	The current height of the UAV above terrain below the UAV as computed by the terrain elevation packets (packet 31) sent by the ground station and the current UAV height above sea level.	Meters	
F94	Height	Read	The current height of the UAV above the	Meters	

Label	Variable Name	R/W	Description	Units	Range
	Above Home		home altitude		
F95	True Airspeed	Read	The true airspeed of the UAV based on % per thousand feet rule	M/s	
F96	Estimated Differential Pressure Bias	Read	The estimated differential pressure bias	Kpa	
F97	Laser Distance	Read	Value returned by laser range finder	Meters	>0
F98	Gimbal Target Speed	R/W	Ground speed of gimbal target (used to help gimbal predict “lead” target	M/S	
F99	Gimbal Target Heading	R/W	Ground track of gimbal target (used to help gimbal predict “lead” target	radians	+/- pi
F100	Convoy Relative Bearing	R/W	The relative bearing from the convoy of the UAV station point (0 is in front of convoy, 1.57 is right of convoy)	Radians	+/- pi
F101	Convoy Follow Range	R/W	Distance UAV keeps between itself and convoy along relative bearing	Meters	> 0
F102	LPF roll angle	R	The roll angle as determined by yaw rate and airspeed. Slow response	Radians	+/- pi
F103	LoL effort	R	Loss of lift effort – elevator effort	Radian	
F104	RPM	R	RPM as measured by RPM sensor	RPM	0 -> 22,000
F105	Fuel Quantity	R	Fuel Quantity as measured by analog input 2	NA	NA
F106	Deep Stall Glide Slope	R/W	The calculated glide slope used during deep stall to hit the Landing	Meters/Meter Alt	NA
F107	Engine Govern Eff	R	The effort produced by engine governor	%	NA
F108	AX no filt	R	X acceleration with no filtering	m/s^2	-100 - >100
F109	Alt Voltage	R	Alternate input voltage	Volts	+/-
F110	Flap Position		Flap Position	Radians	
F111	Height Above Launch		The height above the launch point.	Meters	
F112	Home Altitude		The MSL altitude of the home point	Meters	
F113	Servo Voltage	R	The servo supply voltage (2.3 autopilot only)	Volts	
F114	Barometric Pressure		Barometric Pressure	kPa	
F115	Differential Pressure		Differential Pressure	kPa	
F116	Barometric Laser Offset		Pressure sensor altitude bias. Determined using a laser rang-finder for Height-Above-Ground measurements	Meters	+/-
F117	X in the path frame		Distance from the path	Meters	
F118	Pitch<-Alt	R	Desired pitch angle from glide slope	Radians	

Label	Variable Name	R/W	Description	Units	Range
	Feedforward				
F119	Desired Climb Rate During Landing		Desired climb or descent rate during the approach phase of landing	m/s	
F120	Ground Sensor HAG Value		Height above ground reading from a ground sensor (such as a laser range-finder)	Meters	
F121	User Defined Desired Altitude		Last commanded altitude from the user, may be overridden by failsafes.	Meters	
F122	MSL WGS84 Offset		Offset between Altitude in MSL and Altitude in Meters Above the WGS84 Ellipsoid	Meters	
F123	HAG Rate		Height-Above-Ground rate. Used for terrain following.	m/s	
F124	Debug Float 4	R/W	Debug value used by developers		
F125	Debug Float 5	R/W	Debug value used by developers		
F126	Debug Float 6	R/W	Debug value used by developers		
F127	Debug Float 7	R/W	Debug value used by developers		

A.2 Description of Autopilot Byte Variables

Table A-2 Description of Autopilot Byte Variables

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td>B0</td><td>PID tuning enable</td><td>Read/Write</td><td>Enables the automatic transmission of PID tuning packets from the autopilot to the Virtual Cockpit. This can be enabled by the user by starting the PID grapher in the Virtual Cockpit.</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B1</td><td>PID tuning loop ID</td><td>Read/Write</td><td>The PID loop number for the PID tuning packets. This is automatically selected by the user selecting the appropriate PID loop in the PID screen.</td><td>#</td><td>0->14</td></tr>
<tr><td>B2</td><td>GPS fix quality</td><td>Read Only</td><td>The fix quality as reported by the GPS. 0 = no fix, 1=2d fix, 2=3dfix.</td><td>#</td><td>0->2</td></tr>
<tr><td>B3</td><td>GPS num satellites</td><td>Read Only</td><td>The number of satellites tracked by the GPS receiver.</td><td>#</td><td>0->12</td></tr>
<tr><td>B4</td><td>Att reference</td><td>Read/Write</td><td>This byte selects the type of heading estimate used by the navigation routines. 1=magnetic heading(F8), 2=ground track heading (F7), 3=interpolated ground track(F9). By default this is set to 3.</td><td>#</td><td>1->3</td></tr>
<tr><td>B5</td><td>Airborne</td><td>Read Only</td><td>Airborne Flag. This flag is set when the autopilot detects that the aircraft is airborne. This is based on airspeed, ground speed, and altitude.</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B6</td><td>Alt tracker mode</td><td>Read Only</td><td>The state of the altitude tracker. 3= altitude hold mode (altitude controlled by pitch, airspeed controlled by throttle), 4= climb mode (throttle=climb throttle (P17), airspeed controlled by pitch), 5= decsent mode (throttle=0, airspeed controlled by pitch). 0 = alt tracker off.</td><td>State</td><td>0, 3,4,5</td></tr>
<tr><td>B7</td><td>Number cmds</td><td>Read Only</td><td>The number of waypoints and loiter points uploaded to the autopilot.</td><td>#</td><td>0->229</td></tr>
<tr><td>B8</td><td>Command mode</td><td>Read Only</td><td>The state of the navigation script.
<table><tr><th>Mode</th><th>Description</th></tr><tr><td>0</td><td>Navigation script disabled</td></tr><tr><td>1</td><td>Initialize new command</td></tr><tr><td>2</td><td>Enroute to relative waypoint</td></tr><tr><td>3</td><td>Loitering</td></tr><tr><td>4</td><td>Circle Landing</td></tr><tr><td>5</td><td>Taking Off (Takeoff Phase 1)</td></tr><tr><td>6</td><td>Climbout (Takeoff Phase 2)</td></tr><tr><td>7</td><td>Not used</td></tr><tr><td>8</td><td>Approach Landing</td></tr></table></td><td>State</td><td>0->8</td></tr>
<tr><td>B9</td><td>Current cmd</td><td>Read Only</td><td>The number of the current command being executed by the navigation script. User defined commands are commands 0->229. The following table shows the reserved commands.</td><td>#</td><td>0->255</td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><th>Cmd #</th><th>Description</th></tr>
<tr><td>0->229</td><td>User defined commands (waypoints and loiters – NAV Mode commands)</td></tr>
<tr><td>230</td><td>Go home (Home mode)</td></tr>
<tr><td>231</td><td>Loiter at home</td></tr>
<tr><td>232</td><td>Loiter now (Loiter mode)</td></tr>
<tr><td>233</td><td>Takeoff (Takeoff mode)</td></tr>
<tr><td>234</td><td>Circle Land (Not used)</td></tr>
<tr><td>235</td><td>Circle Land now (low batt failsafe)</td></tr>
<tr><td>236</td><td>Approach land (Land mode)</td></tr>
<tr><td>237</td><td>Rally (Rally mode)</td></tr>
<tr><td>238</td><td>Goto LOL Rally (goto)</td></tr>
<tr><td>239</td><td>Loiter at LOL Rally (loiter)</td></tr>
<tr><td>240</td><td>Land at LOL Rally (land)</td></tr>
<tr><td>241</td><td>Generic land (land)</td></tr>
<tr><td>242</td><td>Follow Mode loiter (loiter)</td></tr>
<tr><td>243</td><td>Convoy station cmd (special loiter)</td></tr>
<tr><td>244</td><td>Reserved</td></tr>
<tr><td>245</td><td>Reserved</td></tr>
<tr><td>246</td><td>Reserved</td></tr>
<tr><td>247</td><td>Reserved</td></tr>
<tr><td>248</td><td>Targeting mode cmd (loiter)</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>B10</td><td>New GPS packet</td><td>Read Only</td><td>Goes high when a new GPS packet has been received by the GPS receiver (must have lock)</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B11</td><td>Update GPS</td><td>Read Only</td><td>Goes high when a new GPS packet has been received and the ground track velocity is above threshold. This is used to update complementary filters for ground track heading.</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B12</td><td>Restore flash defaults</td><td>Read/Write</td><td>If set to 1, the next time update flash is clicked, the autopilot will over write the PID gains and UAV Parameters with the default values. USE WITH CAUTION</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B13</td><td>GPS sim mode</td><td>Read/Write</td><td>The autopilot has a GPS simulator that loosely simulates the kinematics of an aircraft controlled by an autopilot. The simulator has 3 modes.
<table>
<tr><th>Mode</th><th>Description</th></tr>
<tr><td>0</td><td>GPS sim off</td></tr>
<tr><td>1</td><td>GPS lock only, no kinematics. Home position initialized</td></tr>
<tr><td>2</td><td>GPS lock only, no Kinematics. Allows user to update GPS relative position and speed using F23-F27.</td></tr>
<tr><td>3</td><td>Full Kinematic and GPS simulation. Aircraft flies to waypoints, holds heading, altitude, and airspeed based on current UAV mode(vel, alt, nav, etc)</td></tr>
</table>
To use the Kinematic simulator, place GPS sim in mode 1, wait 2 seconds, and then set GPS sim to mode 3.</td><td>State</td><td>0->3</td></tr>
<tr><td>B14</td><td>RC Mode</td><td>Read/Write</td><td>Boolean value indicating if autopilot is in RC</td><td>Boolean</td><td>0->1</td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td>Enabled</td><td></td><td>Mode.
This value is set using ch5 switch on RC transmitter. The normal UAV modes are disabled and gray out when RC Mode is enabled. RC Mode FLC is used in RC Mode (P19)</td><td></td><td></td></tr>
<tr><td>B15</td><td>Landing stage</td><td>Read Only</td><td>Approach landing stage. This is only valid when autopilot is in landing mode.
<table>
<tr><th>Stage</th><th>Description</th></tr>
<tr><td>0</td><td>Initializing land mode</td></tr>
<tr><td>1</td><td>Flying to Approach point (Rally point)</td></tr>
<tr><td>2</td><td>Circling down around approach point.</td></tr>
<tr><td>3</td><td>Break out altitude reached, turning in towards glide slope</td></tr>
<tr><td>4</td><td>Flying down glide slope</td></tr>
</table></td><td>State</td><td>0->4</td></tr>
<tr><td>B16</td><td>Prepare to launch</td><td>Read Only</td><td>A flag used for Takeoff Mode.</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B17</td><td>RSSI value</td><td>Read Only</td><td>RSSI as read from the Aerocomm modem (Not implemented)</td><td>#</td><td>0->255</td></tr>
<tr><td>B18</td><td>Cal mag</td><td>Read Only</td><td>Magnetometer calibration mode. To cal the mag use the calibration packet</td><td>State</td><td>0->2</td></tr>
<tr><td>B19</td><td>Nav mode wpt</td><td>Read Only</td><td>The last waypoint executed in nav mode. The next time nav mode is entered, aircraft will fly to this waypoint.</td><td>#</td><td>0->250</td></tr>
<tr><td>B20</td><td>UAV mode</td><td>Read Only</td><td>The current mode of the UAV. Only relevant when RC Mode is not enabled (b14)
<table>
<tr><th>Index</th><th>sensor</th></tr>
<tr><td>0</td><td>Manual Mode</td></tr>
<tr><td>1</td><td>Altitude Mode</td></tr>
<tr><td>2</td><td>Nav Mode</td></tr>
<tr><td>3</td><td>Home Mode</td></tr>
<tr><td>4</td><td>Rally Mode</td></tr>
<tr><td>5</td><td>Loiter Mode</td></tr>
<tr><td>6</td><td>Take Off Mode</td></tr>
<tr><td>7</td><td>Land Mode</td></tr>
<tr><td>8</td><td>Circle Land Mode</td></tr>
<tr><td>9</td><td>Circle Land Now Mode</td></tr>
<tr><td>10</td><td>Pitch/Roll Mode (Joystick 1)</td></tr>
<tr><td>11</td><td>Take Off to Waypoint Mode</td></tr>
<tr><td>12</td><td>Joystick Land Mode</td></tr>
<tr><td>13</td><td>Generic Land Mode</td></tr>
<tr><td>14</td><td>Take Off Joystick Mode</td></tr>
<tr><td>15</td><td>Take Off To WP Joystick Mode</td></tr>
<tr><td>16</td><td>Follow Mode</td></tr>
<tr><td>17</td><td>Loss Comm. Land rally</td></tr>
<tr><td>18</td><td>Safe Mode</td></tr>
</table></td><td>state</td><td>0->10</td></tr>
<tr><td>B21</td><td>Temp comp mode</td><td>Read/Write</td><td>This byte is used to enable the temp comp calibration algorithm and read temp comp parameters from the autopilot.</td><td>#</td><td>0,1,2,21-24,100-120,255</td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><th>Value</th><th>Write</th><th>Read</th></tr>
<tr><td>0</td><td>Disable temp comp</td><td>Temp comp off</td></tr>
<tr><td>1</td><td>Enable temp comp</td><td>Nothing</td></tr>
<tr><td>2</td><td>Request # tc points</td><td>Nothing</td></tr>
<tr><td>3</td><td>Reset temp comp values</td><td>nothing</td></tr>
<tr><td>100-120</td><td>Nothing</td><td>100+#tc points</td></tr>
<tr><td>21-24</td><td>Nothing</td><td>Autopilot movement detected</td></tr>
<tr><td>255</td><td>Nothing</td><td>No temp comp data</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>B22</td><td>Debug byte 1</td><td>Read/Write</td><td>Debug purposes</td><td></td><td></td></tr>
<tr><td>B23</td><td>Debug byte 2</td><td>Read/Write</td><td>Debug purposes</td><td></td><td></td></tr>
<tr><td>B24</td><td>Debug byte 3</td><td>Read/Write</td><td>Debug purposes</td><td></td><td></td></tr>
<tr><td>B25</td><td>Hardware in the Loop (HIL) simulation mode</td><td>Read/Write</td><td>The mode of the Hardware-in-the-loop simulator. When set to 1, the autopilot uses the sensor values from the hardware simulator. The normal sensors are disabled. This value is set automatically by the autopilot when a packet is received from Aviones</td><td>State/Read</td><td>0->1</td></tr>
<tr><td>B26</td><td>New HIL sensor info</td><td>Read Only</td><td>Use by hardware-in-the-loop simulator to indicate the receipt of a new sensor packet from Aviones</td><td>Boolean</td><td>0->1</td></tr>
<tr><td>B27</td><td>Flair Now</td><td>Read/Write</td><td>tells the auto land routine to deep stall the AC</td><td>Boolean/R/W</td><td>0->1</td></tr>
<tr><td>B28</td><td>Gimbal Mode</td><td>Read/Write</td><td>0=RC,1=Joystick,2=Stabilized Joystick</td><td>State/R/W</td><td>0->2</td></tr>
<tr><td>B29</td><td>IO Pin State</td><td>Read/Write</td><td>State of IO pins LSB-> ere 3,4,5 GPS 5, SerA 3,4. This value can be read or written. A write will cause the corresponding pins to change state.</td><td>State/R/W</td><td></td></tr>
<tr><td>B30</td><td>GPS Valid Timer</td><td>Read</td><td>Number of seconds until home position will be found</td><td>Seconds</td><td>>0</td></tr>
<tr><td>B31</td><td>Camera Zoom</td><td>Read</td><td>Camera zoom , 0=wide, 100 = Full zoom</td><td>%</td><td>0->100</td></tr>
<tr><td>B32</td><td>Deploy Chute</td><td>R/W</td><td>Flag indicating chute has been deployed</td><td>State</td><td>0/1</td></tr>
<tr><td>B33</td><td>Kill Engine</td><td>R/W</td><td>Flag indicating engine has been killed. 1=Kill engine, 0=reset</td><td>State</td><td>0/1</td></tr>
<tr><td>B34</td><td>Launch State</td><td>R</td><td>Launch state information</td><td>NA</td><td></td></tr>
<tr><td>B35</td><td>Parachute State</td><td>R</td><td>Parachute state information</td><td>State</td><td></td></tr>
<tr><td>B36</td><td>Trigger AUX1</td><td>R/W</td><td>Used to trigger or reset the AUX1 servo. 1=trigger, 0=reset</td><td></td><td>0/1</td></tr>
<tr><td>B37</td><td>Trigger AUX2</td><td>R/W</td><td>Used to trigger or reset the AUX2 servo. 1=trigger, 0=reset</td><td></td><td>0/1</td></tr>
<tr><td>B38</td><td>Trigger Waypoint Servo</td><td>R/W</td><td>Used to manually trigger or reset the waypoint servo. 1=trigger, 0=reset</td><td></td><td>0/1</td></tr>
</table>

Label	Variable Name	Read/Write	Description	Units	Range
B39	Camera Focus Mode	R/W	Camera focus mode for Sony FCB camera. 0=auto focus, 1=infinity focus		0/1
B40	Camera Shutter Speed	R/W	Shutter speed for Sony FCB camera		0->0x15
B41	Camera Iris	R/W	Iris setting for Sony FCB camera		0->0x11
B42	Camera Gain	R/W	Camera gain setting for Sony FCB camera		0->0x15
B43	Camera Exposure Mode	R/W	Exposure mode for Sony FCB camera 0=auto exposure, 1=manual exposure		0/1

A.3 Description of Autopilot Integer Variables

Table A-3 Description of Autopilot Integer Variables

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td>I0</td><td>PID tuning send time</td><td>Read/Write</td><td>The time in Milliseconds between PID tuning packets.</td><td>Ms</td><td>0->65536</td></tr>
<tr><td>I1</td><td>Status to GCS send time</td><td>Read/Write</td><td>The time in Milliseconds between standard telemetry packets sent by the autopilot to the Virtual Cockpit. The value is only relevant if broadcast is enabled. If broadcasts are disabled (P38 0x0200 set to 1 – see P38 Appendix E), then standard telemetry packets will only be sent when requested by the Virtual Cockpit and this value will have no effect.</td><td>Ms</td><td>0->65536</td></tr>
<tr><td>I2</td><td>FLC</td><td>Read/Write</td><td>Feed Back Loop Configuration. This value is a bitmask that controls which PID loops are enabled. This value should only be set using the PID window in the Virtual Cockpit. See FLC in Appendix E.</td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>I3</td><td>Sys status</td><td>Read Only</td><td>Bitmask containing various status bits that describe the state and initialization of the autopilot. The values are designed to be read only by the user.

<table>
<tr><th>Bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Servos are initialized</td></tr>
<tr><td>1</td><td>0x0002</td><td>Pressure (airspeed, alt) initialized</td></tr>
<tr><td>2</td><td>0x0004</td><td>GPS home initialized</td></tr>
<tr><td>3</td><td>0x0008</td><td>2d or 3d GPS lock</td></tr>
<tr><td>4</td><td>0x0010</td><td>Servo Cal is running</td></tr>
<tr><td>5</td><td>0x0020</td><td>RC Mode enabled</td></tr>
<tr><td>6</td><td>0x0040</td><td>Precision data logger has data (finished logging)</td></tr>
<tr><td>7</td><td>0x0080</td><td>Valid GPS Comm.. (GPS receiver detected)</td></tr>
<tr><td>8</td><td>0x0100</td><td>Flash needs to be written</td></tr>
<tr><td>9</td><td>0x0200</td><td>Communications bad (no Comm.. Received for lost Comm.. Timeout time)</td></tr>
<tr><td>10</td><td>0x0400</td><td>Low battery</td></tr>
<tr><td>11</td><td>0x0800</td><td>RC check box not selected on this agent</td></tr>
<tr><td>12</td><td>0x1000</td><td>Temp comp is running</td></tr>
<tr><td>13</td><td>0x2000</td><td>Waypoints have been uploaded (airplane has waypoints)</td></tr>
<tr><td>14</td><td>0x4000</td><td>Aircraft is airborne</td></tr>
<tr><td>15</td><td>0x8000</td><td>Mag cal is running</td></tr>
</table></td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>I4</td><td>Cmd period</td><td>Read/Write</td><td>Navigation script execution period.</td><td>Ms</td><td>10->1000</td></tr>
<tr><td>I5</td><td>Fixed throttle</td><td>Read/Write</td><td>Throttle trim value. This value is summed into the throttle. Useful for testing the throttle. Whole number percentage</td><td>Percent(%)</td><td>0->100</td></tr>
</table>

Label	Variable Name	Read/Write	Description	Units	Range
I6	Time since last RC over Comm..	Read Only	Time in m/s since the last RC controller packet was received by the autopilot from the Commbox	Ms	0->65536
I7	Time since last Comm...	Read Only	Time in m/s since the last communications packet was received from the Virtual Cockpit or Commbox.	Ms	0->65536
I8	Time since last GPS lock	Read Only	Time in m/s since the last valid GPS lock packet was received by the autopilot from the GPS receiver	Ms	0->65536
I9	Time since last GPS Comm	Read Only	Time in m/s since the last GPS packet(lock or no lock) was received by the autopilot from the GPS receiver	Ms	0->65536
I10	Time since last good battery	Read Only	Time in m/s since the battery voltage was above the low battery threshold voltage.	Ms	0->65536
I11	Temp R	Read Only	Temperature of the yaw gyro - autopilot board temp	Degrees C	0->200
I12	Failsafe status	Read/Write	Failsafe status bitmask. Represents which failsafes have triggered. (see bit table below)	Bitmask	0->65536
I13	Sensor check results	Read Only	The results of the last sensor check (sensor check button in VC). The sensor check routine checks the autopilot sensor to see if they are within loose limits for a level aircraft that is not being moved. Used to help pre-flight the aircraft	Bitmask	0->65536

I12 Failsafe status bitmask:

Bit	Bitmask	Description
0	0x0001	RC Mode level failsafe triggered
1	0x0002	RC Mode go home with GPS lock failsafe triggered
2	0x0004	RC Mode go home without GPS lock failsafe triggered
3	0x0008	Lost Comm. with GPS lock failsafe triggered
4	0x0010	Lost Comm. without GPS lock failsafe triggered
5	0x0020	Lost Comm. while not airborne failsafe triggered (not used)
6	0x0040	Low battery with GPS lock failsafe triggered
7	0x0080	Low battery without GPS lock failsafe triggered
8	0x0100	Critical battery with GPS lock failsafe triggered
9	0x0200	Critical battery without GPS lock failsafe triggered
10	0x0400	Lost GPS circle failsafe triggered
11	0x0800	Lost GPS auto-land failsafe triggered
12	0x1000	Lost Comm Rally Land triggered
13	0x2000	Min Hag triggered
14	0x4000	Flight term triggered
15	0x8000	Lost Comm.. Landing trig

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>P gyro good</td></tr>
<tr><td>1</td><td>0x0002</td><td>q gyro good</td></tr>
<tr><td>2</td><td>0x0004</td><td>r gyro good</td></tr>
<tr><td>3</td><td>0x0008</td><td>Ax accelerometer good</td></tr>
<tr><td>4</td><td>0x0010</td><td>Ay accelerometer good</td></tr>
<tr><td>5</td><td>0x0020</td><td>Az accelerometer good</td></tr>
<tr><td>6</td><td>0x0040</td><td>Differential pressure good</td></tr>
<tr><td>7</td><td>0x0080</td><td>Absolute pressure good</td></tr>
<tr><td>8</td><td>0x0100</td><td>Pitch estimate good</td></tr>
<tr><td>9</td><td>0x0200</td><td>Roll estimate good</td></tr>
<tr><td>10</td><td>0x0400</td><td>Lost GPS circle failsafe triggered</td></tr>
<tr><td>11</td><td>0x0800</td><td>Temperature in bounds</td></tr>
<tr><td>12</td><td>0x1000</td><td>Mag x good or not present</td></tr>
<tr><td>13</td><td>0x2000</td><td>Mag y good or not present</td></tr>
<tr><td>14</td><td>0x4000</td><td>Not used</td></tr>
<tr><td>15</td><td>0x8000</td><td>Not used</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>I14</td><td>Failsafe Status2</td><td>Read only</td><td>Failsafe status 2
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Loss of GPS chute</td></tr>
<tr><td>1</td><td>0x0002</td><td>Low rpm rally descent</td></tr>
<tr><td>2</td><td>0x0004</td><td>Low rpm pop chute</td></tr>
<tr><td>3</td><td>0x0008</td><td>Loss of control</td></tr>
<tr><td>4</td><td>0x0010</td><td>Min HAG Laser Failsafe</td></tr>
<tr><td>5</td><td>0x0020</td><td></td></tr>
<tr><td>6</td><td>0x0040</td><td></td></tr>
<tr><td>7</td><td>0x0080</td><td></td></tr>
</table>
</td><td>Bitmask</td><td></td></tr>
<tr><td>I15</td><td>System Flags 1</td><td>Read only</td><td>System Flags 1
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Sensor broadcast enabled</td></tr>
<tr><td>1</td><td>0x0002</td><td>Sensor broadcast raw ad</td></tr>
<tr><td>2</td><td>0x0004</td><td>Broadcast mag enabled</td></tr>
<tr><td>3</td><td>0x0008</td><td>Broadcast servo ppm</td></tr>
<tr><td>4</td><td>0x0010</td><td>Broadcast servo rad</td></tr>
<tr><td>5</td><td>0x0020</td><td>Pid servo disconnect enabled</td></tr>
<tr><td>6</td><td>0x0040</td><td>Servo pos hold enabled</td></tr>
<tr><td>7</td><td>0x0080</td><td>Sensor check enabled</td></tr>
<tr><td>8</td><td>0x0100</td><td>pitch auto trim enable</td></tr>
<tr><td>9</td><td>0x0200</td><td>Airspeed cal done</td></tr>
<tr><td>10</td><td>0x0400</td><td>roll auto trim</td></tr>
<tr><td>11</td><td>0x0800</td><td>empty</td></tr>
<tr><td>12</td><td>0x1000</td><td>Freewave Modem needs transmit slot set</td></tr>
<tr><td>13</td><td>0x2000</td><td>Obsoleted</td></tr>
<tr><td>14</td><td>0x4000</td><td>Engine RPM ok</td></tr>
<tr><td>15</td><td>0x8000</td><td>Broadcast mixed telem</td></tr>
</table>
</td><td>Bitmask</td><td></td></tr>
<tr><td>I16</td><td>System Flags 2</td><td>Read only</td><td>System Flags 2
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Gimbal Mode0 bit</td></tr>
<tr><td>1</td><td>0x0002</td><td>Gimbal Mode 1 bit</td></tr>
<tr><td>2</td><td>0x0004</td><td>Mixed telem2 enabled</td></tr>
<tr><td>3</td><td>0x0008</td><td>MSL Alt calibrated</td></tr>
</table>
</td><td>Bitmask</td><td></td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td>4</td><td>0x0010</td><td>Home Alt set</td></tr>
<tr><td>5</td><td>0x0020</td><td>Alt override enabled</td></tr>
<tr><td>6</td><td>0x0040</td><td>Airspeed over-ride enabled</td></tr>
<tr><td>7</td><td>0x0080</td><td>Flair enabled</td></tr>
<tr><td>8</td><td>0x0100</td><td>Side look camera selected</td></tr>
<tr><td>9</td><td>0x0200</td><td>Holding single servo pos</td></tr>
<tr><td>10</td><td>0x0400</td><td>Holding single servo pos (rad)</td></tr>
<tr><td>11</td><td>0x0800</td><td>Servo Cal flash write needed.</td></tr>
<tr><td>12</td><td>0x1000</td><td>HAG good (have terrain data)</td></tr>
<tr><td>13</td><td>0x2000</td><td>UTC time in synch with GPS</td></tr>
<tr><td>14</td><td>0x4000</td><td>Gimbal retracted</td></tr>
<tr><td>15</td><td>0x8000</td><td>Gimbal in safe pos</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>I17</td><td>System Flags 3</td><td>Read only</td><td>System Flags 3
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Parachute deployed</td></tr>
<tr><td>1</td><td>0x0002</td><td>Engine killed</td></tr>
<tr><td>2</td><td>0x0004</td><td>Low fuel</td></tr>
<tr><td>3</td><td>0x0008</td><td>External IO board plugged in</td></tr>
<tr><td>4</td><td>0x0010</td><td>Camera bank 2 selected</td></tr>
<tr><td>5</td><td>0x0020</td><td>Waypoint servo trigger</td></tr>
<tr><td>6</td><td>0x0040</td><td>Simulation mode enabled</td></tr>
<tr><td>7</td><td>0x0080</td><td>Climb fault</td></tr>
<tr><td>8</td><td>0x0100</td><td>Broadcast onboard control telemetry</td></tr>
<tr><td>9</td><td>0x0200</td><td>Generator fault</td></tr>
<tr><td>10</td><td>0x0400</td><td>Wind estimate OK</td></tr>
<tr><td>11</td><td>0x0800</td><td>Aux 1 servo triggered</td></tr>
<tr><td>12</td><td>0x1000</td><td>Aux 2 servo triggered</td></tr>
<tr><td>13</td><td>0x2000</td><td>Flaps Bit 0</td></tr>
<tr><td>14</td><td>0x4000</td><td>Flaps Bit 1</td></tr>
<tr><td>15</td><td>0x8000</td><td>Gimbal Target MSL</td></tr>
</table>
</td><td>Bitmask</td><td></td></tr>
<tr><td>I18</td><td>Time since last good RPM</td><td>Read only</td><td>The amount of time in .1 second increments since last good RPM.</td><td>Time</td><td></td></tr>
<tr><td>I19</td><td>Time since last good RPM comm</td><td>Read only</td><td>The amount of time in .1 second increments since last packet RPM board.</td><td>Time</td><td></td></tr>
<tr><td>I20</td><td>IO expander status</td><td>Read only</td><td>The status of the IO expander board if plugged in.</td><td>Time</td><td></td></tr>
<tr><td>I21</td><td>Time since launch detect</td><td>Read only</td><td>The time since launch detect in 50th of second.</td><td>Time</td><td></td></tr>
<tr><td>I22</td><td>Launch Status</td><td>Read only</td><td>Status of the catapult launch routine.</td><td></td><td></td></tr>
<tr><td>I23</td><td>Climb</td><td>Read Only</td><td>Status of duration of climb fault condition</td><td></td><td></td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Read/Write</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td>Fault Counter</td><td></td><td></td><td>seconds * 10</td><td></td></tr>
<tr><td>I24</td><td>Flaps Level</td><td>R/W</td><td>0=off, 1=low, 2=med, 3=high</td><td></td><td>0-3</td></tr>
<tr><td>I25</td><td>Aux 1 servo pos</td><td></td><td>Position in ppm of aux 1 servo</td><td>us ppm</td><td></td></tr>
<tr><td>I26</td><td>Aux 2 servo pos</td><td></td><td>Position in ppm of aux 2 servo</td><td>us ppm</td><td></td></tr>
<tr><td>I27</td><td>System Flags 4</td><td></td><td>System Flags 4
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>KAP Version Sent / Reboot indication</td></tr>
<tr><td>1</td><td>0x0002</td><td>Alternate voltage enabled</td></tr>
<tr><td>2</td><td>0x0004</td><td>MSL Mode enabled</td></tr>
<tr><td>3</td><td>0x0008</td><td>Aerius Laser Configured</td></tr>
<tr><td>4</td><td>0x0010</td><td>Good height sensor readings</td></tr>
<tr><td>5</td><td>0x0020</td><td>Enable minimum HAG</td></tr>
<tr><td>6</td><td>0x0040</td><td>Enable Laser-aided landing</td></tr>
<tr><td>7</td><td>0x0080</td><td>Opti-Logic laser configured</td></tr>
<tr><td>8</td><td>0x0100</td><td></td></tr>
<tr><td>9</td><td>0x0200</td><td></td></tr>
<tr><td>10</td><td>0x0400</td><td></td></tr>
<tr><td>11</td><td>0x0800</td><td></td></tr>
<tr><td>12</td><td>0x1000</td><td></td></tr>
<tr><td>13</td><td>0x2000</td><td></td></tr>
<tr><td>14</td><td>0x4000</td><td>Reference time initialized</td></tr>
<tr><td>15</td><td>0x8000</td><td>Reference time needed</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>I28</td><td>System Flags 5</td><td></td><td>System Flags 5
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td></td></tr>
<tr><td>1</td><td>0x0002</td><td></td></tr>
<tr><td>2</td><td>0x0004</td><td></td></tr>
<tr><td>3</td><td>0x0008</td><td></td></tr>
<tr><td>4</td><td>0x0010</td><td></td></tr>
<tr><td>5</td><td>0x0020</td><td></td></tr>
<tr><td>6</td><td>0x0040</td><td></td></tr>
<tr><td>7</td><td>0x0080</td><td></td></tr>
<tr><td>8</td><td>0x0100</td><td></td></tr>
<tr><td>9</td><td>0x0200</td><td></td></tr>
<tr><td>10</td><td>0x0400</td><td></td></tr>
<tr><td>11</td><td>0x0800</td><td></td></tr>
<tr><td>12</td><td>0x1000</td><td></td></tr>
<tr><td>13</td><td>0x2000</td><td></td></tr>
<tr><td>14</td><td>0x4000</td><td></td></tr>
<tr><td>15</td><td>0x8000</td><td></td></tr>
</table></td><td></td><td></td></tr>
</table>

Appendix B

B.1 Description of UAV Parameters

Table B-1 Description of UAV Parameters

Label	Variable Name	Data Type	Description	Units	Range
P0	Phi lower limit	Float	Lower limit on commanded roll angle sent from Virtual Cockpit. This value does not affect commands generated by control loops.	Radians	
P1	Phi upper limit	Float	Upper limit on commanded roll angle sent from Virtual Cockpit. This value does not affect commands generated by control loops.	Radians	
P2	Theta lower limit	Float	Lower limit on commanded pitch angle sent from Virtual Cockpit. This value does not affect commands generated by control loops.	Radians	
P3	Theta upper limit	Float	Upper limit on commanded pitch angle sent from Virtual Cockpit. This value does not affect commands generated by control loops.	Radians	
P4	Alt lower limit	Float	Lower limit on commanded altitude sent from Virtual Cockpit.	Meters	
P5	Alt upper limit	Float	Upper limit on commanded altitude sent from Virtual Cockpit.	Meters	
P6	IAS lower limit	Float	Lower limit on commanded airspeed sent from Virtual Cockpit.	m/s	
P7	IAS upper limit	Float	Upper limit on commanded airspeed sent from Virtual Cockpit.	m/s	
P8	Default loiter radius	Float	Loiter radius used in Loiter Mode	Meters	
P9	Debug 1	Float	Debug value		
P10	Alt Tracker Descent Throttle	Float	The Throttle commanded by the altitude tracker during descent mode	Percent (%)	0->100
P11	Takeoff throttle	Float	Throttle used in Takeoff Mode	Percent (%)	0->100
P12	Takeoff pitch	Float	Pitch used in first part of Takeoff Mode. In second stage of takeoff pitch is controlled from airspeed.	Radians	
P13	Takeoff trans altitude	Float	Altitude above launch point at which Spiral Takeoff Mode transitions from using takeoff pitch to controlling pitch from airspeed error. If spiral take off mode is active, aircraft will begin spiral at this altitude. Use “P85 Takeoff Rotate Altitude” for Waypoint Takeoff transition altitude.	Meters	>0
P14	Min go home alt	Float	The minimum go home altitude. If home button is clicked and UAV is below this altitude, UAV will climb to this altitude. Not used if low battery failsafe has triggered.	Meters	>0
P15	Waypoint radius	Float	The radius used in Nav Mode to determine if waypoint has been reached. This is the pre-turn distance if xtrack is enabled.	Meters	> 0
P16	Alt tracker window	Float	The window size in meters between which altitude tracker will use pitch to control altitude and throttle to control airspeed. If the altitude error exceeds	Meters	>0

<table>
<tr><th>Label</th><th>Variable Name</th><th>Data Type</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>window size, alt tracker enters climb or decent mode. Climb mode uses climb throttle (P17) and pitch to control airspeed. Descent mode uses zero throttle and pitch to control airspeed.</td><td></td><td></td></tr>
<tr><td>P17</td><td>Alt tracker climb throttle</td><td>Float</td><td>Throttle used in climb mode by alt tracker</td><td>Percent (%)</td><td>0->100</td></tr>
<tr><td>P18</td><td>Minimum throttle</td><td>Float</td><td>The minimum throttle that can be commanded by control algorithms. Used to prevent stalling gas or glow engine.</td><td>Percent (%)</td><td>0->100</td></tr>
<tr><td>P19</td><td>RCMode FLC</td><td>Unsigned int</td><td>FLC used by control algorithms in RC Mode. Typically this is set to enable rate damping on two or three axis when pilot-in-the-loop control is enabled (RC mode)</td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>P20</td><td>Manual Mode FLC</td><td>Unsigned int</td><td>FLC used by control algorithms in Manual Mode. Typically this is set to enable rate damping, and to control pitch from airspeed. Altitude is maintained by user commanded throttle. Roll angle is controlled and desired roll is set by user from Virtual Cockpit.</td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>P21</td><td>Alt Mode FLC</td><td>Unsigned int</td><td>FLC used by control algorithms in Altitude Mode. Typically this is set to enable rate damping, Altitude, and airspeed control. There are three options for altitude and airspeed control:
1. Altitude is controlled by throttle and airspeed is controlled from pitch (alt tracker disabled).
2. Altitude is controlled by pitch and airspeed from throttle. (alt tracker disabled).
3. Alt tracker enabled and airspeed and altitude controller configured based on size of altitude error. Altitude, velocity, and roll angle commanded by user through Virtual Cockpit.</td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>P22</td><td>Nav Mode FLC</td><td>Unsigned int</td><td>FLC used by control algorithms in Nav, Home, Loiter, and Rally Modes. Basically, the FLC used by the autopilot any time aircraft is navigating using GPS. Heading and roll loop FLC will be overwritten (enabled and disabled) by NAV script as needed.</td><td>Bitmask</td><td>0->65536</td></tr>
<tr><td>P23</td><td>Boot UAV Mode</td><td>Unsigned char</td><td>The UAV mode the autopilot sets on boot up.
<table>
<tr><th>Index</th><th>sensor</th></tr>
<tr><td>0</td><td>Manual Mode</td></tr>
<tr><td>1</td><td>Altitude Mode</td></tr>
<tr><td>2</td><td>Nav Mode</td></tr>
<tr><td>3</td><td>Home Mode</td></tr>
<tr><td>4</td><td>Rally Mode</td></tr>
<tr><td>5</td><td>Loiter Mode</td></tr>
<tr><td>6</td><td>Take Off Mode</td></tr>
<tr><td>7</td><td>Land Mode</td></tr>
<tr><td>8</td><td>Circle Land Mode</td></tr>
<tr><td>9</td><td>Circle Land Now Mode</td></tr>
<tr><td>10</td><td>Pitch/Roll Mode (Joystick 1)</td></tr>
<tr><td>11</td><td>Take Off to Waypoint Mode</td></tr>
<tr><td>12</td><td>Joystick Land Mode</td></tr>
<tr><td>13</td><td>Generic Land Mode</td></tr>
<tr><td>14</td><td>Take Off Joystick Mode</td></tr>
<tr><td>15</td><td>Take Off To WP Joystick Mode</td></tr>
<tr><td>16</td><td>Follow Mode</td></tr>
</table></td><td>UAV Mode</td><td>0->18</td></tr>
</table>

Label	Variable Name	Data Type	Description	Units	Range
			17 Loss comm. land rally 18 Safe Mode 19 PID tune Mode (not used) 20 Convoy follow mode 21 Targeting mode		
P24	Servo Mixing	Unsigned int	Elevon mixing is the only type of mixing currently available. It can also be used for V-tail. This is enabled by setting this value to 1.	Bitmask	0->1
P25	Aileron scalar	Float	This value converts micro seconds of servo PPM to radians of aileron deflection. This value is airframe and servo installation dependent and should be determined by comparing what the autopilot thinks the control deflection is (F70 -> F74) with the actual control deflection as measured with an angle gauge. Before this is done, the trims should be uploaded so the values are centered around zero.	Rad/uS	
P26	Elevator scalar	Float	This value converts micro seconds of servo PPM to radians of elevator deflection. This value is airframe and servo installation dependent and should be determined by comparing what the autopilot thinks the control deflection is (F70 -> F74) with the actual control deflection as measured with an angle gauge. Before this is done, the trims should be uploaded so the values are centered around zero.	Rad/uS	
P27	Throttle scalar	Float	This value converts micro seconds of servo PPM to percent of throttle deflection(0 -> 100). This value is airframe and servo installation dependent and should be determined by comparing what the autopilot thinks the control deflection is (F70 -> F74) with the actual control deflection as measured with an angle gauge. Before this is done, the trims should be uploaded so the values are centered around zero.	%//uS	
P28	Rudder scalar	Float	This value converts micro seconds of servo PPM to radians of rudder deflection. This value is airframe and servo installation dependent and should be determined by comparing what the autopilot thinks the control deflection is (F70 -> F74) with the actual control deflection as measured with an angle gauge. Before this is done, the trims should be uploaded so the values are centered around zero.	Rad/uS	
P29	Ch6 scalar	Float	This value converts micro seconds of servo PPM to radians of ch6 deflection. This value is airframe and servo installation dependent and should be determined by comparing what the autopilot thinks the control deflection is (F70 -> F74) with the actual control deflection as measured with an angle gauge. Before this is done, the trims should be uploaded so the values are centered around zero. Ch6 can only be accessed internally in the autopilot or through the servo expansion board.	Rad/uS	
P30	Ch7 scalar	Float	Not Used in Ma7.1	Rad/uS	
P31	Aileron servo bias	Float	The value in micro seconds sent to the servo for neutral control surface deflection. The control deflection in radians is converted to micro seconds and then this value is summed in and sent to the	Micro Seconds	0->2000

<table>
<tr><th>Label</th><th>Variable Name</th><th>Data Type</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>servo. This value can be adjusted by the user manually or by using the upload trims function on the Commbox. At which point the current RC stick positions will be used as the bias. This value is summed in prior to elevon mixing.</td><td></td><td></td></tr>
<tr><td>P32</td><td>Elevator servo bias</td><td>Float</td><td>The value in micro seconds sent to the servo for neutral control surface deflection. The control deflection in radians is converted to micro seconds and then this value is summed in and sent to the servo. This value can be adjusted by the user manually or by using the upload trims function on the Commbox. At which point the current RC stick positions will be used as the bias. This value is summed in prior to elevon mixing.</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P33</td><td>Throttle servo bias</td><td>Float</td><td>The value in micro seconds sent to the servo for neutral control surface deflection. The control deflection in radians is converted to micro seconds and then this value is summed in and sent to the servo. This value can be adjusted by the user manually.</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P34</td><td>Rudder servo bias</td><td>Float</td><td>The value in micro seconds sent to the servo for neutral control surface deflection. The control deflection in radians is converted to micro seconds and then this value is summed in and sent to the servo. This value can be adjusted by the user manually or by using the upload trims function on the Commbox. At which point the current RC stick positions will be used as the bias.</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P35</td><td>Ch6 servo bias</td><td>Float</td><td>The value in micro seconds sent to the servo for neutral control surface deflection. The control deflection in radians is converted to micro seconds and then this value is summed in and sent to the servo. This value can be adjusted by the user manually or by using the upload trims function on the Commbox. At which point the current RC stick positions will be used as the bias. Ch6 can only be accessed internally in the autopilot or through the servo expansion board.</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P36</td><td>Ch7 servo bias</td><td>Float</td><td>Not Used in Ma7.1</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P37</td><td>Ch8 servo bias</td><td>Float</td><td>Not Used in Ma7.1</td><td>Micro Seconds</td><td>0->2000</td></tr>
<tr><td>P38</td><td>UAV inits</td><td>Unsigned int</td><td>Bitmasked value that is used to configure various autopilot behavior.
<table>
<tr><th>bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Use aileron for yaw rate and heading rate control</td></tr>
<tr><td>1</td><td>0x0002</td><td>Calculate desired yawrate</td></tr>
<tr><td>2</td><td>0x0004</td><td>Enable auto trim from ailerons and elevator</td></tr>
<tr><td>3</td><td>0x0008</td><td>Servo Bias initialized</td></tr>
<tr><td>4</td><td>0x0010</td><td>Use MSL altitudes</td></tr>
<tr><td>5</td><td>0x0020</td><td>Use onboard GPS to correct MSL altitude during flight.</td></tr>
<tr><td>6</td><td>0x0040</td><td>Automatically switch to between low and high power on the</td></tr>
</table></td><td>Bitmask</td><td>0->65536</td></tr>
</table>

<table>
<tr><th>Label</th><th>Variable Name</th><th>Data Type</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td><table>
<tr><td></td><td></td><td>Aerocomm modem based on distance from home,</td></tr>
<tr><td>7</td><td>0x0080</td><td>Alt=msl alt-launch alt</td></tr>
<tr><td>8</td><td>0x0100</td><td>Empty</td></tr>
<tr><td>9</td><td>0x0200</td><td>Disable broadcast packets</td></tr>
<tr><td>10</td><td>0x0400</td><td>Enable gimbal auto retract</td></tr>
<tr><td>11</td><td>0x0800</td><td>Enable gimbal auto extend</td></tr>
<tr><td>12</td><td>0x1000</td><td>Enable Packet Forwarding</td></tr>
<tr><td>13</td><td>0x2000</td><td>Update alt with new home pos</td></tr>
<tr><td>14</td><td>0x4000</td><td>Use inductive current shunt</td></tr>
<tr><td>15</td><td>0x8000</td><td>Enable gimbal auto safe</td></tr>
</table></td><td></td><td></td></tr>
<tr><td>P39</td><td>Altitude Corr From Airspeed</td><td>Float</td><td>Altitude correction factor based on airspeed – used to correct for pressurized cabin.</td><td>Kpa correction/kpa of diff pressure</td><td></td></tr>
<tr><td>P40</td><td>Orbit course gain</td><td>Float</td><td>Course error to desired roll angle gain used by orbit algorithm. Unit is radians of roll angle per radian of course error.</td><td>Rad/Rad</td><td></td></tr>
<tr><td>P41</td><td>Orbit xt gain</td><td>Float</td><td>Cross track error to course correction used by orbit algorithm. Unit is radians of course correction per meter of cross track course error.</td><td>Rad/meter</td><td></td></tr>
<tr><td>P42</td><td>Max orbit roll</td><td>Float</td><td>The maximum roll angle that can be commanded by the orbit algorithm.</td><td>Rad</td><td></td></tr>
<tr><td>P43</td><td>Max orbit xt effort</td><td>Float</td><td>The maximum course correction from cross track error. Used by the orbit algorithm.</td><td>Rad</td><td></td></tr>
<tr><td>P44</td><td>Xtrack hand distance</td><td>Float</td><td>The hand point or steer point used by the cross track control algorithm to navigate between waypoints. It is also used as the pre-turn distance. The autopilot will steer to a point in meters in front of the cross track intersect point on the course determined by this value. This value is only used if cross track is enabled. (P49)</td><td></td><td></td></tr>
<tr><td>P45</td><td>Debug 2</td><td>Float</td><td>Not used</td><td></td><td></td></tr>
<tr><td>P46</td><td>Debug 3</td><td>Float</td><td>Not used</td><td></td><td></td></tr>
<tr><td>P47</td><td>PID derivative corner frequency</td><td>Float</td><td>LPF corner frequency used by all PID controllers. The PID error is low pass filtered and then the derivative is taken.</td><td>Hz</td><td></td></tr>
<tr><td>P48</td><td>Loss of lift gain</td><td>Float</td><td>Roll angle to elevator deflection gain used as a feed forward component to compensate for the offset in lift vector during a bank. Not used at this time – set to zero.</td><td>Rad/rad</td><td>0</td></tr>
<tr><td>P49</td><td>WP Nav config</td><td>Unsigned int</td><td>Bitmask used to configure waypoint navigation behavior. This value is used to enable cross track control and other things.<table>
<tr><th>Bit</th><th>Bitmask</th><th>Description</th></tr>
<tr><td>0</td><td>0x0001</td><td>Use waypoint altitude</td></tr>
<tr><td>1</td><td>0x0002</td><td>Enable vector path following in landing mode</td></tr>
<tr><td>2</td><td>0x0004</td><td>Enable cross track control</td></tr>
<tr><td>3</td><td>0x0008</td><td>Use alt tracker in nav, loiter, rally, home, land, and take off modes</td></tr>
<tr><td>4</td><td>0x0010</td><td>Orbit clockwise in nav, loiter, rally, land, and take off modes.</td></tr>
</table></td><td>Bitmask</td><td>0->65536</td></tr>
</table>

Label	Variable Name	Data Type	Description	Units	Range
			5 | 0x0020 | Use minimum go home alt in home mode 6 | 0x0040 | Use waypoint velocity 7 | 0x0080 | Auto Calc pre-turn distance		
P50	Airplane Address	Unsigned int	Communication Address of the airplane. All Communication packets that are addressed to a different address will not be accepted.	Address	2->65536
P51	Modem Channel	Unsigned char	RF channel of the Aerocomm series digital modems. The autopilot will attempt to re-program the modem to this value on autopilot boot or anytime this value is changed by the user. If a different modem is used, this value will have no affect. This value must match the modem channel of the Commbox	Channel #	0->255
P52	Mag declination	Float	Magnetic declination in radians	Radians	
P53	Mag inclination	Float	Magnetic inclination in radians	Radians	
P54	Trim airspeed	Float	Airspeed in meters per second (m/s) about which the aircraft has been trimmed. This is the airspeed at which the aircraft should be flown when gains are tuned. Ideally the aircraft would maintain level flight at this airspeed with all control surfaces neutral and throttle set at trim throttle. As the measured airspeed deviates from this value the control efforts will be scaled. Control efforts are only scaled down (See F63 – never exceeds 1). The Pitch from Airspeed and Throttle from Airspeed feed forward values are calculated from this point (P62, P63)	m/s	>0
P55	Cruise airspeed	Float	Desired airspeed in m/s used in Manual Mode, Altitude Mode, Loiter Mode, Home Mode, and Rally Mode. Not used in Nav, Take-Off, Land Mode.	m/s	>0
P56	Trim Throttle	Float	Throttle in % at which aircraft maintains level flight at trim velocity. This value is summed into the throttle from airspeed PID effort	Percent(%)	0->100
P57	Trim AOA	Float	Trim angle of attack. Pitch angle at which the aircraft maintains level flight at trim throttle and trim airspeed with neutral control surface deflections. This value is added to the control efforts of the pitch from airspeed and pitch from altitude PID loops	Radians	
P58	Pitch velocity feed forward	Float	Feed forward component for pitch from airspeed PID loop. This value converts airspeed (desired airspeed – trim airspeed) to desired pitch offset. In almost all cases this value will be negative. The results are summed into the pitch from airspeed control effort	Radians/(m/s)	<=0
P59	Throttle velocity feed forward	Float	Feed forward component for throttle from airspeed PID loop. This value converts airspeed (desired airspeed – trim airspeed) to desired throttle offset. In almost all cases this value will be positive. The results are summed into the throttle from airspeed control effort	Percent(%)/(m/s)	>=0
P60	Low battery voltage	Float	Voltage at which battery is considered low. Used for low battery failsafe. Should be set high enough that the aircraft has time to fly home. This value can be set through the Failsafe screen.	Volts	>0
P61	Critical low battery voltage	Float	Voltage at which battery is considered critically low. Used for critically low battery failsafe. If voltage	Volts	>0

Label	Variable Name	Data Type	Description	Units	Range
			drops below this value, aircraft automatically lands at current location if critically low battery failsafe is enabled. Typically, this value is set at the threshold level that battery damage or autopilot brown out may occur (for 3-cell lithium, 9 volts, autopilot brown out at 6.5 volts). This value can be set through the Failsafe screen.		
P62	Low battery failsafe time	Float	Time in seconds that battery must be below low battery voltage (P64) for low battery failsafe to trigger. This value can be set through the Failsafe screen.	Seconds	>=0
P63	GPS circle failsafe time	Float	Time in seconds that must pass between last valid GPS lock and GPS failsafe circle to enable.	Seconds	>=0
P64	GPS land failsafe time	Float	Time in seconds that the aircraft will circle in attempt to re-acquire GPS lock after GPS failsafe has triggered. After timer expires, aircraft will auto-land at current location. This value can be set through the Failsafe screen.	Seconds	>=0
P65	Lost comm. Go home timeout	Float	Time in seconds between the last valid communication from the Virtual Cockpit to the autopilot before lost communications failsafe triggers. This value can be set through the Failsafe screen.	Seconds	>=0
P66	RC Mode Level timeout	Float	Time in seconds between last valid RC over comm. Packet is received by autopilot from Commbox and RC Mode failsafe will place the aircraft in Alt Mode and command current altitude. This failsafe is only active in RC Mode. This value can be set through the Failsafe screen.	Seconds	>=0
P67	RC Mode go home time out	Float	Time in seconds between last valid RC Mode Packet is received by autopilot from Commbox and RC Mode failsafe will place the autopilot in home mode. This failsafe is only active in RC Mode. This value can be set through the Failsafe screen.	Seconds	>=0
P68	Failsafe config	Unsigned int	Bitmask that is used to determine failsafe behavior. This value is through the configuration options in the failsafe screen. See Appendix C.	Bitmask	0->65536
P69	UAV Mode config	Unsigned int	Bitmask used to configure autopilot modes (for example whether to use Alt tracker in alt mode). (see bit table below)	Bitmask	0->65536

bit	Bitmask	Description
0	0x0001	Use alt tracker in alt mode
1	0x0002	Enable RPV mode
2	0x0004	Use optimal loiter radius in loiter now mode (based on altitude and airspeed). Else use default loiter radius.
3	0x0008	Use camera centric loiter center point in loiter now mode when side look camera is selected. Else use current position of aircraft as loiter center point.
4	0x0010	Enable countdown timer for take off. When enabled, autopilot will set throttle= warning throttle at t-2 seconds and full throttle at t=0

<table>
<tr><th>Label</th><th>Variable Name</th><th>Data Type</th><th>Description</th><th>Units</th><th>Range</th></tr>
<tr><td></td><td></td><td></td><td>
<table>
<tr><td></td><td></td><td>seconds.</td></tr>
<tr><td>5</td><td>0x0020</td><td>Empty</td></tr>
<tr><td>6</td><td>0x0040</td><td>Gimbal Present</td></tr>
<tr><td>7</td><td>0x0080</td><td>Schedule Ruder with Throttle</td></tr>
<tr><td>8</td><td>0x0100</td><td>Schedule Elevator with Throttle</td></tr>
<tr><td>9</td><td>0x0200</td><td>Enable Ground Mode</td></tr>
<tr><td>10</td><td>0x0400</td><td>Enable Catapult Launch</td></tr>
<tr><td>11</td><td>0x0800</td><td>Enable Catapult Launch Motor Trigger</td></tr>
<tr><td>12</td><td>0x1000</td><td>Use climb rate for alt tracker</td></tr>
<tr><td>13</td><td>0x2000</td><td>Dead Reckon using magnetometer</td></tr>
<tr><td>14</td><td>0x4000</td><td>Parachute delay engine kill</td></tr>
<tr><td>15</td><td>0x8000</td><td>Enable gimbal bay door on aux1 channel</td></tr>
<tr><td>16</td><td>0x10000</td><td>Enable landing pitch feedforward</td></tr>
<tr><td>17</td><td>0x20000</td><td>Enable landing pitch feedforward in flare</td></tr>
<tr><td>18</td><td>0x40000</td><td>Enable deep stall gain scheduling</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>P70</td><td>HIL aileron scalar</td><td>Float</td><td>Scales the aileron deflection to account for model differences between actual aircraft and hardware in the loop (Aviones) simulation. Prevents the need to re-tune gains for use with Aviones Hardware-in–the-loop-simulator.</td><td>Rad/rad</td><td></td></tr>
<tr><td>P71</td><td>HIL elevator scalar</td><td>Float</td><td>Scales the elevator deflection to account for model differences between actual aircraft and hardware in the loop (Aviones) simulation. Prevents the need to re-tune gains for use with Aviones Hardware-in-the-loop simulator.</td><td>Rad/rad</td><td></td></tr>
<tr><td>P72</td><td>HIL throttle Scalar</td><td>Float</td><td>Scales the throttle deflection to account for model differences between actual aircraft and hardware in the loop (Aviones) simulation. Prevents the need to re-tune gains for use with Aviones Hardware-in-the-loop simulator.</td><td>%/%</td><td></td></tr>
<tr><td>P73</td><td>HIL rudder Scalar</td><td>Float</td><td>Scales the rudder deflection to account for model differences between actual aircraft and hardware in the loop (Aviones) simulation. Prevents the need to re-tune gains for use with Aviones Hardware-in-the-loop simulator. (HIL)</td><td>Rad/rad</td><td></td></tr>
<tr><td>P74</td><td>Des yawrate LPF freq</td><td>Float</td><td>Corner frequency on low pass filter for calculated desired yawrate. Used to prevent commanding yawrate changes too quickly. Only relevant if calc des yawrate is enabled.</td><td>Hz</td><td>>=0</td></tr>
<tr><td>P75</td><td>Des yawrate limit</td><td>Float</td><td>Limit on the calculated desired yawrate from desired roll angle. Only relevant if calc des yawrate is enabled.</td><td>Rad/sec</td><td>>=0</td></tr>
<tr><td>P76</td><td>Throttle Slew Rate Limit</td><td>Float</td><td>The limit on the maximum commanded slew rate on the throttle channel by the Throttle airspeed and Throttle altitude PID loops.</td><td>%/Second</td><td></td></tr>
<tr><td>P77</td><td>Auto Trim LFP frequency</td><td>Float</td><td>The low-pass filter cutoff frequency for the error accumulator for the auto trimmer. This frequency should be smaller for bigger airplanes. This is to prevent the auto trimmers from trimming to fast. Should be around .1 hz for most hand launched UAVs.</td><td>Hz</td><td>0->2</td></tr>
</table>

Label	Variable Name	Data Type	Description	Units	Range
P78	Auto Trim Aileron Gain	Float	The integrator gain on the aileron auto trimmer. The units are radians of aileron trim per radian second of roll angle error.	Rad/(radian second)	
P79	Auto Trim Elevator Gain	Float	The integrator gain on the elevator auto trimmer. The units are radians of elevator trim per radian second of pitch angle error.	Rad/(radian second)	
P80	Auto Trim Aileron Limit	Float	The maximum amount of aileron trim that can be accumulated by the auto trimmer. This value is in radians of aileron deflection.	radians	
P81	Auto Trim Elevator Limit	Float	The maximum amount of elevator trim that can be accumulated by the auto trimmer. This value is in radians of elevator deflection.	radians	
P82	RPV desired roll gain	Float	This value converts aileron stick deflections on the RC controller to desired roll angles. This is only active if RPV mode is enabled. The units are radians of desired roll per micro second of aileron stick deflection.	Radians/uS PPM	
P83	RPV desired airspeed	Float	This value converts elevator stick deflections on the RC controller to desired velocity increments. This is only active if RPV mode is enabled. The units are m/s desired airspeed offset per micro second of elevator stick deflection.	(m/s)/uS PPM	
P84	RPV desired altitude	Float	This value converts rudder stick deflections on the RC controller to desired altitude increments. This is only active if RPV mode is enabled. The units are meters desired altitude offset per micro second of rudder stick deflection.	meters/uS PPM	
P85	Takeoff rotate altitude	Float	Altitude above launch point at which Waypoint Takeoff Mode transitions from using takeoff pitch to controlling pitch from airspeed error. If takeoff to waypoint mode is enabled, the aircraft will began steering a course to take off waypoint at this altitude. Use “P13 Takeoff Transition Altitude” for Spiral Takeoff transition altitude.	Meters	>0
P86	Gimbal Washout Freq	Float	The washout frequency of the gimbal stabilization algorithm. This is the rate at which the gimbal will re-center on the commanded gimbal position.	Rad/sec	>0
P87	Airspeed Correction Factor	Float	A scalar used to scale differential pressure correct for pressurized cabin and single ported pitot system.	Kpa/Kpa	Around 1
P88	IO Config 1	Float	Bitmask that configures port E IO pins on Kestrel 2.x autopilots.	Bitmask	
P89	IO Config 2	Float	Bitmask that configures port A and GPS port IO pins on Kestrel 2.x autopilots.	Bitmask	
P90	Current Shunt R Value	Float	The resistance of the current shunt resistor in Ohms - typ. .001.	Ohms	>0
P91	Current Shunt ADC Offset	Float	The zero current offset of the current shunt in ADC counts.	ADC count	>0
P92	Battery Capacity	Float	The full charge capacity of the flight pack in MAH.	MAH	>0
P93	Elevator Throttle FF	Float	Radians of elevator per % throttle.	Rad/%	
P94	Elevator->Throttle FF Limit	Float	Limit in Radians of elevator for Elevator->Throttle feed-forward.	Rad	
P95	Take Off Timer Reset Value	Float	The starting value of the Take off timer.	Seconds	>0

Label	Variable Name	Data Type	Description	Units	Range
P96	Take Off Warning Throttle	Float	The throttle value used at t-2 seconds from take off.	% Throttle	>0
P97	Ch8 servo scalar	Float	Not Used in Ma7.1	Rad/uS	>0
P98	Gimbal Azimuth Limit Maximum	Float	The minimum commanded value to the azimuth servo. This limit will constrain what can be commanded by the gamepad and the GPS target tracker. Positive values of azimuth point out the right wing. 0 points straight out the nose, -1.57 points straight out the left wing, 1.57 points straight out the right wing. Typically, the servo limit is set first, then this is set to roughly match it.	Radians	-3.14 to 3.14
P99	Gimbal Azimuth Limit Minimum	Float	The minimum commanded value to the azimuth servo. This limit will constrain what can be commanded by the gamepad and the GPS target tracker. Positive values of azimuth point out the right wing. 0 points straight out the nose, -1.57 points straight out the left wing, 1.57 points straight out the right wing. Typically, the servo limit is set first, then this is set to roughly match it.	Radians	-3.14 to 3.14
P100	Gimbal Elevation Limit Maximum	Float	The maximum commanded value to the elevation servo. This limit will constrain what can be commanded by the gamepad and the GPS target tracker. Positive values of elevation point down. 0 points straight out the nose, 1.57 points straight down. This limit works together with the servo limit. Typically, the servo limit is set first, then the radian limit is set to roughly match it.	Radians	0 to 1.57
P101	Gimbal Elevation Limit Minimum	Float	The minimum commanded value to the elevation servo. This limit will constrain what can be commanded by the gamepad and the GPS target tracker. Positive values of elevation point down. 0 points straight out the nose, 1.57 points strait down. Typically, the servo limit is set first then the radian limit is set to roughly match it.	Radians	0 to 1.57
P102	Convoy Rear Dist	Float	Convoy mode rear following distance	Meters	>0
P103	Convoy Side Dist	Float	Convoy mode side following distance	Meters	>0
P104	Convoy Gnd speed thresh	Float	Convoy mode ground speed threshold	m/s	>0
P105	Convoy Gnd speed gain	Float	Convoy mode ground speed gain		>0
P106	Minimum Height Above Terrain	Float	The height above terrain at which the min HAG (minimum Height Above Ground) failsafe will trigger	Meters	>0
P107	Min Hag Climb to altitude	Float	The height above terrain the UAV will climb to if the min HAG (minimum Height Above Ground) failsafe triggers	Meters	>0
P108	Lost Comm Land time	Float	The time in seconds between the last comm. Packet and when the UAV will begin an auto-land. This value should be configured using the failsafe screen.	Seconds * 10	>0
P109	Flight Termination Time	Float	The time in seconds between the last comm. Packet and when the flight termination failsafe will trigger. This value should be configured using the failsafe screen.	Seconds * 10	>0
P110	Flight Term Channel 1	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0	US PPM	0, 1000-2000

Label	Variable Name	Data Type	Description	Units	Range
	position		the channel will be ignored.		
P111	Flight Term Channel 2 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P112	Flight Term Channel 3 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P113	Flight Term Channel 4 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P114	Flight Term Channel 6 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P115	Flight Term Channel 7 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P116	Flight Term Channel 8 position	Uint	The position which will be commanded to the servo if the flight termination failsafe activates. If set to 0 the channel will be ignored.	US PPM	0, 1000-2000
P117	Flight Term IO pin config	UCHAR	One hot IO pin activation with flight term failsafe. See IO pin config in .xls spreadsheet.	Bitmask	
P118	Forward look camera angle	Float	The angle from the horizon of the forward look camera. This is used in fixed camera platforms to determine center of loiter now circles and to draw the camera frustrum (flashlight) view in the VC. 0=straight out nose, 1.57 = straight down.	Radians	0->1.57
P119	Side look camera angle	Float	The angle from the horizon of the Side look camera. This is used in fixed camera platforms to determine center of loiter now circles and to draw the camera frustrum (flashlight) view in the VC. 0=straight out left wing, 1.57 = straight down.	Radians	0->1.57
P120	Gimbal Az bias	Float	The azimuth bias of the gimbal. This value should be calculated using gimbal calibration algorithm.	Radians	
P121	Gimbal El bias	Float	The elevation bias of the gimbal. This value should be calculated using gimbal calibration algorithm.	Radians	
P122	Convoy Forward Distance	Float	Tuning parameter for Convoy mode - how far ahead of convoy station point before turning around.	Meters	>0
P123	Gimbal Retract Alt	Float	The altitude above home at which point the gimbal is retracted.	Meters	> 0
P124	Gimbal Extend Alt	Float	The altitude above home at which point the gimbal is extended.	Meters	>0
P125	Gimbal Retract PPM	Float	The PPM value in u.S. sent to the gimbal servo to retract gimbal.	uS	700-2300
P126	Gimbal Extend PPM	Float	The PPM value in u.S. sent to the gimbal servo to extend gimbal.	uS	700-2300
P127	Gimbal Safe Azimuth Angle	Float	The gimbal azimuth angle at which gimbal is considered safe.	Radians	+/-pi
P128	Gimbal Safe Elevation Angle	Float	The gimbal elevation angle at which gimbal is considered safe.	Radians	0->pi
P129	Forward Looking Horizontal FOV	Float	The forward looking (or gimbal) field of view of the camera located on the airplane. Important for targeting applications.	Radians	0->pi
P130	Side Looking Horizontal FOV	Float	The side looking field of view of the camera located on the airplane. Important for targeting applications.	Radians	0->pi

Label	Variable Name	Data Type	Description	Units	Range
P131	Max Zoom Scale	Float	The maximum amount the camera can zoom. (1 for No zoom, 2 for 2X, 10 for 10X, etc)	N/A	N/A
P132	Min Engine RPM	Float	Minimum RPM allowed by engine governor	RPM	2,000 - >22,000
P133	Engine Governor Gain	Float	Gain – RPM error to % (.0001) per second seems to work ok.	%/RPM error per second	
P134	FS config2	Uint	Bitmask that is used to determine failsafe behavior. This value is through the configuration options in the failsafe screen. See Appendix C.	Bitmask	
P135	Low fuel warning level	Float	Level at which low fuel bit is set – fuel sensor must be calibrated and plugged into analog input 2	NA	NA
P136	Deep Stall Elev Pos	Float	Elevator position used during deep stall - neg is nose up.	Radians	NA
P137	Deep Stall Throttle Gain	Float	Throttle % from meters error from glide slope.	%/meters	NA
P138	Parachute Deploy PPM	Float	Parachute deploy position in us PPM.	Micro seconds	1000->2000
P139	Parachute Stow PPM	Float	Parachute stow position in us PPM.	Micro seconds	1000->2000
P140	WP Servo Actuate PPM	Float	The PPM position sent to the waypoint servo on arrival to actuation waypoint.	Micro seconds	1000->2000
P141	WP Servo Reset PPM	Float	The PPM position sent to the waypoint servo to reset.	Micro seconds	1000->2000
P142	WP Servo Waypoint	Float	The Waypoint-1 at which servo will actuate.	Wayp-1	NA
P143	WP Servo Actuation Time	Float	Number of seconds servo will stay actuated.	Seconds	NA
P144	Boot Camera	Float	Camera that will be selected on boot up 0=forward,1=side,2=bank2 forward, 3=bank2 side.	NA	0->3
P145	Flair PID	Float	PID FLC for flaring.	Bitmask	NA
P146	Flair Pitch	Float	Pitch value used during flair.	Radians	NA
P147	Desired Pitch Slew Limit	Float	Slew rate limit on desired pitch.	Radians/sec	NA
P148	Launch Elev Trim Offset	Float	Elevator offset used during launches.	Radians	NA
P149	Launch Elev Blank Time	Float	Blanking time for Elevator during launches (open loop).	.5 seconds	NA
P150	Launch Elevator Offset Time	Float	Amount of time Elevator offset is added in during launch.	.5 seconds	NA
P151	Launch Accel Threshold	Float	Amount of X Acceleration for launch detection.	(m/s^2)	NA
P152	Launch Gyro Blank Period	Float	Amount of time after launch to blank gyros.	.5 seconds	NA
P153	Launch Motor Start Time	Float	Time after launch at which motor will start.	.5 seconds	NA
P154	Launch Theta Offset	Float	Offset caused by g loading on pitch gyro.	Radians	NA
P155	D pitch Slew Limit in Altitude mode	Float	The slew rate limit on desired pitch when the Pitch from altitude loop is enabled	Radians/sec	>0
P156	D Roll Slew Rate Limit	Float	The slew Rate limit on desired roll angle in NAV mode and Orbit mode	Radians/sec	>0
P157	Climb Rate Lower Limit	Float	Lower limit on maximum desired descent rate	m/s	<0

Label	Variable Name	Data Type	Description	Units	Range
P158	Climb Rate Upper Limit	Float	Upper limit on maximum desired climb rate	m/s	>0
P159	Throttle climb rate ff	Float	Feed forward effort - % throttle per m/s of desired climb rate	%/(m/s)	>0
P160	Aux1 servo actuate ppm	Uint	The ppm value sent to aux servo 1 to actuate	Us ppm	>700
P161	Aux1 servo reset ppm	Uint	The ppm value sent to aux servo 1 to reset	Us ppm	>700
P162	Aux2 servo actuate ppm	Uint	The ppm value sent to aux servo 2 to actuate	Us ppm	>700
P163	Aux2 servo reset ppm	Uint	The ppm value sent to aux servo 2 to reset	Us ppm	>700
P164	Ext io board config	Ulong	Configuration for the external io board	Bitmask	>=0
P165	RPM gear box multiplier	Float	RPM sensor gear box multiplier	Ratio	0<=n<=1
P166	Rudder->Throttle FF	Float	Radians of ruder per % throttle	Rad/%	
P167	Rudder->Throttle FF Limit	Float	Limit in Radians of rudder for Rudder->Throttle feed-forward	Radians	
P168	Launch Rudder Offset	Float	Offset on rudder used during launching	Radians	
P169	Launch Elevator Offset	Float	Offset on elevator used during launching	Radians	
P170	Alternate voltage cal	Float	Calibration value for alternate voltage on A/D 3	AD/volt	
P171	Generator Fault Voltage	Float	Threshold for generator fault flag – if generator voltage falls below this value a fault is issued	Volts	
P172	Flight Termination Ch9 Servo Pos	UInt	The servo position Ch9 will be set to if the flight termination failsafe activates. Set in failsafe screen	Us PPM	
P173	Flight Termination Ch10 Servo Pos	UInt	The servo position Ch10 will be set to if the flight termination failsafe activates. Set in failsafe screen	Us PPM	
P174	Flight Termination Ch11 Servo Pos	UInt	The servo position Ch11 will be set to if the flight termination failsafe activates. Set in failsafe screen	Us PPM	
P175	Servo Mixing 2	UInt	Enable disable advanced mixing – see *Installation and Configuration Guide* for details	Bitmask	
P176	Flaps Low	Float	Flaps low position	Radians	
P177	Flaps Medium	Float	Flaps medium position	Radians	
P178	Flaps High	Float	Flaps high position	Radians	
P179	Ch9 Servo Bias	UInt	Microseconds of servo bias – servo neutral point	Us	
P180	Ch10 Servo Bias	UInt	Microseconds of servo bias – servo neutral point	Us	
P181	Ch11 Servo Bias	UInt	Microseconds of servo bias – servo neutral point	Us	
P182	Ch9 Scalar	Float	Radians of control deflection to microseconds of servo PPM	Rad/us	
P183	Ch10 Scalar	Float	Radians of control deflection to microseconds of servo PPM	Rad/us	
P184	Ch11 Scalar	Float	Radians of control deflection to microseconds of servo PPM	Rad/us	
P185	Modem Transmit Power	UInt	Transmit power	Percent	0->100
P186	Rudder-> DYawrate FF	Float	Radians of rudder per rad/sec desired yawrate	Rad/(rad/sec)	

Label	Variable Name	Data Type	Description	Units	Range
P187	Rudder-> DYawrate FF Limit	Float	Limit in radians of rudder for Rudder->yawrate feed-forward.	Radians	
P188	Aileron->Airspeed FF	Float	Radians of aileron per (m/s)^2 above trim airspeed	Rad/(m/s)^2	
P189	Aileron->Airspee FF Limit	Float	Limit in radians of aileron for aileron->airspeed feed-forward.	Radians	
P190	Modem Radio ID	UInt	Freewave modems only		2300000-2399999
P191	Pitch PID Lower Limit, Takeoff	Float	Lower limit of desired pitch for Pitch<-alt, Pitch<-airspeed in stage 1,2 of takeoff	Radians	
P192	Pitch PID Lower Limit	Float	Lower limit of desired pitch for Pitch<-alt, Pitch<-airspeed	Radians	
P193	D Pitch PID Slew, Takeoff	Float	Slew rate for pitch<-airspeed during takeoff stages 1 and 2.	Rad/sec	
P194	Throttle slew rate limit, land	Float	The slew rate in %/second for the throttle from alt loop during landing.	%/sec	
P195	Deep Stall Fixed Pitch	Float	Fixed pitch during deep-stall, if fixed pitch mode is set	Radians	
P196	Gimbal Slew Gain	Float	Gimbal slew speed from gimbal position error	(rad/s)/rad	
P197	Gimbal Slew Integrator	Float	Gimbal slew speed form gimbal position error integrator.	(rad/s)/rad	
P198	Gimbal max slew rate	Float	Maximum gimbal slew speed when close to correct position	rad/s	
P199	Line Following Gain	Float	Gain for vector path following	rad/m	
P200	Orbit Gain	Float	Gain for tracking orbits using vector path following	Rad/m	
P201	Max Height Sensor Reading	Float	Maximum height that and installed height sensor can detect	Meters	
P202	Minimum HAG value	Float	Minimum allowed height above ground in Laser MinHAG mode.	Meters	
P203	Payload Init	UInt	Bit mask which sets payload device startup settings	Bitmask	
P204	Future Use 1		Reserved for future use		
P205	Future Use 2		Reserved for future use		
P206	Future Use 3		Reserved for future use		

Appendix C

C.1 Extra Datalog Parameters

The following table describes the additional precision datalog variables available.

Table C-1 Extra Datalog Parameters

Variable Name	Description	Units	Range
[Pitch] actual [Pitch] d_error [Pitch] desired [Pitch] effort fd [Pitch] effort fi [Pitch] effort fp [Pitch] i_error [Pitch] local_effort [Pitch] total_error	Pitch control loop variables: ▪ d_error = Derivative Error ▪ desired = loop desired value ▪ effort fd = effort contributed by derivative error and gain ▪ effort fi = effort contributed by integral error and gain ▪ effort fp = effort contributed by proportional error and gain ▪ i_error = integral error ▪ local_effort = the sum total of effort for this PID loop ▪ total_error = the sum total of error for this PID loop	N/A	
[Pitch Rate] actual [Pitch Rate] d_error [Pitch Rate] desired [Pitch Rate] effort fd [Pitch Rate] effort fi [Pitch Rate] effort fp [Pitch Rate] i_error [Pitch Rate] local_effort [Pitch Rate] total_error	Pitch Rate control loop variables	N/A	
[Roll] actual [Roll] d_error [Roll] desired [Roll] effort fd [Roll] effort fi [Roll] effort fp [Roll] i_error [Roll] local_effort [Roll] total_error	Roll control loop variables	N/A	
[Roll Rate] actual [Roll Rate] d_error [Roll Rate] desired [Roll Rate] effort fd [Roll Rate] effort fi [Roll Rate] effort fp [Roll Rate] i_error [Roll Rate] local_effort [Roll Rate] total_error	Roll Rate control loop variables	N/A	
[Roll<-Heading] actual [Roll<-Heading] d_error [Roll<-Heading] desired [Roll<-Heading] effort fd [Roll<-Heading] effort fi [Roll<-Heading] effort fp [Roll<-Heading] i_error	Roll From Heading control loop variables	N/A	

Variable Name	Description	Units	Range
[Roll<-Heading] local_effort [Roll<-Heading] total_error			
[Rud<-Yaw Rate] actual [Rud<-Yaw Rate] d_error [Rud<-Yaw Rate] desired [Rud<-Yaw Rate] effort fd [Rud<-Yaw Rate] effort fi [Rud<-Yaw Rate] effort fp [Rud<-Yaw Rate] i_error [Rud<-Yaw Rate] local_effort [Rud<-Yaw Rate] total_error	Rudder From Yaw Rate control loop variables	N/A	
[Thr<-Airspd] actual [Thr<-Airspd] d_error [Thr<-Airspd] desired [Thr<-Airspd] effort fd [Thr<-Airspd] effort fi [Thr<-Airspd] effort fp [Thr<-Airspd] i_error [Thr<-Airspd] local_effort [Thr<-Airspd] total_error	Throttle From Airspeed control loop variables	N/A	
[Thr<-Alt] actual [Thr<-Alt] d_error [Thr<-Alt] desired [Thr<-Alt] effort fd [Thr<-Alt] effort fi [Thr<-Alt] effort fp [Thr<-Alt] i_error [Thr<-Alt] local_effort [Thr<-Alt] total_error	Throttle From Altitude control loop variables	N/A	
[Pitch<-Airspd] actual [Pitch<-Airspd] d_error [Pitch<-Airspd] desired [Pitch<-Airspd] effort fd [Pitch<-Airspd] effort fi [Pitch<-Airspd] effort fp [Pitch<-Airspd] i_error [Pitch<-Airspd] local_effort [Pitch<-Airspd] total_error	Pitch From Airspeed control loop variables	N/A	
[Pitch<-Altitude] actual [Pitch<-Altitude] d_error [Pitch<-Altitude] desired [Pitch<-Altitude] effort fd [Pitch<-Altitude] effort fi [Pitch<-Altitude] effort fp [Pitch<-Altitude] i_error [Pitch<-Altitude] local_effort [Pitch<-Altitude] total_error	Pitch From Altitude control loop variables	N/A	
[PPM_VALUES] Aileron [PPM_VALUES] Elevator [PPM_VALUES] Throttle [PPM_VALUES] Rudder [PPM_VALUES] Ch6 [PPM_VALUES] Ch7	PPM Servo values for outputs: Aileron, Elevator Throttle, Rudder, Ch6, Ch7	Micro-seconds	
[SERVO_OUT] Aileron [SERVO_OUT] Elevator [SERVO_OUT] Throttle [SERVO_OUT] Rudder [SERVO_OUT] Ch6 [SERVO_OUT] Ch7	Servo output values converted to radians for outputs :Aileron, Elevator Throttle, Rudder, Ch6, Ch7	Radians	

Variable Name	Description	Units	Range
[SERVO_POS_HOLD] Aileron [SERVO_POS_HOLD] Elevator [SERVO_POS_HOLD] Throttle [SERVO_POS_HOLD] Rudder [SERVO_POS_HOLD] Ch6 [SERVO_POS_HOLD] Ch7	Ground station commanded position hold values in radians for outputs: Aileron, Elevator Throttle, Rudder, Ch6, Ch7	Radians	
[SERVO_RX] Aileron [SERVO_RX] Elevator [SERVO_RX] Throttle [SERVO_RX] Rudder [SERVO_RX] Ch6 [SERVO_RX] Ch7	Servo received value position from the Commbox for outputs: Aileron, Elevator Throttle, Rudder, Ch6, Ch7	Micro-seconds	
[SERVO_SCALAR] Aileron [SERVO_SCALAR] Elevator [SERVO_SCALAR] Throttle [SERVO_SCALAR] Rudder [SERVO_SCALAR] Ch6 [SERVO_SCALAR] Ch7	Servo conversion scalar from micro-seconds to radians for outputs: Aileron, Elevator Throttle, Rudder, Ch6, Ch7	Micro-seconds	

Appendix D

D.1 Description of UAV Parameter UAV Init

See Communications Guide

D.2 Description of UAV Parameter WpNAV CFG

Table D-1 Description of UAV Parameter WpNAV CFG

Bit	Bitmask	Name	description	User configurable
0	0x0001	Use waypoint desired altitude in NAV mode	If this bit is set, the desired altitude from the waypoints will be used in NAV mode. If this bit is not set, the current desired altitude or the altitude from the PID tune screen in the Virtual Cockpit will be used (if different from current desired alt).	Yes
1	0x0002	Use vector path following in land mode	During the rally-land sequence, vector path following can be enabled. This has been demonstrated to reduce lateral path error during landing on some platforms.	Yes
2	0x0004	Use cross track control in NAV mode	If enabled, the aircraft will fly a course between waypoints. If disabled, the aircraft will fly the bearing to the next waypoint.	Yes
3	0x0008	Use Altitude Tracker in NAV Mode	If enabled, the autopilot will use the Altitude Tracker in NAV mode. If disabled the autopilot will use the airspeed and altitude control loops as specified in the NAV Mode FLC parameter (P22).	Yes
4	0x0010	Orbit Clockwise	When set, all loiters will be in a clockwise direction, when unset, all loiters will be counter clockwise.	Yes
5	0x0020	Use minimum go home altitude	When set, the aircraft will climb to the minimum go home altitude when home mode is entered unless the low battery failsafes are active.	yes
6	0x0040	Use desired waypoint desired airspeed in NAV mode	If this bit is set, the desired airspeed from the waypoints will be used in NAV mode. If this bit is not set, the current desired airspeed or the airspeed from the PID tune screen in the Virtual Cockpit will be used (if different from current desired airspeed).	yes
7	0x0080	empty		
8	0x0100	empty		
9	0x0200	empty		
10	0x0400	empty		
11	0x0800	empty		
12	0x1000	empty		

Bit	Bitmask	Name	description	User configurable
13	0x2000	empty		
14	0x4000	empty		
15	0x8000	empty		

D.3 Description of Feedback Loop Configuration (I2)

Table D-2 Description of Feedback Loop Configuration

Control	Source	Value	Bit Mask
Throttle Control	Fixed	0x0000	0x0003 (0000 0000 0000 0011)
	Airspeed	0x0001	
	Altitude	0x0002	
Elevator Control	Fixed	0x0000	0x000C (0000 0000 0000 1100)
	Pitch	0x0004	
	Pitch Rate	0x0008	
	Pitch + Pitch Rate	0x000C	
Aileron Control	Fixed	0x0000	0x0030 (0000 0000 0011 0000)
	Roll	0x0010	
	Roll Rate	0x0020	
	Roll + Roll Rate	0x0030	
Rudder Control	Fixed	0x0000	0x00C0 (0000 0000 1100 0000)
	Yaw Rate	0x0040	
	empty		
Pitch Control	Fixed	0x0000	0x0700 (0000 0111 0000 0000)
	Airspeed	0x0300	
	Altitude	0x0400	
Roll Control	Fixed	0x0000	0x0800 (0000 1000 0000 0000)
	Heading	0x0800	
Climb Rate	Throttle from climbrate	0x1000	
	Climbrate from altitude	0x2000	

D.4 Description of UAV Parameter Failsafe CFG (P72)

Table D-3 Description of UAV Parameter Failsafe CFG

Bit	Bitmask	name	description	User configurable
0	0x0001	Enable Loss of GPS failsafe	Enables the loss of GPS failsafe routine	Yes
1	0x0002	Enable Low Battery failsafe	Enables the low battery failsafe routine	Yes
2	0x0004	Enable Critical battery failsafe	Enables the critical battery failsafe routine – low battery must be enabled	Yes
3	0x0008	Empty		No
4	0x0010	Enable RC Mode Failsafe	Enables the RC Mode Failsafe	Yes
5	0x0020	Enable Loss Comm failsafe	Enables the Loss of Link failsafe. The loss of comm failsafe refers only to the modem communication.	Yes
6	0x0040	Loss comm. fly to rally	Loss of comm. failsafe will fly to rally instead of home	Yes
7	0x0080	Loss GPS fly to rally	Loss of GPS failsafe will fly to rally instead of home	Yes
8	0x0100	RC Mode go to rally	Loss of comm. In RC Mode will fly to rally instead of home	Yes
9	0x0200	Low battery go to rally	Low Battery Failsafe will fly to rally instead of home	Yes
10	0x0400	Loss comm. land rally	Loss of comm. failsafe will fly to rally point and then land.	Yes
11	0x0800	Enable min Hag Failsafe	Enables the minimum height above ground failsafe	Yes
12	0x1000	Enable Flight Termination	Enables the flight termination failsafe	Yes
13	0x2000	Enable Lost Comm Land	Enables the Lost Comm Land Failsafe	Yes
14	0x4000	Lost Comm land at approach land	When enabled the lost comm. Land failsafe will use the approach land.	Yes
15	0x8000	empty		

Appendix E

E.1 Commbox flash values

The Commbox flash parameters are all stored in floating point representation. Unless otherwise stated, a standard floating point value (4 bytes) is used.

Table E-1 Commbox flash values

#	Variable	Description	Unit	Range
0	Modem channel number	The RF channel number of the Aerocomm modem. This must correspond to the RF channel number of the Airplane modem	#	16->47
1	Low Battery Threshold	The voltage at which the power LED will turn red	Volts	8->10
2	Critical Battery Threshold	The voltage at which the power LED rapidly blink red.	Volt	6->10
3	Commbox Config	Used to enable video overlay, video channel changing, etc.	32 bit mask	
4	Antenna Pointer Azimuth Calibration	The azimuth angle of the Antenna Pointer on startup. This is used to calibrate the angle offset of the Antenna Pointer	Radians	0-2*pi
5	Antenna Pointer Azimuth Command	Only used for debug purposes	Radians	0-2*pi
6	Transmit Power	The transmit power in percent. Valid only for Microhard and Freewave Modems	percent	0-100
7	Radio ID	Used for Freewave Modems only currently	#	0-239999
8	Frequency	Frequency Key for Freewave Modems		0-15
9	Video Channel	Sets video channel, toggling GPIO port as binary open drain output. Enable bit must be set in Commbox Configuration.	4 bit	0-15
10	Selected Agent Address	Selected UAV agent address, used to match Commbox video overlay with agent selected in Virtual Cockpit	#	1-9999
11	Antenna Pointer Type	Integer specifying the type of antenna pointer in use. (0=Faulhaber MCBL-2805, 1=Directed Perception PTUD46)	#	0-1
12	Antenna Point Elevation Calibration	The elevation angle of the Antenna Pointer on startup. This is used to calibrate the angle offset of the Antenna Pointer	Radians	±pi/2
13	Antenna Pointer Elevation Command	Only used for debug purposes	Radians	0-2*pi

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