
Piccolo System User's Guide



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1 Introduction

Piccolo is a complete integrated avionics system for small unmanned aircraft. The system includes avionics hardware and software, ground-station hardware and software, and a development and simulation environment. This document is the end-user's manual for the *Piccolo* system, and provides a basic description, interface guidelines, and system setup.

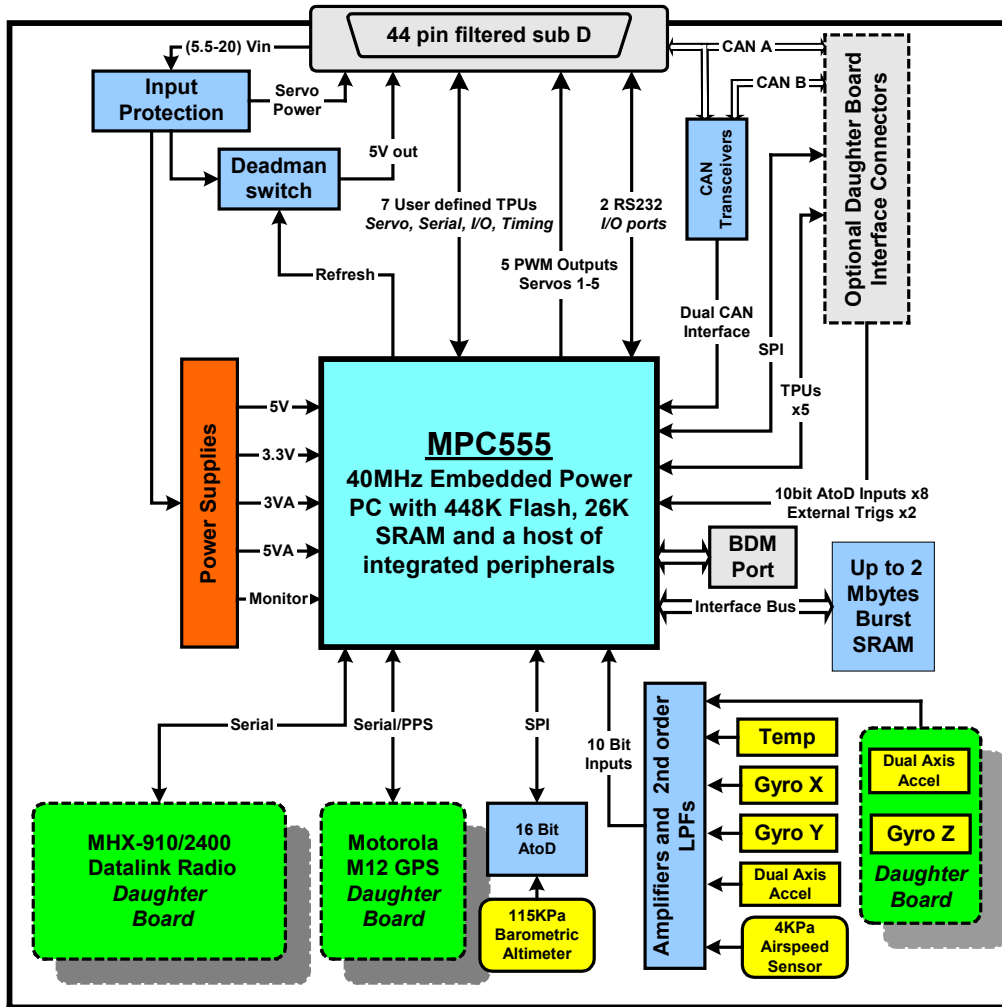


Figure 1. Piccolo block diagram

1.1 Features

- Exceptional integration and processing power from the MPC555 main processor.
- Small size: 4.8" x 2.4" x 1.5"
- Weight 212 grams (7.5oz) with radio, GPS and enclosure. 90 grams (3.1oz) without radio and enclosure.
- 3-axis rate and acceleration measurements.
- Deadman's switch for safety.
- Expandable using the external interface or daughter board connector.

- Complete hardware integration including sensors, datalink, and servo drivers.
- Wide range of software support, including complete end-user programmability.
- Reference software design for ground station and simulation tools.
- Fully autonomous or pilot in the loop operation.
- Capable of being installed in multiple attitudes.

1.2 CPU

The heart of *Piccolo* is the MPC555 microcontroller. This is a new breed of automotive controller based on the PowerPC architecture. The MPC555 marries an enormous array of interfaces to a powerful RISC engine that delivers 40Mhz PowerPC operation, including hardware floating point.

1.3 Sensors

There are two generations of the system, the original *Piccolo* and the newer *Piccolo Plus*. *Piccolo Plus* uses three ADXRS300 gyros and two two-axis ADXL210e accelerometers, which combined with its CPU horsepower gives *Piccolo* the ability to run sophisticated filters; and allows installation in any attitude. The earlier generation *Piccolo* uses three Tokin CG-16D rate gyros and two two-axis ADXL202 accelerometers.

The Motorola M12 GPS provides *Piccolo* with its basic groundspeed and position. The M12 is differential capable, and *Piccolo* will supply it with any DGPS corrections received over the datalink. The *Piccolo* ground station is capable of generating these corrections using its own M12.

Piccolo includes a dual ported mpxv50045 4kPa dynamic pressure sensor, an absolute ported mpx4115a barometric pressure sensor, and a board temperature sensor. Together these sensors provide the ability to measure true air speed and altitude. Combined with the GPS the air data sensors allow *Piccolo* to generate an estimate of winds aloft each time the aircraft turns by fitting true airspeed against GPS groundspeed. The wind estimate is useful since it enables an intelligent selection of heading when the wind speed exceeds the flight speed of the aircraft.

The system also estimates the attitude of the aircraft and the gyro biases on-line through a Kalman filter which uses the GPS-derived pseudo-attitude as the measurement correction.

1.4 Servos

Piccolo includes 10 servo outputs. These outputs are geared for model aircraft servos, which require pulse-width modulated signals, and 4-6 volt power. Alternatively some servo systems use a CAN (Controller Area Network) bus to provide the servo signals. *Piccolo* includes two independent CAN buses. In either case the servo power supply is a separate input to *Piccolo* so that transient servo loading doesn't disable core system functions.

1.5 Datalink

Piccolo includes a sophisticated datalink that is built on the MHX 910/2400 radio modem from Microhard Systems Inc. The datalink has up to 40Kbaud of throughput and is used for command and control, autopilot telemetry, payload data transfer functions, differential GPS corrections

uplink, and pilot in the loop modes. The datalink architecture allows multiple aircraft to be controlled by a single operator from a single ground station.

1.6 Payload interface

An unmanned aircraft is only as useful as its payload. Accordingly, *Piccolo* provides several means of connecting to payloads, including CAN, asynchronous serial, and discrete I/O. Data received from the payload(s) can be downlinked over the main datalink.

1.7 Piccolo Plus

Piccolo Plus is the current generation of the *Piccolo* system. The *Piccolo Plus* was introduced in early 2004 as a form-fit-function replacement for the *Piccolo* avionics. It utilizes new inertial sensors to improve the performance and robustness of the system. For the purposes of this manual the *Piccolo* and the *Piccolo Plus* are equivalent units.

1.8 Piccolo II

Piccolo II is a derivative of the *Piccolo Plus* avionics which contains an additional daughterboard with a new GPS with faster output rate, and an additional external connector which provides analog input lines, Iridium modem lines, additional digital lines, and a secondary payload serial port. The GPS unit installed on *Piccolo II* is the μ Blox TIM LP, with an output rate of 4 Hz. This unit replaces the Motorola M12 existing on the *Piccolo Plus* avionics.

2 Avionics

Avionics refers to the airborne component of the *Piccolo* system. It is the most complicated part of the system and requires the most care in setup. Most of the setup is actually done through the operator interface software, and is described in that section. This section deals with the physical installation of the avionics.

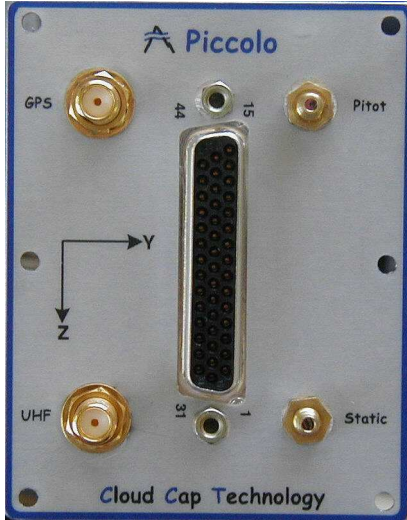


Figure 2 - Piccolo Front Panel



Figure 3. Piccolo II Front Panel

2.1 Front panel connections

All connections to the Piccolo are through the front panel as shown in Figure 2 and include the filtered 44-pin vehicle interface connector, GPS and UHF antenna SMA connectors as well as the Pitot and Static pressure port nipples which are compatible with 3/32" ID tubing.

Table 1 outlines the functionality of each pin on the external interface connector. A complete flight harness reference schematic with power and servo leads is available for review on our [downloads](#) page.

Table 1. Vehicle Interface Connector Pin-out.

PIN	NAME	TYPE	LEVEL	FUNCTION	
15	GND			Gnd for servo 1	1
30	SERVO_Vout		*	Power for servo 1	
44	PWMSM[0]	O	5V	Servo 1 signal output - Left Aileron	
14	GND			Gnd for servo 2	2
29	SERVO_Vout		*	Power for servo 2	
43	PWMSM[1]	O	5V	Servo 2 signal output - Left Elevator	
13	GND			Gnd for servo 3	3
28	SERVO_Vout		*	Power for servo 3	
42	PWMSM[2]	O	5V	Servo 3 signal output - Left Throttle	
12	GND			Gnd for servo 4	4
27	SERVO_Vout		*	Power for servo 4	
41	PWMSM[3]	O	5V	Servo 4 signal output - Left Rudder	
11	GND			Gnd for servo 5	5
26	SERVO_Vout		*	Power for servo 5	
40	PWMSM[4]	O	5V	Servo 5 signal output - Left Flap	
39	TPU_A[0]	I/O	5V	Servo 6 signal output - Right Aileron	SPARE I/O
38	TPU_A[1]	I/O	5V	Servo 7 signal output - Right Elevator	
37	TPU_A[2]	I/O	5V	Servo 8 signal output - Right Throttle	
36	TPU_A[3]	I/O	5V	Servo 9 signal output - Right Rudder	
35	TPU_A[4]	I/O	5V	Servo 10 signal output - Right Flap	
25	USER_Vout	O	*		PWR/GND
24	USER_Vout	O	*		
23	USER_Vin_1	O	*	Servo power input 4.8-6V DC (4 or 5-cell pack)	
6	SWITCHED_USER_Vout	O	*	Switched Output Voltage (Driven by Deadman's Switch)	
10	GND			Ground	
9	GND			Ground	CAN
8	GND			Ground	
7	CAN_GND			CAN Ground	
22	CAN_HI_A	I/O	CAN	CAN A Serial High	SERIAL COMMS
21	CAN_LO_A	I/O	CAN	CAN A Serial Low	
34	TXD_RS232	O	232	User RS232 Output - TPU_B[0]	
33	RXD_RS232	I	232	User RS232 Input - TPU_B[1]	SERIAL COMMS
5	TPU_B[2]	I/O	5V	User Configurable I/O	
20	TPU_B[3]	I/O	5V	User Configurable I/O	
4	GND				
19	*PROGRAM/USER	I	5V	Program/User Mode Control Input - MPIO32B5	
18	*HRESET	I	5V	Hardware Reset - active low	SERIAL COMMS
3	GND			Ground	
32	SCI_2_TX_232	O	RS232	Program Port/Ground Station Interface/User Serial	
31	SCI_2_RX_232	I	RS232	Program Port/Ground Station Interface/User Serial	
16	USER_Vin_2/EXT_NC1			Second servo power input (default) or NC1 (optional)	
1	VIN			Main DC Input - 5.5-20 Vin	
2	GND				
17	GND/EXT_NC2			Second servo power ground (default) or NC2 (optional)	

* - These pins are ganged together onboard the Piccolo. Typically one is used as the servo power input with the rest available as outputs to power servos or payloads.

The *Piccolo II* provides, in addition to the standard Vehicle Interface Connector, a 25-pin MicroDot connector located between the GPS and UHF antenna connectors - see Figure 3. The pin-out listing the functionality of each pin on the MicroDot connector is presented in Table 2.

Table 2. Piccolo II MicroDot Connector Pin-out

PIN	NAME	TYPE	LEVEL	FUNCTION
24	CAN_LO_B	I/O	CAN	Serial TX/RX
13	CAN_HI_B	I/O	CAN	Serial TX/RX
12	AIN0	I	5V	10 bit analog input
11	AIN1	I	5V	10 bit analog input
10	AIN2	I	5V	10 bit analog input
9	AIN3	I	5V	10 bit analog input
22	AGND			Analog ground
23	AGND			Analog ground
21	TPU_B8	I/O	5V	GPIO3
19	TPU_B9	I/O	5V	GPIO4
17	TPU_B10	I/O	5V	GPIO5
15	TPU_B11	I/O	5V	GPIO6
8	GND			Ground
18	GND			Ground
20	GND			Ground
7	TXD1_232	O	RS232	Iridium TXD
6	RXD1_232	I	RS232	Iridium RXD
16	GND			Ground
5	TXD2_232	O	RS232	Iridium DTR
4	RXD2_232	I	RS232	Iridium CD
14	GND			Ground
3	TXD3_232	O	RS232	Payload2 RS-232 Tx
2	RXD3_232	I	RS232	Payload2 RS-232 Rx
1	GND			Ground
25	No Connection			

2.2 Power options

Piccolo accepts 8 to 20V DC (3.6 Watts at 12 Volts nominal) input power. This power is regulated down to internal voltages required for the main board. A second input, 4.8 to 7V DC, is used to power the servos (either a 4 or 5-cell battery pack can be used). It can be applied to any one of the unused servo power or user_vout pins (we typically use pin 23).

2.3 Servo options

Piccolo has ten PWM (Pulse Width Modulation) outputs available for servos. There are two basic modes of operation, 5-channel mode, and 10-channel mode. Most systems will use 10-channel mode. In either mode individual servo control signals can be reassigned to other payload control functions. Details of the different servo options can be had from section 4.11.

2.4 Installation location and orientation

There is no limitation on the installation location of *Piccolo*. However in general you should choose a location that will minimize vibration (see the “[Vehicle Integration Guidelines](#)” document for further installation details). For large aircraft it is preferred to mount the avionics

close to the center of gravity in order to reduce the acceleration that results from centripetal motion and changes in angular rate.

The orientation of the avionics in its final installation is important. The avionics has a natural coordinate system, which is marked on the front panel. The coordinate system uses English aircraft conventions, with the X-axis pointing through the nose, the Y-axis out the right wing tip, and the Z-axis pointing down. You do not have to install the avionics in its natural coordinate system; however the Euler angle rotations between the avionics coordinate system and aircraft coordinate system must be known.

2.5 Air data system

Piccolo has pressure port inputs for total (or Pitot) pressure and static pressure. A 4KPa differential pressure sensor measures the difference between the total pressure and static pressure to determine the dynamic pressure. A 115KPa absolute pressure sensor measures the static pressure. An accurate air data system is critical to the performance of Piccolo. Both the dynamic and static pressures are used in the primary control loops. In addition the dynamic pressure is used to calculate the true air speed, which is used for wind measurement.

The total and static pressure ports should be plumbed to pressure probes (see “[Vehicle Integration Guidelines](#)” document for further details).

2.6 GPS antenna

The GPS antenna should be mounted on the aircraft where it has a clear view of the sky. In particular consider how the antenna’s view of the sky will change with aircraft pitch and roll motion. Ideally the antenna should be mounted on a large metal groundplane, however satisfactory performance can be had with a small (a few inches across) groundplane made of foil or metal tape on the aircraft.

2.7 Communications antenna

A 900MHz or 2.4GHz ISM band $\frac{1}{4}$ wave or similar antenna will need to be installed on the host airframe. You should try to maximize the separation between the GPS and UHF antennas to minimize potential interference. Again refer to the “[Vehicle Integration Guidelines](#)” document for examples and further details.

3 Ground Station

Piccolo’s ground station is based upon the same hardware that makes up the avionics package. It manages the communication link to one or more avionics systems, interfaces to the pilot in the loop console, and provides a command and control stream to the operator interface PC.

3.1 Power

The ground station is powered through the included power supply that provides DC power. A battery is included in the ground station for backup operation in case the main input power is lost. When main power is connected the battery will be charging (Yellow LED). The ground station will not be on until the external switch is turned on (Green LED).

3.2 Connections

The Ground Station connects to the operator interface PC through a standard 9-pin serial cable. The ground station GPS Antenna is connected to the rear panel SMB connector and the ground station UHF antenna is hooked up to the BNC connector. The pilot console connects through the included 6-pin circular DIN pilot console cable. Please refer to the *Quick Setup Guide* for photos and a complete descriptions of each component.

3.3 Pilot in the loop

Pilot in the loop commands are input to the ground station through a Futaba compatible buddy-box 6-pin DIN connector. The ground station will attempt to decode up to 9 pulses in the serial train. They are: aileron, elevator, throttle, rudder, autopilot on/off (gear), flaps, brakes, parachute, and ignition. The fifth channel, usually used for retract landing gear, is used to select autopilot on/off status. A pulse longer than 1.5ms on this channel selects autopilot off. A short pulse selects autopilot on. Although the ground station will decode up to 9 pulses, only the first 5 pulses are strictly required. Any pulses not supplied by the pilot console will be given default values.

The power switch on the Futaba pilot console should be left off; it will receive its power from the ground station. In addition the RF module of the pilot console can be removed since it serves no purpose in this application.

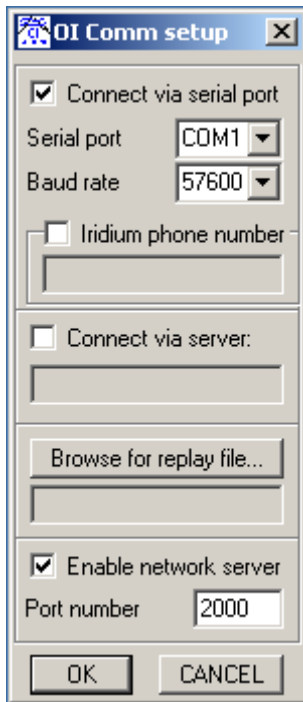
4 Operator Interface

The Operator Interface (OI) is a software system that runs on a Windows PC and provides a command and control interface for Piccolo operators. Most of the system features are accessible from this interface, and so we will use this part of the user's guide to describe many of the basic capabilities of the system.

4.1 Installation and running

The operator interface must be correctly installed before it can be used. A windows installer¹ file, "Operator Interface.msi" is provided for this. Double click on the file to launch the installer. The onscreen instructions are simple to follow and amount to choosing where you'd like the operator interface to be installed.

4.2 Running



Once installed the Operator Interface executable can be run like any Windows application. After the application has been launched, the communication setup dialog will appear on the screen - see Figure 4.

The default option is to connect to the groundstation over the COM1 serial port, at 57600 baud, and run as a TCP/IP server on port 2000. Other connection options are: connecting as a client to an Operator Interface server, connecting to the avionics through an Iridium satellite modem, or opening a binary telemetry file for replay. Once the connection parameters are set as desired, press the "OK" button to continue loading the Operator Interface program.

The connection options can also be specified through command line switches listed in Table 3. The method is still functional - if command line arguments are provided, the system will not display the comm setup dialog, but will instead use the parameters directly.

Figure 4. Comm setup dialog.

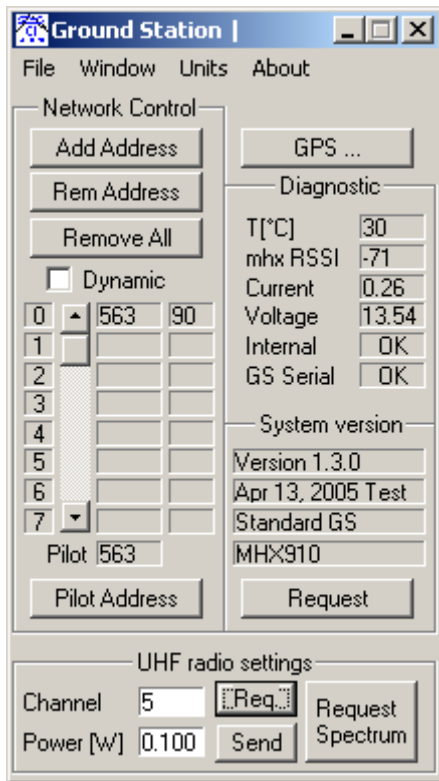
Table 3. Command line switches

Switch	Meaning
-P=	Controls the serial port that the OI will use to connect to the ground station. For example -P=2 will cause the OI to look for the ground station on COM2.

¹ The windows installer is a relatively new component of Windows. Windows 2000 and XP include the windows installer; however older versions of Windows must have the installer installed (ironic, I know). If your version of Windows does not recognize the .msi extension it is because you need the windows installer. Use the WinInstall9X.exe or the WinInstallNT.exe files to install the installer.

-B=	Changes the baud rate used for the serial connection. The nominal connection to the ground station is done at 56K (57600). However specialty applications may require a different baud rate.
-LISTEN=	Enables the OI to act as a server. In this mode the operator interface will listen for incoming TCP connections and send and receive Piccolo packets over the connection. The port number used for the listening mode is passed on the command line, for example -LISTEN=2000 will cause the OI to listen for clients on port 2000.
-SERVER=	Enables the OI to connect to a Piccolo data server (which could be another OI in server mode). The data passed on the switch controls the computer name and port number that the OI will try to connect to. For example -SERVER=MyServerName:2000 will cause the OI to initiate a TCP connection to a computer call MyServerName, on port 2000. This switch cannot be used at the same time as -LISTEN or -P.
-R=	Enables the OI to replay a binary log file. The data passed on the switch is the name of the binary log file (usually *.tel). This switch cannot be used with any of the other switches except -LISTEN.

4.3 Ground station screen



After the Operator Interface has started and the communications have been set-up, the first visible window is the ground station dialog, Figure 5.

4.3.1 File Menu

The File menu has the option to bring up the communication setup dialog as well as the command to exit the Operator Interface application.

4.3.2 Window Menu

The Window menu has options for minimizing or restoring any avionics windows in the system, for selecting any avionic window, and for cascading or tiling the avionics windows. Also from this menu, you can open a dialog for Iridium modem control, groundstation and avionics panels for displaying uplink message history. In addition, the avionics dialog can be reconfigured in one of three view modes available: simple view (avionics setup pages are hidden), advanced read-only (avionics setup pages can only be viewed but not edited), and advanced view (all pages are shown and all parameters can be edited).

Figure 5. Operator Interface ground station window

4.3.3 Units Menu

The units menu allows the user to select the units that telemetry are displayed in. Angles can be displayed in decimal degrees, degrees minutes seconds, or in radians. Anything which is not an angle can be displayed in either Metric or English units.

4.3.4 GPS

The GPS button invokes a dialog that gives a display of the current ground station GPS data, and the differential base station setup.

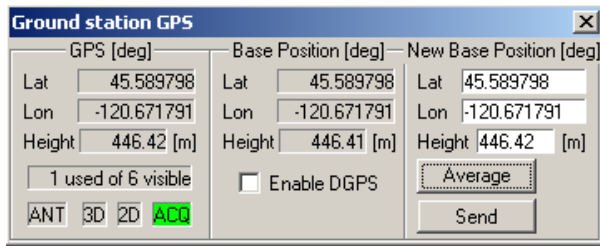


Figure 6. Groundstation GPS window

The left panel will display the GPS status and current position solution. The right panel allows the user to specify a base position by either typing the coordinates of the base station (if accurately known) or by running a time average of the groundstation GPS solution if the Average button is pressed. The base position can be updated by pressing the Send button. The middle panel allows the user to see the current base position, and to enable sending of GPS corrections to the avionics.

4.3.5 Network Control

The ground station manages simultaneous communications to multiple avionics by using a polling scheme in which it periodically requests communications from each avionics in a list. The list is composed of *Piccolo addresses*, which are the serial number of each avionics.

The Add Address button can be used to send a message to the ground station telling it to add the requested serial number to its polling list. The Pilot Address button works like the Add Address button, except it tags the address to receive manual pilot commands from the pilot console. Only one pilot address can exist in the system. The Rem Address button is used to remove addresses from the list, except the pilot address. Remove All will remove all addresses from the list, again excepting the pilot address. The ground station stores the list of serial numbers in non-volatile memory so any changes made to the list are not lost when the ground station is powered down.

If the Dynamic box is checked, the groundstation will switch to dynamic network management mode. This includes the ability to detect new avionics not yet in the polling list, as well as remove avionics that are not responding. The dynamic network management does not affect the pilot address.

In practice there is only enough bandwidth for about 10 avionics at one time. If there are avionics in range that you do not wish the groundstation to talk to, either disable the dynamic network management, or use a different radio channel.

The text box next to each avionics slot displays the link ratio, which is the percentage (from 0 to 100) of communications frames sent by the ground station that are correctly acknowledged by the avionics.

4.3.6 Diagnostic

The diagnostic group contains diagnostic data from the ground station. $T[^\circ\text{C}]$ is the temperature of the main board in degrees Celsius. The boards have been tested from 0 to 80°C. $Mhx\ rssi$ is

the receive signal strength indicator from the MHX radio. It is in units of dBm and ranges from -71 (strong signal) to -115 (no signal). When communicating with multiple avionics the `RSSI` field will be a composite of the different signal strengths. `Current` refers to the input current to the ground station, and is displayed in Amps. `Voltage` is the input voltage, which should always be near 12 Volts for the ground station. The `Internal` signal is a composite of all of the internal voltages of the ground station. `OK` will be displayed here if the internal diagnostics are nominal, else the offending system will be displayed. `GS Serial` indicates if the serial communication to the ground station is function, `OK` will be displayed here if it is, else `BAD` will be displayed.

4.3.7 MHX radio settings

The MHX radio settings allow the user to control the power output and the hopping pattern of the Microhard radio in the ground station. The radio is a frequency hopping spread spectrum system, which means that it doesn't use a single frequency, but instead hops along a pattern of frequencies. One radio in any network is a master (always the ground stations) and slaves in the network synchronize their hopping to match the master. In order to operate multiple ground stations in close proximity they must be using different hopping patterns to avoid interference. Pushing the `Req` button will request the current hopping pattern and power output of the radio. Pushing the `Send` button will update the hopping pattern and power output of the radio.

The request spectrum button is used to invoke a special feature of the radio, which allows it to operate as a spectrum analyzer. The radio will sample all of its channels and return a text-based result, which allows the user to see the background noise level on every channel. Note that when any of these radio features are invoked the radio will be taken offline, suspending communications for a short while.

4.3.8 System version

The system version panel provides several lines of text containing the version information of the groundstation hardware and software, as well as a button that can be used to request this information from the groundstation.

The first text line will display the software version number. The second line will display the release date for the software and whether it is an actual release or a test version. The third line of text will display the type of groundstation hardware, and the last line will display the type of radio that the groundstation is equipped with.

4.4 Avionics Window

When a Piccolo avionics is added to a network slot in the Groundstation, a new window is created which is specific to that avionics. The window is built upon a tab dialog box, with each tab displaying a different part of the system. The top of the tab dialog displays the address of the avionics, the number of milliseconds that the avionics has been on since last power-up or reset, and the date and time from the GPS, see Figure 7.

Just under the title bar is a series of lights that are used as alarms. They represent the six most important parameters regarding the health of the vehicle. The alarms are giving in order of decreasing priority from left to right. For each parameter the light will be red if the data indicates that parameter is out of range:

- `ALT` is the altitude alarm. The altitude alarm is based upon the altitude limits specified for the avionics (see section 4.9).

- IAS is the indicated airspeed alarm. Similar to the altitude alarm the IAS alarm is based upon the airspeed limits for the avionics (see section 4.9).
- SYS is the system diagnostic alarm. It is based upon the main input voltage, and the board temperature. The main input voltage limit that will trigger the alarm are 11 and 15 Volts. The avionics temperature limits that will trigger the alarm are 0 and 80 degrees C.
- GPS is the GPS alarm. It is based upon the health of the GPS receiver as indicated by the number of satellites and PDOP (precision dilution of precision) value. The alarm will be triggered if the GPS does not have a 3D fix, or if the PDOP is larger than 5.
- LINK is the wireless link alarm. It is based upon the avionics RSSI and the link ratio and it will be activated if the RSSI drops below -101, or if the link drops below 85%.
- COM is the communications alarm. It is based upon the communications timeout specified for the avionics (see section 4.9).

An audio output can be enabled for the alarm system. If one or more of the parameters are alarming, and if the audio output is enabled, then a warning will be given every two seconds for the alarm with the highest priority.

Below the flight parameter alarms, the next row of lights consists of the flight termination alarms. If any of the flight terminations is asserted, the corresponding light will be red instead of green. There are currently three flight termination alarms:

- Aerodynamic termination. If the light is off (neither green, nor red) then the aerodynamic termination is not armed. If armed, the light will be green. If asserted, it will be red.
- Engine kill. In addition to changing the color of the light, it will also provide the status of the ignition (on or off).
- Deadman line. The light will turn red if the deadman line is dropped.

4.5 Telemetry page

The telemetry page displays data from all the sensors of the system. This display in Figure 7 is shown in advanced mode.

4.5.1 GPS data

The GPS data gives the information received from the GPS onboard the avionics. The GPS data are updated once per second. The data in Figure 7 indicate that the vehicle is currently sitting on the ground, in Hood River, Oregon. Notice the PDOP value. This is the precision dilution of precision number, which is based purely on the geometry of the visible satellite constellation. Typical values should be less than 5. There are usually always at least six satellites visible, and sometimes as many as 10. In some cases, the number of visible satellites will be zero. This will occur if the GPS receiver does not have a complete GPS constellation almanac. Once the almanac download is complete this value will be correct. If you are seeing high PDOP values, or too few satellites, that indicates the GPS is not performing well, typically due to problems with the antenna configuration.

On the Status line there is a series of lights which describe the status of the GPS receiver. These are the following:

- DGPS - it should be green if the differential corrections have been enabled at the groundstation, and gray if DGPS is not enabled.
- ANT - green if GPS antenna is connected to the avionics, red otherwise.
- 3D, 2D, ACQ - one of these three will be green depending on which state the GPS receiver is in - ACQ if it is acquiring, 2D if it has a 2D solution, and 3D if it has a 3D position solution.
- DR - as long as GPS outputs position and velocity data, the DR will stay gray. When GPS cannot provide solution, the Piccolo navigation will fall-back to dead-reckoning, and the DR light will turn red.

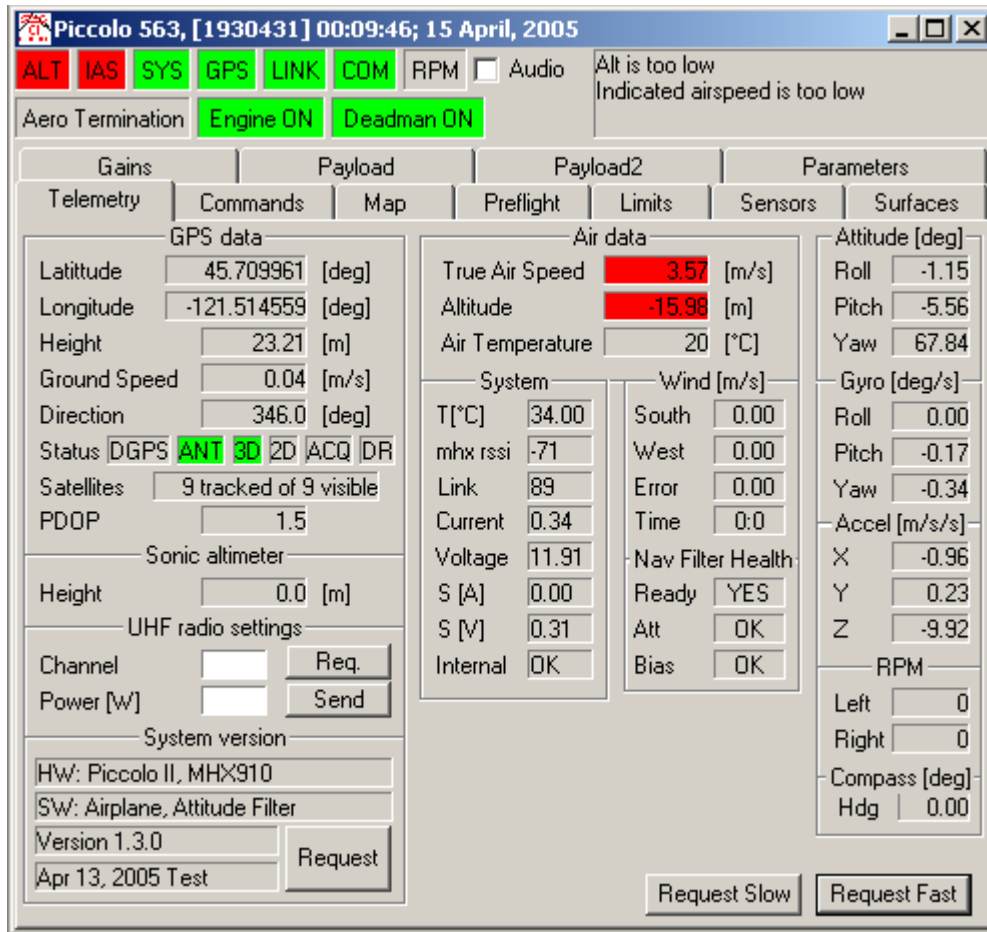


Figure 7. Telemetry page

4.5.2 Air data

The air data gives the airspeed and barometric altitude information. The temperature indicated is based on the internal board temperature with an offset to account for warming in the box.

4.5.3 Attitude

The attitude display gives the estimated Euler attitude angles for the vehicle, which are obtained by Kalman-filtering the rate gyro outputs and correcting the outputs using the pseudo-attitude derived from inertial reference frame accelerations. If the vehicle is not moving, the

accelerometers are used for this purpose, while the GPS-derived acceleration is used during the flight. Thus, the system will output vehicle roll and pitch angles both on the ground and in flight. However, the estimation of heading (yaw) requires motion since it is based on measuring the groundspeed and wind speed vectors.

4.5.4 System

The system group contains diagnostic data from the avionics. This data is identical to that from the ground station.

- `T[°C]` is the temperature of the main board in degrees Celsius. The boards have been tested from 0 to 80°C for *Piccolo*, and -40 to 85°C for *Piccolo Plus*.
- `RSSI` is the receive signal strength indicator from the MHX radio. It is in units of dBm and ranges from -71 (strong signal) to -115 (no signal).
- `Link` is a percentage from 0 to 100, which represents the acknowledgment ratio. On each communications frame the ground station polls an avionics and waits for its response. At the end of the frame the avionics sends an acknowledgement packet to the ground station to indicate the frame is complete. The ground station now tracks the percentage of the received acknowledgements and sends that data to the operator interface, where the user can use it as a metric for communications performance. This is most useful in situations where there may be interference. In that case the RSSI signal may still indicate good strength, but packets may be dropped due to the interference.
- `Current` refers to the input current, and is displayed in Amps.
- `Voltage` is the input voltage, which should always be between 8 and 20 volts.
- `S[V]` is the servo voltage, and `S[A]` is the servo current. The servo voltage and current are only available on *Piccolo Plus* and *Piccolo II*.
- The `Internal` signal is a composite of all of the internal voltages of the avionics. `OK` will be displayed here if the internal diagnostics are nominal, else the offending system will be displayed.

4.5.5 Winds

The winds group displays the latest data from the wind-finding by maneuver calculation. Winds are named for the direction they come from, hence South wind is the component of the wind from the South going to the North. The time of the wind calculation is also provided, as is estimated wind error. The wind data are an integral part of the sensor fusion algorithms on the vehicle as well as the navigation system. In addition they can be useful when planning longer range flights.

4.5.6 Nav Filter Health

The Nav Filter Health panel displays several important parameters regarding the Kalman filter that estimates the attitude of the vehicle and the gyro biases.

- `Ready` field informs if the Kalman filter has been initialized and it is operational.
- `Att` field reads OK if the covariance of the attitude solution is within normal limits.
- `Bias` field reads OK if the covariance of the gyro bias states is within normal limits.

4.5.7 Gyro and Accelerometers

The gyro and accelerometer data follow standard US aircraft sign conventions; i.e. the X-axis points through the nose, the Y-axis through the right wing, and the Z-axis down. Hence when flying at a one-g loading the Z accelerometer will indicate -9.8 m/s/s.

4.5.8 RPM

External IO lines 5 and 20 (TPU_B2 and B3) are provided for measuring RPM. The RPM is measured by sampling the time between falling edges on the signals. TPU_B2 is used to measure left engine RPM and B3 is used to measure right engine RPM.

4.5.9 Request Fast/Slow

The request fast and request slow buttons alter the rate at which the telemetry data are sent. The system defaults to slow mode in which it sends data once per second. In fast mode the data are sent 20 times a second (or as fast as available bandwidth will allow). Fast mode is provided for diagnostic purposes and is not used for routine flying.

4.5.10 UHF radio settings

The UHF radio settings allow the user to control the power output and the hopping pattern of the Microhard radio in the avionics. The radio is a frequency hopping spread spectrum system, which means that it doesn't use a single frequency, but instead hops along a pattern of frequencies. It is possible to work with multiple ground stations by configuring each ground station to use a different hopping pattern and then changing the hopping pattern of the avionics to match the desired ground station. Pushing the `Req` button will request the current hopping pattern and power output of the radio. Pushing the `Send` button will update the hopping pattern and power output of the radio. When changing hopping patterns the avionics will automatically revert to the previous setting if communications are not established with a ground station on the new pattern. Note that while requesting or changing the radio settings the radio will be taken offline and communications will be suspended for a few seconds. As a result you should not request or change the radio settings when flying under manual control.

4.5.11 Sonic altimeter

This field will display the sonar altitude reading if a sonar is connected to the avionics. In current version of our software the sonar altimeter is not used by the autopilot for control of the airplane. The sonar measurement is included with the autopilot telemetry and displayed here.

4.5.12 Compass

This field will display the magnetic heading measurement, if a Honeywell HMR-2300 magnetometer is connected to the avionics. In addition to displaying the value here, the magnetic heading is also used on-board, if available, in the attitude filter.

4.6 AP commands

The autopilot commands page displays the current autopilot command status, and allows you to change the commands. In the upper left hand corner the green box indicates that the autopilot is on. This is because the global autopilot switch on the pilot console is on; or the console is not plugged into the ground station; or this avionics is not selected for manual control. If manual control were selected from the pilot console the `AUTOPILOT ON` box would be red, and would read `MANUAL`.

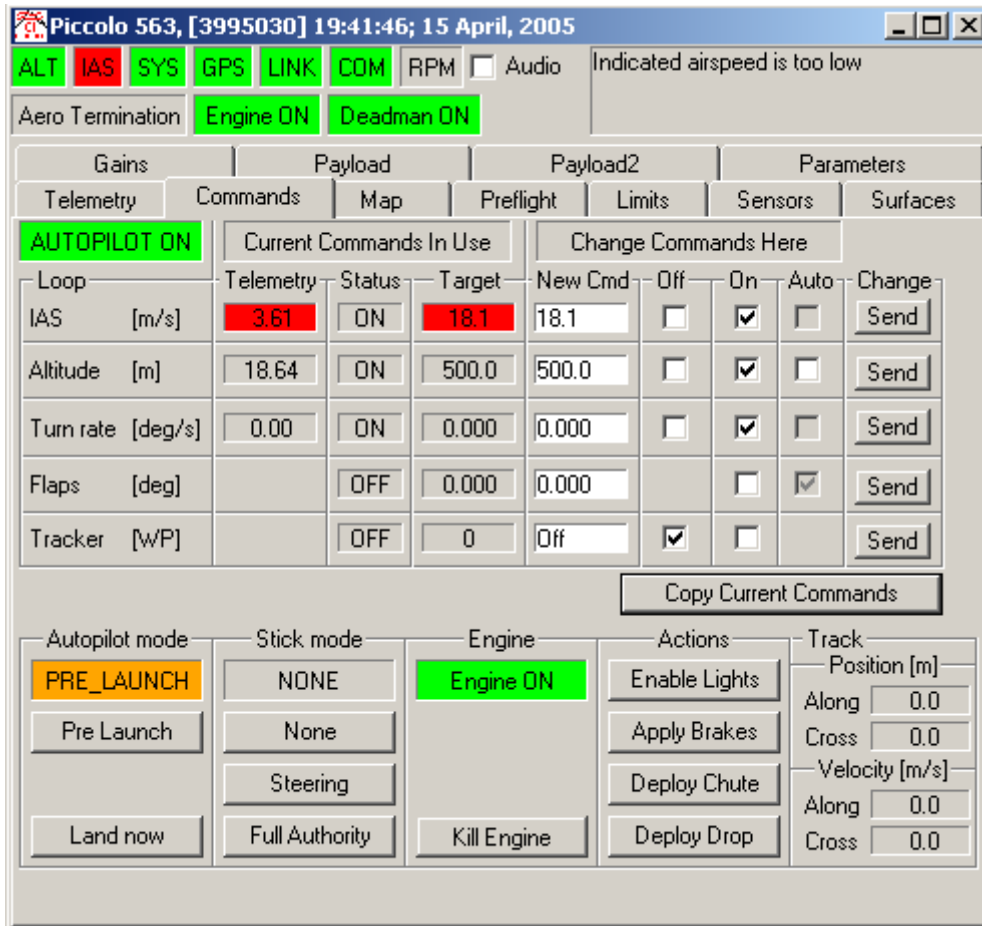


Figure 8. Autopilot commands page

4.6.1 Current autopilot status

The top-left half of the autopilot command page gives the current status. There are five autopilot loops, and hence five rows in the table. The first column of the table gives the telemetry data that is appropriate for that loop. The second column of the table gives the status of each individual loop (AUTO, ON, or OFF). The third column gives the commanded value for each loop.

The AUTO states means that the loop is enabled and the command for that loop is automatically generated. This applies only to the turn rate and altitude commands when the tracker is on. ON or OFF indicate the loop is enabled or disabled respectively. The actual loop status is a logical OR of the global autopilot status and the loop status. Hence it is possible to have a loop on, but still have the autopilot off.

4.6.2 Changing autopilot commands

The top-right half of the autopilot command page provides a location for changing the current commands individually. The desired commands entered in these fields are then are sent by pushing the Send button for each loop. The Copy Current Commands button will copy the information from the status display into the command fields.

4.6.3 Autopilot Mode

The Autopilot Mode panel displays the current operating mode the autopilot is set to, and allows the user to command manually 2 of the 7 operating modes available. Here is a listing of all of the operating modes.

Table 4. Autopilot Modes

Mode	Description
Pre-launch	The vehicle is waiting for a launch indication. This is the state that the system starts in, and is also the state it goes to when the user commands auto-launch. In this state all outputs are held to the trim condition, with the exception of the throttle which is held at the prelaunch throttle value.
Transition	Auto launch is in progress. The system enters this state when the airspeed reaches 75% of the minimum airspeed limit. In this state the autopilot is watching the dynamic pressure. If it falls below 50% of the minimum value the system goes back to pre-launch. If, after a half second the dynamic pressure remains above half the minimum value the autopilot switches to the next state. In this state all outputs are held to the trim condition, with the exception of the throttle which is held at the prelaunch throttle value.
Climb-out	System is airborne, waiting for GPS to settle. In this state the autopilot is turned on, except that the turn rate command is held to zero. The autopilot will stay in this state for seven seconds.
Flying	The standard operating mode.
Landing	Aircraft navigates the landing pattern. In this state the minimum altitude limit does not apply.
Final Approach	Aircraft is on final approach. The autopilot is watching for the vehicle's altitude to reach the flare altitude. If it does reach the flare altitude before reaching the landing waypoint, it will kill the engine, update the airspeed command to the flare speed, and level the aircraft.
Touchdown	Engine has been killed prior to touchdown. In this state the autopilot does not navigate the flightplan segment, instead it keeps the aircraft in a wings-level attitude.

The three buttons on the panel control the user-selectable operating modes.

- The `Pre Launch` button puts the avionics into pre-launch mode. When entering this mode with the autopilot on, the autopilot will suspend execution of the main control loops, leaving their outputs at the trim position, with the exception of the throttle which will be set to its prelaunch value. The autopilot will stay in this mode until the airspeed signal reaches 75% of its minimum command value. When this happens the autopilot will pause for 0.5 seconds, and then proceed through the transition and climb-out states until it reaches the flying state.
- The `Land now` button will initiate an automatic landing, by sending the aircraft to the landing pattern entry waypoint, if a landing flightplan has been uploaded to the aircraft. The current landing pattern entry point can also be viewed and manually updated from the limits page. Once the autopilot is in landing mode, the `Land now` button will change

to Go Around. If the Go Around button is clicked, the aircraft will abort the current approach and attempt a new one by going back to the landing pattern entry waypoint.

4.6.4 Stick Mode

The Stick Mode panel displays and updates the level of stability-augmented manual control on the aircraft. At the top of the panel, the current mode is displayed. There are three stick modes, and the corresponding buttons are provided below. By stability augmentation, we refer to manually assisted autonomous flight, in which all control loops are active but the individual loop commands are offset with values provided from the pilot console.

- If mode is set to `None`, then all control loop commands are internal (either from the Operator Interface, or from the Navigator, but none from the pilot console).
- In `Steering` mode, the turn rate command is obtained from the aileron stick on the pilot console. The mapping of this control is such that with the stick centered and no trim the turn rate command is zero, while at full stick deflection the aircraft turns, with a bank angle command equal to the maximum bank angle limit.
- The `Full Authority` mode adds the ability to control the airspeed loop with the elevator stick, the throttle and flap signals from the pilot console are applied directly (open-loop). The lateral control is like the `Steering` mode explained above, however in addition the rudder signal from the pilot console is appended to the rudder output from the internal yaw damper.

4.6.5 Engine

The Engine panel displays and updates the engine status. The current engine/ignition status is presented at the top of the panel, while the button to kill or enable the engine is at the bottom of the panel.

The `Kill Engine` button gives the user the ability to override the altitude control loop and force the throttle output to zero. The engine kill feature can be driven by the user, through the button on the autopilot page, or driven by the deadman status logic, see section 4.9 for details.

4.6.6 Actions

The Actions panel provides a list of toggle buttons, which can act as on/off switches for various UAV systems. For the buttons to work, the I/O lines must be configured for the specific actions, on the Payload page.

The UAV systems that can be controlled by these buttons are:

- Lights: can be turned on or off, from the user interface or as a result of tracking a waypoint.
- Parachute: can be deployed from the user interface, or as a result of reaching a waypoint, or by manual control, using the eighth channel of the pilot console.
- Drop: can be deployed from the user interface, or as a result of reaching a waypoint.
- Brakes: can be actuated from the user interface, or by manual control, using the seventh channel of the pilot console.

Each of these actions needs a hardware line to function. Accordingly the payload interface (4.13) has been expanded to include options for any I/O line to do any of these functions. The

lights functions use discrete output. The other functions can be driven as discrete outputs, or as pulse width signals (e.g. for servo control).

4.6.7 Track data

Below the autopilot status display the tracker input variables are displayed. They are: the along track distance, which is the distance to go before reaching the waypoint; the cross track distance, which is the perpendicular distance from the track to the vehicle (positive right); and the along and cross track velocities.

4.7 Map

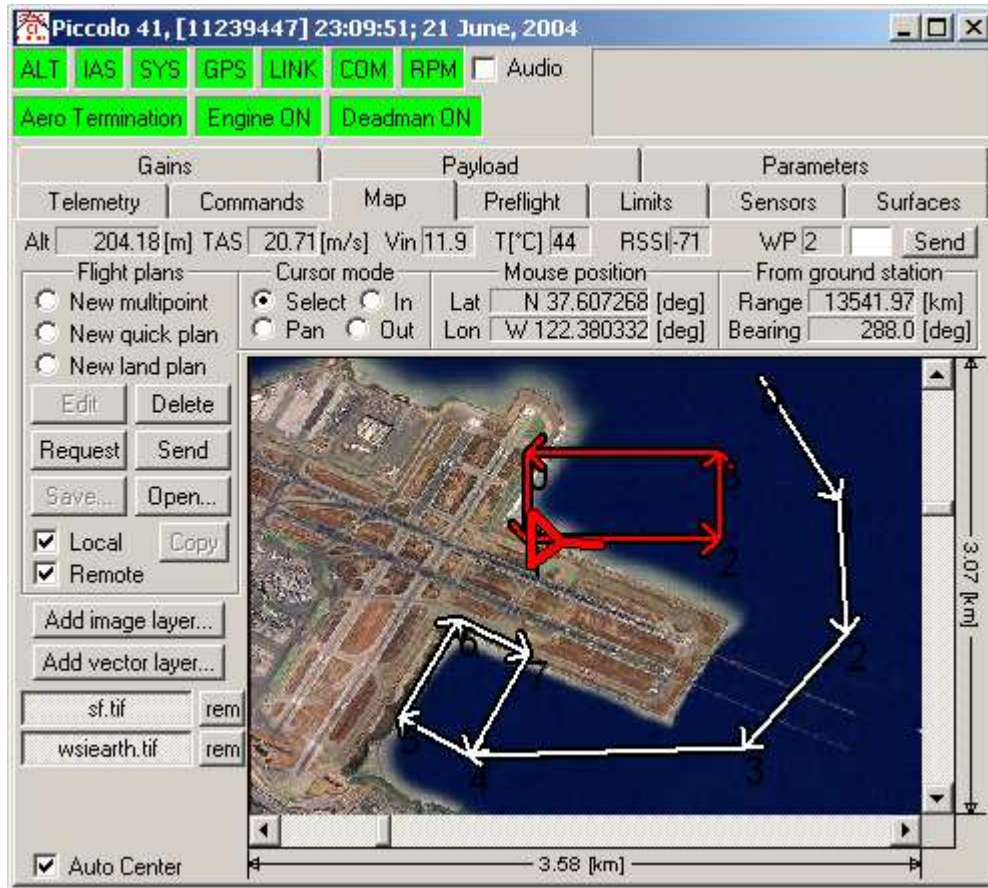


Figure 9. Map page

The map page displays the current location of the vehicle, and provides an interface for creating flight plans. The map is built on ESRI's MapObjects, which means that it is capable of displaying geo-referenced raster files, as well as vector shape files. To add a layer to the map select the button `Add image layer` or `Add vector layer`. Each layer added is displayed below the add buttons. In Figure 9 there are two layers, which are named `sf.tif` and `wsiearth.tif`. The layers can be turned off by pressing the button that contains the layer name. Layers can be removed by the `rem` button next to the layer name.

Whenever the mouse pointer is over the map the location of the pointer is displayed at the top of the map. The map can be zoomed in by selecting the `In` radio button and using the mouse to

click and drag a rectangle on the map. The rectangle will become the extents of the map. Zooming out is accomplished by selecting the `Out` radio button and clicking on the map. Each click expands the map area by 50%. To move the map select the `Pan` button, and click and drag the map with the mouse. Or use the scroll bars to pan the map.

At the top of the map page the most important data from the telemetry stream are displayed: the altitude, true air speed, input voltage, board temperature, and receive signal strength from the radio. In addition the waypoint (shown as WP in the upper right corner) that the vehicle is currently tracking is displayed. The waypoint command can be changed by entering a new waypoint and clicking `Send`.

The map also displays flight plans for the vehicle. There are two types of flight plans displayed: remote plans and local plans. The display of either type of flight plan can be turned on or off using the `Local` or `Remote` check boxes. Remote plans are those that are stored onboard the avionics, i.e. remote from the operator interface, and they are drawn in red. Local plans are those that are stored on the operator interface, i.e. they have not yet been sent to the avionics, and they are drawn in white.

To see the flight plans that are onboard the avionics press the `Request` button. This will trigger the avionics to send all of its flight plans.

4.7.1 All about flight plans

Flight plans are made of linked lists of waypoints. Each waypoint encodes latitude, longitude, altitude, and the index of the next waypoint to be used. The avionics has storage for 100 waypoints. These waypoints can be used to make one flight plan that is 100 waypoints long, or 50 flight plans with two waypoints each, or any combination between. The key concept is that all flight plans must close. This means that at some point the next waypoint must point to a waypoint that was previously in the list. In Figure 9 the flight plan is made of waypoint 10, which goes to 11, which goes to 12, to 13, to 14, to 15, to 16, and back to 14. Note that although all flight plans must close, they do not have to be a loop. In the sequence given above the aircraft will end up flying the triangle between waypoints 14, 15 and 16.

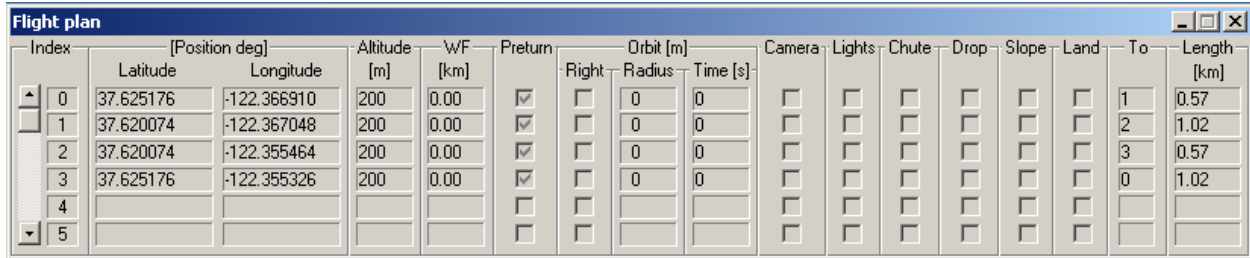
Flight plans also encode altitude. Each time the navigator switches waypoints it changes the altitude command to the value in the waypoint it is going to. To edit a flight plan, including the altitude, push the `Select` radio button, highlight the flight plan and then click `Edit`. The dialog in Figure 10 dialog will appear.

In addition to the basic position, the flight plans include a feature called the wind-finding interval (`WF` in Figure 10). This interval describes the time between performing s-turns along the flight plan. The s-turns allow the avionics to measure the wind. You can disable the wind-finding by setting the interval to zero or less than zero.

Each waypoint also has a feature called pre-turn, which can be enabled or disabled according to the check box in Figure 10. Pre-turn allows the avionics to estimate when to turn so that it doesn't overshoot the segment that follows the waypoint. When you create a flight plan in the Operator Interface pre-turn will be on by default; however if you need to guarantee the vehicle flies over a waypoint you can disable the pre-turn for that point.

A waypoint can be declared as orbit waypoint, in which case the aircraft will circle the waypoint rather than flying to it. This can be enabled or disabled according to the Orbit radius in Figure 10. An orbit waypoint has a rotation sense, a radius, and an orbit time associated with it. Check

the `Right` box to have the airplane fly the orbit in a clockwise sense, or leave the checkbox blank to have the airplane orbit counter-clockwise. During the orbit, the aircraft will maintain a constant distance to the waypoint according to the `Radius` specified in the edit box. The airplane will orbit the waypoint for the time specified in the `Time` edit box, after which the Navigator will switch to the next waypoint. If the orbit time is zero the vehicle will orbit indefinitely.



Index	[Position deg]		Altitude [m]	WF [km]	Preturn	Orbit [m]			Camera	Lights	Chute	Drop	Slope	Land	To	Length [km]
	Latitude	Longitude				Right	Radius	Time [s]								
0	37.625176	-122.366910	200	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	1	0.57
1	37.620074	-122.367048	200	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	2	1.02
2	37.620074	-122.355464	200	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	3	0.57
3	37.625176	-122.355326	200	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0	1.02
4					<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		
5					<input type="checkbox"/>	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		

Figure 10. Flight plan edit dialog

The next four checkboxes are related to the actions described in Section 4.6.6. If you would like the airplane to perform these actions autonomously, check one or more of the four action flags. The parachute and drop actions are performed when the vehicle reaches the waypoint. The lights function is applied while the aircraft is flying to the waypoint.

The next waypoint flag is the `Slope`. If `Slope` is not checked, the altitude control will track a constant altitude, which is the altitude of the target waypoint. The airplane will go to this target altitude immediately and maintain the command until it switches to the next waypoint. If `Slope` flag is set, then the aircraft will attempt to track a slope leading from origin waypoint to target waypoint; thus, the airplane will climb/descent at constant rate, such that it reaches the waypoint altitude when it is in the proximity of the target waypoint. This mode is used in creating a landing pattern, but it can be used for other purposes as well.

The next waypoint flag is the `Land`. Check this box to mark the waypoint as a touchdown waypoint, thus making the current flightplan a landing pattern, and the current track segment a final approach. If you do not intend to perform an automatic landing, leave this checkbox blank.

Note that Figure 10 shows the dialog for a remote plan, which cannot be edited. If the plan were local the edit boxes would be white (i.e. editable) and any changes made would be reflected on the map.

4.7.2 Making new flight plans

To make a new flight plan select the `New multipoint` radio button. Then, using the mouse, click on the map once for each waypoint. To end the flight plan double click. The flight plan will automatically close. To control which point it closes to, double click on top of the desired point. When you are finished the OI will prompt you for the flight plan altitude. After entering the altitude the new flight plan is drawn as a local plan on the map. There is only ever one local plan, so the previous local plan will be discarded. The local plan can be edited to include any altitude information or fine-tuning of the position data.

Alternatively you can make a simple two waypoint flight plan by clicking `New quick plan`. Using this option a flight plan is built from the current location of the vehicle to the wherever you click on the map. A quick plan dialog window is displayed to set various parameters (see Figure 11). The horizontal position and altitude of the target waypoint can be specified more accurately if desired; the target waypoint can be setup as an orbit waypoint.

Also the same dialog allows the user to specify what to do with the newly created plan. If `Send Immediately` box is checked, the flightplan will be sent to the avionics immediately after the OK button is clicked. If the `Track Immediately` box is checked, the Navigator will also switch waypoint to this new plan immediately after the OK button is clicked. The default waypoints for the quick plan are 98 and 99, but this option can be overwritten by specifying a different starting index in the edit box at the bottom of the dialog.

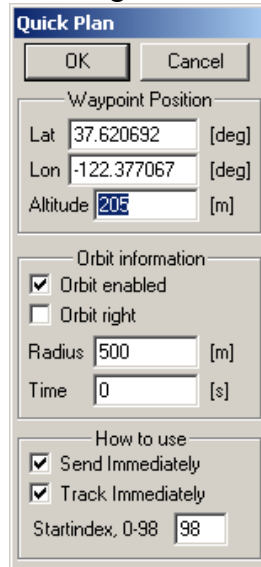


Figure 11. Quick plan dialog.

4.7.3 Sending flight plans

To send a local flight plan to the avionics press `Send`. The map will prompt for the starting waypoint index. The index you choose depends on what plans are already onboard the avionics. After sending the flight plan the avionics will echo the plan back to the map, and it will be displayed in red. The local plan, displayed in white, will remain.

4.7.4 Editing flightplans

Only local flightplans can be edited. If you would like to edit a remote flightplan, first make a copy by selecting the remote flightplan with the mouse and clicking the `Copy` button. Then select the white colored local copy of the plan and click the `Edit` button. If you cannot select the local plan due to the fact that the remote plan is drawn on top of it, uncheck the `Remote` button to turn off the display of remote flightplans.

4.7.5 Dragging waypoints

As of software version 1.1.9 and later you can click and drag waypoints. To do this choose the `Select` radio button. Then click and drag on a waypoint. When you release the mouse button the waypoint location will be updated. If the flight plan was local the change occurs immediately. If the flight plan was remote the change is sent to the avionics and the screen will be redrawn when the avionics echoes the new waypoint position.

4.7.6 Making landing flight plans

Landing flight plans can be built by hand, but most of the time they are done using the landing plan feature of Piccolo. To make a landing pattern, select the "New land plan" radio button. Click on the map, at the location where you would like the touchdown waypoint to be; now the

mouse cursor drags an imaginary line segment. Next click on the map in the direction of the runway that the aircraft should follow (that is, click an arbitrary point on the direction of the final approach), see Figure 12.



Figure 12. Two points used for creating a landing pattern.

After the two waypoints have been selected, the system will present a landing plan dialog, as in Figure 13.

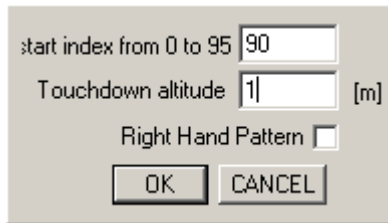


Figure 13. Landing plan dialog.

In the dialog, specify the starting index of the landing plan, keeping in mind that an auto generated landing plan always has 6 waypoints. Also, provide the altitude of the touchdown waypoint and the sense of the pattern. After clicking the OK button, the parameters of the landing pattern (those provided in the dialog and on the map) will be sent to the aircraft, which will generate the landing flightplan based on these and on the current aircraft settings (such as approach length, glideslope angle). The auto-generated landing plan will then be sent to the ground and displayed on the map page, as in Figure 14.



Figure 14. Landing plan generated by the avionics.

How does the Piccolo generate a landing plan? In Figure 15 we can see a listing of the flightplan, which was presented in Figure 14. We can see that the entry waypoint 90 and the next one have the same altitude, while the rest of the waypoints have decreasing altitude and slope flag enabled. Also, we can see that the last waypoint, 95, is the touchdown point since it has the Land flag enabled and the lowest altitude.

Flight plan																
Index	[Position deg]		Altitude [m]	WF [km]	Preturn	Orbit [m]			Camera	Lights	Chute	Drop	Slope	Land	To	Length [km]
	Latitude	Longitude				Right	Radius	Time [s]								
90	37.620598	-122.379208	158	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	91	0.45
91	37.616995	-122.381543	158	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	92	1.20
92	37.612041	-122.369462	74	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	93	0.26
93	37.613307	-122.366986	58	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	94	0.26
94	37.615645	-122.367126	42	0.00	<input checked="" type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	95	0.60
95	37.618122	-122.373167	1	0.00	<input type="checkbox"/>	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	90	0.62	

Figure 15. Waypoint listing for a landing plan.

The landing plan is a box-shaped plan on which the cross-wind leg before the final approach has been divided in two smaller segments such that the airplane makes three 120° turns instead of two 90° turns. The geometry of the landing plan is presented in Figure 16.

If D is the length of the final approach, as specified in the aircraft parameters, then the size of the landing plan will be 2D long by 0.75D wide. The first cross-wind segment will be constant-altitude, while the down-wind, the two small cross-wind segments and the final approach will have a constant glide slope angle, as defined in the aircraft parameters.

The landing pattern entry and go-around point will be, in this example, waypoint 90. The entry point will always be the first waypoint in the plan, and the autoland waypoint specified in the mission parameters.

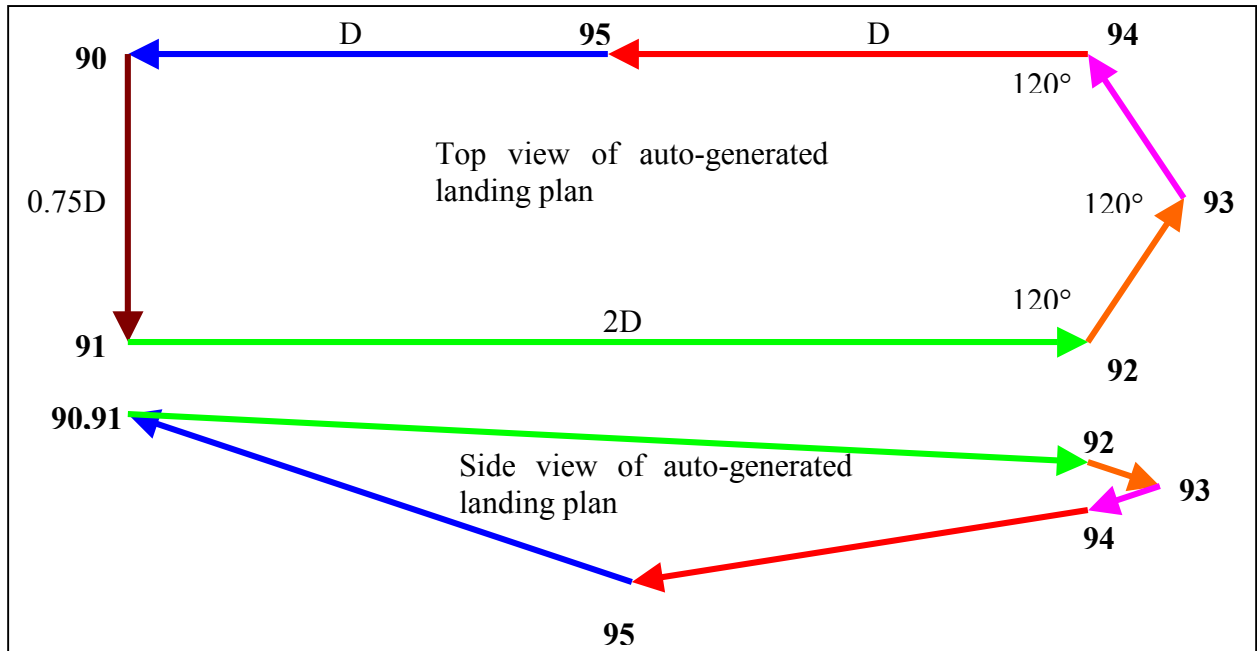


Figure 16. The auto-generated landing plan diagram (top and side views)

4.7.7 *Geo-referencing your own map file*

If you have an image of the area you wish to fly and you want to use this image for your map you will need to geo-reference it. The map will accept geo-referenced TIFF image files; so your first step is to get your image in TIFF format. The geo-referencing is done through a separate file, called a world file that has the same name as the image file, but with the extension “tfw”. The world file contains six numbers, one on each line, and has the following format:

```
degrees longitude per x pixel
0
0
degrees latitude per y pixel (negative)
Longitude of the upper left corner (positive East)
Latitude of the upper left corner (positive North)
```

The geo-referencing assumes that the image is linear, therefore it must be a rectilinear projection, and it must be oriented so that North and South are in the vertical direction. Note that the y-axis scale factor should be negative; this is a result of computer graphics coordinates systems which increase downwards. An example world file, which is for Wasco airport in Oregon, follows:

```
0.00005140576
0.000000000
0.000000000
-.00005140576
-120.68207806
45.591328
```

4.8 Preflight

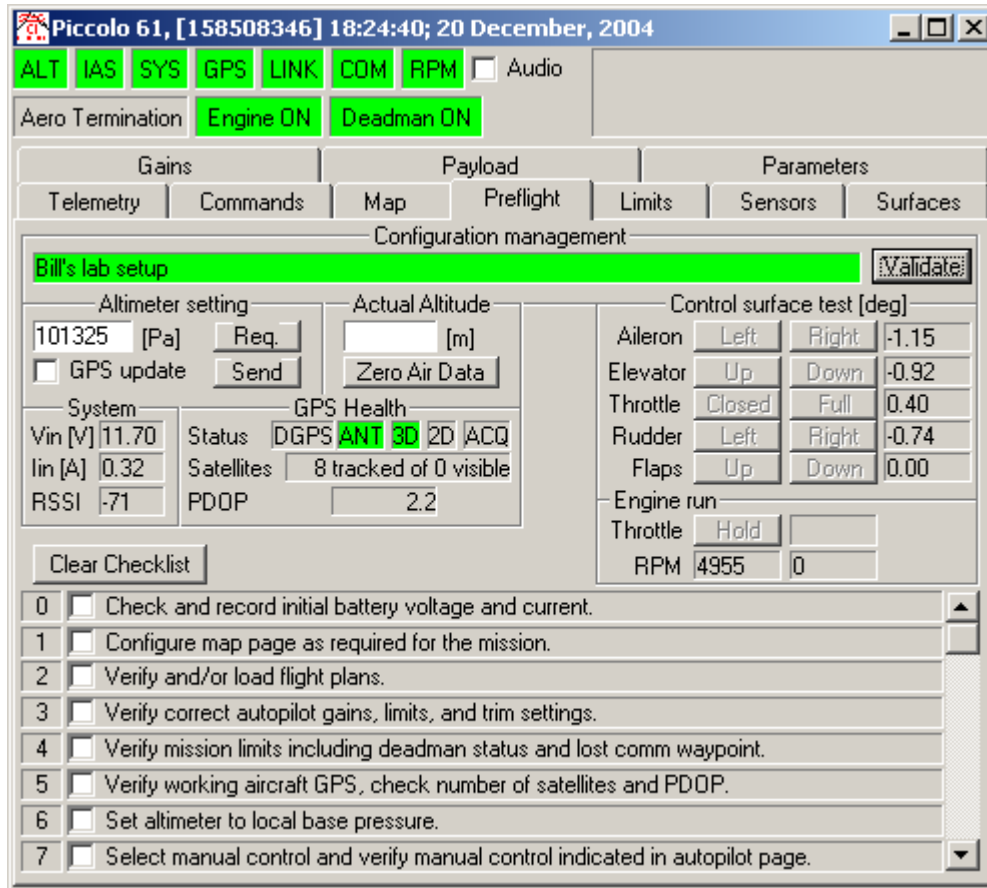


Figure 17. Preflight checklist.

The preflight page gives a user-configurable preflight checklist. Each item of the checklist is represented by a box that can be checked to indicate that step has been done. The checklist can be configured through a simple text file, "preflight.txt" in the working directory of the Operator Interface application. If the file doesn't exist the OI will create a generic preflight list. However if the file exists, then each line of the file will become an item in the preflight page checklist. For a detailed description of the generic preflight checklist items see the document "[Preflight Checklist for the Piccolo System](#)".

In addition to the checklist, the preflight page includes some of the user interface elements required to perform the checklist items, including the altimeter setting, sensor zeroing, GPS health, system health, and control surface tests.

4.8.1 Altimeter setting

The preflight page has the altimeter setting request and send button. The altimeter setting is the atmospheric pressure at seal level used to calculate barometric altitude. Push the `Req` button to learn the current setting; and push the `Send` button to alter the setting to whatever is in the edit box. If the GPS update box is checked before sending the altimeter setting, then the system will periodically adjust its altimeter setting during the flight such that the barometric altitude output matches the GPS altitude solution.

4.8.2 Zero Air Data

The air data sensors (dynamic and barometric pressure) can be zeroed to take out any residual error before launch. This action should be performed only when the aircraft is on the ground, not moving, and with the dynamic pressure port shielded from wind. To do this press the `Zero Air Data` button. The sensor readings at the time the button is pushed will be stored as the sensor offset and applied to subsequent readings. If the `Actual Altitude` field contains a value when the sensors are zeroed then the barometric pressure zero is also adjusted to match the actual altitude. It is best to zero the barometric pressure sensor after setting the altimeter setting.

4.8.3 Control surface tests

The control surface test functions are only available when the system is in pre-launch mode and is not in manual control. The purpose of these tests is to provide means for making sure that the control surfaces move freely and in the right direction, in the case when no pilot console is attached to the groundstation.

To test a control surface, press one of the direction buttons, to move the control surface in that direction. When a button is pressed, a pilot stream packet is being sent, similar to the ones provided from the pilot console. After the pilot timeout elapses, the control surface returns to the trim value. The pilot timeout can be adjusted on the `Autopilot Limits` page.

4.8.4 Validate

Pushing the validate button will cause the operator interface to downlink parameters from the aircraft and compare them against a file of parameters. The file name is based upon the description field (a string field stored on the avionics and requested by the operator interface), or, if the file doesn't exist, the OI will prompt the user to supply it. If the comparison shows that all parameters are correct, the operator interface will indicate "validation succeeded!". If any parameter does not match the offending parameter will be displayed to the user.

This feature is intended to allow operators to make sure that the avionics is correctly configured for the aircraft that they are operating. Accordingly the parameters that are compared are those which are specific to a *type* of aircraft, but not a specific vehicle. Hence the sensor calibrations, surface calibrations, and autopilot trims are not compared.

4.9 Autopilot limits

The limits page is used to view and alter the autopilot and mission limits.

4.9.1 Command limits

The airspeed, altitude, and turn rate commands are limited by max and min dynamic pressure, max and min altitude, and max and min bank angle. The `Piccolo` autopilot is mostly de-coupled between longitudinal and lateral control, hence extending the bank angle limits beyond 30° should only be done with caution.

4.9.2 Output limits

In addition to the command limits this page also shows the output limits. The five outputs from the autopilot will not exceed the values given here. To see the current limits press the `Request Limits` button. To change the limits press the `Send Limits` button.

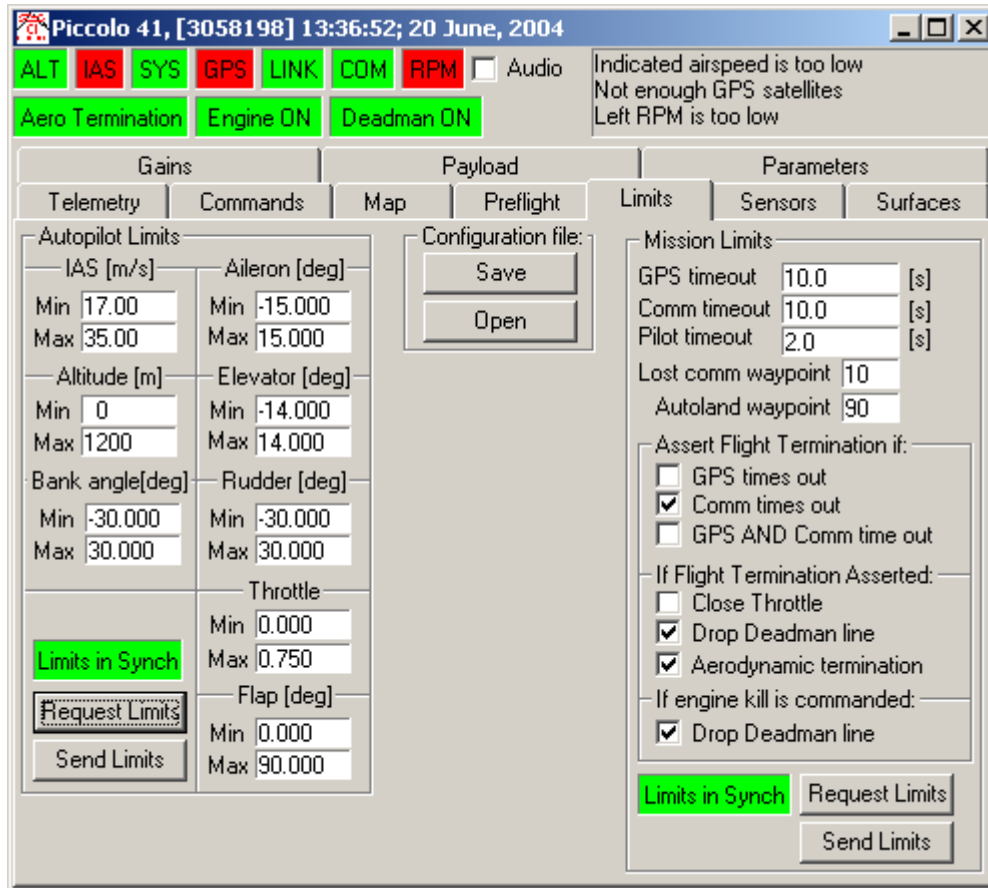


Figure 18. Autopilot limits page

4.9.3 Mission limits

The limits page also shows the mission limits.

- The *Pilot timeout* gives the amount of time the system will remain in manual control mode without new manual control inputs. If this timeout elapses the system will automatically switch to autopilot mode. The pilot timeout should never be set to zero as this will block the possibility of manual flight.
- If communications fail entirely for the time defined in *Comm timeout* the avionics will take action by flying the flight plan indicated by the `Lost comm waypoint`. It is important to note that the lost communications waypoint identifies a whole flight plan, not just a single waypoint. When the communications timeout elapses, the avionics examines the lost comm flight plan and makes an intelligent choice of the waypoint to use. The choice is based on finding the waypoint that is closest to the avionics AND which is closer to the termination point of the flight plan than the avionics is.
- The *GPS timeout* defines the amount of time for the aircraft to continue to perform normally without a new GPS solution. When the time expires, the GPS timeout will be asserted for flight termination.
- The *Autoland waypoint* defines the entry point to the landing flightplan. It can be specified on this page, but it will also be updated every time a new landing plan is created

from the Map page. When the `Land now` button is clicked on the Autopilot Commands page, the navigator will send the aircraft to this waypoint. Also, when the landing is aborted, the navigator will send the aircraft to this waypoint.

The Flight Termination panel allows the user to specify which conditions have to be met for flight termination to be asserted. Depending on which checkboxes are checked, the flight termination may happen if GPS times out, or comm times out or both GPS and communications time out.

The next panel below allows the user to specify what the system should do when flight termination is asserted. The available actions can be:

- Close the throttle - this will cause the airplane to glide to the ground while still tracking or attempting to track the current flightplan.
- Drop deadman line - the deadman is an output switch which requires a continuous hardware refresh in order to stay active. Hence if the system fails for any reason the switch will turn off. For safety the deadman can be connected to the engine ignition, or some flight termination system (parachute deployment, for example).
- Aerodynamic termination - this will close the throttle, command maximum right aileron and rudder, up elevator, and maximum flaps.

The deadman can also be dropped when the user (or flight termination, or landing logic) kills the engine. This is useful for vehicles which are using the deadman line as an engine on/off feature.

4.10 Sensors

The sensors page gives the current sensor readings, the gyro bias estimates, the magnetometer calibration, the ability to zero the sensors and set the avionics orientation with respect to the aircraft body-frame.

4.10.1 Zeroing sensors

There are two sensor zeroing buttons:

- The `Zero All` button will remove residual errors in all inertial and air data sensors. This includes the 3 accelerometers, the 3 rate gyros, the Pitot and static pressure sensors. Since the system automatically estimates gyro biases, the `Zero All` function is seldom necessary.

Warning ! The Zero All function requires the aircraft to be perfectly level and motionless. Since accurate level orientation is difficult to achieve in the field, this function should be used only in the lab.

- The `Zero Air Data` button will remove residual errors in the Pitot and static pressure sensors. If the `Actual Altitude` field contains a value when the sensors are zeroed then the altitude zero is also adjusted to match the actual altitude. When zeroing the air data systems be sure there is no effect from wind on the pitot tube. The best way to do this is to shield the pitot tube from the wind. When shielding the pitot tube be sure that the tube is still vented to the atmosphere, i.e. don't completely seal it.

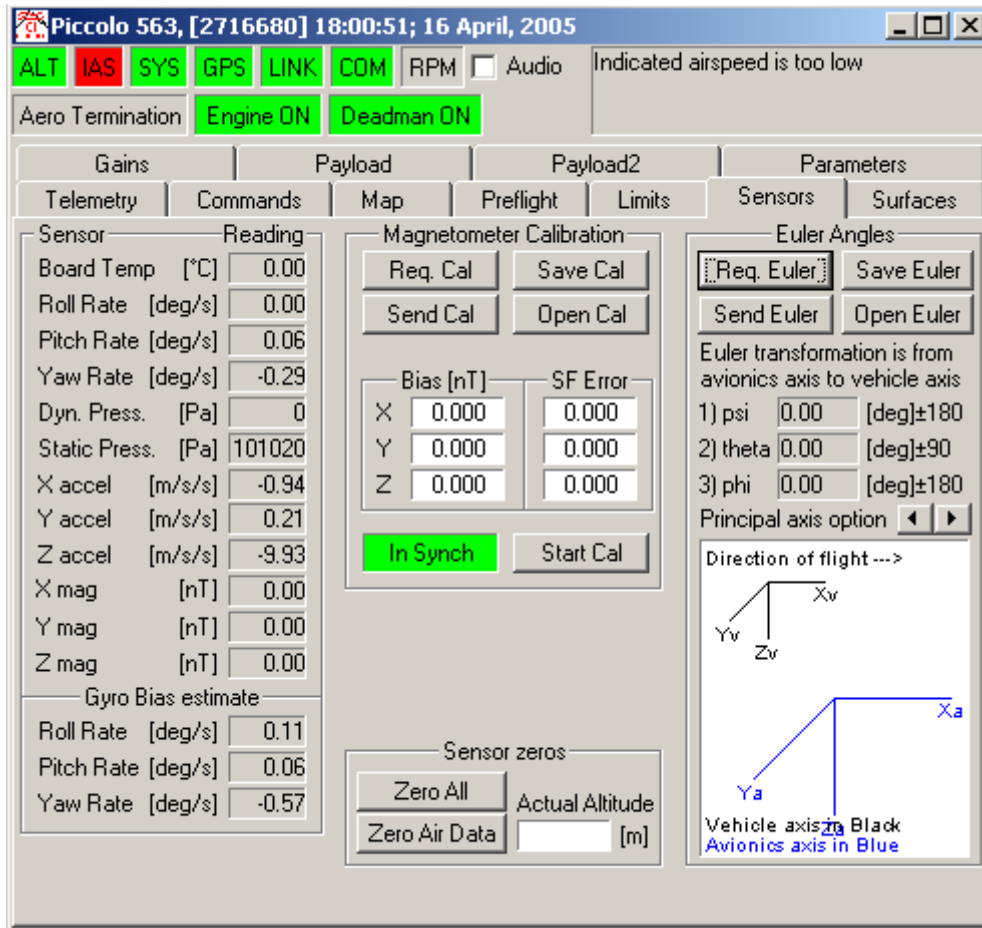


Figure 19. Sensor calibrations

4.10.2 Gyro bias estimate

Even with temperature compensation the gyros have more drift than is acceptable for flight control. Hence the avionics continuously estimates the bias error in the gyros using data from the GPS. The bias estimates are displayed in the gyro bias estimate box.

4.10.3 Gyros in the original Piccolo

The gyros are the most crucial sensors for basic stability of the vehicle. They are also the most sensitive to disturbances. In particular the most common problem with the gyros results from rapid temperature changes. These errors are most visible in the gyro bias numbers. The gyros have about $\pm 100^\circ/s$ at 10 bits of dynamic range. Hence if the bias value approaches these limits the gyros will stop functioning as the sampling hardware becomes saturated. The gyro calibration scheme used in the Piccolo provides for a hardware shift of the gyros. Hence the actual offset number displayed on the calibration pages represents an offset in hardware rather than software. The Piccolo software will automatically shift the gyro hardware bias if it detects that the gyro errors are becoming too large for correct operation of the system.

4.10.4 Gyros in Piccolo Plus and Piccolo II

The gyros used in *Piccolo Plus* are much more stable and robust than those used in *Piccolo*; as well as having more dynamic range ($\pm 300^\circ/s$ at 16 bits). Hence the hardware shifting done in *Piccolo* has been eliminated in *Piccolo Plus* and *Piccolo II*.

4.10.5 Installation orientation

Since the avionics has 3-axis gyros and accelerometers it can be installed in any orientation and the readings rotated to match the installation angles. The installation orientation is given by the three Euler angles Yaw (psi), Pitch (theta), and Roll (phi). Currently the Operator Interface only supports choosing Euler angles that are along principal axes of the vehicle. There are 24 different possible principal axes orientations, which can be selected with the `Principal axis options` spin buttons. The Euler angles are used to describe the rotation from the avionics coordinate frame to the vehicle coordinate frame. The avionics coordinate frame is marked on the front panel of the box. To change the angles press the `Send Euler Angles` button.

4.11 Surfaces

The surfaces page is used to control how the five autopilot outputs are mixed and matched to generate up to ten servo outputs; and also to provide the calibration information to go from surface angle to servo pulse width.

4.11.1 Actuator calibrations

In a real airplane the surface position, direction of travel, and amount of travel depend on the actuator to surface linkage design. In order to account for variations in the linkage the autopilot and/or mixer outputs are translated to actuator signals via calibration data. The calibration data account for sign convention, surface neutral, travel limits, and any non-linearities in the surface motion.

Each channel has its own calibration data, an example of which can be seen in Figure 20. The data relates the actuator pulse width in microseconds to the surface motion in degrees. In the case of the throttle the surface position is interpreted as fraction of full scale, and is always between 0.0 and 1.0. The surface position data are usually given in ascending order, and the pulse widths are in ascending or descending order. The sign convention on the surface deflection has the following rules: flaps, ailerons, and elevators are all positive down. Rudders are positive right. For ruddervators the sign convention follows the elevator rule, i.e. positive down.

The autopilot outputs 5 signals that are then adjusted using the output mode (5 or 10 channel) and mixing rules. The resulting outputs are then converted to pulse widths via piecewise-linear interpolated lookups through each channel's calibration data. If the requested deflection is outside of the table, then the pulse width is limited to the extremes in the table. Although the pulse width column in Figure 20 is regularly spaced, this is not required. Note the extreme pulse width values of 1103 and 1929. These correspond to $\pm 100\%$ pulse width as measured from a Futaba pilot console.

The `Request all data` button will trigger the avionics to send all of its surface setup information. On the left of the page the mixing options are given. To change only the mixing options alter the settings accordingly and then press the `Send Config` button. To change all surface settings including mixing and calibrations, use the `Send all data` button.

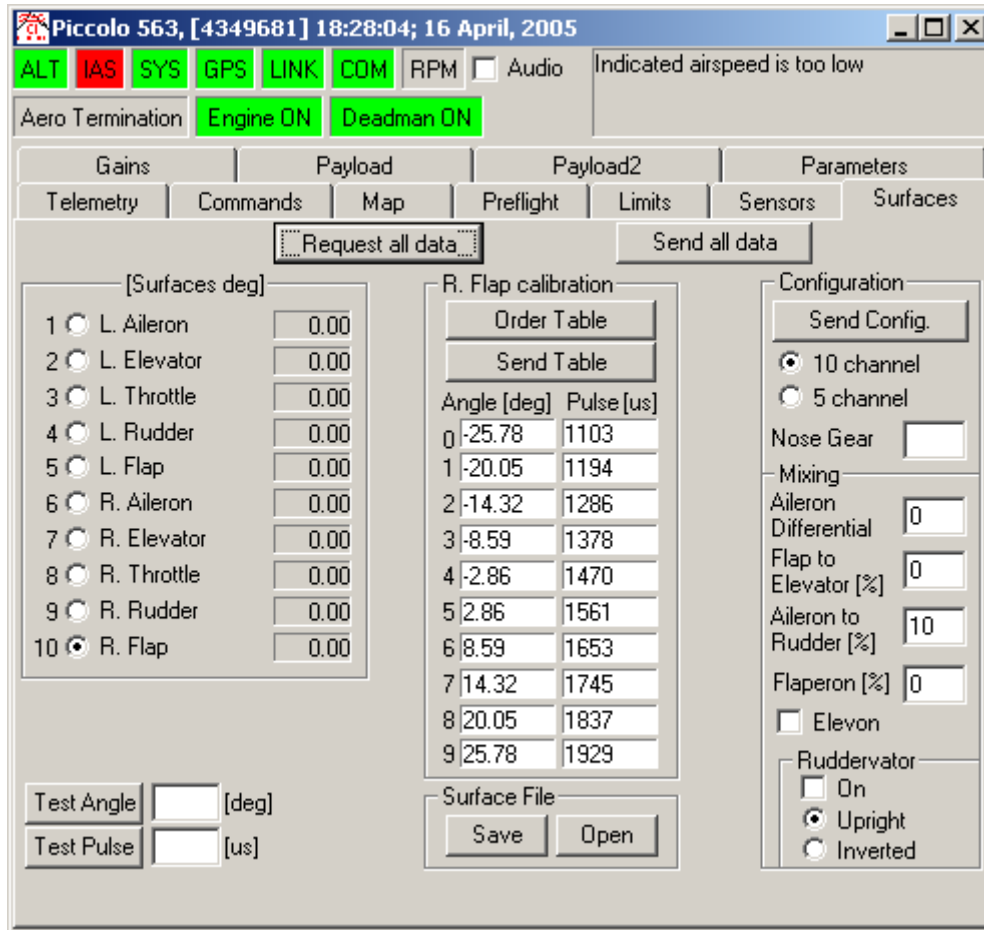


Figure 20. Surface calibration page

The surfaces page only shows the pulse width to angle calibration for one surface at a time. The surface displayed is chosen with the `Surface` selection radio buttons. To change the surface calibration table enter in the new table data; then press `Order Table`, which will put the table in order of increasing angles, then press `Send Table`.

In order to determine the calibration numbers it is helpful to be able to explicitly set the pulse width being sent to any given channel. This can be done with the surface test feature in the bottom left corner of the page. To use the feature the autopilot must be on (i.e. not in manual control). Enter in a desired pulse width and press the `Test Pulse` button. The requested pulse width will be sent out the selected channel for 60 seconds. While the pulse is being sent you can measure the actual surface deflection. By doing this for each desired pulse width the surface calibration table can be built up. The inverse function of commanding the surface to deflect a certain angle is also available, using the `Test Angle` button.

4.11.2 5 channel mode

In this mode only 5 output channels are used. The channel mapping depends on the type of mixing option that is to be supported, see Figure 21. Note that in 5-channel mode flaperon and elevon mixing cannot be used simultaneously, elevon and ruddervator mixing cannot be used simultaneously, and aileron differential is only available in flaperon mode.

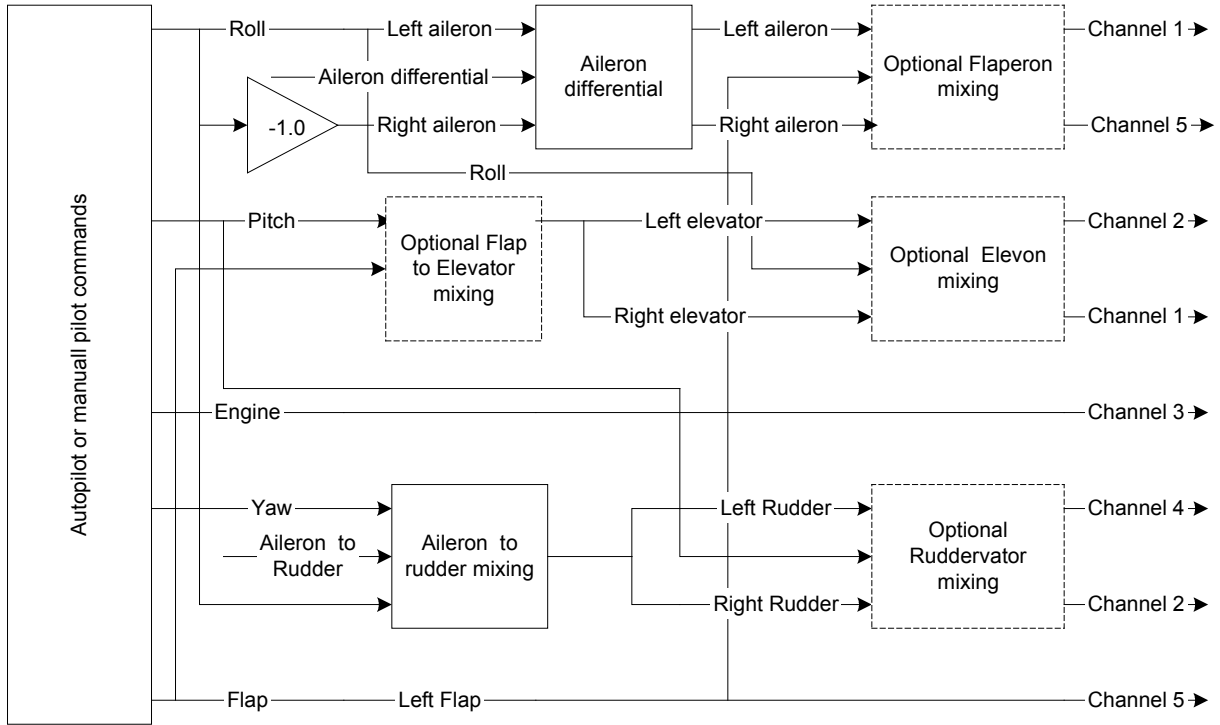


Figure 21. 5-channel servo output diagram

4.11.3 10 channel mode

In this mode all 10 output channels are used. The channel mapping depends on the type of mixing option that is to be supported, see Figure 22.

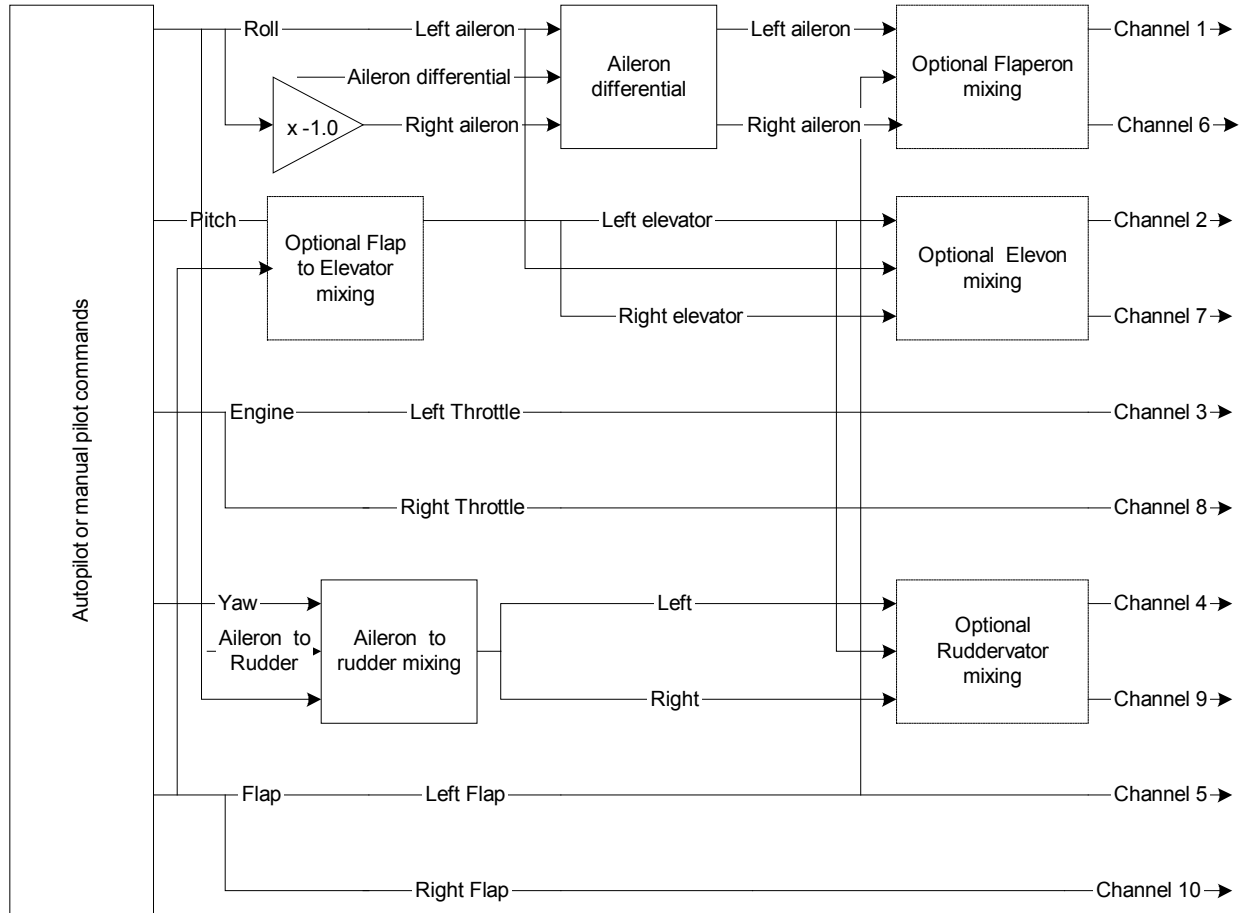


Figure 22. 10-channel servo output diagram

4.11.4 Aileron differential

Aileron differential is used to control the ratio of up aileron motion to down aileron motion. By adjusting the aileron differential the designer can guard against tip stall induced by downward aileron motion, or remove asymmetries caused by the up aileron moving into more sluggish air than the down aileron.

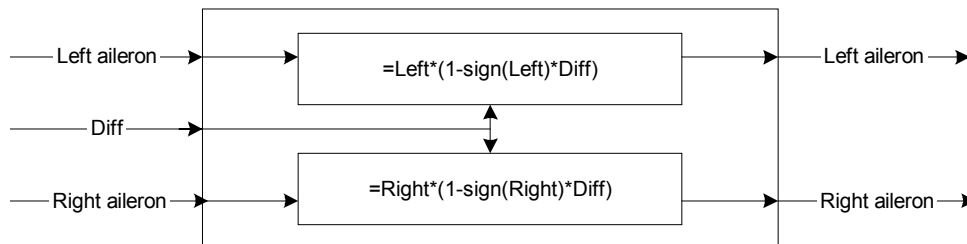


Figure 23. Aileron differential

The differential parameter in Figure 23 controls how the differential is applied. When differential is zero the up and down aileron motions are equal; when it is 1.0 the ailerons only move upwards; and when it is -1.0 the ailerons only move downwards.

4.11.5 Aileron to rudder mixing

In this mode the aileron output from the autopilot is summed with the rudder output to form a new rudder output. The aileron output is unchanged. This feature is useful for aircraft that have strong adverse yaw characteristics that must be countered; or for aircraft which have their primary roll control via the rudder.

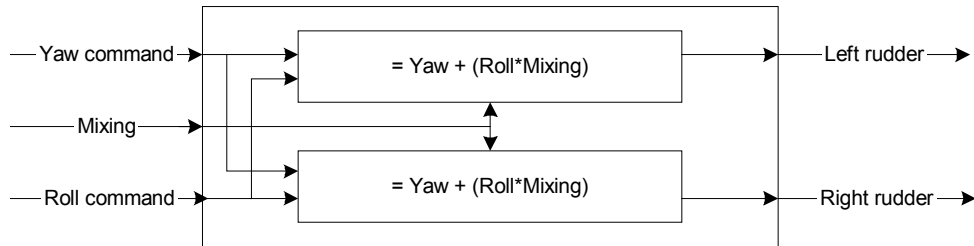


Figure 24. Aileron to rudder mixing

4.11.6 Flap to elevator mixing

The flap to elevator mixing is used to compensate for the change in elevator trim as the flaps are moved. Most vehicles will use a positive amount of flap to elevator mixing (i.e. positive flap deflection causes positive elevator deflection).

4.11.7 Flaperon mixing

In this mode the ailerons are used to provide aileron and flap functions. This is done by biasing the aileron outputs with the flap output, according to Figure 25. Note that the flaperon value can be positive or negative. A flaperon of 100% will cause the ailerons to move down as far as the flaps move down. A flaperon of -100% will cause the ailerons to move up as far as the flaps move down.

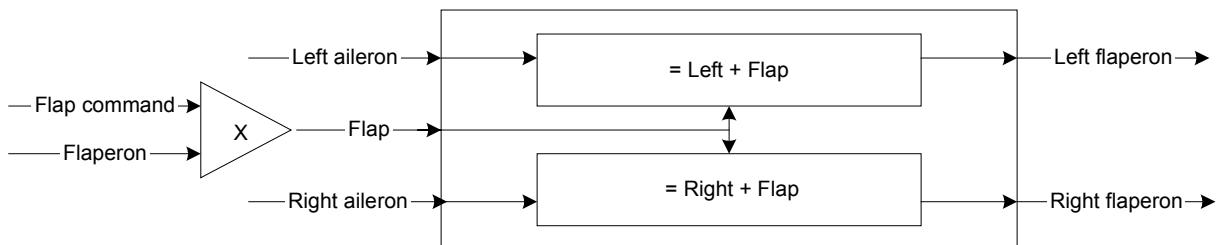


Figure 25. Flaperon mixing

4.11.8 Elevon mixing

In this mode two elevator like surfaces are used to provide aileron and elevator functions. This is done by biasing the elevator outputs with the aileron output according to Figure 26.

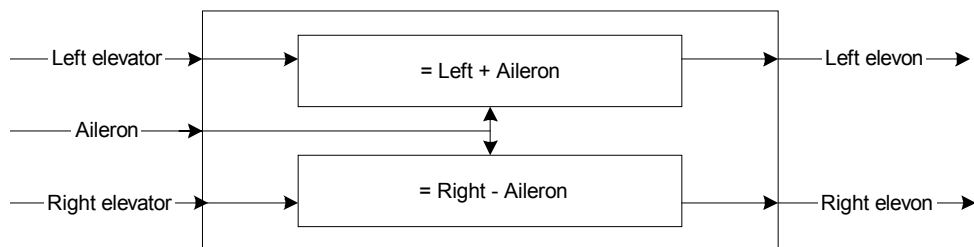


Figure 26. Elevon mixing

4.11.9 Ruddervator mixing

This mode is used for V-tail operation, in which the rudder and elevator outputs are mixed together. Ruddervator mixing depends on the type of V-tail, either upright (V) or inverted (Λ). When defining rudder motion for a V-tail, the sign convention follows the same one used in the elevators.

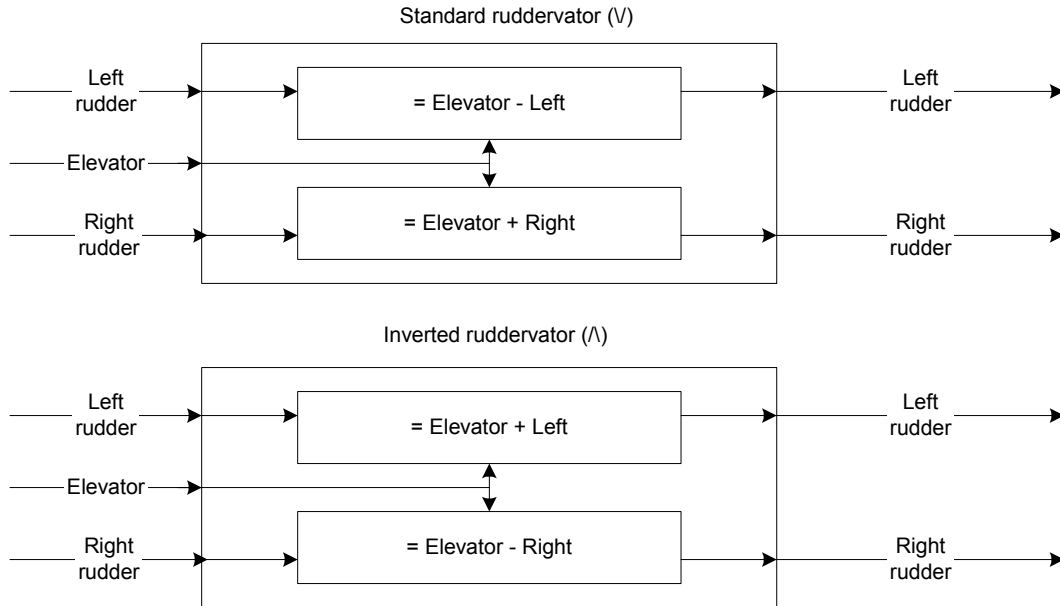


Figure 27. Ruddervator mixing

4.11.10 Nose Gear

A separate channel can be specified for the nose gear, by typing the desired channel number (from 1 to 10) in the Nose Gear edit box. This allows separate calibration of the gear servo and independent control of the vehicle steering on the ground.

4.12 Autopilot gains

The gains page is used to view and alter the autopilot gains.

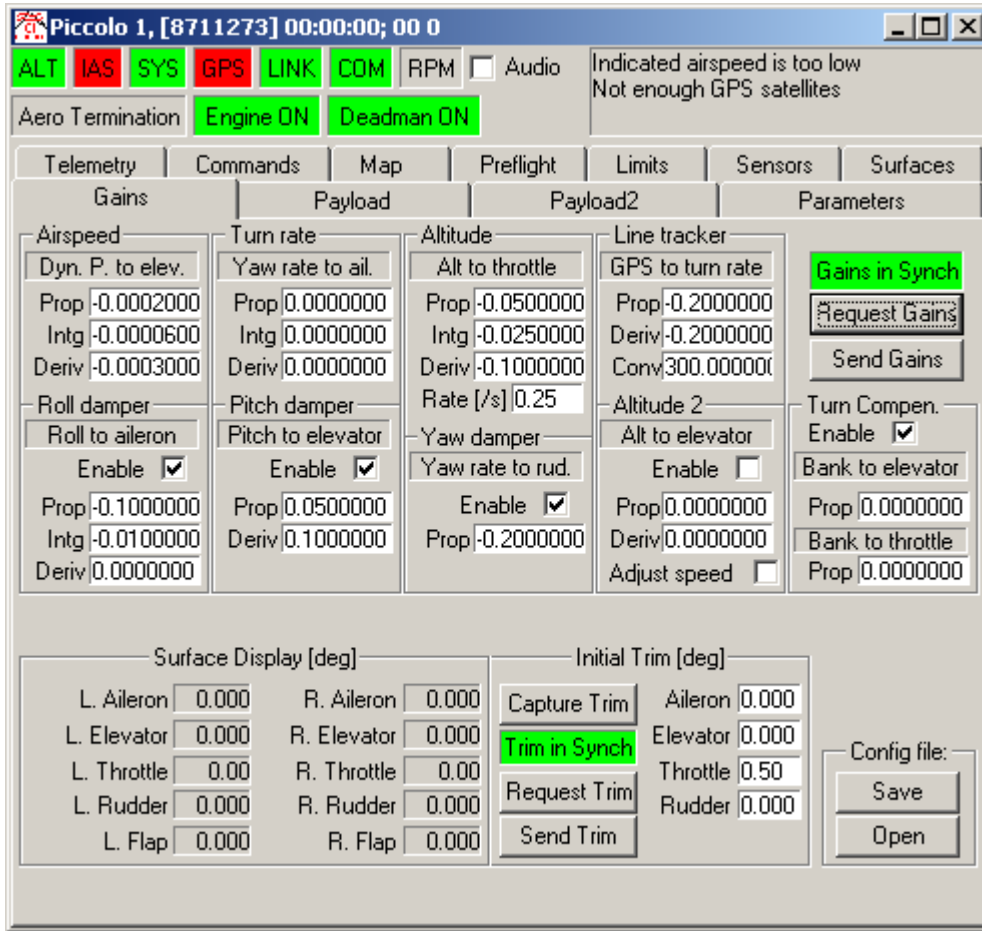


Figure 28. Autopilot gains page

Table 5. Autopilot loops

Loop	Inputs	Outputs	Scaling	Notes
Dynamic Pressure	Dynamic pressure error [Pa]	Elevator [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Maintains a commanded dynamic pressure.
Altitude	Barometric altitude error [m]	Throttle [0-1]	No scaling	Maintains a commanded altitude.
Roll	Roll angle error [rad]	Aileron, Rudder [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Maintains a commanded bank angle.
Tracker	Position, Velocity	Turn rate Command [rad/s]	Convergence parameter scales with square of airspeed, reference at 25	Drives the turn rate loop to achieve desired track targets.

			m/s	
Turn	Yaw rate [rad]	Aileron, Rudder [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Alternative turn rate control for maintaining a commanded turn rate.
Pitch	Pitch angle [rad]	Elevator [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Damps out pitch oscillations.
Yaw	Yaw rate [rad/s]	Rudder [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Damps out yaw oscillations.
Altitude2	Barometric altitude error [m]	Elevator [rad]	Gains scale with dynamic pressure, reference at 380 Pa.	Improved tracking of commanded altitude or glideslope.
Adjust speed	Barometric altitude error [m]	Dynamic pressure command [Pa]	No scaling	Improved tracking of commanded altitude or glideslope.
Turn compensator	Bank angle [rad]	Elevaotr [rad], Throttle [0-1]	Gains scaled in control law.	Helps maintain the TAS command when entering or exiting a turn.

To see the current gains press the Request Gains button. When the avionics responds the Gains in Synch field will turn green. To change the gains alter one of the fields and push the Send Gains button. Adjustments to the gains should be done first on the simulator before fine-tuning in flight. See the “Steps to Autonomous Flight” and “Initial Flight Test Cards” for more information about setting gains.

4.12.1 Dynamic pressure to elevator

These gains are used to feed dynamic pressure error (in Pascals) to the elevator (in radians). This controls the airspeed of the vehicle, and helps damp slow (phugoid) longitudinal oscillations.

4.12.2 Yaw rate to aileron

These gains are normally not used, since the roll angle to aileron gains do a better job of managing the turn rate of the vehicle. However certain classes of vehicle may work better with these gains. They are used to control the turn rate of the vehicle by feeding the yaw rate (in radians per second) to the aileron command (in radians).

4.12.3 Altitude to elevator

Version 1.3.0 introduces a new altitude controller. The derivative gain term of this loop sets the vertical rate command and is interpreted as meters per second of vertical rate per meter of altitude error. The proportional and integral terms feedback vertical rate error (in meters per second) to the throttle. The altitude rate term controls how quickly the autopilot can move the throttle.

4.12.4 GPS to turn rate

This loop is used to steer the vehicle to the waypoint. The proportional and derivative terms feedback heading error (in radians) to turn rate command (in radians per second). The convergence parameter (in meters) controls the shape of the trajectory the vehicle flies as it approaches track. Larger values produce smoother operation but take more time to converge.

4.12.5 Roll to aileron

These terms feed back the bank angle error (in radians) to the aileron command (in radians). This is the primary method of controlling the vehicle turn rate. The autopilot will not allow an integral gain term to be set for this loop and for the yaw rate to aileron loop at the same time.

4.12.6 Pitch to elevator

These terms feed back the pitch angle (in radians) to the elevator (in radians). This helps damp some pitch oscillations. It is not strictly required, but can help to improve the longitudinal performance of the autopilot.

4.12.7 Yaw rate to rudder

This term feeds back the yaw rate (in radians per second) to the rudder (in radians). It is used to damp yaw oscillations.

4.12.8 Altitude to elevator

These terms are used to improve the ability of the autopilot to hold altitude. They are not normally required, but can make a difference for certain cases, such as autoland where tight control of the altitude is required.

When enabled the adjust speed option will cause the autopilot to change its dynamic pressure command in order to reach the target altitude. This can be useful when the system is operating in air with large vertical motions (thermals).

4.12.9 Turn compensation

- When turn compensation is enabled the autopilot adjusts the pitch rate command fed to the pitch damper to
- The bank to elevator term is used to help keep the nose up through a turn. It represents the change in elevator angle needed to affect the change in load factor dictated by the bank angle. The gain supplied should be calculated according to the formula: $W / (S_w(\delta CL/\delta E))$, where:
 - W is the weight of the vehicle in Newtons.
 - S_w is the wing area in square meters.
 - $\delta CL/\delta E$ is the change in lift coefficient per change in elevator.
- The bank to throttle term is used to help maintain the energy state of the vehicle through a turn. It represents the change in throttle needed to balance the increase in drag due to the change in load factor. The gain supplied should be calculated according to the formula: $W / (\pi e AR(\delta P/\delta T))$, where:
 - W is the weight of the vehicle in Newtons.
 - e is the span efficiency factor.
 - AR is the aspect ratio

- $\delta P/\delta T$ is the change in power (in Watts) per throttle motion.

4.12.10 Surface display

The gains page also gives a display of the current control surface positions, both the left and right. The labels on the control surface display will update according to the type of mixing selected in the surfaces page (i.e. elevons, ruddervator, etc.).

4.12.11 Initial Trim

To the right of the surface display is the initial trim value. Whenever a loop is turned from off to on, its integrator gets initialized. The turn rate, airspeed, altitude, and yaw damper loops get initialized to the value displayed in the Initial trim display. The other loop integrators get initialized to 0. To request the current trim setting push `Request Trim`. You can enter trim values and push the `Send Trim` button to change them. You can also tell the avionics to use its current loop commands as the trim value by pushing the `Capture Trim` button.

4.13 Payload pages

The payload pages give the user the ability to control and reconfigure the I/O lines on the 44-pin external connector and - in the case of a Piccolo II - the additional I/O lines on the 25-pin microdot connector. Ordinarily the manipulation of these lines is done through third-party applications, which can provide the user with an application specific interface. However, the Operator Interface provides a generic payload control display that can be used for testing purposes - see Figure 29 for the first payload page and Figure 30 for the second payload page.

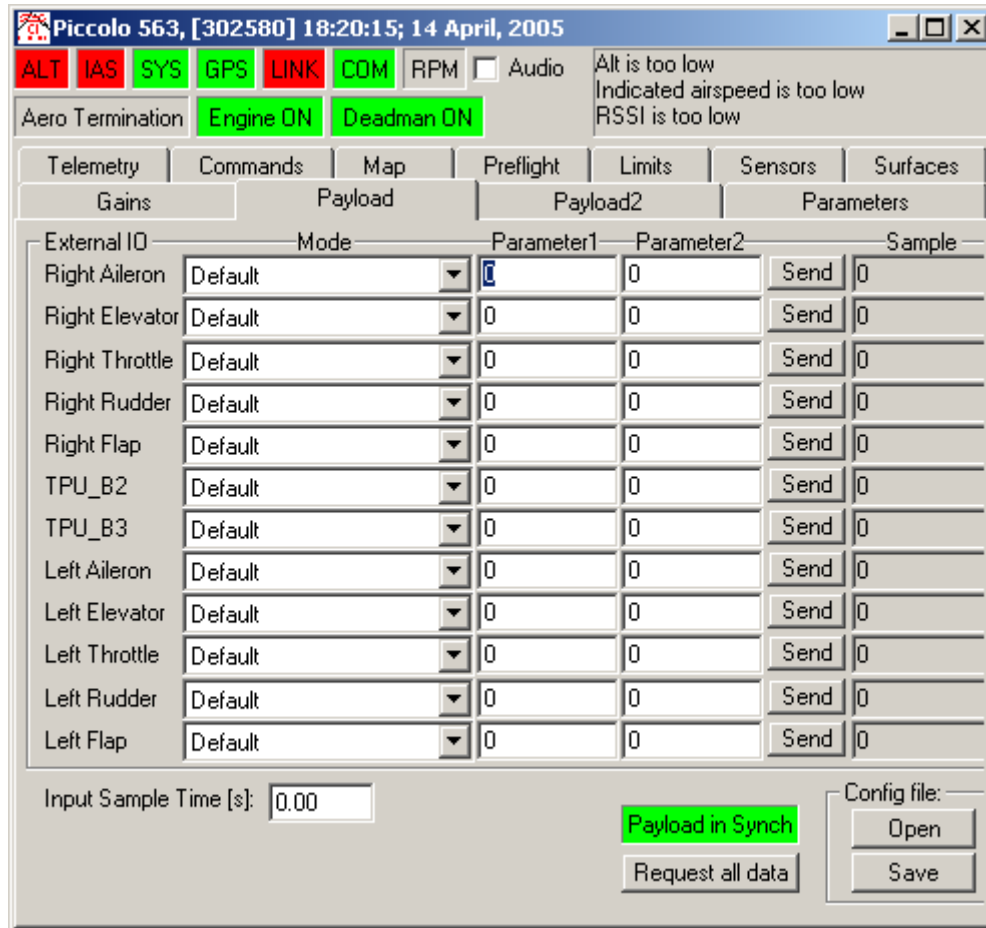


Figure 29. The first payload page.

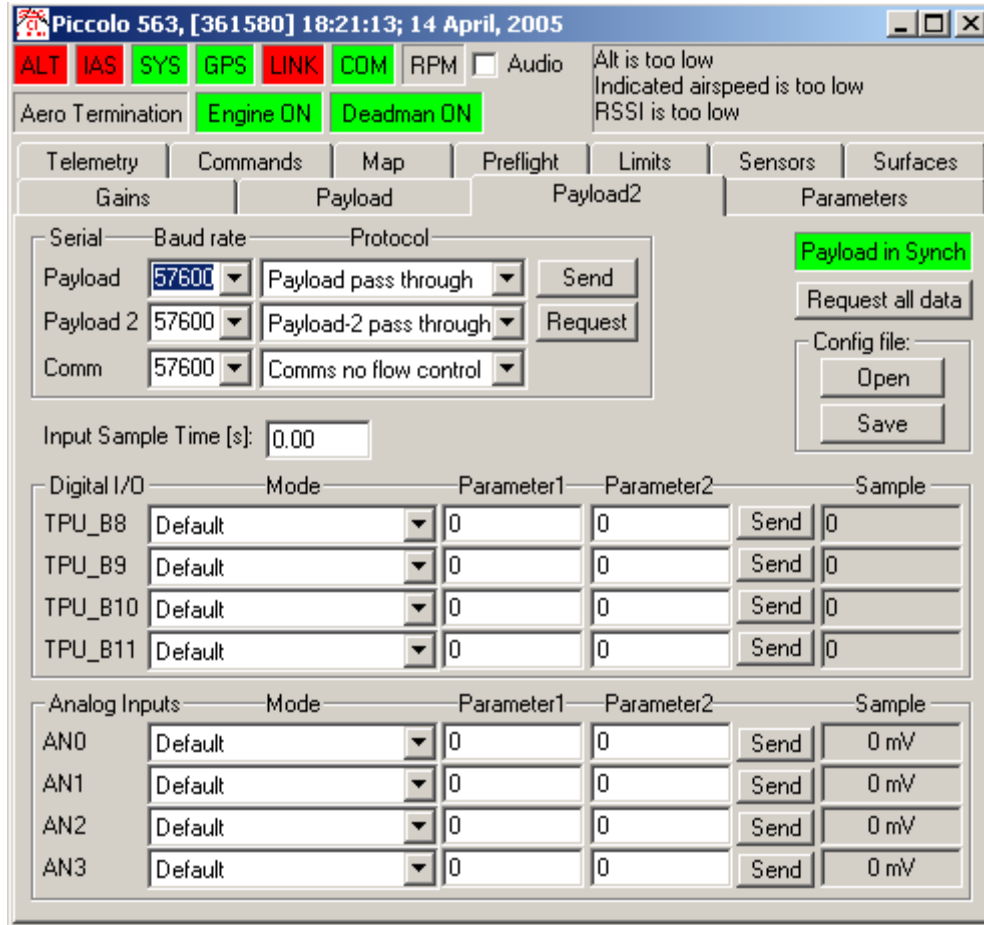


Figure 30. The second payload page.

For the Piccolo and Piccolo Plus avionics, there are twelve I/O lines and two serial ports that can be manipulated. On the Piccolo II, there are sixteen digital I/O lines, three serial ports, and four analog inputs available. Consult Table 6 to find out what I/O lines are available on your avionics.

Table 6. I/O line availability.

I/O Line	Availability		
	Piccolo	Piccolo Plus	Piccolo II
Right Aileron	x	x	x
Right Elevator	x	x	x
Right Throttle	x	x	x
Right Rudder	x	x	x
Right Flap	x	x	x
TPU B2	x	x	x
TPU B3	x	x	x
Left Aileron	x	x	x
Left Elevator	x	x	x
Left Throttle	x	x	x
Left Rudder	x	x	x
Left Flap	x	x	x
TPU B8			x

TPU B9			x
TPU B10			x
TPU B11			x
AN0			x
AN1			x
AN2			x
AN3			x
Payload	x	x	x
Payload 2			x
Comm	x	x	x

4.13.1 Digital I/O Lines

Each of the digital I/O lines has a primary function and several alternate functions. For each digital I/O line, the function can be changed by selecting it from the pull-down list - see Figure 31, filling-in Parameter1 and Parameter2 if necessary, and clicking the Send button for that particular I/O line.

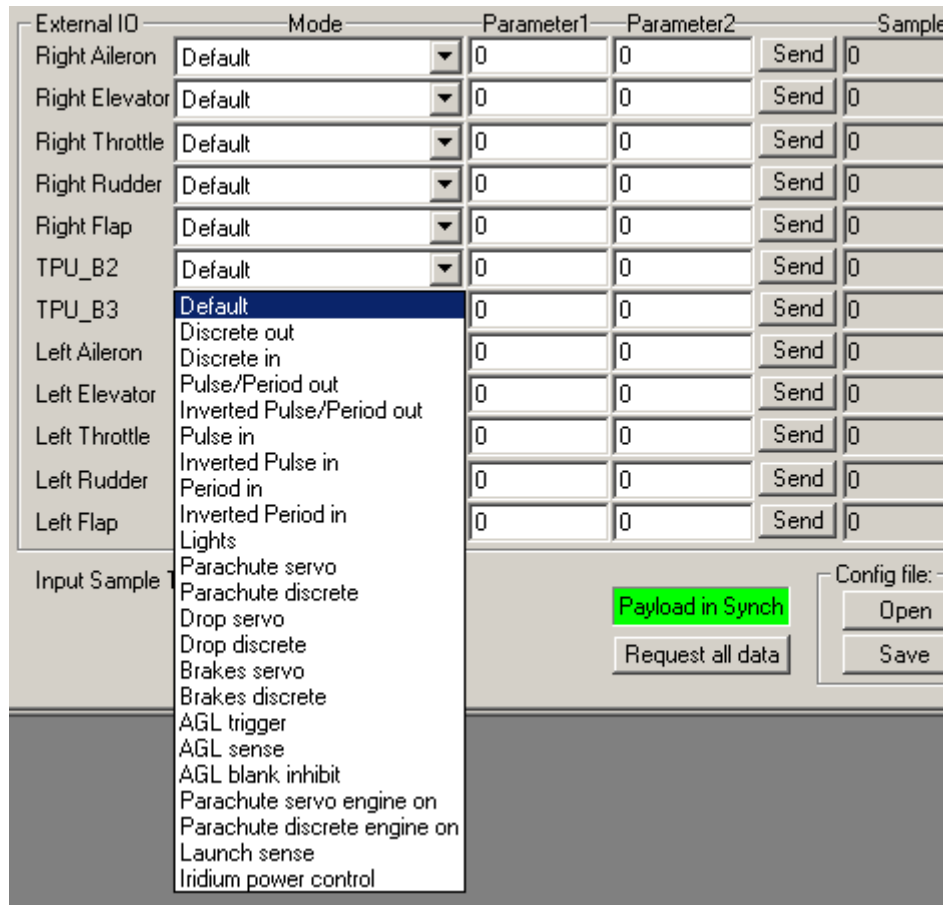


Figure 31. Pull-down list with all available functions.

See Table 7, Table 8, and Table 9 for a description of all functions / modes of operation. Please note that the digital lines listed in Table 8 are accessible only on the Piccolo II avionics.

Table 7. Digital I/O lines available on the 44-pin connector for payload expansion

Pin	Name	Type	Primary function	Alternate functions
44	PWMSM[0]	I/O	Left aileron pulse	Discrete I/O; pulse/period output
43	PWMSM[1]	I/O	Left elevator pulse	Discrete I/O; pulse/period output
42	PWMSM[2]	I/O	Left throttle pulse	Discrete I/O; pulse/period output
41	PWMSM[3]	I/O	Left rudder pulse	Discrete I/O; pulse/period output
40	PWMSM[4]	I/O	Left flap pulse	Discrete I/O; pulse/period output
39	TPU_A[0]	I/O	Right aileron pulse	Discrete I/O; pulse/period I/O
38	TPU_A[1]	I/O	Right elevator pulse	Discrete I/O; pulse/period I/O
37	TPU_A[2]	I/O	Right throttle pulse	Discrete I/O; pulse/period I/O
36	TPU_A[3]	I/O	Right rudder pulse	Discrete I/O; pulse/period I/O
35	TPU_A[4]	I/O	Right flap pulse	Discrete I/O; pulse/period I/O
5	TPU_B[2]	I/O	Left RPM	Discrete I/O; pulse/period I/O
20	TPU_B[3]	I/O	Right RPM	Discrete I/O; pulse/period I/O
31-32	Comm Port	Serial	Comms, no flow control, at 57,600 baud	External comm at user baud rate; Payload stream data at user baud rates less than 56K; Secondary payload stream data at user baud rates less than 56K; NMEA output; Honeywell HMR2300 magnetometer protocol.
33-34	Payload Port	Serial	Payload stream data at 57,600 baud	External comm at user baud rate; Payload stream data at user baud rates less than 56K; Secondary payload stream data at user baud rates less than 56K; NMEA output; Honeywell HMR2300 magnetometer protocol.

Table 8. Digital I/O lines available on the 25-pin microdot connector (Piccolo II only)

Pin	Name	Type	Primary function	Alternate functions
21	TPU_B[8]	I/O	Disabled	Discrete I/O; pulse/period I/O
19	TPU_B[9]	I/O	Disabled	Discrete I/O; pulse/period I/O
17	TPU_B[10]	I/O	Disabled	Discrete I/O; pulse/period I/O
15	TPU_B[11]	I/O	Disabled	Discrete I/O; pulse/period I/O
1-3	Payload 2 Port	Serial	Secondary payload stream data at 57,600 baud	External comm. at user baud rate; Payload stream data at user baud rates less than 56K; Secondary payload stream data at user baud rates less than 56K; NMEA output; Honeywell HMR2300 magnetometer protocol.

Table 9. Modes of operation for the payload digital lines.

Modes	#	Description
Default	0	Signal operates as its primary function
Discrete Out	1	Operates as a discrete output.
Discrete In	2	Operates as a discrete input.
Pulse/Period Out	3	Generates a repeating square wave with user specifiable period and high time.
Inverted Pulse/Period Out	4	Generates a repeating square wave with user specifiable period and low time.
Pulse In	5	Measures the time between the rising and falling edge the signal, only valid for the TPUs.
Inverted Pulse In	6	Measures the time between the falling and rising edge of the signal, only valid for the TPUs.
Period In	7	Measures the time between rising edges, only valid for the TPUs.
Inverted Period In	8	Measures the time between falling edges, only valid for the TPUs.
Lights	9	Turn lights on or off.
Parachute Servo	10	Actuate a servo to trigger parachute release. Engine will also be killed.
Parachute Discrete	11	Assert/deassert an I/O line to trigger parachute release. Engine will also be killed.
Drop Servo	12	Actuate a servo to trigger drop mechanism.
Drop Discrete	13	Assert/deassert an I/O line to trigger drop mechanism.
Brakes Servo	14	Actuate a servo to engage brakes.
Brakes Discrete	15	Assert/deassert an I/O line to engage brakes.
AGL Trigger	16	Trigger the sonic AGL sensor.
AGL Sense	17	Sample the sonic AGL sensor, only valid for the TPUs.
AGL blank inhibit	18	Used to inhibit blanking for low altitude readings, only valid for the TPUs.
Parachute Servo Engine on	19	Actuate a servo to trigger parachute release. Engine will remain on.
Parachute Discrete Engine on	20	Assert/deassert an I/O line to trigger parachute release. Engine will remain on.
Launch sense	21	Used to hold the autopilot in prelaunch mode even when the airspeed signal indicates it is flying, only valid for the TPUs.
Iridium power control	22	One digital line must be dedicated to this type of output if an Iridium modem and its associated power control hardware are connected to the avionics. The function allows the user to turn the Iridium modem power on/off.

Each signal line has two 32-bit parameters that are used to describe its functionality. The meaning of each parameter depends on the mode of operation and they are listed in Table 10.

Table 10. Parameters for different operational modes of the payload digital lines.

Modes	Meaning of first parameter	Meaning of second parameter
Default	N/A	N/A
Discrete Out	Zero for low output, nonzero for high output.	N/A

Discrete In	N/A	N/A
Pulse/Period Out	Period of the output signal in nanoseconds.	Pulse width of the output signal in nanoseconds.
Inverted Pulse/Period Out	Period of the output signal in nanoseconds.	Pulse width of the output signal in nanoseconds.
Pulse In	Number of input periods over which to accumulate the signal.	N/A
Inverted Pulse In	Number of input periods over which to accumulate the signal.	N/A
Period In	Number of input periods over which to accumulate the signal.	N/A
Inverted Period In	Number of input periods over which to accumulate the signal.	N/A
Lights	State of the output line when the lights are off	N/A
Parachute Servo	Pulse width of the signal in nanoseconds when the parachute is retracted.	Pulse width of the signal in nanoseconds when the parachute is deployed.
Parachute Discrete	State of the output line when the parachute is retracted.	N/A
Drop Servo	Pulse width of the signal in nanoseconds when the drop function is off.	Pulse width of the signal in nanoseconds when the drop function is on.
Drop Discrete	State of the output line when the drop function is off.	N/A
Brakes Servo	Pulse width of the signal in nanoseconds when the brakes are fully released.	Pulse width of the signal in nanoseconds when the brakes are fully applied.
Brakes Discrete	State of the output line when the brakes are off.	N/A
AGL Trigger	N/A	N/A
AGL Sense	N/A	N/A
AGL inhibit	N/A	N/A
Parachute Servo Engine on	Pulse width of the signal in nanoseconds when the parachute is retracted.	Pulse width of the signal in nanoseconds when the parachute is deployed.
Chute Discrete Engine on	State of the output line when the parachute is retracted.	N/A
Launch sense	State of the input line that causes the autopilot to remain in prelaunch.	N/A
Iridium power control	State of the output line. The correlation between low and high states of this line and the actual power-on and power-off states of the Iridium modem depends on the particular Iridium power control hardware that is used.	N/A

The *Sample* boxes that are provided for each of the digital I/O lines are used to display the input value, for the lines which are configured as inputs. All of the digital inputs are sampled and sent from the avionics to the ground at once, at the fixed time intervals specified by the *Sample Time*

box, but no faster than 100 ms. If the sample time is zero, the inputs are not sampled and no samples are being downloaded to the groundstation.

Here are some examples of setting-up digital lines:

1. Configuring the TPU_A[3] line to output a constant PWM servo output. The specification to the output we want is: pulse period 20 ms, pulse width 1.219 ms. We pick the appropriate mode of operation for the TPU_A[3] line which on the Payload page is listed by its primary function (right rudder). Then we set the first parameter to 20000000 nanoseconds, and the second parameter to 1219000 nanoseconds. At this time the settings should look like in Figure 32. Finally we press the *Send* button to send these new settings for this particular digital line to the avionics.



Figure 32. Configuring a digital line for constant PWM servo output.

2. Configuring the TPU_B[3] line to sample a discrete input. We want the avionics to sample a digital line and send the measurement to the ground at a fixed rate of 4 Hz. Since the TPU line goes straight into the avionics processor, we would have to make sure that the voltage on this line will never exceed 5 V. Assuming this condition is met, we can sample the line with the settings shown in Figure 33. We then press the Send button and at that time the line will be re-configured and the rate at which the digital input are sampled and downloaded will be set to 4 Hz.

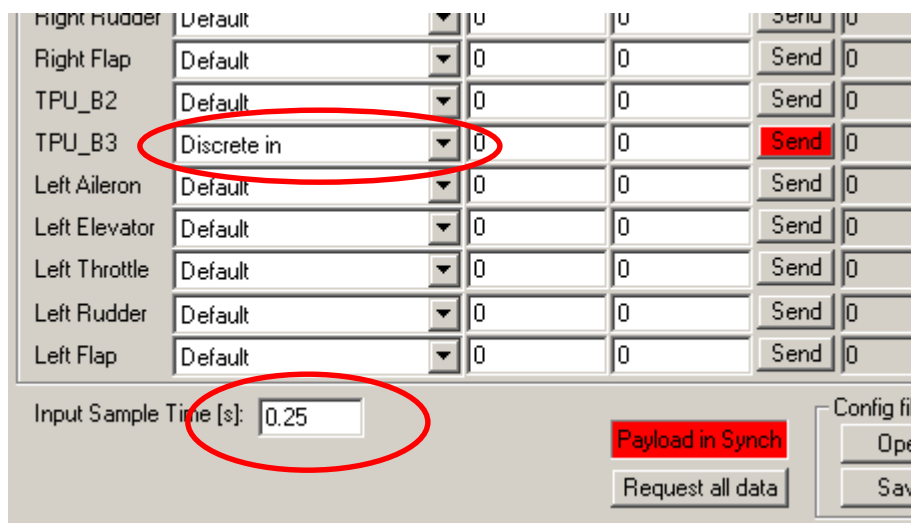


Figure 33. Configuring a digital line for discrete input.

4.13.2 Analog Input Lines

For the Piccolo II only, the payload page allows the user to configure the scaling and display of the analog readouts of the 4 input lines available on the avionics.

Each line has a primary function and several alternate function. Please note that these functions refer only to how the measurement is scaled and displayed. The only "physical" function of these lines is analog voltage input, in the 0 - 5 Volt range. The analog channels are listed in Table 11, and their modes of operation in Table 12.

Table 11. Analog input lines available on the 25-pin microdot connector (Piccolo II only)

Pin	Name	Type	Primary function	Alternate functions
12	AN0	AIN	Analog measurement in millivolts	Raw ADC counts; Custom analog measurement with offset and scale factor
11	AN1	AIN	Analog sample in millivolts	Raw ADC counts; Custom analog measurement with offset and scale factor
10	AN2	AIN	Analog sample in millivolts	Raw ADC counts; Custom analog measurement with offset and scale factor
9	AN3	AIN	Analog sample in millivolts	Raw ADC counts; Custom analog measurement with offset and scale factor

Table 12. Modes of operation for the analog input lines

Modes	#	Description
Default	0	Signal operates as its primary function - millivolt measurement output, range is 0 to 5000 mV.
Raw input	1	Outputs the analog measurement in raw ADC counts, range is 0 to 1023.
Scaled input	2	Customize the analog measurement with an offset and a scale factor.

As shown in Table 13, the two parameters are only used when the line is configured for scaled input mode. In this mode of operation, the analog measurement will be offset by the number specified in Parameter1 and scaled by the number specified in Parameter2 as shown in the formula below:

$$\text{Scaled Input} = (\text{Scale Factor} / 1,000,000) \times (\text{Raw Input} - \text{Offset})$$

Table 13. Parameters for different operation modes for the analog input lines

Modes	Meaning of first parameter	Meaning of second parameter
Default	N/A	N/A
Raw input	N/A	N/A
Scaled input	Measurement offset in ADC counts	Scale factor (number of

	(range is 0 to 1023) (number of counts for a zero-reading).	custom units per ADC count and multiplied by one million).
--	---	--

As an example, if we have a temperature sensor with a range of -40 to 80 deg. C, and 0 to 5 V analog output range, we would need the following settings:

The scale factor is the range of the sensor measurement divided by the range of the A/D converter which is 1023 counts, and multiplied by one million:

$$\text{ScaleFactor} = (80 + 40) / 1023 * 1000000 = 117302$$

The offset represents the number of A/D converter counts when the thermometer is measuring 0 deg. C. Normally this would be obtained through calibration, but for this example we can assume a linear dependence:

$$\text{Offset} = 40 / (80 + 40) * 1023 = 341 \text{ counts}$$

Setting the mode of the analog input line to "Scaled Input" and putting the offset and scale factor computed above in parameter 1 respectively parameter 2, we obtain the settings shown in Figure 34.

The sampling of the analog inputs in the avionics happens at the same time the digital inputs are sampled, and the time interval between samples can be adjusted from the "Sample Time" edit box. The smallest sample time allowed is 0.1 seconds. If the sample time is set to zero, the input lines will not be sampled.

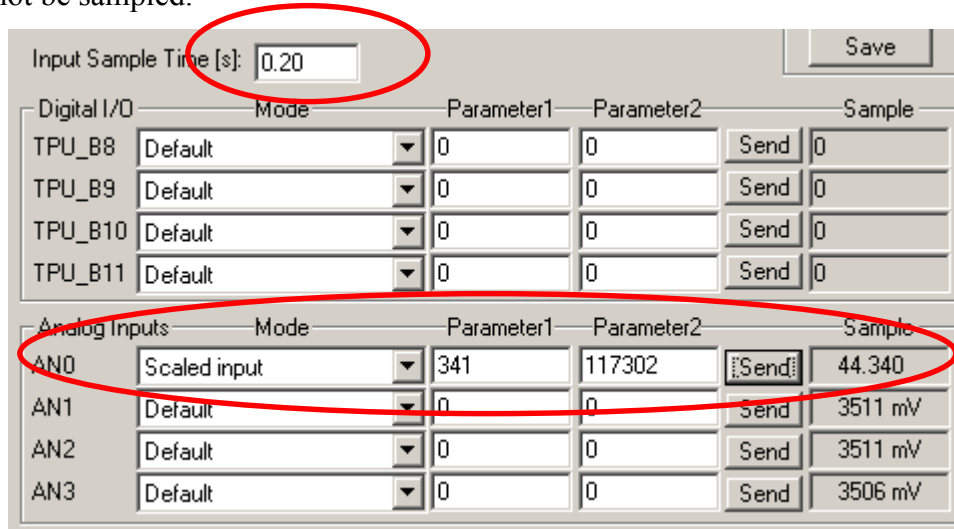


Figure 34. Example of custom scaling for analog measurement on input line AN0.

4.13.3 Serial Ports

The payload control page also gives the ability to set the protocol and baud rate for the three external serial ports. The ports are named according to the default functions:

- The communications port is nominally used for external communications using the same communications protocol that runs over the internal UHF link.

- The payload port is nominally used to send a bi-directional primary payload stream of data between the Operator Interface and the avionics.
- The payload 2 port, available only on the Piccolo II avionics, is nominally used to send a bi-directional secondary payload stream of data between the Operator Interface and the avionics.

However, each port can perform any one of the functions in Table 14.

Table 14. Protocols for external serial ports

Protocol	#	Meaning
Default	0	<ul style="list-style-type: none"> • Payload port: Transparent payload stream input and output. • Payload 2 port: Transparent secondary payload stream input and output. • Comm port: Standard Piccolo communications, without wireless half duplex flow control
Comms, Piccolo flow	1	Standard Piccolo communications, with wireless half duplex flow control
Comms no flow control	2	Standard Piccolo communications, without wireless half duplex flow control
Payload pass through	3	Transparent payload stream input and output.
NMEA out	4	Output of the NMEA strings GPGGA and GPRMC for each GPS sample.
Payload-2 pass through	5	Secondary transparent payload stream input and output.
Magnetometer 2300	6	Honeywell HMR2300 3-axis magnetometer protocol, fixed baud rate at 9600.
Reserved1	7	N/A
Reserved2	8	N/A

The protocol for each of the serial ports can be changed by selecting it from a pull-down list, as show in Figure 35.

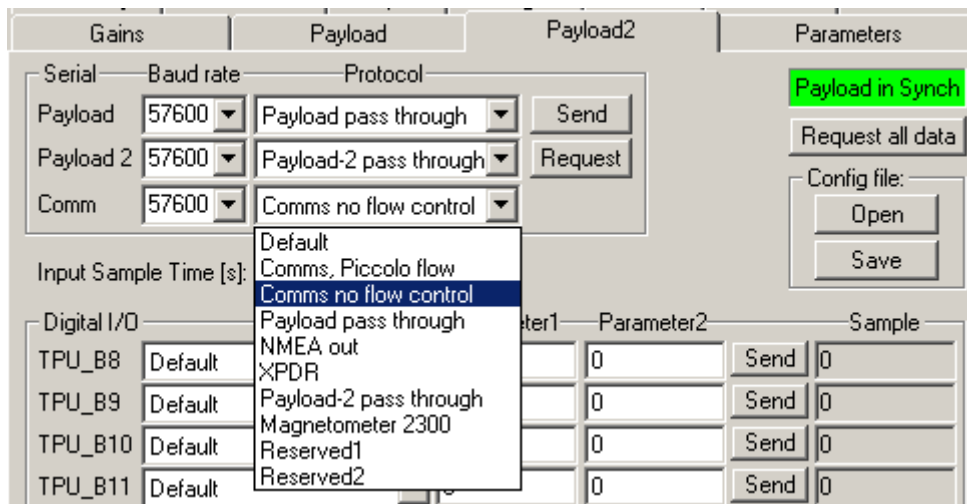


Figure 35. Selecting the serial port protocol.

See the document “Piccolo Communications” for details of the standard Piccolo communications protocol.

4.14 Parameters Page

The parameters page contains aerodynamic, landing, and launch data specific to the aircraft.

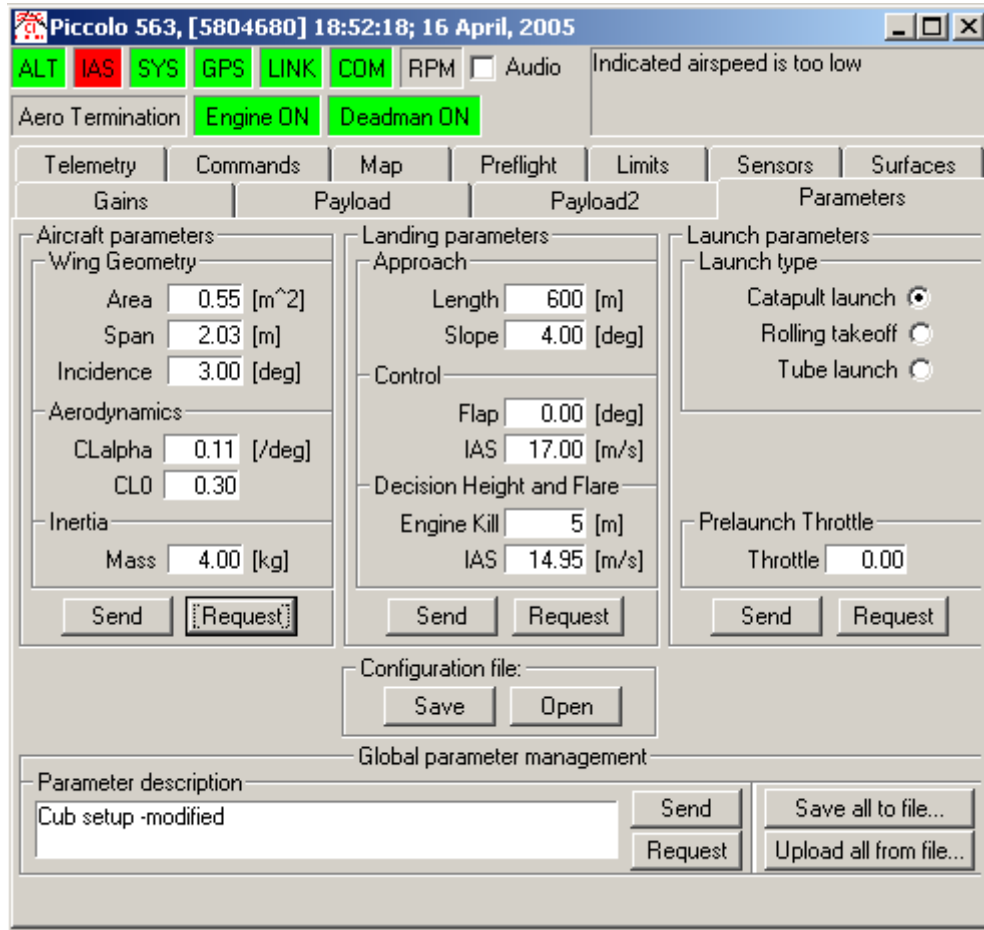


Figure 36. Aircraft Parameters page.

4.14.1 Aircraft parameters

- Wing area: The wing area is the primary area that the aerodynamic lift coefficient data are referenced to.
- Wing span: The tip to tip distance of the primary lifting surface of the vehicle.
- Incidence: The angle between the reference chord of the wing and the aircraft x-axis.
- $C_{L\alpha}$: The lift curve slope of the aircraft.
- C_{L0} : The lift coefficient at zero angle of attack.
- Mass: The gross mass of the vehicle.

These data are used primarily to estimate the angle of attack of the aircraft. The angle of attack is estimated by first estimating the lift coefficient according to the wing area, mass, dynamic pressure, and Z-axis acceleration. Then the angle of attack is calculated according to $\text{Alpha} =$

$(C_{Lest} - C_{L0})/C_{Lalpha}$. Finally the angle of attack of the x-axis is calculated according to $\text{Alpha} = \text{Alpha} - \text{Incidence}$.

4.14.2 Landing parameters

The landing parameters give the data that the avionics will use to build a automating landing flight plan.

- Approach length: The final approach length.
- Approach slope: The glideslope of the final approach.
- Landing flaps: The flap setting to use when flying a landing flight plan.
- Landing IAS: The indicated airspeed to use when flying a landing flight plan.
- Engine Kill decision height: The height above the touchdown point at which to kill the engine and change airspeed.
- Flare IAS: The indicated airspeed to use after killing the engine.

4.14.3 Launch parameters

The launch parameters provide the necessary data to setup for an autonomous launch. The system currently only supports catapult launching. The prelaunch throttle setting gives the throttle setting that is used while the autopilot mode is in prelaunch. As soon as the autopilot leaves prelaunch mode the throttle will change to the throttle trim value. A typical fuel-powered aircraft will have the prelaunch throttle set to 1, so that the system is at maximum power while on the catapult. A typical electric power aircraft will have the prelaunch throttle set to zero so the electric motor remains off until the autopilot leaves the prelaunch state.

4.14.4 Global parameter management

Similar to the parameter validation feature on the preflight page (4.8.4) this part of the parameters page allows the user to download or upload all the parameters used in the validation process. Select `Save all to file` or `Upload all from file` to save or upload parameters respectively. As with the validation feature this does not affect sensor calibrations, surface calibrations, or autopilot trims.

The parameter description field gives space to provide a string description of the parameter settings. The description is stored in EEPROM on the avionics with the other parameters. Press `Send` to update the description or `Request` to get the current description. Note that any changes made to the parameter settings will cause the parameter description to say “modified”

5 Development environment

The development environment is the set of tools that allows the vehicle designer to configure the avionics and software to accommodate the specific application. The tools that make up the development environment include:

- Avionics hardware, with built-in debugging and communication resources.
- Software compiler/debugger and driver source code.
- Control systems design and analysis tools.
- Auto-code generation tools for control systems and state machines.
- Aircraft simulation model.
- Hardware in loop simulation tools.

While there are many small avionics systems available, few provide all the tools listed above. *Piccolo* is novel in part because the development environment was designed in from the beginning.

5.1 Software environment

Piccolo includes built-in software that will be suitable for many applications, however for those applications that require fine control over the software, the software source code for the entire *Piccolo* system can be licensed.

5.2 Design environment

In recent years new design tools for control systems have come to maturity. The popular *Matlab* environment with its controls simulation package *Simulink*, has been augmented by the addition of the autocode tool *Real-Time-Workshop (RTW)*. Using these tools control system designers can graphically model physical plants and design control laws and state machines. The resulting designs can then be automatically coded in C using *RTW*, compiled using the software environment, and downloaded to the target system. *Piccolo* has more than enough CPU muscle to run complicated autcoded algorithms. Indeed the basic control software that comes with *Piccolo* was designed in exactly this fashion, and Cloud Cap has made the design available to developers.

5.3 Hardware in loop simulation

Hardware-in-loop (HIL) simulation is a cornerstone of unmanned aircraft development. Well-designed simulators allow the aircraft control laws and mission functionality to be tested without risking hardware in flight test. Although HIL simulation cannot replace flight-testing, it measurably reduces the likelihood of failure by detecting bugs and deficiencies in the lab.

To facilitate this vital (and typically difficult) function the *Piccolo* developers kit includes a hardware in the loop simulator that can be used to test the performance of a *Piccolo* implementation. The HIL simulator is based upon the external CAN interface. When in simulation mode *Piccolo* sends control surface signals and receives sensor inputs from the CAN interface. A PC with a CAN interface card running the HIL simulation software completes the necessary hardware. See the documents “[Hardware in the Loop simulator for the Piccolo Avionics](#)” and the “[Piccolo Quick Setup Guide](#)” for more details on how to use the simulator.

5.4 Software in loop simulation

Software in loop simulation provides the same functionality as the hardware-in-loop simulation, with the difference that the Piccolo and groundstation firmware run on a PC instead of the actual avionics and groundstation hardware; therefore, the method has the advantage that besides one or two networked PCs, no other hardware is necessary.

- The GroundstationPC and PiccoloPC software applications will take the place of the groundstation and Piccolo avionics.
- A network TCP/IP socket on port 3000 replaces the CAN-bus connection between the Simulator and the avionics.
- The wireless connection between the avionics and the groundstation is replaced by a multicast network connection to address 224.0.0.1 on port 4004.
- The serial connection between the groundstation and the Operator Interface is replaced by a CommSDK network connection on port 2000.
- To run the software-in-loop simulation, the main computer can be used to run the Simulator, PiccoloPC, GroundstationPC, and the Operator Interface. Alternatively, if a second computer is available, you can run the Simulator and PiccoloPC on the main computer, and run the GroundstationPC, Operator Interface, and the FlightGear visual display on the secondary computer.
- If a Windows-compatible joystick is available the GroundstationPC application will use it as Pilot console.
- Multiple PiccoloPCs can be run by using the command line switch `-SN=` to set the serial number of each software avionics.

Here are the steps to follow when setting up the software-in-loop simulation:

1. On the main computer, launch the PiccoloPC application.
2. On the main computer, launch the GroundstationPC application.
3. On the secondary computer, launch the Operator Interface with the following command line:

```
operatorinterface -SERVER=[MAIN_COMPUTER]:2000
```

where you need to replace `[MAIN_COMPUTER]` with the network name of the computer running GroundstationPC.

4. Make sure that you see the groundstation telemetry, and add the avionics to the network addresses list if necessary.
5. On the main computer start the Simulator, and from the "External" menu select "AP Simulation" such that the simulator sends its data to a TCP/IP socket instead of CAN bus, and specify the computer name as "localhost" if PiccoloPC runs on the same computer.
6. Make sure that in the Operator Interface you can see the sensor data that is being sent from the Simulator, and in the Simulator you can see the control surfaces that are being sent by the PiccoloPC. If everything looks in order, the software simulation is ready to run.