Cloud Cap
TECHNOLOGY

Goodrich ISR Systems

Piccolo Vehicle Integration Guide

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Piccolo Vehicle Integration Guide Change Log

October 7, 2010

- Section 6: Changed Piccolo SL VIN to 4.5 - 28 volts.

September 30, 2010

- Figure 16: Updated Piccolo SL Interface Cable schematic.

April 26, 2010

- Section 5: Updated flight harness information.

December 2, 2009

- Section 7.1.2: Updated with throttle calibration information.

1 Introduction

This guide is intended to provide some insight and guidance into the issues and steps involved in installing a Piccolo autopilot into an airframe. The goal with this guide is not to provide detailed step-by-step instructions for installation, but to outline the important points that should be considered. While the details of each installation varies, there are common issues that should be taken into consideration. Ultimately you will need to develop an understanding of your particular installation, its capabilities, and limitations. Your success will depend on attention to detail and thorough testing prior to flight.

2 Piccolo Airframe Installation

The main mounting issue is vibration due to engine noise. Engine vibration, mainly in the roll axis, can couple into the rate sensors reducing their signal to noise ratio. In extreme cases this can cause problems for the autopilot. Every effort to reduce coupling of engine induced vibration should be made. Ideally you would like to have a perfect mechanical low pass filter with the cutoff set below the lowest engine frequency (typically in the 30-50 Hz range).

2.1 Orientation

Proper orientation is a critical step in the aircraft integration process that greatly influences the performance of the Piccolo autopilot. The Piccolo Command Center allows you to select the avionics orientation with respect to the aircraft's. It also makes the required transformations that are stored in the Piccolo.

It is very important that the Piccolo be installed with its principal orthogonal axes aligned with that of the aircraft's.

2.2 Mechanical Mounting

2.2.1 Soft Foam Block Mount

One of the simplest solutions for mounting is to cut a block of soft foam and use it to mount the Piccolo in the fuselage. In **Figure 1**, the Piccolo is mounted in tail section of a SWARM UAV (a square avionics box in a round fuselage). If this method is used make sure the orientation is fixed and stable, i.e. the avionics will not rotate, move fore and aft, or yaw itself from its original level mounting position with respect to the wings during flight.

Figure 1 - Piccolo in Fuselage

2.2.2 Captive Soft Mount

Another option is to design a captive soft mount for the avionics. **Figure 2** and **Figure 3** display the possible horizontal or vertical mounting options generic avionics mounting kit available from Cloud Cap Technology. Foam rubber is currently used for a vibration-dampening source between the two mounting plates. **Figure 4** displays the mounting kit for an APV-3 flight test aircraft from RnR Products Inc. It is specific for the APV-3 airframe. It also displays a Piccolo mounted in the APV-3. This mounting design enables the opportunity to remove or install the Piccolo unit for testing applications.

IMPORTANT! To ensure proper adhesion, remove all decals from the Piccolo housing. Prep both the housing and the L-bracket before applying epoxy and mating the two parts.

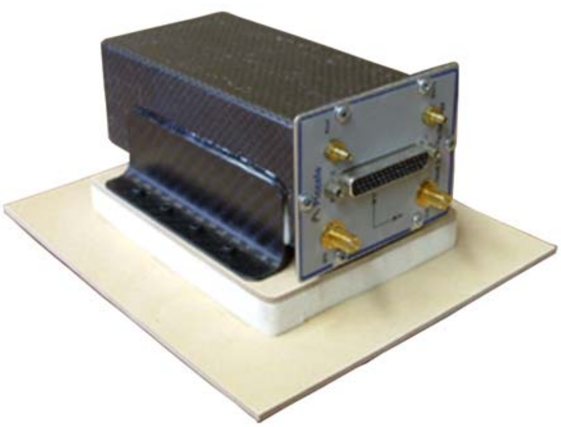

Figure 2 - Generic Mount (Horizontal)

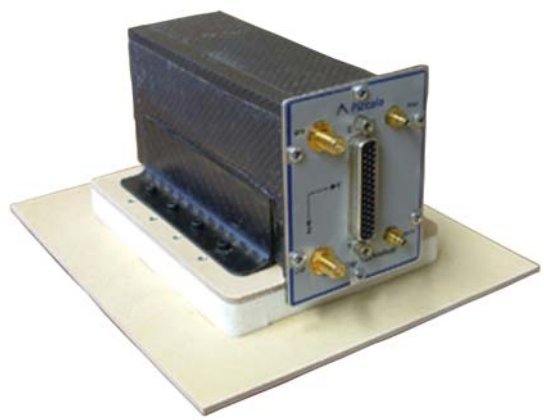

Figure 3 - Generic Mount (Vertical)

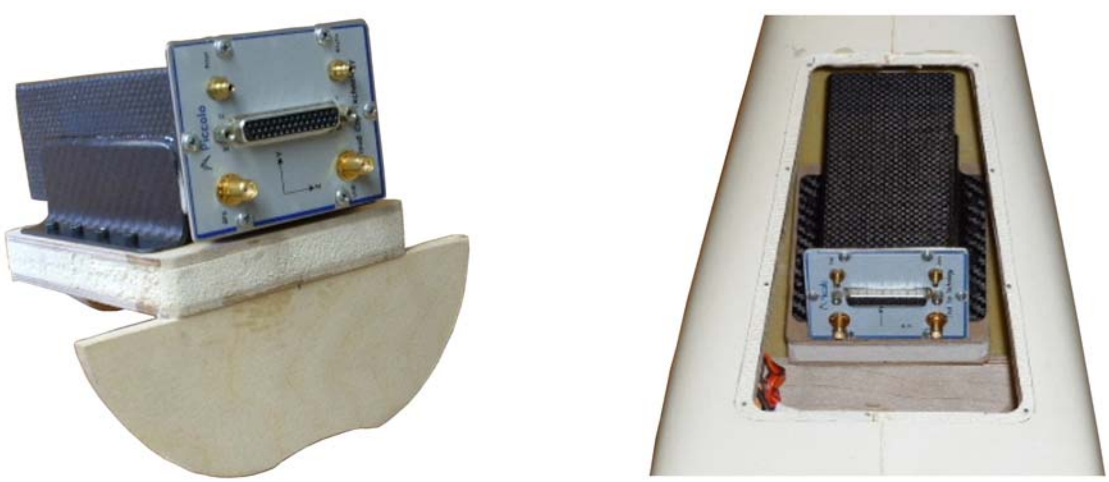

Figure 4 - Piccolo APV-3 Aircraft Mount

2.2.3 Engine Soft Mounts

If soft mounting the avionics are not viable, or there are other vibration sensitive payloads to consider, such as a video camera with zoom, a third option is to dampen the vibration at its source with soft engine mounts. **Figure 5** displays engine vibration dampening mounts. Many existing platforms use a combination of engine and avionics soft mounts to solve this problem.

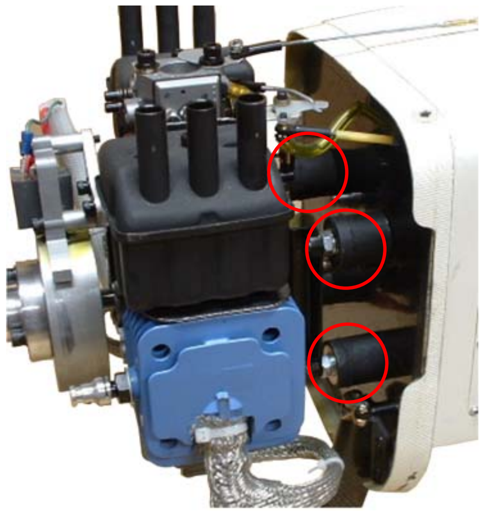

Figure 5 - Engine vibration dampening mounts

2.3 Alignment Procedure

The following steps outline a basic alignment procedure for the Piccolo autopilot.

1. **Pitch Axis**: Using a level, align the aircraft with the pitch axis at zero. This is considered level flight for the aircraft using the bottom flats of the aircraft's wings as a reference point. Level the top of the Piccolo autopilot box parallel to this level flight orientation.
2. **Roll Axis**: Using the level on top of the wings, position the aircraft at level flight with the roll axis. Align the Piccolo Autopilot in parallel with this zero degree roll axis (perpendicular to direction of flight).
3. **Yaw Axis:** Find the zero point in the yaw axis. If the aircraft has flat sides (parallel to direction of flight), turn the aircraft on its side and then define the zero degree yaw using a level. If the aircraft doe not have flat sides, scribe a line on the center of the mount or the Piccolo autopilot parallel to the sides of the Piccolo autopilot box. Align it with the center of the aircraft in the direction of flight by taking measurement off the inside of your aircraft's fuselage. If the Piccolo autopilot is visible through a hatch, check its placement by standing behind the aircraft's tail and visually lining up the scribed line with respect to the aircraft alignment.
4. Once the Piccolo is mounted and aligned, it is important to test the mounting system for vibration. See section 7.1.6 for more information regarding vibration testing.

3 Antenna Integration

There are two antennas that must be installed on the airframe. The first one is the COMM antenna used for line of sight communications between the Piccolo autopilot and the Ground Station. The second is the GPS antenna used for position and velocity determination. The GPS is a receive only antenna. The COMM antenna is both a receive and transmit antenna. (Typically Piccolo's are configured for 1-watt transmit power.)

RF interference presents problems for small aircraft. Every effort should be made to minimize the potential problems from the start. While every installation is unique, there are two primary objectives when considering initial antenna placements.

1. It important to maximize antenna separation. Mount the antennas as far apart as physically possible.
2. Find a convenient spot on the top surface of the airframe or wing with an unobstructed view of the sky for the GPS antenna.

Try to locate both antennas on the fuselage and not on the wing as shown in **Figure 6.** This offers the best configuration for testing both the GPS and COMM installations without the wing installed. This mounting system eliminates a potential failure mode with the RF connectors since they are not being connected and disconnected each time the wing is removed. It also makes the assembly/disassembly much easier.

3.1 GPS Antenna

The MK-4 GPS antenna supplied with the Piccolo is a 3-5 volt active patch that requires mounting on a small ground plane. Any 3-volt active or passive patch should work, but make sure that is thoroughly tested against the MK-4 supplied with the Piccolo. While the supplied antenna does work without a ground plane, performance will not be optimal.

Note: *The GPS is the single most important sensor. Care should be taken to ensure maximum performance at all flight attitudes.*

Adding even a small ground plane a few inches larger than the antenna will enhance the GPS performance substantially. The ground plane can be put on the inside or outside of the mounting surface. Make sure the antenna is securely mounted to it (both mechanically and electrically).

Figure 6 displays the ground plane configurations for both antennas on a trainer aircraft from RnR Inc. The shaded areas display the location of the ground planes mounted inside the fuselage.

Another issue to be aware of is RF shading if the antenna is mounted inside the fuselage or wing. To prevent this, make sure the top surface of the antenna (the radome) is not touching anything, and the radome cover does not attenuate the incoming GPS signals. If the antenna is placed in a wing near a carbon spar or servo leads, its performance will be degraded.

For hard mounting the antenna, CCT recommends using the two small tapped holes. (Make sure to use Locktite on the mounting screws). In **Figure 7**, there is an unobstructed view of the GPS antenna. This placement provides optimum performance while offering reasonable separation from the engine and the aft mounted COMM antenna.

Figure 6 - GPS Antenna and 902-928 MHz ground planes

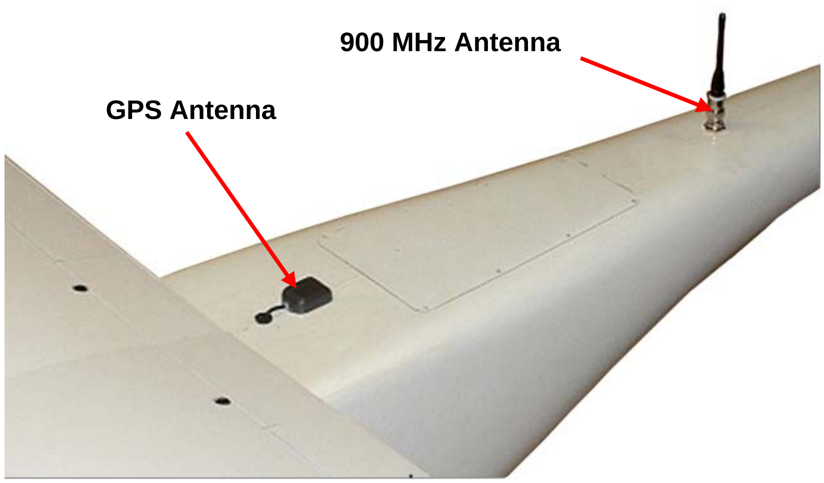

Figure 7 - GPS and 900 MHz Antenna Location

Note: *During GPS testing, if the GPS performance is not 100% at every flight attitude, there could be a problem with interference or improper antenna placement.*

3.2 COMM Antenna

There are a multitude of COMM antenna options. The theory behind each one is beyond the scope of this document. Instead, this document outlines one possible solution that meets the requirement for local line-of-sight flight operations for test and evaluation purposes only.

Piccolo product options support communications link implementations in many frequency ranges. The most common is the 902-928 MHz ISM unlicensed band, or the 2.4 GHz ISM unlicensed band.

Antenna requirements:

- Easy fabrication and installation
- No matching network or balun design required (choose a design whose feed point impedance is close to 50 ohms)
- It should have an omni directional radiation pattern
- The gain should be close to unity
- Should be vertically mounted on the aircraft

The ¼ wave dipole or ground plane antenna meets all of these requirements and generally you can get it working without any tuning. This type of antenna does require a ¼ wavelength ground plane.

- For 902-928 MHz band radios, (at center band frequency of 912 MHz) the radius of a circular ground plane is 8.22 cm (3.24").
- For 2.4 GHz band radios, the radius of a circular ground plane is 3.12 cm (1.23").

The ¼ wave radiating element is placed in the center of the ground plane (**Figure 8**) with the radiating element connected to the feed line (center conductor of the coax). The ground plane is connected to the coax shield.

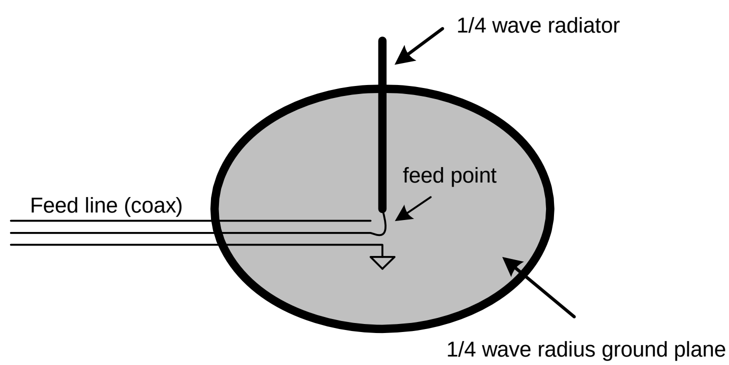

Figure 8 - Antenna Schematic

This type of antenna has a feed point impedance of approximately 52 ohms, which complements a standard 50 ohm coax. This allows you to connect the feed line directly to the antenna without any matching network or balun. Even if the geometry is not perfect (which can cause an impedance mismatch) you should get reasonable performance.

The antenna can be made from a ¼ wave radiating element cut to the proper frequency, or use a purchased antenna elements provided in the Piccolo Developer's Kit.

The ground plane can be make out of conductive foil or thin sheeting cut to size and bonded to an aircraft surface. The ground plane can be placed on the inside or outside of the fuselage or wing. Make sure that the coaxial antenna feed ground has a good electrical connection to the ground plane: with the provided antennas, this electrical connection for the 902-928 MHz band is at the top surface (antenna side) of the ground plane, and for the 2.4 GHz antenna, this electrical connection is at the bottom surface of the ground plane.

As stated above, location of the antenna on the aircraft is important to optimize COMM link margin. When deciding where to locate and antenna, consider the following:

- Try to find a location on the fuselage. This facilitates testing in the lab without wings attached and eliminates the concern for RF connections when removing the wings.
- Pattern gain of the ¼ wave stub antenna is higher on the antenna side of the ground plane. It may be that the best antenna performance will be with the antenna on the bottom of the aircraft. In tests with the trainer aircraft from RnR Inc., 2.4 GHz link performance was up to 15 dB better with the antenna mounted on the bottom vs. the top of the fuselage.
- Keep COMM and other aircraft antennas separated to reduce signal interference to a minimum.
- Be aware of blockage by other elements of the aircraft. For example, landing gear may be an issue for mounting on the bottom, and engine components may be a RF blocking source when antenna is mounted on the top.

3.3 COMM Link Antenna Options

902-928 MHz:

- **¼ wave Antenna**: BNC mount, Radial/Larsen # KD14freq(912) BNC mount cut to 912MHz
- **COMM Antenna Cable:** BNC Female Bulkhead to SMA male plug. See CCT web pages for reference schematic and ordering info.
- **Ground Plane**: Circular ground plane radius is 3.24 inches. Electrical connection to feed ground is on the top side of the ground plane.

Figure 9 - 902-928 MHz ¼ Wave Antenna

2.4 GHz:

- **¼ wave Antenna**: Maxrad # MSSO2300-XXX (24 inch cable) or MSSO2300-YYY (48 inch cable) .
- **COMM Antenna Cable:** Integral to antenna. Has SMA male plug for connection to avionics.
- **Ground Plane**: Circular ground plane radius is 1.23 inches. Electrical connection to feed ground is on the bottom side of the ground plane.

Figure 10 - 2.4 GHz ¼ wave Antenna

A flight test aircraft with the 902-928 MHz COMM antenna installation is shown in **Figure 6.** The ground plane is mounted on the inside of the fuselage (shown in **Figure 7**). Note this is not the antenna you should use on a production aircraft because of the following factors:

- Added drag
- BNC connectors are not weatherproof
- Weight
- Does not provide maximum range/sensitivity compared to a quality engineered antenna

Figure 11 displays the 2.4 GHz COMM antenna mounted on the bottom of the fuselage. (The ground plane is installed inside the fuselage.) This antenna is small and has a low profile when mounted on the bottom an aircraft.

If you have access to a network analyzer or signal source and a SWR meter you can check the match and fine-tune your antenna system for maximum performance. The best way to verify performance is to test it.

Figure 11 - 2.4 GHz COMM Antenna (Bottom Mounted)

4 Air Data Systems

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.

4.1 Pitot System

The pitot reference is created by facing a simple tube into the airflow. The tube should face the prevailing wind for all possible pitch and yaw attitudes. **Figure 12** shows and under wing mounting example.

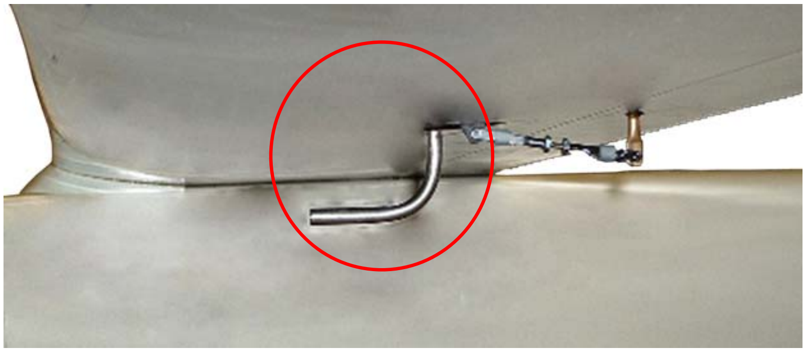

Figure 12 - Under wing Pitot Tube Mount

This simple pitot tube is made with soft aluminum tubing bent for optimal exposure throughout flight. The location on the bottom of the wing places the pitot tube out of the way of the propeller wake, and keeps the prevailing flow facing the tube even for a wide range of pitch attitudes. Inside the wing the aluminum tubing is fastened to soft Tygon tubing that extends through the fuselage back to the Piccolo avionics.

Basic installation requirements:

- The pitot tube must face into the airflow
- The pitot tube must not be in the propeller wake (a thrusting propeller adds total pressure to the flow and will corrupt the reading)
- There should be no leaks or obstructions in the path between the pitot port inlet and the sensor in the avionics

The pitot tube shown in **Figure 12** is suitable for flying in the rain, due to the large opening (¼ inch) that prevents the bridging of a drop of water. If a water droplet bridges the pathways of the Pitot tube, it would obstruct the total pressure path. For slow speed vehicles the pitot tube needs be ¼ inch in diameter to prevent water droplets from bridging across it.

4.2 Static System

An accurate static pressure system is more complicated than the pitot system. Many small UAVs do not include a static pressure reference, instead using the internal fuselage pressure as the static pressure. This is a bad idea because the fuselage is not typically vented in any consistent way and may host pressures that are far from static.

Typically full size aircraft go through a test and evaluation period in which a position on the fuselage exterior is found that is close to static pressure, and is used for the static source. Until such an evaluation can be done it is recommended that a static reference similar to **Figure 13** is used.

Figure 13 - Static Tube Right Wingtip Mount

The location of the Static tube on the wing was based on a location that would not be influenced by the fuselage pressure disturbance. It is also far enough in from the wingtip to prevent damage during take off or landing if the wing tip touched the ground. The static system shown in **Figure 13** is made of a ¼ inch carbon tubing. The end of the tube is plugged and rounded off to minimize the disturbance to the air flowing over the tube. There are a ring of four small holes drilled symmetrically around the shaft. The holes are the static pressure source. In the wing, the back side of the shaft is sealed and connected to soft Tygon tubing that runs back to the static port on the Piccolo autopilot. When using this type of static source, be observant of the following issues:

- A squared off or rough tip will cause disturbances that will affect the static pressure. This can be mitigated by moving the static pressure holes further back along the tube.
- The mount structure behind the tube can influence the static pressure field (assuming the vehicle is subsonic). If the structure is large (like a fat fuselage) the effect can be significant. While the exact effect is difficult to predict without some form of computational fluid dynamics; a rough rule of thumb is that the static pressure holes should be in front of the structure a distance of twice the structure diameter (assuming a blunt axisymmetric structure like a UAV fuselage).

4.3 Pitot/Static Combined

The Pitot/Static combined pressure system (**Figure 14**) provides both the dynamic and static pressure from a single probe assembly. It is a compact system, designed with a rainwater catchment system to prevent moisture bridging from occurring within the tubing. Features a durable titanium and carbon fiber design, and can easily be removed for transportation or storage purposes. The kit includes tube, 2 port hub, and mounting clamps. For proper operation the The Pitot/Static system should be mounted in a clean air flow.

Figure 14 - Pitot/Static Combined Pressure System

5 Flight Harness

A flight harness supports the aircraft servo configuration. Typical flight harness assemblies are available from CCT or you can build your own.

- Piccolo Flight Harness - p/n: 500-01045-00
- Piccolo SL Flight Harness and interface Cable - p/n 500-02163-00
- Piccolo LT Flight Harness and interface cable - p/n 500-01152-00

Flight harness guidelines:

- Make all leads as short as possible (minimize extra wire length). This will help with RF coupling from onboard transmitter that can interfere with RC hobby servos.
- Avoid using servo lead extensions. The extra wire and connectors can cause problems.
- When routing the servo and RF leads, try to keep them separated as much as possible. They should be cleanly routed and tied down.
- Never run coax in parallel with unshielded servo wires. Working with a neat and clean installation will make RF troubleshooting much easier.
- Use crimp pin and socket connectors, **do not use solder cup type connectors**. Solder joints on wiring harnesses can fail due to vibration unless proper strain relief is provided.

The schematic for a typical Piccolo flight harness with ailerons is shown in **Figure 15**. The Piccolo SL and LT flight harness and interface cable are shown in **Figure 16** and **Figure 17**. Detailed flight harness and interface schematics in a PDF format can also be downloaded from our website on the Downloads page.

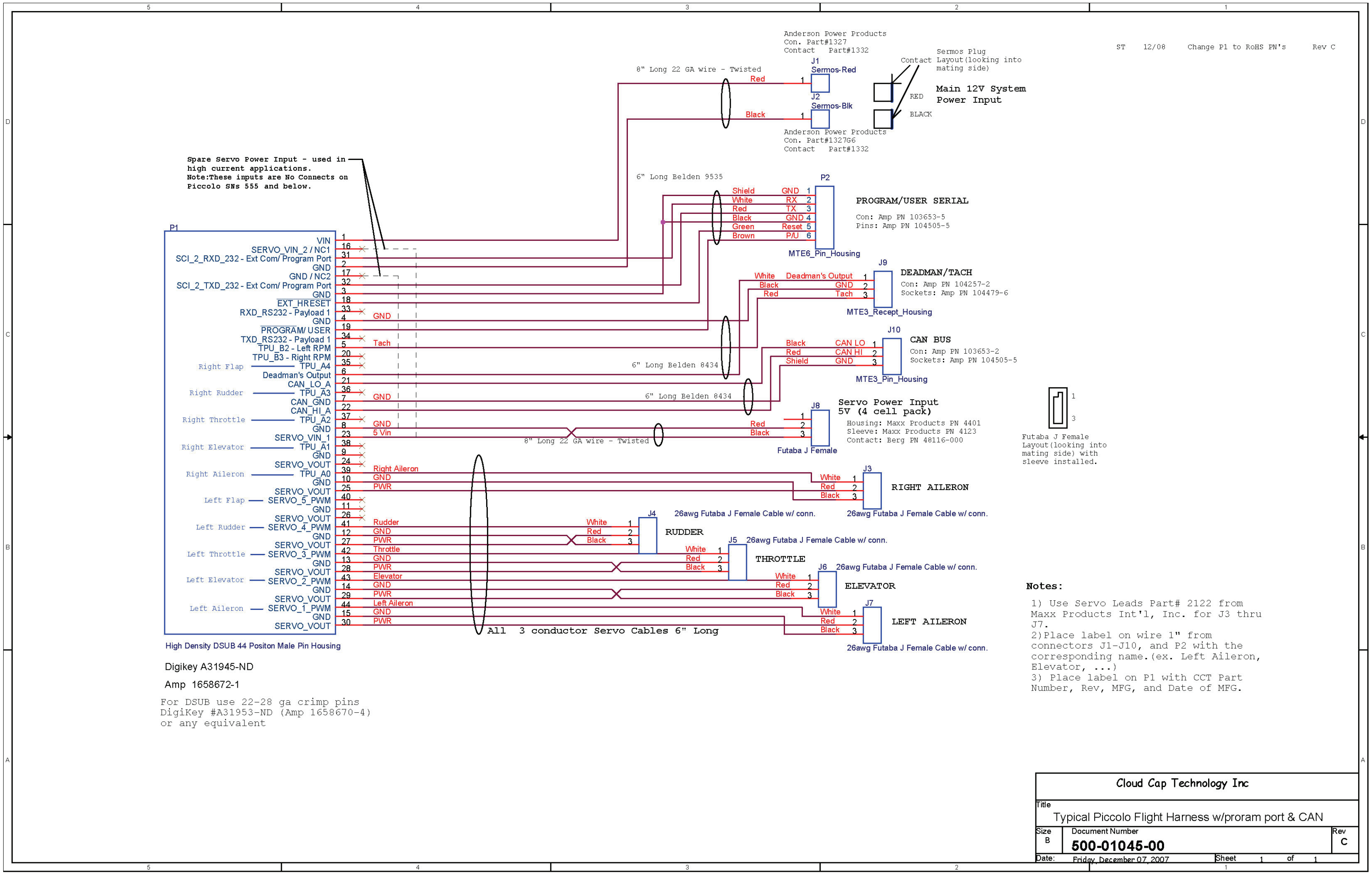

Figure 15 - Typical Piccolo Flight Harness Schematic

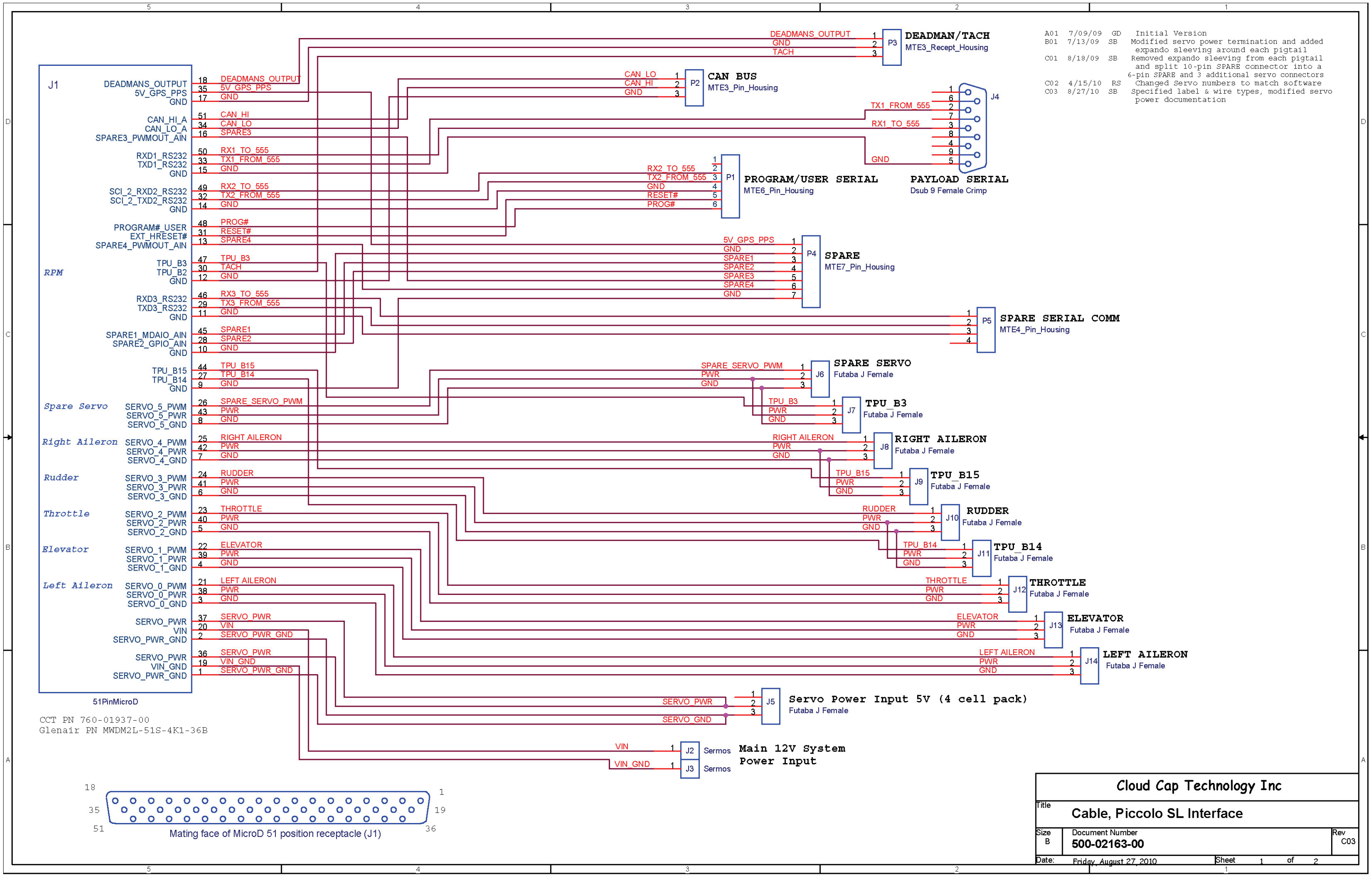

Figure 16 - Piccolo SL Flight Harness and Interface Cable Schematic

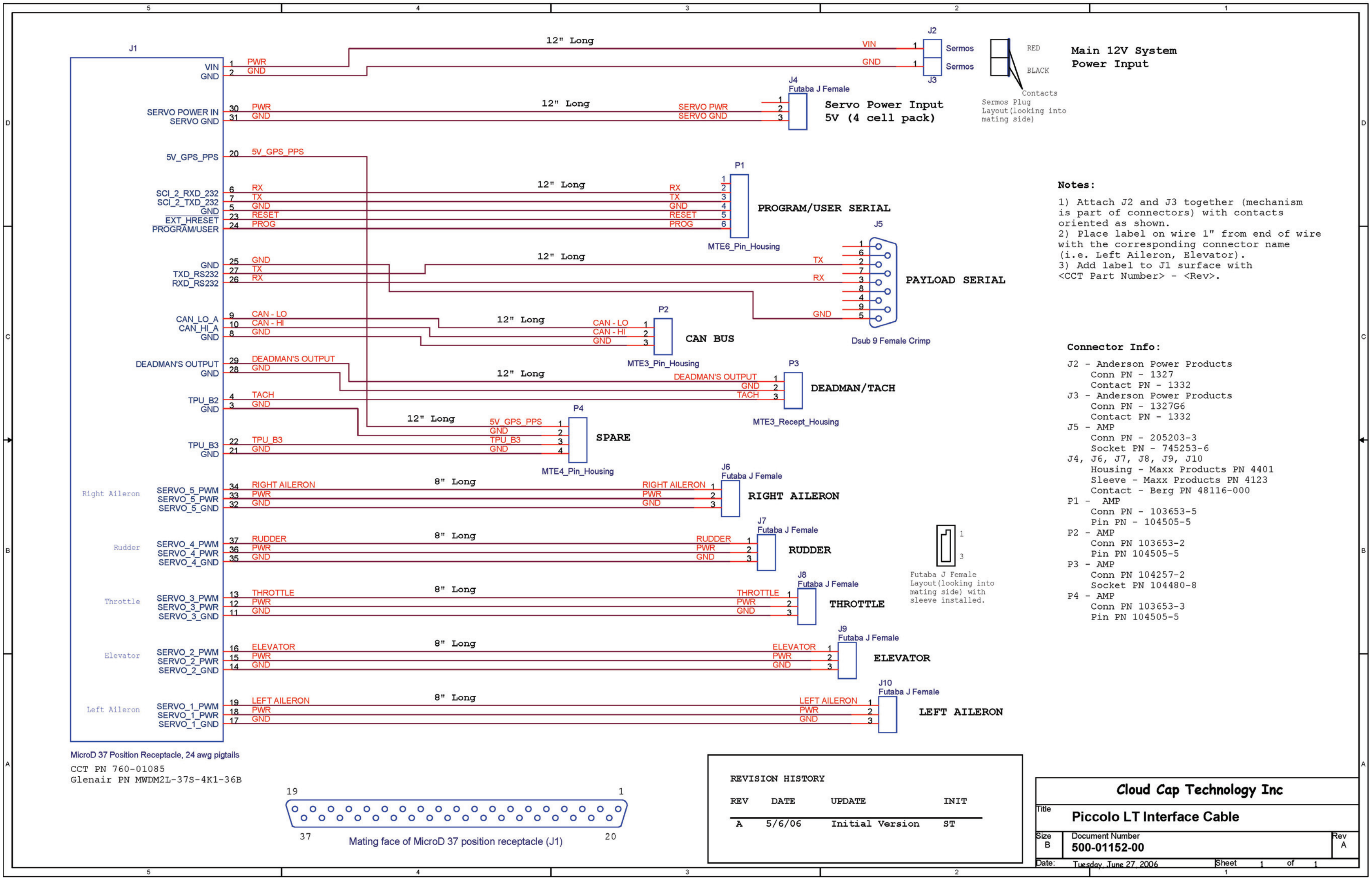

Figure 17 - Piccolo LT Flight Harness and Interface Cable Schematic

6 Power Sources

6.1 Piccolo Power

Piccolo accepts 8 to 20V DC input power. The Piccolo LT accepts 4.8 to 24 volts. The Piccolo SL accepts 4.5 to 28 volts. This power is regulated down to internal voltages required for the main board. For flight testing purposes a 12 Volt, 2700 mAh, 10-cell NiMH pack is recommended. Since the Piccolo will nominally draw 300 milli-Amps at 12 Volts (3.6 watts) this type of pack can be used safely for several hours. Cloud Cap Technology stocks both Piccolo and Servo packs. Contact us for pricing.

6.2 Servo Power

A typical model aircraft servo operates on 4.8 to 6 Volts. The amount of power drawn by a servo depends on its size and the loading, which can be mechanical or aerodynamic. However even the smallest servos can draw high amounts of current for short periods of time. When a servo first begins moving there is a large surge of current as the motor energizes its windings and builds up the kinetic energy of the rotor and gear train. For this reason the servos are not powered by Piccolo, but through their own separate input power. Typically a 4 or 5 cell pack is used. See the *Aircraft Integration Suppliers* tab on the Piccolo Accessories page of our website for details on pack vendors. Sizing of the pack is left to the user and depends on the application requirements, number, and size of the servos.

6.3 Deadman Power

The deadman switch consists of a power MOSFET driven by a watchdog timer circuit. Under normal operation the timer circuit is refreshed by software and the deadman switch remains on. If the system fails, either due to software or hardware failure, the deadman switch powers off. This switch can be connected to an ignition system, or some other flight termination system to provide a measure of safety in the event that the system fails. The deadman switch is powered by the servo input power and can supply up to 1 Amp. For more information, see the *Tach-Deadman Integration Guide*.

7 Integration Testing

7.1.1 Orientation Configuration and Test

It is crucial to the autopilot performance that the Piccolo Avionics orthogonal axis are aligned with that of the aircraft's in the final installation. The avionics has a reference coordinate system that 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. There is no need to install the avionics in its natural coordinate system, however the Euler angle rotations between the avionics coordinate system and the aircraft coordinate system must be known.

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 the principal axes of the vehicle. There are 24 different possible principal axis orientations. The angles describe the rotation from the avionics coordinate frame to the vehicle coordinate frame.

When applying the angles, the default is as follows:

- The coordinate system is rotated about the Z-axis (psi)
- The coordinate system is rotated about the new Y-axis (theta)
- The coordinate system is rotated about the new X-axis (phi)

It is difficult to visualize the entire process. Using the **`Sensor Telemetry`** window of the Piccolo Command Center is helpful. The most important thing is to test the results. To verify correct orientation, complete the following steps:

1. Rotate the aircraft nose right, and then nose left. The yaw rate sensor should indicate positive and negative values respectively.
2. Rotate the aircraft nose up, and then nose down. The pitch rate sensor should indicate positive and negative values respectively.
3. Rotate the aircraft roll right, and then roll left. The roll rate sensor should indicate positive and negative values respectively.

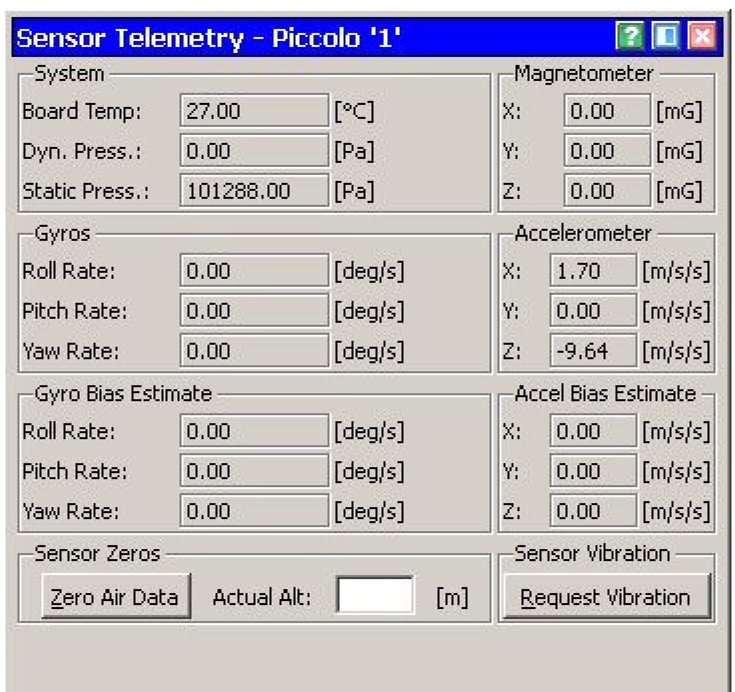

Figure 18 - Sensor Telemetry

In a real vehicle 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 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.

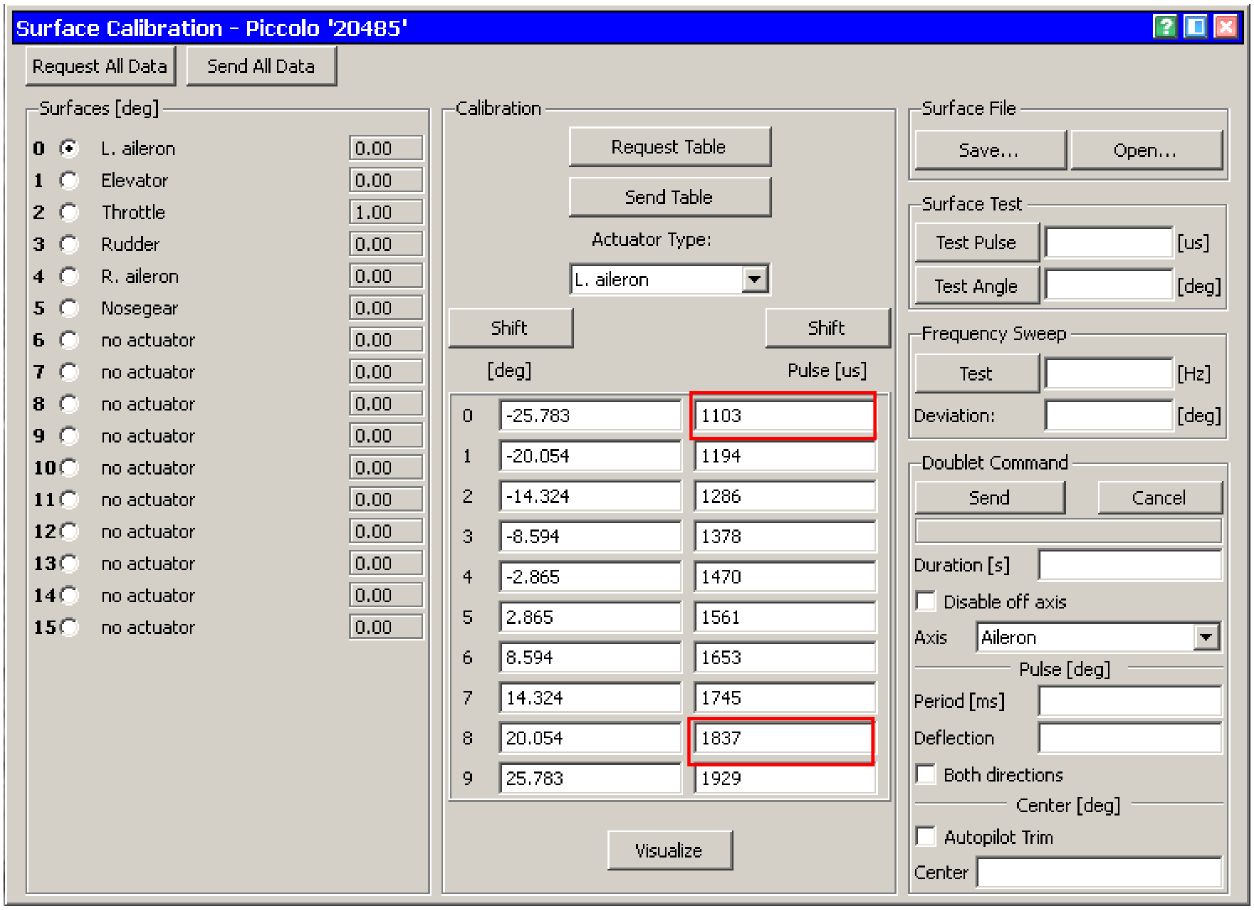

Figure 19 - Surface Calibration

7.1.2 Actuator Calibrations

Each channel has its own calibration data. The data relates the actuator pulse width in microseconds to the surface position. The surface position data are usually given in ascending order, and the pulse widths are in ascending or descending order.

Although the pulse width column shown in **Figure 19** is regularly spaced, this is not required. Note the pulse width values of 1103 and 1929. These correspond to ±100% pulse width as measured from a Futaba pilot console.

The **`Request all data`** button triggers the avionics to send all of the surface setup information. The **`Surface Calibration`** window only displays the pulse width-to-angle calibration for one surface at a time. The surface displayed is chosen with the radio buttons shown on the left side of the window. To change the surface calibration table, do the following:

1. Enter in the new table data
2. Select the actuator type from the drop down box
3. 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 of the **`Surface Calibration`** window (**Figure 20**).

Figure 20 - Surface Test

To use the feature, the autopilot must be on (i.e. not in manual control) and it must be in pre launch mode. 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.

7.1.2.1 Throttle Calibration

Allow the engine to warm up before performing a throttle calibration. After each Pulse Width command, allow the engine to settle at the RPM location. In a static situation, the engine power is approximately proportional to RPM^3. To calibrate the throttle:

1. Command pulse widths from 1103-1970 and measure the corresponding RPM.
2. Allow the engine to warm up before performing a throttle calibration.
3. After each Pulse Width command, allow the engine to settle at the RPM location before measuring RPM.
4. To determine the throttle setting for each pulse width, normalize the RPM^3 with RPM^3 maximum value. For example in **Table 1,** the throttle setting for the 1674 pulse would be THR= $5681^3/7804^3$=0.386

Table 1 - Throttle Setting Table

Throttle Pulse Width	RPM	RPM^3	Normalized Throttle (RPM^3/RPM^3_{Max})
1970	0	0	0.000
1807	1787	5.71E+09	0.012
1735	4021	6.5E+10	0.137
1695	4989	1.24E+11	0.261
1674	5681	1.83E+11	0.386
1629	6236	2.43E+11	0.510
1559	6707	3.02E+11	0.635
1497	7119	3.61E+11	0.759
1403	7489	4.2E+11	0.884
1103	7804	4.75E+11	1.000

The graph in **Figure 21** illustrates the linear relationship between the throttle command and engine power(RPM^3).

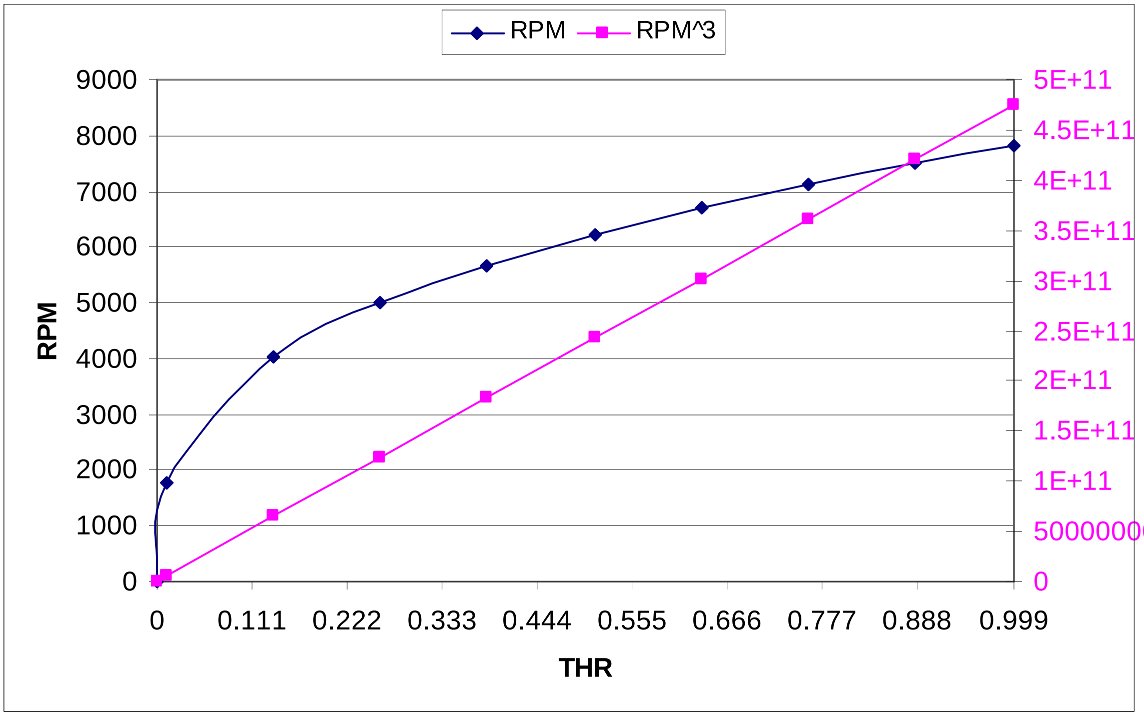

Figure 21 - Throttle Command and Engine Power

7.1.3 Setup Pilot Console

Although Piccolo supports ten different control outputs the autopilot only understands five different control axis – Roll, Pitch, Thrust, Yaw, and Flaps – and outputs five different command signals – Aileron, Elevator, Throttle, Rudder, and Flaps. Mixing rules outside of the autopilot are used to create ten outputs from the five commands. See the *Piccolo User's Guide* for more information. It is important to understand that when the Piccolo is under manual control, only five signals – plus channel 5, autopilot on/off – are sampled. The five manual control signals are passed through the exact same mixing rules to generate the outputs.

The pilot console should not include any mixing that conflicts with the mixing rules on Piccolo – multiple servos for a single control axis, flaperons, elevons, or V-tail. If the vehicle requires these features, then mixing should be setup on the Piccolo and not on the pilot console. The pilot console can be used to control the direction and sensitivity under manual control so servo reversing, dual rate, ATV, and exponential can be used to set the vehicle to the user's preference.

7.1.4 Under Simulation

It extremely important to successfully go through the simulation process BEFORE flying. DO NOT skip steps!

The *Piccolo Setup Guide* provides instructions on how to setup and run a simulation. The simulation environment allows the aircraft control laws and mission functionality to be tested without risking the aircraft in a flight test.

The simulation environment provides an ideal training tool that can be used in the lab. Although simulation cannot replace flight-testing, it measurably reduces the likelihood of failure by detecting bugs and deficiencies before the aircraft and related hardware are put at risk. The task is to create a dynamics model for your specific vehicle. Start with the model that was provided and modify the parameters as required. A description of each parameter can be found in the *Piccolo Simulator* document. Once your model is complete, you can validate it by flying the Piccolo under manual control.

7.1.5 Adjusting Gains

If the vehicle is similar to the Cub trainer aircraft (the default model shipped with the simulation system), then the default gains in your Piccolo may suffice. If this is the case, you can enable the autopilot and fine tune the gains as needed. Many vehicles are sufficiently different, so you must start from the beginning to develop new gains.

Note: *There is no formula for determining gains (the process consist of trial and error). When develop gains for a new vehicle, follow the steps in the Initial Flight Test Cards document.*

7.1.6 Vibration Testing

Once positive control has been achieved you can start the engine and verify proper operation.

1. From the PCC main window, go to **`Window`** » **`Status Windows`** » **`System`**. In the **`Bandwidth`** panel, check the **`Fast Telemetry`** box. This will display and log 20Hz data that allows you to analyze the state of the sensors.

Figure 22 - Bandwidth

2. Slowly run the engine through its full RPM range at the same time watching the sensor data in the **`Sensors Telemetry`** window. You should be watching the rate output of the gyros and the attitude estimation.
3. If you don’t see any large excursions (above single digit readings for the rates) and your attitude estimation is stable (less than a few degree of drift over the entire operational rpm range) then the mounting system should be suitable.
4. If you do see large rates and/or the attitude estimation diverges at a particular rpm (you find an airframe/mount resonance point) you must correct it before you attempt to fly.

   Note: *If you have questions, contact us. We can analyze your telemetry data and make recommendations.*

5. With the engine running, set the throttle limits. The manual piloting limits are set by the control surface calibrations. This provides the pilot full authority over the full throttle range, i.e the pilot should be able to close the throttle and kill the engine.

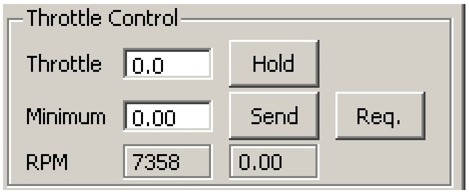

Figure 23 - Throttle Control

   Since this is not acceptable for autopilot operation, from the PCC main window, go to **`Window`** » **`Preflight Windows`** » **`Preflight`**. Set the min and max throttle settings in the **`Throttle Contro`**l section of **`Preflight`** window.

6. Set the minimum throttle to a value that will safely keep the engine idling in all expected flight configurations and orientations. The max throttle limit can be set once airborne and testing is underway.

   Note: *These limits do not affect the range of throw in manual control and once they are set, they will be stored in non-volatile memory onboard the avionics.*

7.2 Field Testing

IMPORTANT! To increase the chances of successful autonomous flight, it is extremely important to test everything on the ground before attempting to fly.

The following steps should be completed before actual field testing begins:

- ☑ Avionics integrated into the airframe
- ☑ Control surfaces calibrated
- ☑ A model of the aircraft for the simulator developed
- ☑ A set of autopilot gains obtained while flying in the hardware-in-loop simulator

If the steps above have not been successfully completed, **DO NOT** proceed. If the above steps have been completed, continue the field test setup by completing the following:

- ☑ Ground station setup and configured
- ☑ Vehicle assembled and ready for power up
- ☑ Antennas installed on a proper ground plane
- ☑ Pilot console connected
- ☑ Power source running
- ☑ Piccolo Command Center running on a laptop computer

After flight operations setup, perform the Piccolo System Preflight Checklist. This checklist is also integrated into the Piccolo Command Center.

7.3 Piccolo System Preflight Checklist

IMPORTANT: Always perform the Piccolo System Preflight Checklist before flying. Failure to perform this checklist may lead to costly mistakes that could result in the loss of an aircraft.

- ☑ Check and record initial battery voltage and current.
- ☑ Configure map page as required for the mission.
- ☑ Verify and/or load flight plans
- ☑ Verify correct controller settings.
- ☑ Verify mission limits including deadman status and lost comm waypoint.
- ☑ Verify working aircraft GPS, check number of satellites and PDOP.
- ☑ Set altimeter to local base pressure, or choose GPS update.[i]
- ☑ Select manual control and verify manual control indicated in autopilot page.
- ☑ Verify control surface trims in manual mode. Adjust using pilot console.
- ☑ Verify manual control, both magnitude and direction, for all control surfaces.
- ☑ Verify the reported control surfaces match the actual control positions.
- ☑ Check air data readings and zero them if needed.[ii]
- ☑ Check the correct operation of the gyros and accelerometers by physically rotating the aircraft and verifying the sensor outputs[iii].
- ☑ Verify that the pitot tube is clear by blowing into it and seeing the airspeed response.
- ☑ Set the initial fuel weight or battery charge state of the vehicle.
- ☑ Configure the autopilot loops as needed, typically all auto, with the waypoint set for the launch plan.
- ☑ Start the engine and verify correct operation through the entire RPM range. Check sensor readings for signs of excessive noise due to engine vibration at different RPMs.
- ☑ Check communications at the far end of the runway strip. RSSI signal should indicate close to the maximum reading (-71 dBm)[iv].
- ☑ Check for aircraft traffic and make any radio calls mandated by air traffic control.
- ☑ Final check on the system: Battery voltage and current, GPS health, RSSI, and sensors.
- ☑ Takeoff and start watch or timer.

7.3.1 Controls Check

- ☑ The first test is to verify your control surface configuration and calibration. Once you power up the aircraft and see telemetry you can take manual control, check the trims, and walk through a complete controls check including throttle.

- ☑ Once this is done, and you are happy with the direction and range of throw, check for any abnormal servo chatter or motion caused by the onboard transmitter.
- ☑ If you do detect any periodic movement, turn off the ground station power, if the chatter disappears you likely are experiencing interference from the onboard 1-watt transmitter. (Piccolo will not transmit if the ground station isn't running.)
- ☑ Make any necessary adjustments to your servo wire routing to correct the interference before proceeding.

7.3.2 Communication Range Checks

Once engine testing is complete, a thorough communications check should be performed.

1. Place the aircraft down range at the far end of the runway or field.
2. If possible, elevate the aircraft. Slowly rotate it in 90-degree increments while the operator records the number in the **`RSSI`** field shown in the **`Ground Station`** window and the **System** window in the Piccolo Command Center. The RSSI numbers should range from -71dBm max received signal strength to -108dBm minimum receive signal strength (edge of comm range).

Note: *The RSSI signals should not fluxuate more than 1 step (~8dBm steps) below -71 or -79dBm. If the RSSI numbers are below -79dBm during this test, there is a problem. Typically while flying overhead the RSSI number should not come off the max value of -71dBm.*

Important: Unless ideal communications have been established between the ground stating and the aircraft, DO NOT attempt to fly the aircraft. Reference the *Communications Troubleshooting* document for troubleshooting information.

7.4 Technical Support

For technical support, contact us by e-mail at supportcct@goodrich.com or phone at +1.541.387.2120. You can also go to the support page on our website.

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[i] The altimeter base pressure, also called the altimeter setting, is the atmospheric pressure *at sea level* for the current location. It is typically available from the local airport or weather service. If you don't know the base pressure than use 101325 Pa or 29.92 in-Hg, which is standard pressure. You can still zero the altimeter, but you won't be able to update the base pressure once the aircraft is flying, hence the barometric altitude will drift with the atmospheric conditions.

[ii] When zeroing the air data sensors the vehicle must be not moving, with the pitot tube shielded from the wind (or, at least, turned 90° from it). Ideally you want to wait approximately five minutes after turning the system on before doing a sensor zero. This gives the avionics time to equilibrate in temperature; which will result in the best sensor zero. You do not have to always perform a zero but you should do so if the dynamic pressure is off by more than 15 Pa.

[iii] To verify correct gyro operation rotate the aircraft nose right and nose left. Verify the yaw rate sensor indicates positive and negative values respectively. Rotate the aircraft nose up and nose down. Verify the pitch rate sensor indicates positive and negative values respectively.

Rotate the aircraft roll right and roll left. Verify the roll rate sensor indicates positive and negative values respectively.

To verify correct accelerometer operation note that when level the X, Y, and Z accelerometers should read 0,0, and –1 g respectively. With the vehicle rotated 90° right wing down the X,Y, and Z accelerometers should read 0, -1, and 0 g respectively. With the vehicle rotated 90° nose down the X,Y, and Z accelerometers should read –1, 0, and 0 g respectively.

[iv] RSSI is the receive signal strength indicator. It is reported from the radio in units of dBm, and ranges from –71 to –115. –71 is the maximum reading. Communications performance will begin to degrade when the RSSI reaches –101 or lower.