2006 Summer Research Report

Piper Cub Modification and Flight Test Program

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Abstract

The aim of this report is to provide the reader a summary of modification work on a one-third scale Piper Cub RC aircraft model. This Piper Cub is modified from a traditional tail design to a V-Tail configuration, which is being used on a Meridian UAV design for the CReSIS project. The ultimate purpose of this project is to perform flight tests on this modified Piper Cub with an automatic flight control system, the Piccolo system.

The major modifications to the Piper Cub includes a tail configuration change, a wing joint structure repair, an engine replacement, firewall modifications, and a fuel system and radio system update. The modification began at the beginning of June and was completed in the middle of August.

Two flight tests in pilot manual mode were successfully performed on Aug-16 and Sep-05. Handling and operating qualities are satisfied according to the pilot points of view. The V-Cub has successfully demonstrated the flying qualities of a V-Tail configuration aircraft model and is now ready to test with the automatic control system.

Following the success of the RC flight test, flight testing with Piccolo autopilot system will proceed. The Piccolo control unit, GPS antenna, COMM antenna, and the Pitot tube will be integrated onto the V-Cub model. A series of ground testing, flight testing and data collecting experiments with Piccolo system will be conducted for educational and operational training purposes. Experiences and knowledge accumulated during the flight test period will be transformed to the Meridian UAV flight test program, which is the ultimate goal of this research project.
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## Abbreviation

<table>
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<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CReSIS</td>
<td>Center for Remote Sensing of Ice Sheets</td>
</tr>
<tr>
<td>UAV</td>
<td>Unmanned Aerial Vehicle</td>
</tr>
<tr>
<td>PDR</td>
<td>Preliminary Design Review</td>
</tr>
<tr>
<td>CDR</td>
<td>Critical Design Review</td>
</tr>
<tr>
<td>RHS</td>
<td>Right Hand Side</td>
</tr>
<tr>
<td>LHS</td>
<td>Left Hand Side</td>
</tr>
</tbody>
</table>
# Introduction

The objective for the Aerospace Engineering Department on the CReSIS program is to design and develop an UAV platform to carry the special designed antenna and radar to perform ice sheet thickness measurements in a specified area in the Antarctica and Greenland. The Meridian UAV design was proposed to fulfill this mission. Three different preliminary designs were presented and the white design, a V-tail high wing design, was selected to enter Phase II as the baseline design configuration after the PDR.

The Piccolo system, an automatic flight control unit, has been selected for use on the Meridian UAV platform for the autopilot system.

In order to obtain more hand-on experience with the Piccolo system, a flight test plan using an RC aircraft model was strongly suggested by the team before the system was actually implemented on the Meridian UAV. To accomplish this, a Piper Cub RC model was selected to perform these flight tests with the Piccolo system.

The Piper Cub was chosen due to its similar design (high wing) to the Meridian UAV (based on the PDR design). This was true except for the tail configuration. The Piper Cub has a traditional tail design while the Meridian UAV has a V-tail design. Because of that, modifications to the tail was required in order to evaluate the handling qualities and controllability of the v-tail configuration aircraft.

The primary objective for this summer was to finish all the necessary modifications and repairs on the Piper Cub and to perform flight testing. The first flight of the Piper Cub was successfully completed on August 16th.
2 Review of Piper Cub

The Piper Cub was built by an aircraft design class (AE721) in 1999. It is a one-third scale model of a full size of Piper Cub. Below some basic information on this aircraft are listed in Table 1.

![Figure 1 Piper Cub]

Table 1 Basic Specifications for the Piper Cub

<table>
<thead>
<tr>
<th></th>
<th>Full Scale Aircraft</th>
<th>1/3 RC Scale Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wing Span</strong></td>
<td>421 in</td>
<td>139.5 in</td>
</tr>
<tr>
<td><strong>Wing Area</strong></td>
<td>25,730.05 in²</td>
<td>2,929.5 in²</td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>225.3 in</td>
<td>74 in</td>
</tr>
<tr>
<td><strong>Engine</strong></td>
<td>50 hp</td>
<td>7.5 hp</td>
</tr>
</tbody>
</table>
3 Piper Cub Structural Modifications

The modifications to the Piper Cub are mainly focused on the following areas:

- Conversion to V-Tail configuration.
- V-Tail mounting structure.
- Wing joint structure.
- Firewall and Engine.
- Systems.

The details of each modification will be discussed in this section.

3.1 V-Tail Modification

3.1.1 Remove the Conventional Tail

The main change to the Piper Cub was to modify the tail from conventional tail to a V-tail configuration. The original design of the tail was not removable. Therefore, structure need to be cut off to remove the tail. To minimum modifications, the structure was cut off at the point where the tail attached. Figure 2 shows the empennage after the tail was removed.

![Empennage of Piper Cub with Tail Removed](image-url)
3.1.2 V-Tail Design

The new V-tail was sized based on the projected area from the original vertical and horizontal tails. This ensures that the V-tail will provide the same effective control areas as the original tail. Although this may not be an optimal sizing method, this is a conservative way to ensure the function of the V-tail without running any stability and controls analysis.

The V-tail is mounted at a forty-five (45) degrees angle referring to the fuselage water line. For quick manufacturing, the cross-sectional shape of the V-tail is designed as a flat platform with no airfoil shape. The V-tail is constructed from basswood beans and 1/32” thick balsa sheet skin, and then covered with Monocot. The tail and control surfaces are connected using the Robart hinge point system. Figure 3 & Figure 4 show the construction of the V-tail.

Figure 3 V-Tail Control Surface
3.1.3 V-Tail Mounting Structure

**Mounting Support**

The V-tail is mounted to the end of empennage where the original tail was. The mounting structure is built based on the existing structure. Because the V-tail needs to be installed at a forty-five (45) degree angle, four M shape structures are designed to provide an angular mounting support. These M shape supports are bonded to the empennage using epoxy, giving a very strong connection to the empennage.

A basswood beam is bonded across the four M shape supports by epoxy so that all supports are connected together to make the tail more rigid. It also provides the mounting surface for the V-tail. The length of the beam is same as the length of the root chord of the V-tail.
Figure 5  V-Tail Mounting Structure

Figure 6  M Shape Mounting Supports
Ideally, the M shape support structures should continue to the bottom of the empennage so that it can form a complete circular frame for a better load path. In fact, this was pointed out by Dr. Hale and Dr. Ewing in the first flight test review. However, as mentioned before, to minimize the modifications to the structure, new supports were built based on the existing structure where original tail was removed.

After the first flight test review board, a compromise approach was proposed to improve the design by reinforcing the first support. The suggestion was to mount two additional struts on both sides of the first support at the bottom of the empennage structure. This change connected the support to the structure underneath so that it formed a complete circular frame. Figure 7 & 8 show the reinforcement on the first support.

Figure 7 Reinforcement of the First Support – Side View
The V-tail is designed to be removable for easy transportation. Each tail is mounted on the support through five (5) countersink screws. Stop nuts are used on the back side of the supports so that only one side needs to be accessed for tail installation. Figure 9 shows the installation of the V-tail.
**Fairing**

A sheet metal made fairing is mounted between the left and right V-tails at the root. The main purpose for this fairing is to create a continued load path from one side of the tail to the other side. It also provides a better aerodynamic surface connection.

This fairing is also removable.

![V-Tail Fairing](image)

**Figure 10  V-Tail Fairing**

**Cable System**

As one can see, the V-tail is only mounted to the structure on one end. Because the V-tail is so long a very high moment arm is created from the tip end. Therefore, the idea for using the cable system is proposed to provide a second load path.
Two cables connect the bottom of empennage structure to the tip of the V-tail at both the RHS and the LHS. Another cable directly connects both tails together. Through this cable system, the tails and the empennage structure are connected together forming a triangle load path such that the bending moment generated by the tails (up or down) will be transferred to the empennage’s structure. In addition, each cable is attached to an adjustable pin. This feature provides an adjustable mechanism to achieve a symmetric installation of the V-tail.

Figure 11  Cable Assembly on the V-tail - RHS
Figure 12  Cable Assembly on the V-tail - LHS

Figure 13  Adjustable pin on the cable.
3.2 Wing Joint Structure Modification

In this section, descriptions are given about the modification of the wing joint structure. This includes the bolt joint structure, the new access door, and the mounting straps.

The original design of the wing joint used two small bolts to mount both wings onto the fuselage, with two additional support struts. These struts connected the wing to the strap at the bottom of the fuselage. The jointing holes on both the wing and the fuselage were seriously damaged from previous use. This was mainly caused by vibrations during flight. This damage needed to be repaired.

3.2.1 Bolt Joint Design

New Bolt Sizing

There are two concerns that needed to be considered before the redesign of the wing joint structure; the hole damage and wing accessibility. To minimum modifications, the existing holes were used. Therefore, the decision was made to re-drill the damaged hole into a bigger standard size. This is the reason why a large diameter bolt (1/4 in diameter) was chosen for the new joint.

Holes Protection

To prevent the holes from wearing again due to vibrations, bushings were installed inside the holes on both the fuselage and wing sides. The bushings were installed within the hole in an interference fit. This provided better protection for the hole and the bushing.
Figure 14  Jig to Re-drill Wing Holes

Figure 15  Wing Joint Structure -Fuselage
Figure 16  Bushing on the Fuselage Side

Figure 17  Bushing on the Wing Side
3.2.2 New Access Door

The previous wing joint design was to insert the bolt from inside the fuselage to the wing section. It was required to tighten the bolt from the inside while holding the other end of the bolt from the outside. To simplify this procedure, nut plates were installed inside of fuselage so that only one way access is now required to install these bolts. A new access door on the wing was added to provide access to the bolt installation. A new access panel was installed on the wing. Each access door is installed with two hinges and is opened and locked using a new locking mechanism.

Figure 18  Nut Plates Installed on the Inner Side of Fuselage
3.2.3 Mounting Straps

The two wings are also supported by two struts connected from the wing to a mounting strap which attaches to the bottom of the fuselage. Before, one strap was used to connect the two struts onto each side. Damage such as bending and wearing were found on the attachment hole. To improve the design, the original strap was replaced by two new steel straps so that each attachment point will connect only to one strut. This significantly reduces the loads to 50 percent of what was carried by each attachment point before.
3.3 Engine and Firewall Change

Two of the major modifications made to the Piper Cub was the engine replacement and the new firewall. The new engine meant that the firewall needed to be modified to fit the new engine mount. Details on these modifications are discussed in this section.

3.3.1 Engine

*Original Engine*

Originally a 3W-70i rear induction engine was used on the Piper Cub. This engine was equipped with an old Hall sensor which was only compatible with its old ignition system. Table 2 shows the basic information on this engine.

<table>
<thead>
<tr>
<th>Cylinder Capacity</th>
<th>4.195 in³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>7.5 HP</td>
</tr>
<tr>
<td>Weight</td>
<td>5.32 lbs</td>
</tr>
<tr>
<td>Speed Range</td>
<td>1300 – 8500 RPM</td>
</tr>
<tr>
<td>Length</td>
<td>6.0 inches</td>
</tr>
<tr>
<td>Width</td>
<td>3.97 inches</td>
</tr>
</tbody>
</table>
The original idea was to use the existing 3W-70i engine on the V-Cub so that no modification would be needed. However, a problem was found when engine tests were run. The engine was not able to start. The ignition unit was found to be malfunctioning. This could not be fixed by our team.

As mentioned before, the old Hall effect sensor on this engine is only compatible with the old ignition system. Three options were available for this problem:

- Order an old ignition unit from the manufacturer in Germany.
- Ship the engine back to Catcus Aviation to retrofit the sensor system.
- Replace the engine with another.

**New Engine**

Option one or two would take at least a few weeks to have the engine ready again. Because of schedule concerns, option three was chosen as the fastest solution. The 3W-75US side induction engine was chosen, since it was available at the airport and was ready to use. Table 3 gives some information on this 3W-75US engine.

Table 3  3W-75US Engine

<table>
<thead>
<tr>
<th>Cylinder Capacity</th>
<th>4.59 in³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>7.5 HP</td>
</tr>
<tr>
<td>Weight</td>
<td>4.9 lbs</td>
</tr>
<tr>
<td>Speed Range</td>
<td>1100 – 8500 RPM</td>
</tr>
<tr>
<td>Length</td>
<td>5.5 inches</td>
</tr>
<tr>
<td>Width</td>
<td>6.0 inches</td>
</tr>
</tbody>
</table>

![Figure 21 3W-75US Engine - Side Induction](image)
Compare the data from Table 2 and Table 3, both engines provide the same amount of horsepower. The 3W-75US is 0.42 lbs lighter than the 3W-70i. In terms of power and weight, the new engine provides the same power as original engine with a lighter weight. So the decision to use the new engine is acceptable and no additional analysis is necessary.

The major difference between these two engines is the arrangement of the induction design, which have different mounting points. Therefore, a modification to the firewall was needed to fit the new engine mount.

3.3.2 Firewall Modification

The new engine has different mounting holes which do not match the existing holes drilled in the firewall. Also, the muffler on the new engine mount extends about 1.5 inches behind the engine. So the engine needed to be shifted to provide a larger space for the muffler installation. A plywood spacer was used to shift the engine forward for this purpose as shown in Figure 24.

Instead of mounting the engine directly to the firewall, an engine mount plate is used as an interface between the engine and the firewall. The reason for using it is that it is better for structural spacing to drill the new holes into firewall. It also provides a strong base to support the engine.

Vibration is always a major concern for engine installation. To minimum the vibration issue, stacks of rubber washers are used as soft engine mounts for vibration dampening purposes. Figure 24 shows the installation of the engine with the rubber washers.
Figure 22  Engine Installation - Front View

Figure 23  Engine Installation - Side View
3.4 Systems Update

3.4.1 Ignition System

The new ignition unit is matched to the new engine. An ignition kill switch is installed on the left hand side of the fuselage to provide quick access for the pilot to the power on/off ignition unit. The ignition unit is installed behind the firewall.
3.4.2 Fuel Tank System

The fuel tank was purchased from the vendor “B & B Specialties.” A 64 oz fuel tank was selected for the V-Cub. For normal RC aircraft, a 64 oz fuel tank is large for this size of aircraft. However, this large fuel tank was chosen for long flight durations for future flight testing with the automatic control system. The fuel tank is installed in the middle of the equipment bay.
3.4.3 Battery

Two 6.0 volt batteries are used to supply the power for the ignition system and all control servos. Both batteries are installed behind the firewall for good C.G. location practice.

![Battery for ignition](image)

![Battery for all control servos](image)

Figure 28  Installation of the Batteries

3.4.4 Receiver and Servo

A Futaba R149DP 9-channel PCM 72MHZ receiver is used for the radio system. It is installed on the bulkhead at the end of the equipment bay. A kill switch is used such that an on/off mechanism is available for the radio system. The switch is installed next to the receiver.

Except for the servo for the engine throttle, the control servos have not been changed. Since the V-tail configuration only requires two servos, one servo previously used for the vertical tail was removed from the empennage to minimize the weight. A new servo was needed for throttle control due to the new engine configuration. Also, new pushrods were made to connect the existing servos to the V-tail’s control surfaces.
Figure 29  Receiver and Kill Switch Installation

Figure 30  New Servo Installation for the Throttle Control
Figure 31  Pushrod Installation for the Throttle Control

Figure 32  Pushrod Installation for the V-Tail control
4 Weight and Balance

Weight and balance is always an important design factor for aircraft stability. In a normal design procedure, a complete analysis including weight and balance is required to ensure the stability of the aircraft.

The weight and balance analysis for the Piper Cub was done by the design team in the AE721 class at 1999. Unfortunately, due to the loss of the document, no data and thus no information is available for reference. So a complete analysis of the modified V-Cub becomes very difficult. Since the Piper Cup was designed to be a stable aircraft, a complete analysis is not necessary. A final C.G. check was performed before first flight to ensure a correct aircraft C.G. location for the V-Cub.

For stability purposes, the aircraft’s C.G. should be as close to the aerodynamic center as possible. It is located at a quarter length of the wing’s chord line. This condition should be satisfied with or without fuel. Based on the final C.G. check, a 2.5 lbs balance plate was placed on the firewall. Below is the result of the C.G. check for the modified V-Cub.

### Table 4 Weight and Balance Record for Pre-Flight C.G. Check

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Empty</th>
<th>Take-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHS main gear load</td>
<td>16.98 lbs</td>
<td>18.12 lbs</td>
</tr>
<tr>
<td>LHS main gear load</td>
<td>17.02 lbs</td>
<td>18.16 lbs</td>
</tr>
<tr>
<td>Tail gear load</td>
<td>3.54 lbs</td>
<td>3.60 lbs</td>
</tr>
<tr>
<td>Total Aircraft Weight</td>
<td>37.54 lbs</td>
<td>39.88 lbs</td>
</tr>
<tr>
<td>Fuel</td>
<td>None</td>
<td>½ gallon</td>
</tr>
<tr>
<td>Balance plate</td>
<td>None</td>
<td>2.5 lbs</td>
</tr>
<tr>
<td>Final C.G. location</td>
<td>28% chord</td>
<td>26.8% chord</td>
</tr>
</tbody>
</table>

(measured from firewall)
5 Cost Analysis

A cost analysis is conducted herein for the V-Cub modification project. This cost analysis only includes the expense due to new parts and materials purchased. Cost due to labor hours, documentation, faculty advisors, pilot labor, and flight test equipment are not included here.

Major components such as the engine, parts for the engine, receiver, crystal, fabric, control horns, fuel tank, fuel lines and batteries were ordered via purchase order. Miscellaneous parts such as fasteners, washers, nuts, wood screws, and cables are all self purchased from the local ACE hardware store or other hobby shops. The following is the summary of the expenses for all materials used on the V-Cub modification.

Purchase Order Summary

Table 5 Purchase Order Summary

<table>
<thead>
<tr>
<th>Date of Expense</th>
<th>Vendor</th>
<th>Items Descriptions</th>
<th>Application</th>
<th>Amount ($ US)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-Jun-06</td>
<td>Catcus Aviation</td>
<td>Engine Parts</td>
<td>Engine System</td>
<td>1124.40</td>
</tr>
<tr>
<td>9-Jun-06</td>
<td>Tower Hobbies</td>
<td>Miscellanea</td>
<td>Miscellanea</td>
<td>353.13</td>
</tr>
<tr>
<td>9-Jun-06</td>
<td>B &amp; B Specialites</td>
<td>Fuel Tank Sys</td>
<td>Fuel Tank Sys</td>
<td>36.90</td>
</tr>
<tr>
<td>5-Jul-06</td>
<td>Tower Hobbies</td>
<td>Battery</td>
<td>Battery</td>
<td>80.95</td>
</tr>
</tbody>
</table>

Total Expense : 1595.38

Note: For more details, please refer to Appendix #1, 2, 3 & 4 for each individual P.O.
### Self-Purchased Summary

Table 6  Summary of Self-Purchased Materials

<table>
<thead>
<tr>
<th>Date of Expense</th>
<th>Vendor</th>
<th>Items Descriptions</th>
<th>Application</th>
<th>Amount ($US)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-Jun-06</td>
<td>ACE Hardware</td>
<td>Fasteners &amp; Greased Cleaner</td>
<td>Wing Structure / Cleaning</td>
<td>8.49</td>
</tr>
<tr>
<td>5-Jul-06</td>
<td>ACE Hardware</td>
<td>Fasteners</td>
<td>Wing Structure</td>
<td>0.64</td>
</tr>
<tr>
<td>6-Jul-06</td>
<td>ACE Hardware</td>
<td>Fasteners</td>
<td>Tail Structure</td>
<td>21.12</td>
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<tr>
<td>12-Jul-06</td>
<td>ACE Hardware</td>
<td>Nuts &amp; Fasteners</td>
<td>Tail Structure</td>
<td>13.11</td>
</tr>
<tr>
<td>13-Jul-06</td>
<td>ACE Hardware</td>
<td>Nuts &amp; Fasteners</td>
<td>Tail Structure</td>
<td>12.54</td>
</tr>
<tr>
<td>19-Jul-06</td>
<td>ACE Hardware</td>
<td>Fasteners / Washers / Nuts</td>
<td>Fuselage</td>
<td>10.81</td>
</tr>
<tr>
<td>24-Jul-06</td>
<td>ACE Hardware</td>
<td>Fasteners / Washers / Nuts</td>
<td>Engine Mount</td>
<td>13.71</td>
</tr>
<tr>
<td>27-Jul-06</td>
<td>ACE Hardware</td>
<td>Crab Cleaner / Brass Tube</td>
<td>Engine Sys / Fuel Sys</td>
<td>6.74</td>
</tr>
<tr>
<td>27-Jul-06</td>
<td>Hetrick Air Services</td>
<td>Fuel</td>
<td>Engine Test</td>
<td>4.85</td>
</tr>
<tr>
<td>27-Jul-06</td>
<td>Hobby Heavey</td>
<td>Threaded Couplers / Fuel Tubing / Spring Locks</td>
<td>V-Tail Cable / Fuel Sys / Door</td>
<td>25.75</td>
</tr>
<tr>
<td>27-Jul-06</td>
<td>Ace Hardware</td>
<td>Fasteners</td>
<td>Access door</td>
<td>3.11</td>
</tr>
<tr>
<td>28-Jul-06</td>
<td>Hobby Heavey</td>
<td>Pull Cable</td>
<td>V-tail Cable</td>
<td>17.83</td>
</tr>
<tr>
<td>30-Jul-06</td>
<td>ACE Hardware</td>
<td>Fasteners / Washers / Nuts</td>
<td>Engine Mount</td>
<td>19.69</td>
</tr>
<tr>
<td>2-Aug-06</td>
<td>George Hobby</td>
<td>Servo Extensions</td>
<td>Servo Wiring</td>
<td>33.80</td>
</tr>
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Total Expense: 220.97

**Total Cost due to Materials = 1,595.38 + 220.97**

\[= 1,816.35 \text{ (US dollars)}\]
6 Flight Test Program

As discussed earlier, the purpose of this project was to modify the Piper Cub to perform flight tests to evaluate the handling qualities of a V-Tail configuration UAV. The V-Cub will also be tested with the Piccolo unit, which is the automatic flight control system. The goal of this flight test program is to gain hands on experience with Piccolo system, which will eventually be migrated to the Meridian UAV project.

6.1 Flight Test Plan

A flight test plan was established during the summer with Dr. Downling, Rylan Jager, and Brad Torgler. The details of the test plans are outlined in the flight test plan document attached as Appendix 5. The flight plan document was prepared by Brad Torgler. Below is a summary of the flight test plan:

- V-Cub modification.
- V-Cub flight test in manual RC mode.
- Software in the loop simulation of the Piccolo system for the V-Cub model.
- Hardware in the loop simulation of the Piccolo system for the V-Cub model.
- Piccolo hardware integration onto the V-Cub model.
- Ground test the V-Cub with the Piccolo hardware system on-board.
- Flight test the V-Cub with the Piccolo system on-board in pilot manual mode (open-loop)
- PID gain selection for the Piccolo autopilot system.
- V-Cub flight testing with the Piccolo in automatic flight control mode.

Note: The flight test schedule shown in Appendix 5 may not reflect the current flight test schedule.
6.2 Flight Test Safety Board Review

A flight test review board is held before the first flight of the V-Cub flight test program. Subjects related to flight testing such as the test procedures, the operational limits, the test area, the ground test instrumentation and the pilot requirements are discussed during the board review. In addition, a flight test plan document is available and is approved by all review board committee members before the first flight. The flight test review board procedures and the flight test document are assigned to flight test engineer Rylan Jager. For more details about the flight tests, please refer to Ref [1].

6.3 Flight Testing

As of today, two flight tests in RC pilot manual mode were successfully performed on the V-Cub. According to the pilot, the handling and operating qualities are satisfactory for further flight testing with the Piccolo autopilot system. Some minor problems were reported by pilot and need to be fixed before the next test flight. Table 7 is a summary of the flight test results.

Table 7 Summary of Flight Test Results

<table>
<thead>
<tr>
<th></th>
<th>1st Flight Test</th>
<th>2nd Flight Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date</strong></td>
<td>Aug 16, 2006</td>
<td>Sep 05, 2006</td>
</tr>
<tr>
<td><strong>Flight Time</strong></td>
<td>≈ 10 min</td>
<td>≈ 10 min</td>
</tr>
<tr>
<td><strong>Weather Condition</strong></td>
<td>Clear</td>
<td>10 miles/hr gust wind</td>
</tr>
<tr>
<td><strong>Pilot Comments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Stable to fly, easy to control</td>
<td>• Relocate the balance plates</td>
</tr>
<tr>
<td></td>
<td>• Replace the mount strap.</td>
<td>• Change 4.8V battery to 6.0V</td>
</tr>
<tr>
<td><strong>Flight Test Data</strong></td>
<td>RC Flight Test</td>
<td>RC Flight Test</td>
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<td></td>
<td>No data available</td>
<td>No data available</td>
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7 Future Work

The ultimate goal of this research project is to perform flight testing on the V-Cub model with the autopilot system. This section documents the first phase of planning prepares for the autonomous flight with the Piccolo system.

**Integration with the Piccolo System**

Following successful flight testing in RC pilot mode, the Piccolo avionics system will be integrated onto the V-Cub model for further flight testing. The Piccolo system includes the following components:

- Pitot tube and static tube.
- GPS antenna
- COMM antenna (902-928 MHz antenna or 2.4 GHz antenna)
- Piccolo control box

**Ground Test**

A complete ground test procedure is essential to a successful flight test. To achieve this goal, a list of ground test procedures is required as outlined below:

- Control box orientation test
- Control surface calibrations
- Setting up the pilot console
- Software and hardware in the loop tests
- PID gains selection for the autopilot mode
- Antenna and communication tests
Flight Test in Manual Mode

For safety concerns, the first flight testing with the Piccolo system will be conducted in manual mode after the completion of the ground tests. The pilot console (transmitter) will be connected with the ground station computer. Commands will be sent from the pilot through the ground station to the on-board control unit received by the COMM antenna. Although initial flight tests are done by pilot command, this test will verify the integrity of the system and the communication network.

During the manual mode flight tests, flight test data (all flight dynamics parameters) will be collected and used to compare and verify the simulation model. Corrections will be made if necessary to achieve an accurate simulation model, which is essential to developing a high performance autopilot system, since the control gains are first selected based on the simulation results.

Autopilot Flight Testing

Autopilot flight tests will only be performed after all the ground testing and simulation tests have been completed successfully. A flight path will be defined first for the autopilot mode. During the flight test, take-off and landing will still be accomplished operated manually by the pilot. There are many details in the autopilot flight tests which are out of the scope of this report. However, the aim of this research project is to develop hands on experience working with the Piccolo system. In order to demonstrate a successful autonomous flight test, successful ground testing and simulation tests are essential and indispensable.
Reference

### Appendix 1

**CReSIS**

**Purchasing Document**

**Billing Address:** Center for Remote Sensing of Ice Sheets  
2335 Irving Hill Road, Lawrence, KS 66045

**Telephone:** 785-864-7761  
**Fax:** 785-864-7753  
**FEID:** 48-0680117  
www.research.ku.edu

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- [ ] Confirmation of Verbal Order (Do **Not** Duplicate)
- [ ] Requisition (**Not** a Purchase Order)
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**Vendor Name & Address:**

Vendor: Cactus Aviation  
Address: 10380 E. Heritage Pl Tucson, AZ 85730

**Vendor Representative:** Bobby Wilson  
**Requested By:** Edmond Leong

**Prepare By:** Edmond Leong

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**Not Valid for Purchases Over $5000**

**Approval and Certification of Available Funds:**

Fund Administrator's Signature  
Name, Title

An Equal Employment Opportunity / Affirmative Action Employer

Prepared By: Edmond Leong
CReSIS
University of Kansas Center for Research, Inc.
PURCHASING DOCUMENT

BILLING ADDRESS: Center for Remote Sensing of Ice Sheets
2335 Irving Hill Road, Lawrence, KS 66045


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TOTAL

SHIP TO:
Department of Aerospace Engineering
2120 Learned Hall
1530 W 15th Street
Lawrence, KS 66045-2221

VENDOR NAME & ADDRESS:
Vendor : Tower Hobbies
Address : Tower Hobbies, PO box 9078, Champaign, IL 61826-9078

Vendor Representative: N / A  Requested By: Edmond Leong
Phone No.: 800-637-6050  Phone No.: 785-727-9360
Fax No.: 800-637-7303

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Estimated Freight Charges

Total Order 353.13

The University of Kansas Center for Research, Inc. is an educational corporation and is exempt from tax levied by the Kansas Retailer's Sales Tax Act under provisions of KSA 79-3606 and KSA 79-3602.

VENDOR NOTE: COD shipments will not be accepted.

Prepared By: Edmond Leong
This number must appear on all invoices.

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2335 Irving Hill Road, Lawrence, KS 66045


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Vendor: B & B Specialties
Address: 14234 Cleveland Road Granger, IN 46530

Vendor Representative: Dick Bennett
Phone No.: 574-277-0499
Fax No.: 574-277-0499

Requested By: Edmond Leong
Phone No.: 785-864-2219

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Prepared By: Edmond Leong
## Appendix 4

### CReSIS

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### Vendor Name & Address:

**Vendor:** Tower Hobbies  
Address: Tower Hobbies, PO box 9078, Champaign, IL 61826-9078

**Vendor Representative:** N/A  
**Phone No.:** 800-637-6050  
**Fax No.:** 800-637-7303

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**Phone No.:** 785-727-9360

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**Release Date:** Sep 25, 2006  **Page:** 37

---

**Prepared By:** Edmond Leong
Appendix 5

Avionics and Piper Cub Flight Test Schedule

TOPICS (dates on following page)

1. Piper Cub modifications complete and aircraft ready for flight tests.

2. Flight test documentation for Piper Cub acting as RC aircraft without avionics.


4. Flight tests without avionics package (as RC aircraft, manual mode only).

5. Hardware-in-loop simulation with the Piccolo.


8. Ground tests following hardware integration before flight tests.


10. Flight test documentation for Piper Cub with avionics on board (RC and semi-autonomous).

11. Flight tests with avionics package as RC aircraft (manual mode only).

12. Flight tests with avionics package as in semi-autonomous mode (within LOS).

13. State space model for Piper Cub (extract eigenvalues, transfer functions, root locus, and modal analysis).*

See next page for timeline and dependency of each topic.

* Not needed for the actual flight testing, but it is desired.

Note: This Flight test document is prepared by Brad Torgler
Appendix 5

Piper Cub Flight Test Milestones and Timeline

1. Now – July 31
2. Now – July 31
3. Now – July 31
4. Aug 1 – Aug 15
5. Now – Aug 15
6. Jul 31 – Aug 15
7, 8. Aug 16 – Aug 30
9. Aug 1 – Aug 30
10. Aug 1 – Aug 30
11. Sept 1 – Sept 30
12. Oct 1 – ??
13. Aug 1 – Aug 30

Note: This Flight test document is prepared by Brad Torgler

Prepared By: Edmond Leong