VERTIGO² ECE Validation Review

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Executive Summary

Nikhil Nair and Duroseme Taylor

A follow-on project to the original VERTIGO project, the VERTIGO2 project has changed its objectives to reflect circumstances throughout the semester while still maintaining progress of the overall goal.

The original objectives of delivering a working prototype of a tilt-rotor Vertical Take-Off and Landing (VTOL) aircraft have been significantly modified by the second year’s team on the basis of a critical design review of the airframe and avionics.

As such, the new objectives were to redesign the avionics suite, control systems and airframe pertaining to vertical flight mode only. The reasons behind this will be discussed later in the report.

The current status of the project points towards a successful completion of the avionics suite (laptop-based control software), replacement of select malfunctioning servos on the rotor nacelles, programming of the onboard PIC, onboard circuit design, manufacture and installation, system-wide integration if time permits followed by a successful static display of rotor control through the joystick.

The avionics suite will be able to fully control any generic tilt-rotor aircraft through the joystick and laptop combination, and will be marketable as such. Being software-based (i.e. run through a laptop and joystick) eliminates the need for expensive, dedicated control devices as used on most kit airplanes and helicopters. Since laptops are more widely used than dedicated aircraft controllers, the market for such an avionics suite will be significantly greater.

As a conclusion to the project the team addresses several missteps made by the previous team, obstacles encountered during this team’s tenure, solutions to said problems and a solid plan for follow-up should successive senior design team’s decide to eventually realize the overall project goal, namely, a fully functional tilt rotor aircraft.
## Current Conceptual Sketches

Nikhil Nair and Mimi Phan

<table>
<thead>
<tr>
<th>Fig 1. Vertigo Place - Rear View</th>
<th>Fig 2. Vertigo Place – Front View</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Fig 1. Vertigo Place - Rear View" /></td>
<td><img src="image2.jpg" alt="Fig 2. Vertigo Place – Front View" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fig 2.2 Vertigo Place - Front View</th>
<th>Fig 3. Wing Cyclic Assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image3.jpg" alt="Fig 2.2 Vertigo Place - Front View" /></td>
<td><img src="image4.jpg" alt="Fig 3. Wing Cyclic Assembly" /></td>
</tr>
</tbody>
</table>
Validation Analysis
Nikhil Nair and Calvin Turzillo

The Circuitry:

The hardware functionality of Vertigo\textsuperscript{2} is aimed towards one main aspect of flight, the vertical take off and landing. To achieve this, three main systems must be considered: rotor rotational speed, rotor pitch control, and power systems.

The rotor rotational speed is controlled by the PIC based main control system. This system feeds a PWM (Pulse Width Modulated) signal to another PIC which in turn acts as an independent feedback system. There are two sets of these rotor rotational speed PIC, henceforth known as Rotational Controllers. The rotational controllers interpret the PWM signal received from the main controller and modify the rotational speed of the rotors accordingly. Also connected to the rotational controllers are tachometers. These tachometers measure the rotational speed of the rotors and report that information to the PIC as a varied voltage between 0 and 5 volts. Using a basic error controlled feedback algorithm, the desired and actual rotational speeds are compared and the error is fed back into the system to correct for the difference. This insures a constant and predictable rotor speed so that maximum lift can be achieved.

The rotor pitch control is composed of six servos, three on each rotor of the aircraft. Since the forward and aft pitch of the rotors is more difficult to control than the lateral movement, two servos are used for increased torque on the squash plate. One servo is then used to control the lateral movement of the squash plate. The squash plate has linkage to the rotor blades which allow the angle of attack to be altered in order to achieve greater or less lift while varying the associated drag. These servos are controlled by a PWM signal generated by the main control system. The value of the PWM signal varies from 0 to 255, which is a standard set up for servo control. The forward and aft servos are sent opposing values such that the squash plate is tilted properly. The lateral movement is sent just the one value as the other side of the squash plate is permanently affixed to the craft to prevent movement. This allows for a pivot point for the lateral movement of the squash plate, but reduces the range of movement. These specs lead the
craft to have faster and more controlled forward and backwards motion, with a slower
and less controlled side to side movement. The movements are coordinated using the
laptop base station which determines the position needed for each servo and sends the
appropriate signal to the PIC main controller.

The power system is composed of a Radio Shack 13.8 volt power supply capable of
providing 15 amps of continuous power. The power is is regulated to the PIC micro-
controllers using 7805 voltage regulators to step down the voltage to 5 volts. The DC
motors use the straight 13.8 volts of power from the power supply.

The Programming

Ryan Strauss and Duroseme Taylor

The programming implementation has changed in some respects. This
is because we decided not to have the aircraft transition into airplane
or horizontal mode, rather, it will stay fixed in the helicopter or
vertical mode. The overlying pseudo model of the
implementation has stayed the same and the language being used
(C++) is still the same. The base
station reads the joystick and sends
appropriate signals to the serial
port which is connected to the PIC
microcontroller. The way we decided to go about solving this problem, however, has
changed.

One aspect of the design that has changed is that the guidance software no longer
continuously loops to scan the
joystick port. Instead, it is now
event based, and a signal from
the joystick is only generated
when the pilot moves the
joystick. A separate C++ class
was created to implement this.
This class simply opens the
joystick port on the laptop and
checks to see whether or not an
action (i.e. joystick movement)
has occurred. When the joystick
is moved, the event generated is
interpreted in two ways: the axis
that is moved (i.e. left/right,
forward/back, etc.) and the strength of the signal (i.e. how much the joystick has moved in a certain direction).

The main program then converts this signal into a two digit hexadecimal value to be sent to the PIC. The advantage of using this format is that the servos have 16 different positions, and it is easier to use a hexadecimal representation to identify these positions. This two digit hexadecimal format is represented by a two element character array. We make this representation by creating 16 different intervals (one for each servo position). Each axis on the joystick goes from 32767 to +32767. For example, pushing the joystick completely to the left reads a value of 32767 and pushing it completely to the right reads a value of +32767. To make even intervals, we divide 32767 by 16, which is approximately equal to 2047. This calculation provides the range of each interval (servo position).

Therefore, the first interval will be from 1 to 2047; the next will be 2048 to 4094, etc. The first interval starts at 1 because a 0 means that no action has occurred on the joystick. The rest of the intervals can be calculated by adding 2047 to the highest value of the preceding interval. Each one of these intervals is represented by a hexadecimal value and the respective character array element is assigned according to the signal that is read from the joystick.

The program also reads the sign of the value from the joystick. The sign and axis number together represent a specific servo on the aircraft to be moved. The program reads this information and assigns the corresponding character array element. After this is done, the character array is ready to be sent to the PIC via the serial port. The corresponding signal is sent to the PIC main controller using serial RS232. The signal is sent in packets of 8 bits containing a start bit, a stop bit and the message. The message contains the address, position or speed of the servo/s to be moved.

The PIC is programmed to infinitely loop until it receives data from the laptop and stores this in a variable. The data is in two parts, as mentioned above; the first 4 bits or the first nibble (least significant nibble) contains the speed of the motor or the servo position where it will be moved. The second nibble (most significant nibble) contains the address of the servo to be changed. The PIC program then checks the variable to identify the device that needs to be changed and how that device needs to change. After the PIC determines which servos need to be moved, it sends the corresponding PWM signal that represents the speed or position to the address of the device that needs to be manipulated.
## Functionality Table

<table>
<thead>
<tr>
<th>Aspect</th>
<th>VERTIGO</th>
<th>VERTIGO $^{1.5}$</th>
<th>VERTIGO$^2$</th>
<th>ACTUAL</th>
<th>Delta/Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power source</td>
<td>On board packs of rechargeable lithium batteries</td>
<td>On board packs of rechargeable lithium batteries</td>
<td>Power drawn from wall outlet through tether</td>
<td>Power drawn from wall outlet through tether</td>
<td>Since horizontal flight is not possible, the plane will not be ‘traveling’ anywhere. As such, to reduce weight load on aircraft, batteries were removed, executive decision taken by VERTIGO$^2$ team. Aircraft will be powered through tether</td>
</tr>
<tr>
<td>Communications medium</td>
<td>Wireless transmission</td>
<td>Wireless transmission</td>
<td>Hardwired by tether (includes power and control communication)</td>
<td>Hardwired by tether (includes power and control communication)</td>
<td>Since aircraft is powered through tether and budget is tight, makes sense to send communications through tether as well. Executive decision made by VERTIGO$^2$ team</td>
</tr>
<tr>
<td>Onboard servos</td>
<td>We were controlling 10 to 12 servos with PWM</td>
<td>We were controlling 10 to 12 servos with PWM</td>
<td>We are controlling 6 servos to control the vertical flight</td>
<td>We are controlling 6 servos to control the vertical flight</td>
<td>Since plane is not able to fly in horizontal mode, associated</td>
</tr>
<tr>
<td>Rotor motors</td>
<td>We were using two direct PWM controlled brush-less DC motors (Hacker C50 15l)</td>
<td>We were using two direct PWM controlled brush-less DC motors (Hacker C50 15l)</td>
<td>We were using two direct PWM controlled brush-less DC motors (Hacker C50 15l)</td>
<td>Two smaller Radioshack 9-18V DC motors (18,000rpm max, 1.98A max)</td>
<td>Original motors are unusable without the proprietary motor controllers (‘misplaced’ by VERTIGO team), so for show purposed VERTIGO(^2) has decided to go with smaller motors to display servo control. Motors are too weak to lift airplane however. The new motors are controlled by tachometers in a closed loop PWM system</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Titling Mechanism</td>
<td>Transition from vertical to horizontal flight</td>
<td>Transition from vertical to horizontal flight</td>
<td>Vertical flight only</td>
<td>Vertical flight only</td>
<td>Former team lead wrongly assumed transition shaft was</td>
</tr>
</tbody>
</table>
easily fixable. In reality, major redesign of wing is required to make transition functional. Since time is at a premium, this feature was left out in favor of concentrating on vertical aspect of flight.

| Joystick Controls | No use of Joystick | No use of Joystick | Continuous Polling, numbers keep generating. When the joystick moves, the value changes to something other than zero. That value is sent to the PIC serially. | Event Based. A thread is running in the background listening in on the occurrence of joystick movement. If the joystick is moved, a value is generated and sent to the PIC serially. | More Efficient, less use of memory. |

**KEY:**
VERTIGO: 1\textsuperscript{st} year’s team
VERTIGO\textsuperscript{1,5}: 2\textsuperscript{nd} year’s team with Luke Alexander as team lead for AE and ECE
VERTIGO\textsuperscript{2}: 2\textsuperscript{nd} year’s team with Mimi Phan and Nikhil Nair as team leads on ECE and AE sides, respectively
Project Closure Activities

Mimi Phan

Currently, the VERTIGO² team has a working base station (joystick controls) and on-board control system (PIC microcontroller). The joystick controls have been programmed according to the control mappings indicated by the aerospace team. The PIC microcontroller has been built, and the necessary software has been implemented.

In preparation for the Senior Design Showcase, the team plans to work hard at integrating the base station with the on-board control system. In addition, the team will attempt to get the motor-controllers working on the plane. For display, the team plans to have a two table set-up with a round-table display for the VERTIGO aircraft. The team will have two display boards, one for each departmental team. The team also plans to exhibit the control system software especially the joystick controls and functionality. If the team successfully gets the plane moving, they plan to run live footage at the booth.

As for launch collateral, marketing brochures and a press release will be developed to promote the VERTIGO² project. The team plans to issue an article through Florida Tech’s Crimson newspaper. Marketing brochures will be given out at the trade show.

Bill of Materials

Mimi Phan

Since the team undergone new design objectives at the start of the spring semester, the bill of materials has reflected this change.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Quantity</th>
<th>Price</th>
<th>Vendors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Programmer/PIC Basic Pro</td>
<td>1</td>
<td>$230.00</td>
<td>melabs</td>
</tr>
<tr>
<td>HS 255 BB Servos</td>
<td>2</td>
<td>$41.98</td>
<td>Servo City</td>
</tr>
<tr>
<td>Logitech Extreme 3D Pro Joystick</td>
<td>1</td>
<td>$34.99</td>
<td>CompUSA</td>
</tr>
<tr>
<td>Capacitors</td>
<td>24</td>
<td>$6.30</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>PK42 6-32 RH Screws</td>
<td>1</td>
<td>$1.99</td>
<td>RadioShack</td>
</tr>
<tr>
<td>50ft KYNAR Red</td>
<td>1</td>
<td>$3.29</td>
<td>RadioShack</td>
</tr>
<tr>
<td>T220 Heatsink</td>
<td>2</td>
<td>$3.38</td>
<td>RadioShack</td>
</tr>
<tr>
<td>1C Perferated Board</td>
<td>1</td>
<td>$3.29</td>
<td>RadioShack</td>
</tr>
<tr>
<td>9-18V HI-SP Motors</td>
<td>2</td>
<td>$10.58</td>
<td>RadioShack</td>
</tr>
<tr>
<td>PIC 18F4431</td>
<td>1</td>
<td>$9.54</td>
<td>Microchip.com</td>
</tr>
<tr>
<td>13.8 V DC 15 AMP Power Supply</td>
<td>1</td>
<td>$79.99</td>
<td>RadioShack</td>
</tr>
<tr>
<td>TIP3055 Transistor</td>
<td>2</td>
<td>$3.58</td>
<td>RadioShack</td>
</tr>
<tr>
<td>8POS Dip Switch</td>
<td>1</td>
<td>$2.39</td>
<td>RadioShack</td>
</tr>
<tr>
<td>7805 5V Regulator</td>
<td>1</td>
<td>$1.59</td>
<td>RadioShack</td>
</tr>
<tr>
<td>TIP3055 Transistor</td>
<td>1</td>
<td>$1.79</td>
<td>RadioShack</td>
</tr>
<tr>
<td>PK2 3A 400K Diode</td>
<td>1</td>
<td>$1.59</td>
<td>RadioShack</td>
</tr>
<tr>
<td>20 MHz Crystal</td>
<td>6</td>
<td>$19.66</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>5V IC Regulator</td>
<td>2</td>
<td>$5.64</td>
<td>Digi-Key</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$454.64</strong></td>
<td></td>
</tr>
</tbody>
</table>
**Financial Status and Budgeted Hours**

Mimi Phan

Funding plays a major role in the success of the VERTIGO² project. Without proper funding, the team would not have the monetary resources to purchase the materials to complete the project. VERTIGO² was fortunate enough to be a dual-departmental team so it was able to receive $200 in funding from each of respective department. Earlier in the spring semester, the ECE team acquired an additional $500 in funding from the IEEE foundation.

The team encountered monetary Despite having some funding, some team members opted to purchase parts on their own expenses and getting reimbursed in the future. As of right now, the team has spent $454.64 on the project.

Another factor that played a major role in the success of the project is teamwork. Without the support and effort of a few individual team members, the project would have failed. From the numbers shown below, the hours performed by each team member seems very low. It was indeed lower than expected. Also, there were some occasions where a few team members didn’t submit activity reports. That also played a major role in the low work turnout.

The budgeted hours are based on 8 hours per week. As of right now, the total for budgeted hours is 184. This is based off of 23 weeks.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hours Worked</th>
<th>Hours Budgeted</th>
<th>Percentage Worked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mimi Phan</td>
<td>203.5</td>
<td>184</td>
<td>100.11%</td>
</tr>
<tr>
<td>Kevin Boyce</td>
<td>74.75</td>
<td>184</td>
<td>40.63%</td>
</tr>
<tr>
<td>Jeff Laub</td>
<td>23</td>
<td>184</td>
<td>12.5%</td>
</tr>
<tr>
<td>Prateek Mohan</td>
<td>70.5</td>
<td>184</td>
<td>38.32%</td>
</tr>
<tr>
<td>Ryan Strauss</td>
<td>73</td>
<td>184</td>
<td>39.67%</td>
</tr>
<tr>
<td>Durosome Taylor</td>
<td>28.5</td>
<td>184</td>
<td>15.49%</td>
</tr>
<tr>
<td>Calvin Turzillo</td>
<td>58</td>
<td>184</td>
<td>31.52%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>531.25</strong></td>
<td><strong>1288</strong></td>
<td><strong>39.75%</strong></td>
</tr>
</tbody>
</table>

Table 3: Hours Worked Vs. Hours Budgeted

**Feed-Forward**

Prateek Mohan and Nikhil Nair

VTOL (vertical take-off and landing) aircraft in general offer significant additional operational capabilities over regular aircraft. These capabilities stem, primarily, from a VTOL aircraft’s ability to take-off and land vertically. This eliminates the requirement of long prepared runways, thereby greatly widening the operational radius of such aircraft.
A tilt-rotor aircraft, in particular, combines traditional helicopter virtues (such as extreme maneuverability, ability to land almost anywhere) with that of conventional propeller-driven aircraft (high efficiency for low speed flight).

The VERTIGO2 prototype is classified as a standard tilt-rotor aircraft, following similar design objectives as the Bell V-22 Osprey. Mechanically, there are several features that can be added or designed into the VERTIGO2 prototype to keep the airframe on the forefront of technology and expand functionality.

Foremost is the need to design the control system for transition and forward flight. The current avionics suite deals exclusively with vertical flight and control and as a result is wired as opposed to being wireless. The avionics have been designed to allow for expansion to forward flight and wireless communication should later teams decide to take up the project. Concurrently, the mechanical transition system has to be redesigned to allow for smooth, unhindered movement between vertical and horizontal modes.

An entirely composite airframe would be a great leap forward from the current balsa wood/ply wood construction. A composite structure would most likely weigh less than the current airframe and also would have better flight characteristics (stiffer structure). Also, twisted prop-rotors are a necessity for efficient forward flight, and such blades would most likely have to be designed in-house since they are not commercially available.

On the avionics side, once full functionality has been realized (vertical, transition and horizontal flight modes), several features can be added on board to make VERTIGO2 a complete military or commercial flight platform. These would include, but are not limited to GPS tracking (integrated with the control system), on board cameras and other visual devices (such as infra-red cameras, night vision cameras, etc.). Integrating GPS into the avionics suite allows the pilot to accurately fly the aircraft to specified coordinates and map his/her progress along the way. GPS also serves as an excellent feedback mechanism as flight velocity, direction, altitude and such can be extracted from the navigation system.

For now, let us deal with military applications for VERTIGO2 since they are most apparent. If the aircraft were to retain its current dimensions, the platform would be most suited to surveillance missions. The ability to cover lots of ground while in horizontal mode, coupled with the ability to hover results in the ideal platform for intelligence gathering and other related missions. Currently on the forefront of avionics design is the ability to fly in flocks autonomously, much like geese do. This is similar to swarm intelligence, where individually each aircraft is ‘stupid’, but collectively the swarm is smart. Applied to a formation of VERTIGO2 aircraft, the designers could exploit aerodynamic characteristics to make long distance flight more efficient (riding other plane’s wing vortices), while quickly surveying/mapping the target area since the planes work together. No doubt the military is actively pursuing such technologies, we believe Dr. Deaton from the School of Aeronautics is currently involved with such a project for the Air Force.
The introduction of neural networks to image processing may one day result in a detections system smart enough to navigate itself through, say, a heavily wooded area. Such capabilities are, naturally, desirable for the military.

On a more benign note, the commercial market for such an aircraft and flight system is also large. Tilt-rotor aircraft are well suited to roles currently occupied by helicopters, such as air ambulances, short-range commuter services and such. The beauty of our flight system is that, unlike conventional helicopters, all the flight controls are naturally mapped to the joystick. Thus, in theory, the aircraft should be much simpler to fly, opening itself to markets previously closed due to the complex nature of the flight system.

In short, the resulting product value proposition is a control system that is supremely easy to learn, smart enough to fly itself most of the time and that can be retro-fitted to existing tilt-rotor aircraft. On the aerospace side, the pros are inherently apparent.

Lessons Learned and Feed-Back

Nikhil Nair and Prateek Mohan

a. Lessons Learned: Technical

The reason we took this project up was because it looked and sounded feasible. Started by the initial VERTIGO team, they were unable to meet all their design objectives for a number of reasons, some outside the scope of this report, others directly relevant to VERTIGO².

A handful of us decided to take this project up on the request of our former team lead Luke Alexander. He had us convinced that in order to run this project we required only an avionics system to be developed from ground up, which we were capable of building. He assured us that everything was fine on the mechanical and structural side and all minor malfunctions that existed would be fixed.

With time, the VERTIGO² project began to show major functionality issues such as being overweight, malfunctioning servos, flawed tilting mechanism, and unusable main-wing DC motors (several of these problems occur often in real-world aircraft development). These are critical system components required for the successful functioning of the VERTIGO² prototype. Initially, these components were presumed to be in pristine working condition as stated by former team lead Luke Alexander. Once a thorough analysis was done, however, it became apparent that the plane had various aspects that would retard the completion of the project. Solutions were found for some of the obstacles, others had to be sidestepped, and some obstacles required redesign or re-stating the team’s objectives.
This led to major design and objective changes, as stated in the Brief for Objective Changes. Our original objective was to vertically lift-off, transition to horizontal flight, transition back to vertical flight, and then land safely. Due to the faulty tilting mechanism, we were restricted to vertical flight unless a major structural redesign of the wing could be undertaken. Since time was at a premium, the team decided to limit the scope of the project to vertical flight, thereby avoiding a thorny issue while simultaneously increasing the chances of a successful design and development. Furthermore, the main motors that powered the rotors were found to be incompatible with existing control software. In short, the motors required expensive motor controllers that were purchased by the VERTIGO team last year. Sadly, these controllers went ‘missing’ during the turmoil at the end of the VERTIGO development process. Fortunately, the VERTIGO$^2$ team was able to repair or replace all the faulty servos on the airframe.

b. Lessons Learned: The Team

Several team characteristics, some good, some bad, have become apparent over the course of VERTIGO$^2$’s tenure.

The lack of dedicated software engineers on the team severely slowed the development of the avionics suite. Developing the necessary algorithms for servo control became a laborious process that greatly taxed the current team’s skills. As such, the team lacks the software skills needed to interface the software with the hardware. For future reference, FIT should emphasize the need to 1) Have ECE and CSE students work together since software and hardware are nothing without each other 2) Modify the existing ECE curriculum to strengthen software skills among the students.

An effort was made to outsource some of the programming to dedicated software engineers, but due to the time constraints, we were unable to find the right individuals. One might question the team’s reliance on software engineers but our objectives clearly state that this project requires the use of a joystick to control this plane. This, in turn, requires programming of the required hardware (joystick and the laptop), and interfacing one hardware device to a completely different hardware device, which as the team found out, can be quite the challenge. On the flip side, however, the team has computer engineers who know how to program and have made a valiant and thus far successful attempt to code all the required systems. So far, the CE programming team has accomplished 80% of the task. Our current status shows that while individual components are done, integrating into a complete system is proving to be troublesome. Still, the team is optimistic that we can have a working avionics suite in time for the Senior Design Showcase.

Aside from the lack of software engineers, the VERTIGO2 team has been well suited to the task at hand. Each of the team members knows what needs to be
done and how to best accomplish the task. This is evident in the progress we have made, the obstacles we have overcome and the general goodwill the team members have for each other. In short, the team has made up for whatever deficiencies were present by working harder and continually being motivated enough to see this project through.

c. Lessons Learned: Project Management

From the ECE side, project management plays a major role in the success of the project. Since the main VERTIGO² objective is to build a control system for an existing aircraft, scheduling and all other management-related tasks are key. In order to complete a working system in the limited amount of time, scheduling is essential. Without……..

From the aerospace side, project management has been more an oversight job. Credit goes to Mimi Phan for remarkable drive in pursuing deadlines on the ECE side, sometimes in the face of resistance from team members.

d. Lessons Learned: Schedule

Scheduling is one thing the team has been on top of, since the start of the project. The team’s only real scheduling mishap occurred when the former team leader Luke Alexander mysteriously quit the team without informing any of the members. A week and a half followed of chaos, but was promptly sorted out but the ECE and AE project leads.

The team truly believes that we are on the way to a successful realization of the VERTIGO² project objectives.

e. Lessons Learned: Business

Monetary considerations have been a key factor in our team, as is the case for most senior design projects. From the beginning, the team had some trouble gaining enough monetary resources to provide the team with the necessary materials required for the project. This may have been due to the fact that the previous team leader, Luke Alexander, was in charge of handling the team’s funding and sponsorships. A moderate lack of funding meant the team was forced to seek alternatives for some design aspects. While this may seem a negative comment, it forced the team to innovate and stretch every penny was far as possible (a holy grail of sorts in any engineering team). This included researching cheaper substitutes for higher priced items, and getting rid of unnecessary materials and design parameters.

Due to redesign and time constraints, some team members opted to purchase materials through personal funds and get reimbursement for them at a later date.
This left some team members with the major burden of having to use personal funds (even if not readily available) to maintain project progress.

One point on contention is the slow and cumbersome process by which the school reimburses senior design teams. True, accountability is necessary, and a myriad of paperwork forces accountability. Not reimbursing for tax on items purchased, however, is inexplicable and not in the best interests of the school or its students. Nevertheless, dealing with upper management (read ECE and AE departments) has been a valuable learning experience.
Appendix 1: Business Plan

Introduction/Project Overview

Nikhil Nair and Mimi Phan

The first phase of the VERTIGO project saw the analysis and design of the aircraft’s geometry, its aerodynamics, and its structural integrity. Problems with the initial design included a poorly designed tilting mechanism, center of mass location, and most importantly an undeveloped control system. The later design problem was simply due to time constraints as the original project was very ambitious in its design objectives. The emphasis of VERTIGO$^2$ is to design the electrical and control systems for the VERTIGO aircraft. The design objectives of VERTIGO$^2$ are as follows:

1. Continue development of control system but solely for vertical flight mode (hover)
2. Repair/modify airframe to flightworthiness
3. Integrate controls and airframe so that improvements can be made later and full functionality eventually realized
4. 

The objectives will ideally be met in two phases—design and testing. The designing objectives are naturally the most important and most consideration will be given to the control system.

The control system will be designed from the ground up by the ECE project team, which is being led by Mimi Phan. Initial concerns for the control and electrical systems will be centered around the type and size that the fundamental processing chip should be and to what limits and parameters the said chip will need to satisfy. In particular, the rotor assemblies of the aircraft each have three independent degrees of motion and it is possible to make each assembly independent of the other.

Product Specifications

Kevin Boyce
The VERTIGO\textsuperscript{2} communication system will be comprised of one radio frequency (RF) controller and one receiver. The initial plan is for this system to have approximately 16 channels from which to transmit the commands to the aircraft. In this design, the one RF controller will be able to control the aircraft in both vertical mode and in horizontal mode. This will be accomplished both on the circuitry side and on the controller side. Two separate circuits on the aircraft will control separate sets of servos used in each mode of flight while on the controller a simple switch will be used to switch the commands it sends to the microprocessors. This should allow the craft to be easily flown by one person. For testing purposes, the craft will initially be tethered using a series of wires so that the mode switching and processor communication can be tested before switching to a wireless system.

This project also encompasses sending non-control related data back to the user. This data includes digital still images, digital video, and GPS information. While all
these may not be in the final build, we must account for their possibility. A separate subsystem will have to be developed to send this data. Most likely it will be sent on a separate frequency than the controller, and also of a higher bandwidth. While using this method the range of the controller will outdo that of the acquired data, this will ensure proper transmission of both sets of data. A simple integration of an RF transmitter hooked to all of these components can accomplish this goal.

**Integration**

The assembly of the entire system is left to the Integration Specialists. This task will encompass the soldering, wiring, and routing of all the electrical components on the aircraft. Skill in all these areas will be required so that all the components will be reliable despite the possible abuse they may feel from the testing phases of the aircraft.

A few of the items the integration team will have to watch out for is external interference, durability, and organization. External interference can result from electrical fields generated by the motors and servos. If enough of a field is present it could interfere with the operation of the microprocessors. These electrical fields could also interfere in the communication between the controller and the aircraft. Durability must also be taken into account when building the aircraft. The craft will be subject to extreme vibrations and possible hard landings. To ensure that minimal repairs will be needed, a durable and reliable construction shall be implemented. Organization is also a key element of the integration phase. When routing wires and placing components, an organized pattern can help with trouble shooting later. Wires shall be bundled and labeled so that electrical routes can easily be tracked.

**Software Development**

Chris Fernando & Prateek Mohan

“Software runs the world”, and that’s exactly how it is for this project. Without software, the aircraft would simply be a big heap of metal.

As a result, some of the mechanical processes that are electronically controlled via software range from being as simple as starting up the engine to multi-step processes as complex as maintaining the aircraft’s heading and ensuring constant radio contact throughout the course of the flight.

With software, one can’t afford to be lax in development, since any bug in the code could cause the aircraft to malfunction and unexpectedly shut its engines down. It either has to be perfect or one should be ready to face imminent failure during flight-testing.

As with other components of the aircraft, software can only run according to the specifications if the hardware operates at its most efficient and optimum level. Therefore, it is imperative that adequate steps be taken to protect the hardware and its surrounding environment from undesirable forces, such as, water, heat, cold, detrimental light.
conditions and extreme atmospheric pressure. The benefits of protecting the hardware would be two-fold, since this way the software would be running as it should and the hardware would be cared for while it is tens of thousands of feet high, away from any human contact.

The programming languages that will be used for this project are C, C++, and Assembly (multiple processor families). C/C++ will be used for the ground base station, while Assembly will be used for on-board flight systems.

Circuitry

The entire on board system circuitry will be designed from scratch. The plan is to develop our own bread board, latch in all the chips (PICs, memory, registers, ports, etc.) needed and then making the necessary connections between these chips using an adequate amount of wiring and soldering.

The chips on every bread board that we develop will be wired using datasheets provided by the vendor of those chips, so we know which wire goes where. This is a crucial aspect for the plane to fly properly because a single bit of miss-wiring will lead to some sort of system failure or some minor failure, which might develop into a major problem. Hence, we will require time and total effort on part of the circuitry team who will have to re-check the wiring on board the plane at least twice or thrice for precautionary measures before flying it.

The above mentioned tasks apply to all control systems within the project, whether they are outside or inside the plane. The batteries from the previous VERTIGO team are currently undergoing tests to check whether they still hold an adequate amount of charge. If they do not, they cannot be re-charged. Most likely, these batteries are still rechargeable. However if not, new ones will need to be purchased. A significant amount of batteries will be needed for this project as they will be used in the ground controller unit and on the board of the VERTIGO plane itself.

Product Value Proposition

Nikhil Nair and Mimi Phan

Our delivered product will encompass a complete hovering control system for any tandem proprotor VTOL aircraft.

Customer Base

Duro Taylor

VERTIGO² has a wide range of customer base:
<table>
<thead>
<tr>
<th>Customer Type</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote control pilots &amp;</td>
<td>• simple setup and excellent documentation</td>
</tr>
<tr>
<td>Hobbyists</td>
<td>• learn how to fly an airplane/helicopter combination with a computer</td>
</tr>
<tr>
<td></td>
<td>• showing their friends their new gadget.</td>
</tr>
<tr>
<td>Security Agencies</td>
<td>• simple setup and excellent documentation</td>
</tr>
<tr>
<td>• Military</td>
<td>• mobility; that allows for Military and Security teams to perform surveillance of the front/enemy lines</td>
</tr>
<tr>
<td>• Department of</td>
<td>• The Police department and Homeland Security will use the system for public safety and surveillance of criminals or terrorist.</td>
</tr>
<tr>
<td>Homeland Security</td>
<td></td>
</tr>
<tr>
<td>• Police Department</td>
<td></td>
</tr>
<tr>
<td>Commercial industries</td>
<td>• simple setup and excellent documentation</td>
</tr>
<tr>
<td>• Power companies</td>
<td>• mobility that allows</td>
</tr>
<tr>
<td>• Hollywood</td>
<td>- Power companies to survey electrical systems that are normally out of reach of conventional ways, while also flying over power plants to check for pollution or damage.</td>
</tr>
<tr>
<td>• The Media</td>
<td>- Hollywood/Media companies a full range of different uses for the system such as capture high-speed chase scenes in movies or commercials while hovering in tight places that a conventional helicopter could not</td>
</tr>
</tbody>
</table>

**Competitive Analysis**

<table>
<thead>
<tr>
<th>Company</th>
<th>Strengths</th>
<th>Weaknesses</th>
<th>Opportunities</th>
<th>Threats</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Bell Helicopter V-22 Osprey</em></td>
<td>• Established 1960</td>
<td>• Expensive</td>
<td>• Produce a less expensive product</td>
<td>• Has contracts with the US government</td>
</tr>
<tr>
<td></td>
<td>• Subsidiary of Boeing and Textron Inc.</td>
<td>• Fatal crashes due to the “vortex ring”</td>
<td>• Research to fix the problem</td>
<td>• Have access to facilities, manpower and funds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Limited to defense applications</td>
<td>• Orient the product to civil applications</td>
<td>• Extensive research</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Working product</td>
</tr>
<tr>
<td><em>General Atomics Aeronautical</em></td>
<td>• Established in 1993</td>
<td>• Does not provide VTOL</td>
<td>• Modify product to add the VTOL</td>
<td>• Has a good stand on the market</td>
</tr>
<tr>
<td></td>
<td>• Affiliated to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Systems, Inc</strong></td>
<td>General Atomic Inc</td>
<td>• Expensive capability</td>
<td>• Lower cost capability</td>
<td>domestic and international availability of research, funds and expertise</td>
</tr>
<tr>
<td><strong>Century Helicopter</strong></td>
<td>• Simple Design</td>
<td>• Limited capability and functions regarding speed/payload and maneuver envelope</td>
<td>• Add more functions to improve the product’s capability</td>
<td>• Presence in the market and cater to both experts and novices</td>
</tr>
<tr>
<td><strong>Nascent Technology Corporation</strong></td>
<td>• Partnership with MIT</td>
<td>• Lack of engineering diversity and limited flight capabilities present in a plane</td>
<td>• Diversify team to generate more ideas and make product appealing by adding more flight capabilities</td>
<td>• Well established and funded, more experienced with aerospace technology</td>
</tr>
</tbody>
</table>

**Risk Analysis**

The following items have been identified as possible risks by the VERTIGO² project team. They have been labeled by risk type which is schedule, technical, financial, or marketing.

**Project Risk #1:**
Communication problems exist between VERTIGO² team members.

**Type:** Schedule (People)  **Probability:** Moderate  **Effect:** Tolerable

**Possible Solution:**
Arrangements between team members will need to be made. Management will use leadership to ensure that all members are aware of responsibilities. Contact information of every team member will be made available.
**Project Risk #2:**
Scheduling problems occur. Some items scheduled for completion may not meet their deadline which will cause delays.

*Type:* Schedule  *Probability:* High  *Effect:* Moderate

**Possible Solution:**
Management will need to constantly monitor the process of scheduled tasks, ensure that scheduled action items are met on time. When items need to be worked on, the engineers should be aware of their responsibilities and work accordingly.

**Project Risk #3:**
Some items may have been missed or overlooked during scheduling. Frequent revisions to the schedule will cause major backup during the development of the controller.

*Type:* Schedule  *Probability:* Moderate  *Effect:* Moderate

**Possible Solution:**
Scheduling delays or changes are common problems when dealing with projects or working in the real world. A solution could be having the schedule thoroughly planned in the beginning of project stage to prevent frequent changes. Management and other authorized individuals should ensure that all items are known before the development of the controller. If there are changes made to the schedule, commitment and hard work from all team members should solve the problem.

**Product Risk #1:**
The team has issues getting certain aspects of the controller working whether it is communication of controller with the system or interfacing the electronic system with the airplane.

*Type:* Technical  *Probability:* Moderate  *Effect:* Catastrophic

**Possible Solution:**
Seven members consisting of Computer Engineers and Electrical Engineers are sufficient enough to solve any technical problems that may occur. With each person’s knowledge and experience combined, the team should not have any difficulty with the project. If a solution isn’t found, the team will refer to outside resources such as books/references or even professionals in this specific field.

**Product Risk #2:**
Poor testing can cause major problems. The lack of testing of the VERTIGO electrical system could allow for bugs to go unnoticed.

*Type:* Technical  *Probability:* Moderate  *Effect:* Serious

**Possible Solution:**
Extensive testing must be done. A detailed testing procedure can be written ahead of time to ensure all aspects of the temperature and pressure control system has been reviewed.
Business Risk #1:
A problem could result from lack of resources. Additional and necessary hardware or other resources needed for building the electronic system are not easily obtainable due to low finances or difficulty in finding area retailers who carry the items.

Type: Financial (Tools)  Probability: Low  Effect: Tolerable

Possible Solution:
The team will need to look into getting more funding so the resources can become available. There should not have a problem in finding the resources necessary for the completion of controller. If the team can’t find something, they can dedicate an hour or two to going to a wholesale place in Melbourne. This wholesale store carries items such as resistors to capacitors, second-hand motors, wires, and etc. The great thing is that it is fairly inexpensive.

Business Risk #2:
The team has difficulty finding project sponsors.

Type: Marketing  Probability: Moderate  Effect: Tolerable

Possible Solution:
The VERTIGO² team members will need to plan on marketing their project early on in the fall semester. The project CEO will be working with the school’s financial advisor to gain sponsors and additional funding.

Out-of-Bounds Criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Situation</th>
<th>Project Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.  Plane Crash</td>
<td>The prototype happens to crash during testing, or sustains damages during any other situation.</td>
<td>Due to lack of time, materials, human resources, we might not be able to repair damages.</td>
</tr>
<tr>
<td>2.  Lack of Funding/Sponsorship</td>
<td>We are not able to get any sponsorship, or any other kind of monetary assistance.</td>
<td>Without funding, we would not be able to obtain materials to complete project.</td>
</tr>
<tr>
<td>3.  Integration</td>
<td>Integrating the controller and the aircraft</td>
<td>Would not be able to meet our target completion date</td>
</tr>
<tr>
<td>4.  Lag in processing data due to microprocessor</td>
<td>The microprocessor may take too much time in receiving data or processing data once it is received causing a delay in response.</td>
<td>If problem cannot be fixed, it will cause the controls on the plane to be clumsy.</td>
</tr>
<tr>
<td>5.  Burned/overheated microprocessors on circuit</td>
<td>Due to heat caused by plane or incorrect voltages on the circuit, the microprocessors may fail.</td>
<td>Alterations will have to be made to the plane to keep the chips cooler, and burned parts must be replaced.</td>
</tr>
</tbody>
</table>
6. Loss of transmission
Due to noise in transmission, parts of signal may be lost.
If not compensated for, the plane may respond to noise as commands or not receive commands that are sent.

Budget

Mimi Phan

Since the VERTIGO project is in the second year, parts of the project have already been completed. The aircraft has already been built, and only needs a few minor repairs. The main focus of the project this year is to produce a control system that will be able to move the aircraft.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>High End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontrollers</td>
<td>10</td>
<td>$400.00</td>
</tr>
<tr>
<td>Data Transceivers</td>
<td>1</td>
<td>$125.00</td>
</tr>
<tr>
<td>Video Transceiver</td>
<td>1</td>
<td>$200.00</td>
</tr>
<tr>
<td>Joystick</td>
<td>1</td>
<td>$100.00</td>
</tr>
<tr>
<td>Microcomputer</td>
<td>1</td>
<td>$400.00</td>
</tr>
<tr>
<td>ECE Miscellaneous</td>
<td>1</td>
<td>$200.00</td>
</tr>
<tr>
<td>Servos</td>
<td>4</td>
<td>$200.00</td>
</tr>
<tr>
<td>Software</td>
<td>2</td>
<td>$250.00</td>
</tr>
<tr>
<td>MAE Miscellaneous</td>
<td>1</td>
<td>$150.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$2025.00</strong></td>
</tr>
</tbody>
</table>

Table 3: Budget breakdown

Since this is a multi-departmental project, we are able to get a little more money than the usual ECE only teams. After combining the funds of the AE and ECE teams, we are guaranteed $500. The team will need to do extensive fund-raising to complete the project. The VERTIGO² project leader, Luke Alexander, will be managing the team’s budget. He is in the process of obtaining more funds and possible sponsors. The team hopes to gain approximately $3000 for the project.

Schedule

Mimi Phan

The VERTIGO² team was created recently. Unlike other project teams that were formed in junior design, we did not have the extra semester to plan, gain funds, or work on preliminary documents. The team will spend most of the fall semester working on brainstorming the specifications for the control system, gaining more funding, and completing required documentation. The spring semester will be devoted to building the control system, integrating the control system with the aircraft, testing, and completing final documentation. Luke Alexander and Mimi Phan will be working together to form a schedule for the project.
Team Capabilities/Responsibilities

Luke Alexander is the CEO (Chief Executive Officer) of the VERTIGO² team. Luke has already earned his bachelor degree in Mechanical Engineering, and is currently planning to earn his bachelors in Aerospace Engineering. He has expertise in flight mechanics, stability, and control. He was the Structural Analyst from the original VERTIGO team. With his knowledge and experience from working on the project the previous year, Luke is ideal for the position of lead for the team.

Mimi Phan, ECE Coordinator, is a senior majoring in Computer Engineering. She will be leading the ECE project group in design of the control system. She will be acting as a Programming Specialist as well as substitute Webmaster. She’s had previous experience doing aero research at an Acoustics Research Laboratory. She has a couple of years of experience with writing technical documentation such as user manuals for new software and root cause analysis (analysis documents on problem software). At Florida Tech, she has taken classes like Computer Design and Microcomputer Systems where you build or program boards in assembly to classes like Software Hardware Design/Integration to Network Programming where you program in C++. She also knows XHTML, Javascript, and Photoshop for web development.

Kevin Boyce is a senior majoring in Electrical Engineering. He is VERTIGO² Circuitry Specialist. He has knowledge in circuit design and implementation including having built the Intel 8031 micro-controller. He knows how to build and test circuits. He has experience with programming in C++ and assembly. With his knowledge in circuits, he will be an asset to the team.

Ryan Strauss is a senior majoring in Computer Engineering. He has three positions. He will be working as one of our Circuitry Specialist as well as a Programming Specialist. He will also help with the team’s website. He has knowledge in circuit design and theory. He’s also programmed in C++, assembly, XHTML, XML, and XSL. Ryan will be using his knowledge/skills to assist the team in all aspects of the project.

Tebo Leburu, a senior majoring in Computer Engineering, is one of our Circuit Specialists. She has knowledge in circuit design and implementation including having built the Intel 8031 micro-controller. He has experience with programming in C++ and assembly.

Duro Taylor, another Computer Engineering major, is one of the Programming Specialists. She has experience programming in C++ and assembly as well as doing HTML. She also works on circuit boards in class and during her free time. Duro will be using her knowledge in programming as part of the VERTIGO² team’s programming group.

Prateek Mohan is a senior in Computer Engineering. He also holds three positions in the team. He is working as one of our Circuit Specialist and Programming Specialist. He
will also be working on the team website. Prateek has knowledge in circuit design and implementation including having built the Intel 8031 micro-controller. He has experience with programming in C++ and assembly. He also specializes in PHP and XHTML for web development. Prateek will be using his skills to assist the team in all aspects of the project.

Calvin Turzillo is a senior majoring in Electrical Engineering. He is the Communications Specialist as well as a Circuit Specialist. He has experience in soldering, integration of various types of systems, and RF. With his extensive knowledge in circuitry/communication systems, he will play a major role in the team.

Jeff Laub is an Electrical Engineering major. He is one of the teams Communications Specialists. He has programming experience in C++, assembly, and HTML. He also has knowledge of circuit design including the Intel 8031 microcontroller. He’s also good at soldering.

Chris Fernando is a graduate student majoring in Software Engineering. He has a wide variety of programming experience. He knows how to programming in C/C++, Java, XML, PHP, CSS, and assembly. He will be an asset to the team as well as being of great assistance to the programming team.

**Team Members and Organizational Chart**

VERTIGO² Team Organization

VERTIGO² Project Manager
Luke Alexander

ECE Coordinator
Mimi Phan

Circuitry Group

Programming Group

Communications Group

Web Group

Mimi Phan
The circuitry group will be involved with the electrical design of the controller. They will work with the programming group to make a controller that will have the capability of communicating with the VERTIGO² prototype.

The communications group will be involved with integrating video/sound components with the VERTIGO² prototype/aircraft.
The Web group will work on all aspects of the VERTIGO² website such as layout design, releasing the latest information, and uploading current team documentation.

VERTIGO² Web Team Organization

The programming group will be involved with the creating code that will have the microcontroller communicating with the aircraft.

REFERENCES
Objectives Brief

The original objectives of the VERTIGO project were to:

- Design, manufacture and successfully test a VTOL (Vertical Take Off and Landing) aircraft similar in design the V-22 Osprey.
- Design and develop and working control system to control flight in vertical and horizontal mode.
- Communications between base station and aircraft done wirelessly.

At the end of the first year’s project, the team was in possession of an airframe (with all associated mechanical control systems, such as servos, etc) and several components of a non-integrated electrical control system. When the project was passed on the VERTIGO² team, however circumstance dictated several changes in the objectives. The new objectives are:

- Continue development of control system but solely for vertical flight mode (hover)
- Repair/modify airframe to flightworthiness
- Integrate controls and airframe so that improvements can be made later and full functionality eventually realized

The primary change is from developing a fully functional VTOL aircraft to one with hover/vertical flight capability only. This was necessitated by poor design and construction by the initial VERTIGO team.

The use of straight blade prop-rotors on each of the outboard cyclic mechanisms has inherent aerodynamic inefficiencies at high speed. As the velocity of the airflow through the prop disc increases, the effective angle of attack of the rotor blades decreases. This is due to the linear velocity of the blades being significantly smaller near the hub than at the tips. The result is that at higher velocities, the center portion of the rotors actually produced negative thrust and can stall. Thus while at low speed the prop-rotors might develop sufficient thrust, as the aircraft builds speed, the prop-rotors will become more and more inefficient and eventually stall. This is the reason that the prop-rotors on the V-22 Osprey are twisted (as are all aircraft propellers). Since twisted helicopter blades are not available commercially, a straight bladed design was the only alternative even though forward flight capability was severely compromised.
Figure 1: Tilt mechanism in vertical and horizontal position showing armature conflict with upper wing surface

Upon completion of the airframe by last year’s VERTIGO team, it became apparent that the tilting mechanism for the twin prop-rotors had a major flaw. This involved an armature on the tilt shaft that connected said shaft to the servos. When transition of the prop-rotors to the horizontal position was attempted, it resulted in the armature hitting the upper side of the inside of the wing (see figure 1 above). Since the structure was already designed, the VERTIGO team decided to proceed regardless by fixing the tilt shaft in place with a brace. This locks the rotors in the vertical position. When the project was passed onto the VERTIGO² team, this problem was not known. However, when we eventually did become aware of the problem, Dr. Sepri (Aerospace Team Advisor) counseled against modifying the mechanism since it would require a total redesign of the wing (since the tilt shaft was welded into place on either side and time was at a premium). This problem should have been addressed earlier, but the then the former team leader of VERTIGO² overruled recommendations by the team. As such, the current aircraft cannot transition from vertical to horizontal mode because of design flaws that themselves cannot be corrected without significant redesign.

However, the fact that the rotors are locked in the vertical position does present the VERTIGO² team with several options. Now, the team is free to concentrate on the vertical flight mode which is the main issue of contention with the V-22 Osprey (due to aerodynamic flight characteristics such as Vertical Ring State aka settling with power). The control system that is being developed by the ECE team will only address the vertical mode but will be expandable to full functionality later should the airframe be redesigned.

Since the aircraft will only hover in vertical mode, the communications were changed from wireless to tethered since this would greatly reduce the complexity of the control systems, reduce stress on our already tight budget and allow us to concentrate on how the aircraft handles with the designed control system as opposed to wireless protocols and other such electrical/electronic issues.
The VERTIGO² team sincerely believes that our current path is more suited to the project than the previous objectives. To deliver such a complex system in such a short time is asking for irreversible design flaws to present themselves. We believe in order to successfully design such an aircraft that only certain aspects should be addressed at certain times (i.e. limit the scope for each year’s team). For this team, those aspects will be flightworthiness in vertical mode with a tether.

Continuing teams can then use existing software/hardware and continue work on other aspects of the project including new tilting design and changes to the software aspect of control system to accommodate the tilting feature.

Therefore, the “Product Value Proposition” of the team is:

Our delivered product will encompass a hovering control system for any tandem prop-rotor VTOL aircraft.
Appendix 2: Current Product Specification

The Circuitry:

The hardware functionality of Vertigo² is aimed towards one main aspect of flight, the vertical take off and landing. To achieve this, three main systems must be considered: rotor rotational speed, rotor pitch control, and power systems.

The rotor rotational speed is controlled by the PIC based main control system. This system feeds a PWM (Pulse Width Modulated) signal to another PIC which in turn acts as an independent feedback system. There are two sets of these rotor rotational speed PIC, henceforth know as Rotational Controllers. The rotational controllers interpret the PWM signal received from the main controller and modify the rotational speed of the rotors accordingly. Also connected to the rotational controllers are tachometers. These tachometers measure the rotational speed of the rotors and report that information to the PIC as a varied voltage between 0 and 5 volts. Using a basic error controlled feedback algorithm, the desired and actual rotational speeds are compared and the error is fed back into the system to correct for the difference. This insures a constant and predictable rotor speed so that maximum lift can be achieved.

The rotor pitch control is composed of six servos, three on each rotor of the aircraft. Since the forward and aft pitch of the rotors is more difficult to control than the lateral movement, two servos are used for increased torque on the squash plate. One servo is then used to control the lateral movement of the squash plate. The squash plate has linkage to the rotor blades which allow the angle of attack to be altered in order to achieve greater or less lift while varying the associated drag. These servos are controlled by a PWM signal generated by the main control system. The value of the PWM signal varies from 0 to 255, which is a standard set up for servo control. The forward and aft servos are sent opposing values such that the squash plate is tilted properly. The lateral movement is sent just the one value as the other side of the squash plate is permanently affixed to the craft to prevent movement. This allows for a pivot point for the lateral movement of the squash plate, but reduces the range of movement. These specs lead the craft to have faster and more controlled forward and backwards motion, with a slower and less controlled side to side movement. The movements are coordinated using the laptop base station which determines the position needed for each servo and sends the appropriate signal to the PIC main controller.

The power system is composed of a Radio Shack 13.8 volt power supply capable of providing 15 amps of continuous power. The power is is regulated to the PIC microcontrollers using 7805 voltage regulators to step down the voltage to 5 volts. The DC motors use the straight 13.8 volts of power from the power supply.

The Programming

Ryan Strauss and Durosome Taylor
The programming implementation has changed in some respects. This is because we decided not to have the aircraft transition into airplane or horizontal mode, rather, it will stay fixed in the helicopter or vertical mode. The overlying pseudo model of the implementation has stayed the same and the language being used (C++) is still the same. The base station reads the joystick and sends appropriate signals to the serial port which is connected to the PIC microcontroller. The way we decided to go about solving this problem, however, has changed.

One aspect of the design that has changed is that the guidance software no longer continuously loops to scan the joystick port. Instead, it is now event based, and a signal from the joystick is only generated when the pilot moves the joystick. A separate C++ class was created to implement this. This class simply opens the joystick port on the laptop and checks to see whether or not an action (i.e. joystick movement) has occurred. When the joystick is moved, the event generated is interpreted in two ways: the axis that is moved (i.e. left/right, forward/back, etc.) and the strength of the signal (i.e. how much the joystick has moved in a certain direction).

The main program then converts this signal into a two digit hexadecimal value to be sent to the PIC. The advantage of using this format is that the servos have 16 different positions, and it is easier to use a hexadecimal representation to identify these positions.

This two digit hexadecimal format is represented by a two element character array. We make this representation by creating 16 different intervals (one for each servo position). Each axis on the joystick goes from 32767 to +32767. For example, pushing the joystick completely to the left reads a value of 32767 and pushing it completely to the right reads a value of +32767. To make even intervals, we divide 3276710 by 16, which is approximately equal to 2047. This calculation provides the range of each interval (servo position). Therefore, the first interval will be from 1 to 2047; the next will be 2048 to 4094, etc. The first interval starts at 1 because a 0 means that no action has occurred on the joystick. The rest of the intervals can be calculated by adding 2047 to the highest value of the preceding interval. Each one of these intervals is represented by a hexadecimal value and the respective character array element is assigned according to the signal that is read from the joystick.

The program also reads the sign of the value from the joystick. The sign and axis number together represent a specific servo on the aircraft to be moved. The program reads this information and assigns the corresponding character array element. After this is done, the character array is ready to be sent to the PIC via the serial port. The corresponding signal is sent to the PIC main controller using serial RS232. The signal is sent in packets of 8 bits containing a start bit, a stop bit and the message. The message contains the address, position or speed of the servo/s to be moved.

The PIC is programmed to infinitely loop until it receives data from the laptop and stores this in a variable. The data is in two parts, as mentioned above; the first 4 bits or the first nibble (least significant nibble) contains the speed of the motor or the servo position where it will be moved. The second nibble (most significant nibble) contains the address of the servo to be changed. The PIC program then checks the variable to identify the
device that needs to be changed and how that device needs to change. After the PIC
determines which servos need to be moved, it sends the corresponding PWM signal that
represents the speed or position to the address of the device that needs to be manipulated.

<table>
<thead>
<tr>
<th>Product Device</th>
<th>Specification</th>
<th>Details</th>
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<td>PWM Signals</td>
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<tr>
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Table 1: The Microprocessor
Appendix 3: Current Gantt Chart