Mississippi State University Unmanned Aerial Vehicle Entry into the AUVSI 2004 Student UAV Competition

Ian Broussard *Cornelia Hayes*
Kelly Lancaster *Craig Ross*
Blake Sanders

Mississippi State University

Abstract

The Mississippi State University Unmanned Aerial Vehicle (UAV) Team has constructed an unmanned aerial vehicle, SpyHawk that will be competing in the Association of Unmanned Vehicle Systems International (AUVSI) 2004 Student UAV competition. The vehicle consists of a large-scale airplane that contains a navigational and imaging system. The vehicle communicates with a ground base station that receives navigational and image data from the plane while it is in flight. The team's goal is to demonstrate autonomous flight, navigation, and image processing given a specific set of waypoints. This document summarizes the competition requirements, team objectives, and design specifications.

1.0 Mission Requirements

The 2004 Student UAV Competition was created by AUVSI to challenge undergraduate engineering students to create an autonomous UAV, given various targets and altitude constraints. This year's competition is divided into two key missions. The first mission requires the vehicle to travel to a target location via GPS coordinates and take various high-resolution pictures of a single target at the specified location. The objective of the first mission is to measure the accuracy of the UAV. The second mission requires the UAV to travel to a target area using GPS coordinates. This target will be a 300-foot by 200-foot area that will contain multiple unspecified military targets. The task is to capture the targets in an image format that will allow the operator to determine precise location and orientation of the targets. Mission parameters include operating within a 30-minute time limit, performing a controlled take-off, and maintaining autonomous flight for the remainder of the mission. In addition to the parameters stated, the UAV must make use of the MicroPilot 2028G for success of the mission.

2.0 Design Overview

The SpyHawk UAV is intended to be a low weight and low maintenance vehicle that can perform the mission requirements. To achieve the low weight and low maintenance criteria, the SpyHawk Team utilizes commercial off-the-shelf (COTS) components. In addition, these COTS parts minimize a possible single point failure. The aircraft is assembled from a purchased kit, and then modified to accommodate the navigation and imaging system. A PC-104 computer system is used to interact with both the imaging and the navigational system. The PC-104 is chosen for its fast processing capabilities, compact size, and power efficiency. The main component of the navigational system is the MicroPilot 2028G. The MicroPilot provides autonomous flight and GPS data analysis. The MicroPilot sends the GPS data to the PC-104. The PC-104 then sends this data to the base station via the wireless modem. The main component of the imaging system is the Nikon Coolpix 800 digital camera. This camera is chosen for its digital zoom feature and for its capability to be controlled by software. The PC-104 is used to send the command to the camera to take a picture at the required waypoints provided by the MicroPilot. The PC-104 then sends the image to the base station via the wireless modem. The wireless modem is the MHX 910. This modem is a powerful, long-range modem that can quickly transmit data up to 19 miles, which is well beyond the transmission distance required for this mission. However, the excess transmission distance will help restore system communication in the event of short-term interference or loss of signal. Its own individual battery powers each component. This power strategy is crucial in that it prevents a total shut down from occurring in the system in the event that a component loses power. Each of these components composes a system that can adapt to changes and be easily upgraded.

3.0 Aircraft

3.1 Body

While searching for a suitable airplane, the team determined the following features as the main search criteria:

- High wing aircraft for stability
- Maximum weight of 20 lbs
- Lift-Drag ratio
- Useful load
- Fuel consumption

After reviewing several possible candidates, the team narrowed the selection down to the following three airplanes: the Top Flite 1/5 scale Cessna 182, the ¼ scale Piper Cub, and the Senior Telemaster. For the given mission, the team decided that the Senior Telemaster would be best suited to meet the mission requirements. The Senior Telemaster is chosen because its ease of fabrication, large wing area, stability, and docile handling qualities. Minor modifications to the fuselage are applied to the fuselage to accommodate the UAV systems. The Senior Telemaster is shown in Figure 1:

Figure 1: Senior Telemaster

The Senior Telemaster has the following specifications:

Wingspan	95 in
Wing Area	1330 sq in
Wing Loading	0.01278 lb per sq in
Aspect Ratio	6.7857
Airfoil	Clark-Y
Weight – loaded	17 lbs
Engine	OS 91
Propeller	13 x 6
Length	63 in
Number of Servos	5
Radio	Futaba 9CA

Table 1: Aircraft Specifications

3.2 Engine

An OS 91 glow plug motor as shown in Figure 2 powers the SpyHawk UAV:

Figure 2: OS 91 Engine

This particular motor has the following specifications:

- 2000 – 16,000 rpm
- Output of 2.8 bhp @ 15,000 rpm
- Weight of 19.3 oz
- 0.912 cu in capacity

3.3 Transmitter, Receiver, Servos

Figures 3, 4, and 5 show the transmitter, receiver and servos used for the aircraft.

Figure 3

Figure 4

Figure 5

The transmitter is the Futaba 9CA transmitter. This is an 9-channel PCM transmitter that is fail-safe configurable. The receiver built into the SpyHawk UAV is a Futaba R138DP with the following specifications:

- 8 channels
- 72Mhz band
- Operating voltage range of 3.5-6.0V
- 6000+ ft. range
- Weight of 1.75oz.

The SpyHawk UAV uses 5 HiTEC HS-322HD servos. These servos each operate within a 4.8-6.0 voltage range and each weigh 1.52 oz.

4.0 Computing and Communication System

4.1 PC-104

Figures 6 and 7 below show the PC-104 computer system.

Figure 6: PC-104 (Top)

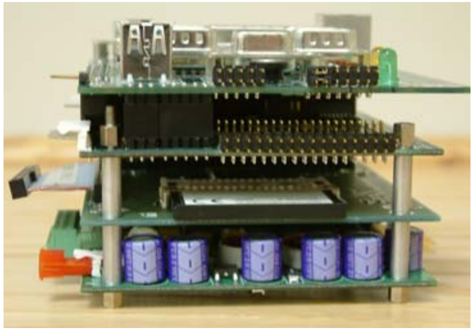

Figure 7: PC-104 (Side)

The main computing system of the SpyHawk is the PC-104. The PC-104 is chosen because of the following features:

- Powerful processing capability
- Power efficiency
- Solid state components

The PC-104 consists of four individual boards that are stacked on top of each other to form a working system.

The first board on the system is the panel I/O board that consists of 2 USB ports, 4 COM ports, 1 LPT1 port, 1 VGA port, mouse port, and keyboard port. This board allows the system to be connected to a standard VGA monitor for programming and configuring. The serial communication ports allow for the RS-232 devices such as the camera, the modem, and the MicroPilot to all be connected to a central computing system.

The second board on the system is the CPU board. This board consists of a 486-DX2 processor that runs at 100Mhz.

The third board is the compact flash and IDE adaptor board. This board contains a SanDisk 2.0Gb CompactFlash Type I card for image file storage. The flash card has two helpful advantages over a hard disk drive. The first advantage is that there are no moving parts on the flash card to malfunction during flight. The second advantage is that the flash card is very compact and lightweight.

The fourth board on the system is the power supply board. This board can accept a DC voltage source in that ranges from 7-30VDC. The board can output 5V at a maximum of 10A or 12V at a maximum of 2A. This power supply board is very efficient and can be powered using a universal 16VDC Laptop battery.

4.2 Wireless Modem

Figure 8 below shows the MHX-910 wireless modem:

Figure 8: MHX-910 Wireless Modem

The PC-104 uses this modem to transmit its data from the plane to the base station. The transmitter connects to the PC-104 via a COM port, while the receiver is connected to the base station computer. This particular modem operates within a frequency range of 902-928Mhz and has a maximum data range of 19 miles. It can transmit at a data rate of 115.2kbps. The operating voltage is 12VDC.

5.0 Navigational and Imaging System

5.1 MicroPilot 2028G

Figure 9 below shows the MicroPilot 2028G:

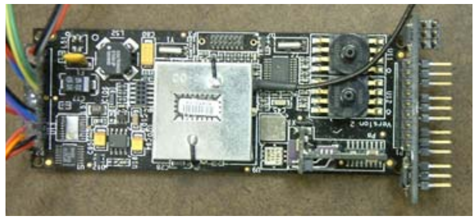

Figure 9: MicroPilot 2028G

The MircroPilot 2028G is a miniature autopilot. The autopilot uses 3-axis rate gyros and 3-axis accelerometers and GPS data for autonomous flight. A standard GPS antenna is mounted on the upper surface of the plane. The MicroPilot 2028G utilizes an ultrasonic Above Ground Level (AGL) sensor that measures the altitude of the airplane below 15 feet. This AGL sensor is used to allow the MicroPilot to perform automated landings. The autopilot guides the airplane by utilizing GPS coordinates entered in the airplane before flight.

The SpyHawk Team enters the waypoints into the PC-104 prior to takeoff. The PC-104 then transfers the coordinates to the MicroPilot. While the plane is in flight, the MicroPilot navigates toward the specified waypoints as it continually sends data to the PC-104. The PC-104 then sends the data to the base station via the wireless modem.

5.2 Camera

The first step in developing the imaging system was to determine which form of media the UAV will capture the targets with. The Nikon Coolpix800 35mm digital camera is chosen to convey high-resolution pictures of multiple targets. Because of limited time and modem speed, a digital camera is chosen instead of a video camera because still photographs do not require as much bandwidth and processing time as real time video transmission. This camera also has a digital zoom feature. This feature is useful in that there is no telescopic lens to extend outside the plain. This feature allowed the camera lens to be inside the plane for protection.

5.3 Power

As a factor of safety, the SpyHawk team proposes to use individual batteries for each component of the system. A 16-volt universal laptop battery is used to power the PC-104, a 12-volt 2.2Ah battery is used to power the MHX-910 modem, and a 6-volt 1.3Ah battery is used to power the MicroPilot 2028G and the AGL sensor. Since the camera is a stock Nikon Coolpix800, four AA batteries can power the camera.

5.4 System Integration

The PC-104 is the central control unit of the SpyHawk UAV System. All aircraft onboard systems integrate with the PC-104. The navigation waypoints are entered into the PC-104 and from there are transferred to the MicroPilot for autonomous flight. At the specified waypoints, the PC-104 instructs the camera to take a number of pictures. The PC-104 then uses the radio modem to transmit the pictures back to the ground station for interpretation. A hardware schematic of the system is shown in Figure 10.

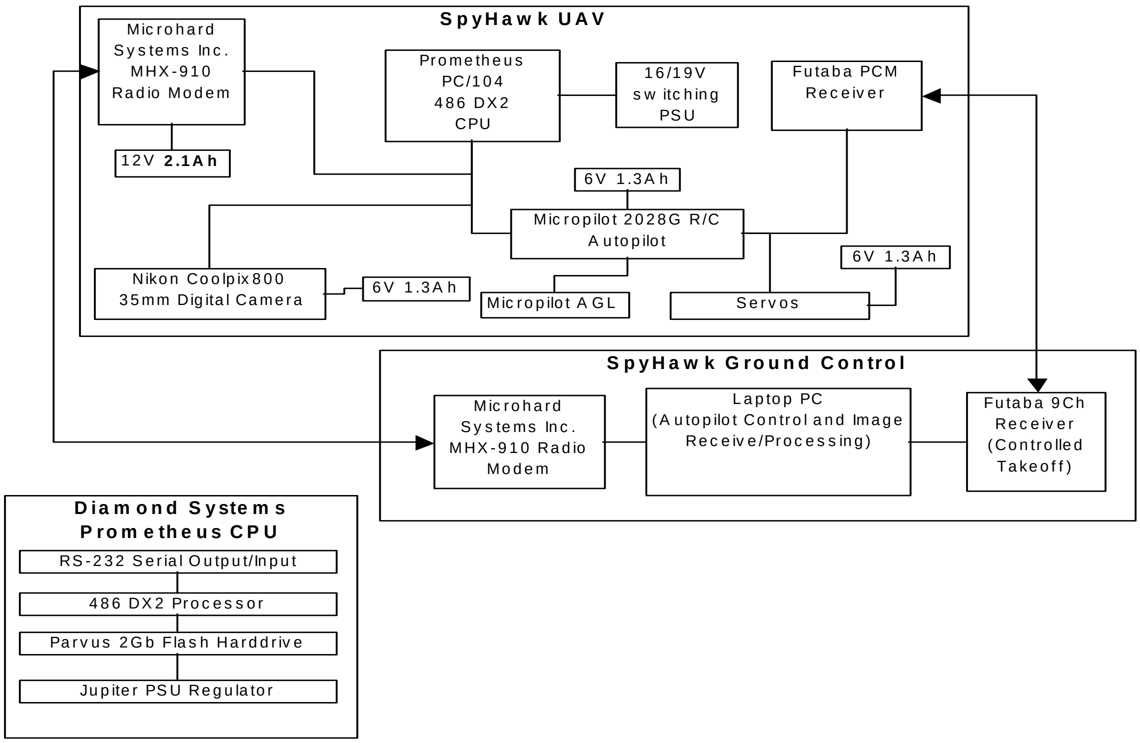

Figure 10: Hardware Schematic

6.0 Software

6.1 Overview

Software for the SpyHawk UAV ties together four hardware components: the MicroPilot, camera, radio modem, and PC-104. Using the PC-104 as the coordinating element, the software regulates communication among the components over serial interfaces. Figure 11 below shows the flow of information among the software processes. The processes are:

- A controlling program which reads data from the MicroPilot 2028G and determines whether the airplane has reached a target
- PhotoPC, an open source project to control digital cameras
- A third program utilizes PhotoPC to control when pictures are taken and how they are transferred to disk
- A fourth program which combines GPS data and image data into one stream to be sent over the modem

SpyHawk Ground Control has one custom-built program which receives data from the radio modem and separates out the GPS data from the image data. Also running on the ground station are National Instruments Vision Assistant, a utility written for National Instruments LabView, and the MicroPilot MP2000 GCS software.

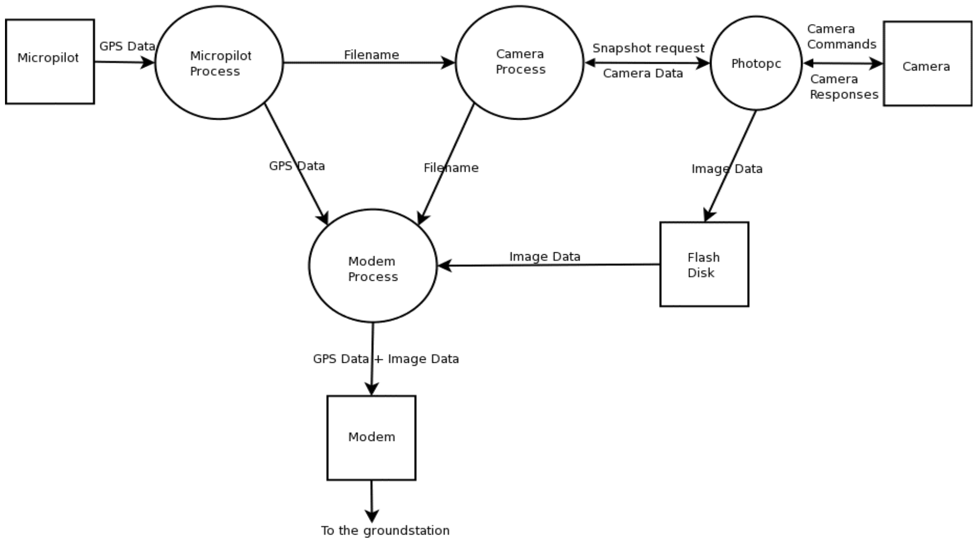

Figure 11: Software Schematic

6.2 MicroPilot Process

The process that interfaces with the MicroPilot constantly reads GPS data from it to determine whether the UAV is passing a target. If so, it signals the camera process that a snapshot is needed. Regardless, it sends the GPS data to the modem. Figure 12 outlines the operation of the process.

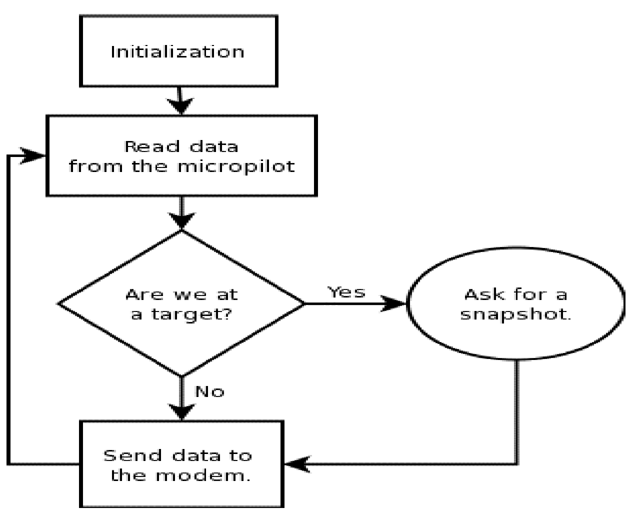

Figure 12: MicroPilot Process Operation

6.3 PhotoPC

Eugene G. Crosser developed PhotoPC for controlling digital cameras, specifically the Epson PhotoPC 500, over a serial line. The source code for the program is free to use and distribute for any purpose. It can be found at http://photopc.sourceforge.net/.

6.4 Camera Process

The camera process simply waits for the command to take a snapshot and, when received, utilizes PhotoPC to do so. Once the picture's taken, it is transferred to disk and the modem process is notified that there is a new picture to send. Figure 13 outlines the operation of the process.

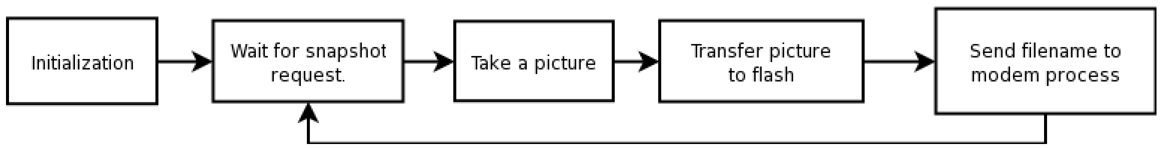

Figure 13: Camera Process

6.5 Modem process

The modem process waits on signals from the camera and MicroPilot processes. Upon reception of either, it encodes the data for transmission over the air and sends it. Since the image files are so large, it is necessary to be able to interleave GPS data with the image data; thus, the files are only sent a buffer at a time. Figure 14 outlines the operation of the process.

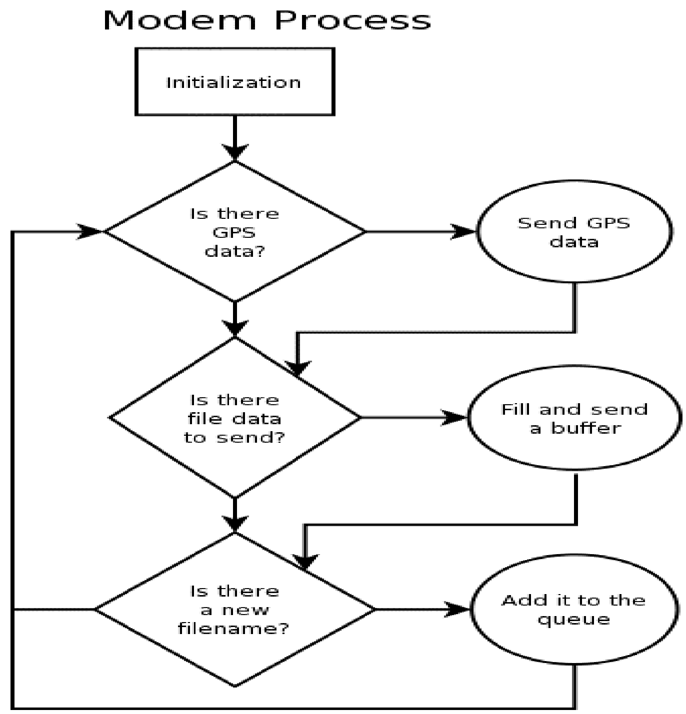

Figure 14: Modem Process

6.6 Custom ground control software

The ground control software waits for data from the radio modem. When new data arrives, the software determines whether it pertains to an image or a GPS location. GPS data is output to a status window while image data is written to a disk.

6.7 Vision Assistant

Vision Assistant allows the user to locate a particular object in an image using a variety of techniques. For the application of the SpyHawk, color matching is used. The color matching method takes a user-generated template and searches for the template among an image also chosen by the user. Since Vision Assistant is a utility for LabView, autonomous search for images as they are received from the SpyHawk UAV is possible. Many military vehicle templates are added to the database, and a sizing function is applied to each to obtain proper locations within an image. This allows the ground control user to locate a more precise location for the target than a simple picture with an overall coordinate assignment. Vision Assistant can also be used to interpret orientation between 0 and 180 degrees. Finally, a spreadsheet is generated with the number of targets in an image, the orientation of each target, and their respective locations.

6.8 MicroPilot MP2000 GCS

The MicroPilot MP2000 GCS utility software comes with the MicroPilot 2028G. This software allows the user to customize the MicroPilot 2028G for flight with a particular aircraft, input a flight path for the aircraft, and virtually track the aircraft during flight. A map style image of the area can be applied to the GUI portion of the software to give the user a better understanding of the area the aircraft is flying over.

7.0 Parts

7.1 Parts Overview

As compared to other UAVs that accomplish the same task, the SpyHawk is an inexpensive aircraft. A breakdown of parts is given below.

7.2 Camera

Olympus D-450 Zoom Digital Camera

- 35mm
- 3x Optical Zoom
- 1.3 Mega pixels
- Windows/MAC compatible
- RS-232 Interface
- Capable of 1280x920 High Quality JPEG resolution

7.3 Radio Modem

MHX-910 OEM Wireless Modem Development Kit

- Two MHX-910 OEM modules
- Two MHX Development Boards
- Two 12 VDC wall adaptors
- Two rubber duck antennas
- Two antenna cables
- Two serial cables
- Manuals
- Schematics

7.4 Controller

PC-104

- Diamond System's Prometheus CPU
- Diamond System's Panel I/O Board
- Diamond System's Jupiter MM-SIO Power Supply
- Parvus System's IDE Flash Disk Controller
- SanDisk 2.0Gb Flash
- Housing
- Manuals
- Schematics

7.5 Batteries

- BatteryMart 12V 2.2Ah Battery
- BatteryMart 6V 1.3Ah Battery
- 16V/19V Universal Laptop Battery

7.6 Aircraft

Senior Telemaster

- OS 91 Glow Plug Motor
- Futaba 9CA PCM Transmitter

7.7 Autopilot

- MicroPilot 2028G

7.8 Extra Materials

- Battery Pod
- Fuselage Materials

8.0 Safety Considerations

8.1 Battery Life

As stated in Section 5.3, each component has its own individual battery source to easily determine if failure of an instrument is due to power. Also each battery is purchased based on a minimum of a thirty-minute run time, as this is the maximum time allotted by the competition. Each battery is tested with its proper component to insure its survivability.

8.2 Heat

Each component also has a low heat output to maintain a stable system during the duration of its run time. Assuming no outside interference, the aircraft is capable of making many runs.

8.3 Weight

The weight of the aircraft is much lighter than the 55-pound limit imposed by the competition. This allows for low wing loading and a short take-off with an off-the-shelf R/C engine.

9.0 Optimization

9.1 Battery Pod

A container for the batteries is constructed and attached to the bottom of the fuselage of the aircraft. Doing so allows for easy access to the power source of the system and easy adjustment of the C.G. of the aircraft.

9.2 Camera Eyelet

A camera eyelet is cut in the bottom of the aircraft’s fuselage to accommodate a position for the camera to have an open view of the area to be photographed.

9.3 Antennae Mounting

Antennae for the MicroPilot 2028G and the radio modem are essential for communications. The radio modem has a swivel antenna mounted towards the rear of the fuselage while the MicroPilot has a GPS antenna mounted directly above the camera on the outside of the aircraft for GPS navigation.

10.0 Conclusions

The SpyHawk UAV and Ground Control Station is a simplistic take on a modern surveillance apparatus. It incorporates off-the-shelf parts for upgradability and easy maintenance.

11.0 Acknowledgements

The SpyHawk Team would like to thank Mr. Calvin Walker and Dr. Randolph Follett for advising and Mr. Tom Stennis for contributing his knowledge of Radio Control flight. Special thanks go to Dr. Anthony Vizzini, Aerospace Engineering Department Head, and Dr. Wayne Bennett, Dean of the Bagley College of Engineering, for their financial support. In addition, thanks go David Lawrence and the Raspet Flight Research Laboratory for the use of the lab to fabricate the airplane and systems. The team also thanks James Davis for graduate student knowledge. SpyHawk team members include:

Ian Broussard - Airframe Development Group Lead
Junior, Aerospace Engineering

Cornelia Hayes– Airframe Development and Report Group Lead
Sophomore, Aerospace Engineering

Mike Wanta – Airframe Development
Freshman, Aerospace Engineering

Sam Curtis – Airframe Development
Freshman, Aerospace Engineering

Marty Brennan – Airframe Development and Pilot
Freshman, Aerospace Engineering

Chris Martin – Airframe Development and Pilot
Sophomore, Aerospace Engineering

Jared Allen – Airframe Development
Freshman, Aerospace Engineering

Eddie Smith – Airframe Development
Senior, Starkville Academy High School

Blake Sanders – Systems Group Lead and Team Lead
Senior, Aerospace Engineering

Craig Ross – Systems, Software Development Lead
Senior, Computer Engineering/Computer Science

Kelly Lancaster – Systems, Hardware Development Lead
Senior, Electrical Engineering

Jeffrey Leng – Systems, Software Development
Senior, Starkville Academy High School

Emmanuel Okoro – Systems, Hardware Development
Senior, Aerospace Engineering

Anthony Vizzini, Jr. – Systems, Format and Design
Junior, Starkville High School