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Non-Violent Uses of Small Unmanned Aerial Vehicles

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In today's modern age of drone strikes by the military, and the cost of electronic technology becoming more and more affordable every day, one may wonder why there are not many small unmanned aircraft being used for useful purposes that are not violent. I am designing, building and programming a model plane that is capable of autopilot flight, along with exploring its possible every day, non-violent uses. The initial prototype is made of form or a similar material with an autopilot system. Speculations of how to use this technology to benefit society are presented.

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Non-Violent Uses of Small Unmanned Aerial Vehicles

By

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Abstract

In today's modern age of drone strikes by the military, and the cost of electronic technology becoming more and more affordable every day, one may wonder why there are not many small unmanned aircraft being used for useful purposes that are not violent. I am designing, building and programming a model plane that is capable of autopilot flight, along with exploring its possible every day, non-violent uses. The initial prototype is made of foam or a similar material with an autopilot system. Speculations of how to use this technology to benefit society are presented.

Background

For decades if not centuries, man has dreamed of the day in which they would have personal robots to do various tasks. Rosie the robot from "The Jetsons" comes to mind. In the show, Rosie did many of the duties of a maid for the Jetson family. This saved them time from doing menial labor. While it's still a ways away for mankind to have a fully functional Rosie with personality and all, there are many real life examples of personal robots. There exists a large hobbyist scene where people are creating small robots to do specialized menial tasks using the growing technology of inexpensive and easy to program micro-controller technology. These microcontrollers are the nerve centers of these personal robots. One of the most widely available and popular types is the Arduino line of micro-controllers. This scene has grown very quickly, even since I began this project. One of Rosie's main limitations was that she didn't have the capability of flight, while the Jetson household was raised up high in the sky. A group known as 3D Robotics has specialized the Arduino brand micro-controller to be used specifically in flight applications. This makes it possible to give an Arduino powered personal robot the capability of flight. As such, it is becoming more and more possible to make a personal small unmanned aircraft.

In the summer of 2005 after my junior year of high school, I was given an incredible opportunity by a group called the Grand Rapids Area Pre-College Engineering Program to participate in an internship at Smith's Industries Aerospace (now GE Aviation systems) in my home town of Grand Rapids, Michigan. During this experience, one of the main projects I was assigned to work on were test stations for the vehicle management computer systems for the X47-B Unmanned Combat Aerial Vehicle. The idea that I was working with equipment which would help guide an air plane to fly itself fascinated me. Today these and other drones are

common place and the industry around them is expanding quickly. While I very much enjoyed my work at Smith's, one thing always bothered me, and still does. The fact that the vehicle I was helping to develop was a combat machine with weapons on it capable of killing people. Even so, the idea of an air craft that can fly itself still fascinates me and sparked the idea for me to make a small one myself in the hopes of finding non-violent and domestic uses for this technology. With the help of a budding hobbyist and micro-controller industry, it seemed logical to pursue this as my senior thesis project.

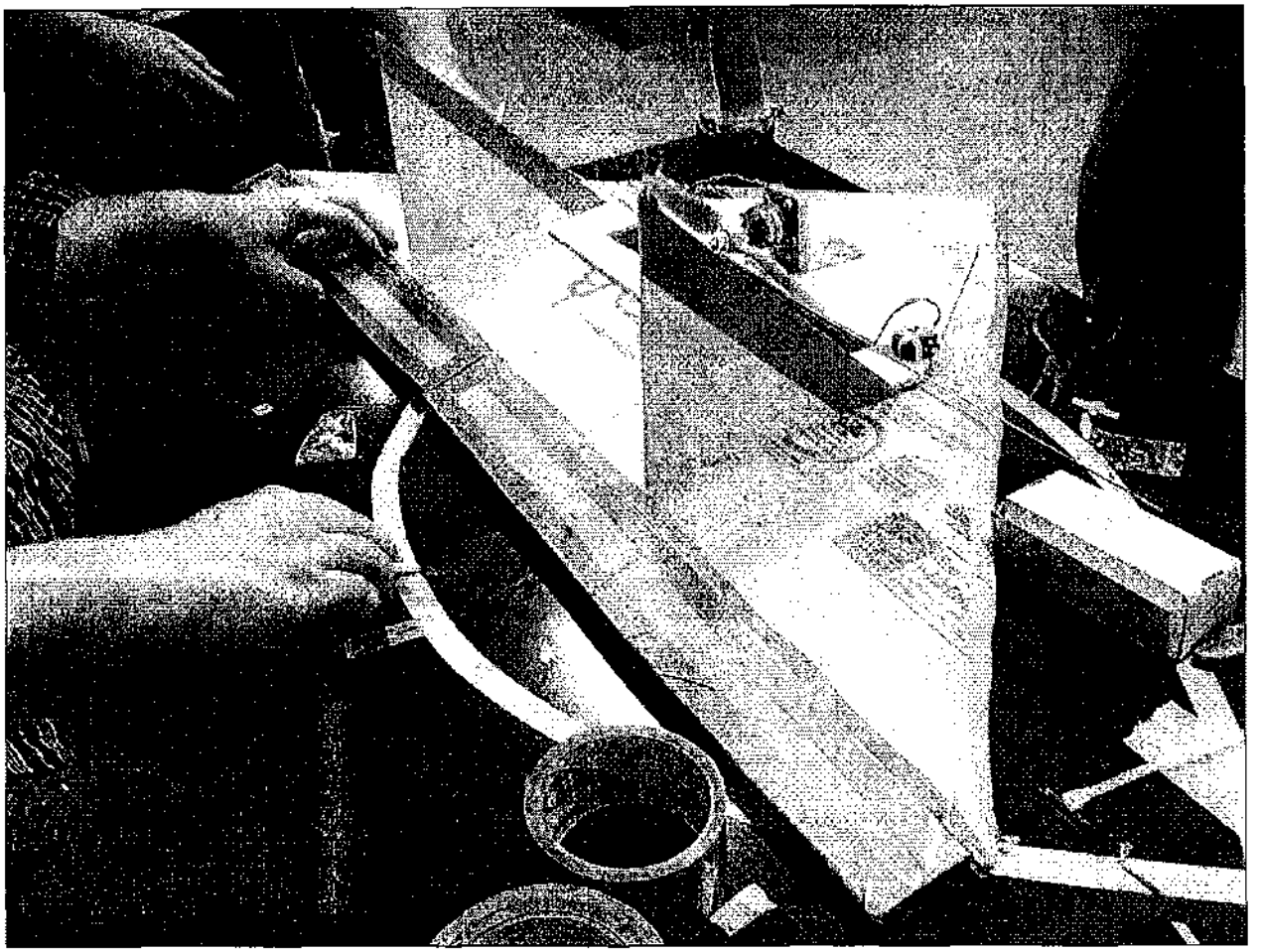
During a Lego robotics class late in my sophomore year, I made a friend who was in the Mechanical Engineering Technology Program. We both wanted to do a really awesome senior project and did some brain storming. We were looking for something never attempted at EMU before. We at last came up with a plane that could fly itself. He would do the mechanical part of making the plane and I would wire it and possibly program it if we couldn't find a programmer to work with us. Unfortunately, that friend ended up graduating early so we didn't get to work together as planned. However, I still wanted to do the project, so I discussed the premise with one of my professors who seemed interested. He decided he wanted to sponsor me and create a class around my idea and asked for my help in designing it. Thus ELEC 279 Unmanned Vehicle Systems came into being.

The summer before it was offered he asked for my help. He said that we could order the supplies for the class and what was accomplished in the class could tie into my project. I was put in charge of ordering the parts for at least three kits to make planes and the associated autopilot hardware. I researched and put together a list of things we would need and put in the order.

The rest of the class was put together by the professor during the summer while I was working. I figured we were just going to do what we bought stuff to do. However, when fall came and the class began, we had a number of non-majors in the class including ROTC students, teaching students, etc. So, instead of being what I imagined, the class had instead become something else. Each group presented one chapter out of the book and made a multiple choice test about the chapter, and in addition to that we did some Lego robot activities that were about unmanned ground vehicles. Each group was also tasked with making an r/c plane to fly as a project using other parts that they had ordered after I had gotten my summer job. The parts I had helped order were in a cabinet locked somewhere, and instead of making unmanned aerial vehicles with an autopilot, we were all making simple foam planes that we would try and fly manually via an r/c controller.

One of the first assignments for that project was to find free plans on the internet on how to build a cheap plane. This was because we all would have to provide most of the materials ourselves for the plane except the electronics associated with it. The common choice for plans was Mikey's RC, a web site where plans can be printed out and then used to cut out foam board to make an air frame. Our group actually used plans from MAKE magazine. It was a foam plane known as the 'towel' plane. One other group used the towel plans as well. Our two groups were the only groups who had planes which actually flew for more than ten seconds before crashing. This class activity brought the inspiration for my prototype plane. One of the Mikey's RC models that none of the groups chose to build was actually perfectly suited to having an autopilot and camera installed on it.

Our Team's Plane from ELEC 279 "The Towel, via plans from MAKE magazine"



Establishing that smaller and cheaper "drones" which can be made for domestic use was one challenge. The next was to find non-violent ways to use this technology for the betterment of mankind. The 3D Robotics Ardupilot device along with a regular R/C plane type body is what I established as the base system to work with. The plan for this ongoing project is to make a base prototype using free plans from the Mikey's RC web site to make a small R/C plane out of easily attainable foam board along with the other electronics needed for a basic R/C plane available from Hobby King and/or other hobby retailers. This creates the possibility of a quickly built and affordable platform for the domestic market to obtain and create. This set up is the prototype for basic testing. Other equipment can be added to this to tailor the plane for the

specific use. Farther along, a fiberglass airframe which costs a bit more than the foam would be used to make a more robust plane more suited to aerial research applications.

There are two main types of do it yourself drone aircraft widely available. The fixed wing plane set up is what I worked on in this project. However, there is also a four or more propeller "quad copter" type as well. The plane type is good for larger areas and speed, while the quad copter is best for smaller areas and accuracy of height and location.

Once the foam prototype plane is launched and tested, it will be used to familiarize myself with the Ardupilot programing and software. Afterward, a larger plane will be constructed for more permanent use using a fiberglass air frame from hobby king.

Discussion of Potential Non-Violent Uses

After one or more planes/aircraft are tested for flight and reliability, sensors and other equipment such as cameras and payloads can be added to the craft to tailor it to the specific non-violent use. Multiple possible non-violent uses have been researched and can be tested with this system as it is intended to be an ongoing research project for the college of technology.

I have discovered that the non-violent possibilities for this type of device are many. As the plane type of UAV (Unmanned Aerial Vehicle) is more meant for speed than the copter type, one potential use for this technology which was suggested during my undergraduate symposium presentation by an audience member was to add an infrared and/or regular camera to the craft and use it to search for danger such as potential new forest fires in the at risk areas in the Western regions of our country, or to help locate injured mountain climbers who need fast assistance.

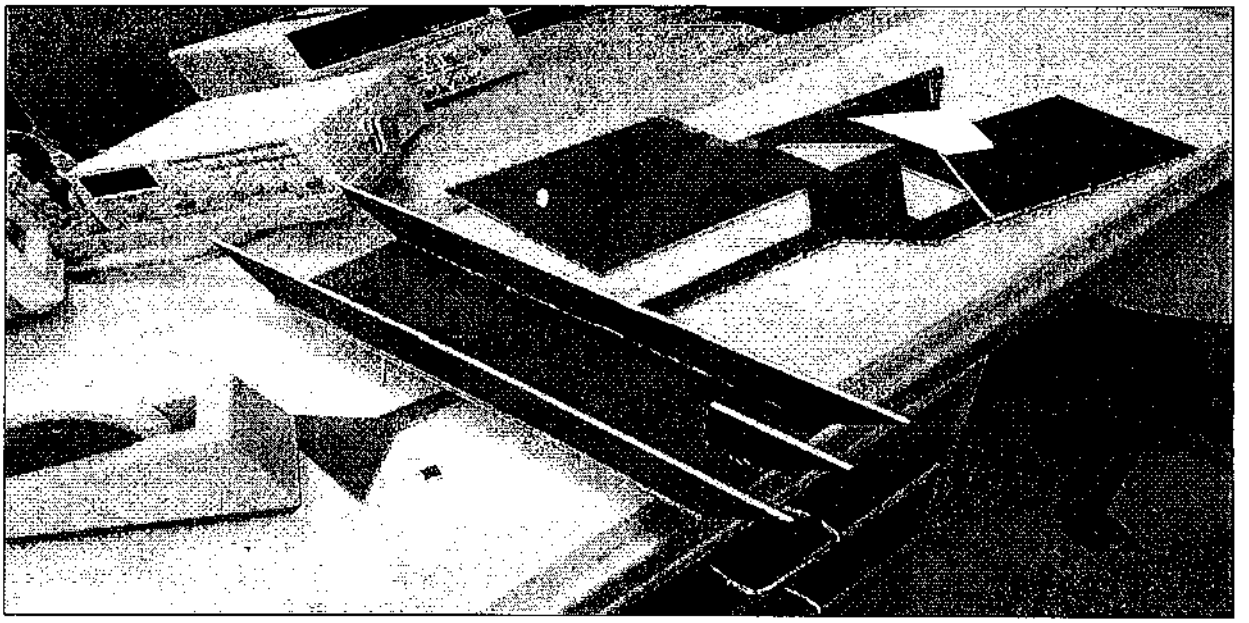
Expanding on this concept, the plane could be the new "St. Bernard," for rescue with a payload of bandages or medicine which it could deliver to the lost/injured while they await rescue. Another potential use, as described in ELEC 279, is for academic and scientific research involving atmospheric chemicals. The craft could be outfitted with various air chemical sensors to record the concentrations of various aerial chemicals in a specific area over time. The same technique could be used to gather all sorts of different kinds of datum so long as a sensor is available to record it. For farmers, this technology could be used to monitor crops and identify issues without the need to drive or walk through the entire field. Many UAVs are already being used by governments for reconnaissance. Spying is a potential non-violent use for this technology worth mentioning. If a small plane is destroyed, at least there would be no loss of human life. More possible uses could be for entertainment, such as following along the path of racers in the Tour de France or marathons in the Olympics. According to http://www.bbc.co.uk/news/technology-25180906, Amazon.com is testing a program to deliver small packages using copter type drones, and could eventually bring it to our country pending FAA approval.

Build Process

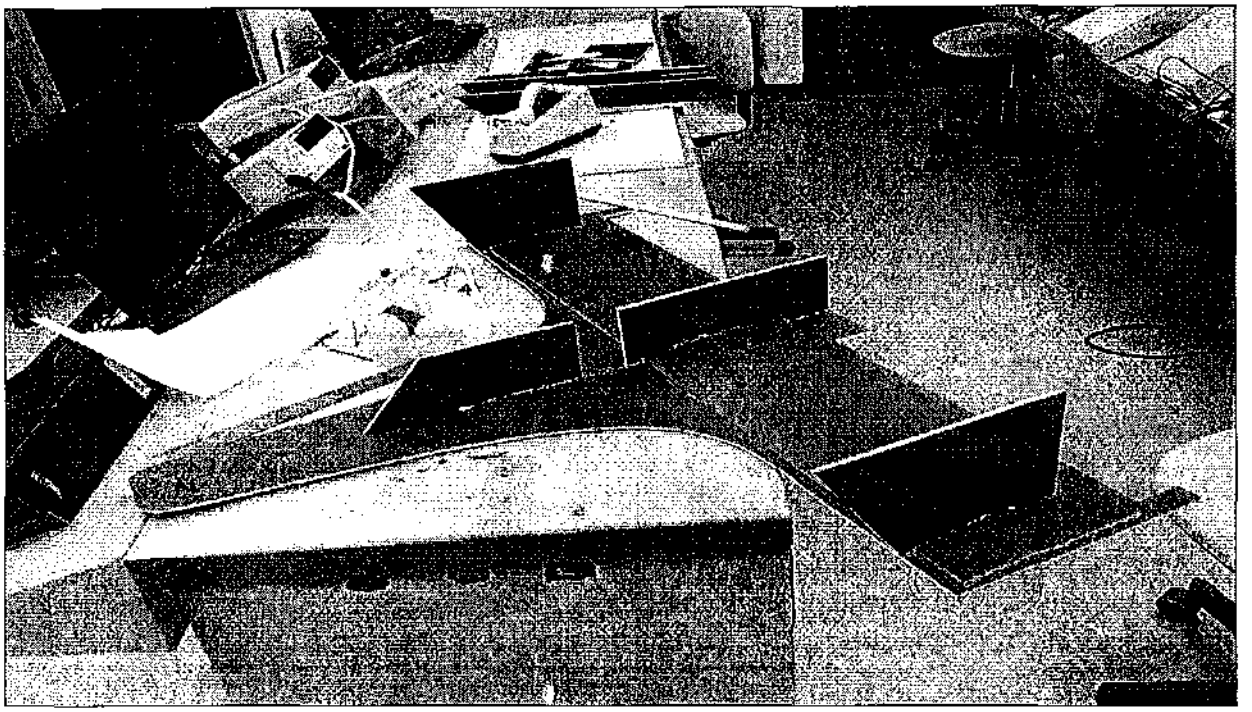
In initiating the build process, I first followed the plans and videos on Mikey's RC for the FPV V3 plane using the materials called for. It was important to get the printer scaling correct so that the pieces of paper would fit on the foam board correctly and so that the dimensions were correct and lined up properly. I also added tooth picks in between the horizontal seams in order to shore up their strength. I just used my x-acto hobby knife for the cutting of the foam board

and the 45 degree beveling on all of the edges. I got push rods and plastic horns from the local hobby shop to connect the servos to the various moving parts. Coat hanger wire could have been used instead of push rod but I was able to get smaller diameter push rod at Nankin Hobby that better matched the holes on the horns they had. The horns were cheap and were used instead of Popsicle stick ends. They move more freely as well.

Build Process of FPV V3 from Mikey's RC, Base:



Build Process of FPV V3 from Mikey's RC, Mid-Section:



In assembling the R/C electronics, I followed generic instructions and advice from the local hobby shop. Various soldering was done on bare wire ends to unify the connectors so that everything can be connected and disconnected as needed by hand. A few connectors were necessary that were not in the Hobby King order. These were obtained at the local hobby shop. Mainly 3.5 mm gold plated female bullet connectors, and matching battery terminals. Heat shrink tubing and/or colored red/black electrical tape was used to cover exposed solder joints and connections.

It is important to note that the 60A ESC I ordered did not include something called a UBEC, or Universal Battery Eliminator Circuit. Without this the Spektrum receiver did not function. If done again, I would order a 70A ESC with a UBEC included in it. Instead, I had to buy a separate UBEC device from the local hobby shop. The 5 Volt output pin and ground wires

had to be hooked up on the throttle input of the Spektrum receiver in order to give it proper power. The autopilot has its own UBEC that came with it, but is only meant for powering the autopilot and it's accessories as it is rated for lower current than a normal UBEC. A 5 Amp or better UBEC is needed. I used the 10 x 7 tri-blade master air screw pusher prop on the motor.

All of the main power connections were unified with the red dean's style connectors, male and female respectively. Properly sized bullet connectors were added to the ESC in order to connect it to the motor. In order to make the motor spin in the correct direction, the A and C wires from the ESC to the motor may need to be reversed depending on the type of propeller. The rest of the wiring was done as per the instructions in the Spektrum receiver instruction manual. Thus concludes the basic R/C plane construction and wiring that was done. The initial test and crashes were done after this.

More recently, after rebuilding the front area of the craft, I added the autopilot and telemetry hardware. At one point the 2.5 version of the Ardupilot hardware was recalled, and I had to send it in to have an item added to it so that it could properly process the air speed sensor's output.

Most of this was done using the instructions at https://code.google.com/p/ardupilot-mega/wiki/home?tm=6, http://plane.ardupilot.com/, and at the DIY drones and 3D Robotics sites. I did the initial setup of the Ardupilot using the mission planner software available at said sites via USB cable before installing it into the air craft. The USB cable provided power to it and it's accessories during the set up procedure which is guided step by step. Everything was pretty straightforward other than the need to cut the silicon tube for the air speed sensor in order to connect it properly to the pitot tube. The connection on the pitot tube going out at an angle is

connected to the bottom port on the sensor and likewise the other to the top via the silicon tubing. It is also important to note that the telemetry radios won't function correctly unless you use 57600 as the bit rate and the correct COM port after installation. Things generally can only plug in one way, other than the plane's telemetry radio. The open pin in the connector for it should go on the opposite side of the pin labeled 'ground' on the radio.

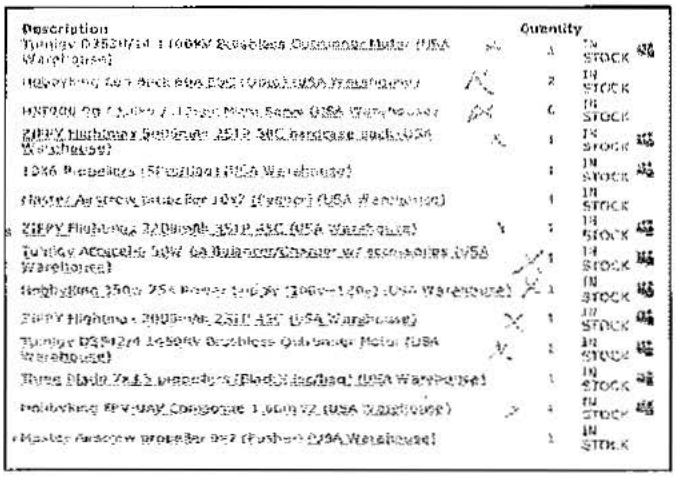
I mounted the APM, telemetry radio, and Spektrum receiver in the bottom bay of the plane and the ESC, UBEC, and GPS receiver on the top of the bottom platform/wing. The battery goes on the nose area so long as a camera is not present in order to properly balance the plane. The plane should balance on the COG line on the Mikey's plans, or even be slightly nose heavy for proper flight. I learned this after the initial crash.

Once initial set up is done, communication from the PC to the Ardupilot can be done via the telemetry radios. This can be used to change the plane's flight plan in flight and to receive information from the built in sensors of the Ardupilot hardware including the GPS, compass, speed sensor, and others. I have not added camera hardware. This could be done after some testing, and might be better suited to the fiberglass airframe rather than the foam prototype.

Back in the summer when I had originally ordered the parts for the class and project, I was promised the use of them to make my senior project throughout the class and afterward. However, this did not happen. I spent the following semester begging to be able to use the parts originally ordered that had been locked away to no avail. I had no other funding to make my project, and as I understood it, I was to have had access to the inventory ordered for our class. This facilitated the need to make a cheaper foam prototype first rather than make the nice one planned that would have used the parts we ordered. While trying to get parts, I started making

the FPV V3 model from Mikey's RC out of foam board and dowel rods as the plans direct. The plans and videos are available at http://mikeysrc.com/FPV_V3.html late in the semester I was able to finally secure funding for the electronics and other parts needed, not just for the prototype, but also a nicer fiberglass model which I planned originally to use as the main project after proving the prototype could work. Photos of these purchase orders follow:

Hobby King Order:



Description	Quantity	
Turnigy D3530/14 1100KV Brushless Outrunner Motor (USA Warehouse)	4	IN STOCK
[illegible]	2	IN STOCK
HXT900 9g / 2.0kg / 0.12sec Micro Servo (USA Warehouse)	6	IN STOCK
ZIPPY Flightmax 5000mAh 3S1P 30C Hardcase Pack (USA Warehouse)	1	IN STOCK
EDGE Propellers 15x10 CW (USA Warehouse)	1	IN STOCK
Master Airscrew Propeller 9x7 (Pusher) (USA Warehouse)	1	IN STOCK
ZIPPY Flightmax 3000mAh 3S1P 40C (USA Warehouse)	1	IN STOCK
Turnigy Accucell-6 50W 6A Balancer/Charger w/ accessories (USA Warehouse)	1	IN STOCK
Hobbyking 250g 25x Power Supply (100~120v) (USA Warehouse)	1	IN STOCK
ZIPPY Flightmax 2000mAh 2S1P 40C (USA Warehouse)	1	IN STOCK
Turnigy D3542/4 1450KV Brushless Outrunner Motor (USA Warehouse)	1	IN STOCK
Prop Blade Zip Ties (Black) (4x/bag) (USA Warehouse)	1	IN STOCK
Hobbyking FPV-UAV Composite 1.0mm V2 (USA Warehouse)	1	IN STOCK
Master Airscrew Propeller 9x7 (Pusher) (USA Warehouse)	1	IN STOCK

3D Robotics Order 1 of 3:

Code	Description	Qty	Price	Total
BR-APMPWRKT2-TELEM915	APM 2.5+ Assembled (Side entry) with 915Mhz (US) Telemetry Set [GPS Module:uBlox LEA-6H GPS module] [Power Module Options:Deans connector]	1	$299.99	$299.99
AC-0005-01-APM25SIDE	Ardupilot Mega 2.5 Case, Side entry	1	$0.00	$0.00
BR-3DR915	3DR Radio 915 Mhz "Air" module (US)	1	$0.00	$0.00
BR-3DRUSB915	3DR Radio USB-915 Mhz "Ground" module (US)	1	$0.00	$0.00
BR-ArduPilotMega-06	APM 2.5 ArduPilot Mega 2.5 Fully Assembled -Side entry-	1	$0.00	$0.00
CA-0001-05	EM-406/uBlox/MTK Adapter Cable 10 cm	1	$0.00	$0.00
CA-0001-33	DF13 6 Position Connector 15 cm	1	$0.00	$0.00
KT-APM25-Cable	Telemetry adapter cable for APM 2.5 (Radio, OSD)	1	$0.00	$0.00
KT-Telemetry-Cable	Telemetry Cable for APM 1.X and APM 2.0	1	$0.00	$0.00
PR-0001-05	3x8 Right Angle Pin Headers	2	$0.00	$0.00
PR-0001-06	6 Pin Right Angle Male Header	1	$0.00	$0.00
PR-0001-14	3x14 Pin Header	1	$0.00	$0.00
PR-0001-22	1x02 Pin Header (H=4mm)	1	$0.00	$0.00
PR-0001-23	2x03 Pin Header (H=4mm)	1	$0.00	$0.00

3D Robotics Order 2 of 3:

^ PR-0001-26	2.00 Shunts	1	$0.00	$0.00
^ USBA-MICROUSB	Micro USB Cable	1	$0.00	$0.00
^ USBA-USBEXT	USB Extension Cable, Type A	1	$0.00	$0.00
^ WI-AW1063-900mhz-2dbi	Antenna 900MHz RP-SMA 2dBi	2	$0.00	$0.00
^ BR-3DRLEA-6	3DR GPS uBlox LEA-6	1	$0.00	$0.00
^ BR-APMPWRDEAN	APM Power Module with Deans Connectors	1	$0.00	$0.00
AC-0001-25	MB1340 XL-MaxSonar®-AE4™ High Performance Ultrasonic Range Finder	1	$39.95	$39.95
BR Dronecell-01	DroneCell	1	$84.99	$84.99
^ CA-0001-SMA	Interface Cable Bulkhead SMA to U.FL	1	$0.00	$0.00
BR-PhoneDrone	PhoneDrone Board for Android	1	$99.99	$99.99
^ PR-0001-13	3x08 Pin Header	2	$0.00	$0.00
^ PR-0001-22	1x02 Pin Header (H=4mm)	2	$0.00	$0.00
^ PR-0001-24	2x18 Female Pin Header	1	$0.00	$0.00
^ PR-0001-25	2x08 Female Pin Header	1	$0.00	$0.00
^ PR-PPPC132LFBN-2x13POS	Conn Header Female 2x13POS .1" GOLD	1	$0.00	$0.00
CA-0002-01	Barrel to Dean Connector 12cm	2	$2.95	$5.90
CA-0005-01	Dean Adapter Combo Cables	1	$8.95	$8.95
CA-0004-01	Dean male to Banana male connector cable	1	$4.95	$4.95
CN-0001-01	Deans Ultra Plug Connector, FEMALE	4	$1.00	$4.00
CN-0001-02	Deans Ultra Plug Connector, MALE	4	$1.00	$4.00
CON-000-02	Female T plug - Male XT60 adapter	2	$2.75	$5.50
CAM-0003-01	Micro Compact Super Vision CCD Camera	1	$139.99	$139.99
BR-RemzibiOSD	Remzibi OSD 3DR	1	$64.99	$64.99
^ PR-0001-05	3x8 Right Angle Pin Headers	1	$0.00	$0.00
^ PR-0001-09	3x2 Right Angle Pin Headers	1	$0.00	$0.00
^ PR-0001-10	1x20 Right Angle Pin Headers	1	$0.00	$0.00
^ PR-0001-27	Battery connector	1	$0.00	$0.00
^ TTL-4PINFTDI	Remzibi OSD cable	1	$0.00	$0.00
SRV-HTC-HS55	HITEC HS-55 MICRO SERVO	6	$12.95	$77.70
PR-0003-02	Servo Extensions Cable 15cm Male-Female	4	$1.75	$7.00
RC-SPEKTRUM-DX8-01	Spektrum DX8 8CH Transmitter with AR8000/TM1000; No Servos	1	$429.99	$429.99
WI-TS352	5.8Ghz 500mW Wireless Video Transmitter-Receiver kit	1	$189.99	$189.99
^ WI-RC805	5.8Ghz 500mW Wireless Video Receiver	1	$0.00	$0.00
^ WI-TS35	5.8Ghz 500mW Wireless Video Transmitter	1	$0.00	$0.00

3D Robotics Order 3 of 3:

KT-MPXV7002DP-01	Airspeed Kit with MPXV7002DP	1	$24.95	$24.95
^ AC-0001-03	Silicone Tubing 1 ft	1	$0.00	$0.00
^ AC-0001-04	Pitot Tube - Combined Static & Dynamic Probes	1	$0.00	$0.00
^ PR-0001-06	6 Pin Right Angle Male Header	1	$0.00	$0.00
^ PR-0003-03-12cm	Servo Extension Cable 12cm Female-Female	1	$0.00	$0.00

I had only a couple of days to add the electronics to the prototype to get it to fly, never mind add the autopilot to get it to fly by itself, and never mind the camera or anything else. I added the electronics and tested it the morning of the senior design project presentation day. It was very windy that day. After three attempts to launch with it crashing immediately on launch, it did start to take off. Unfortunately, I had failed to learn how to balance the plane on the center of gravity line properly, and the wind was also causing difficulties. I had not secured the battery to the frame very well. This combination of issues caused the battery to slide backwards into the propeller and break off one of the three prop blades. This caused the motor to detach from the motor mount and ultimately the worst crash yet. I ended up with nothing to present but a crashed plane and thus had to take an incomplete for the course.

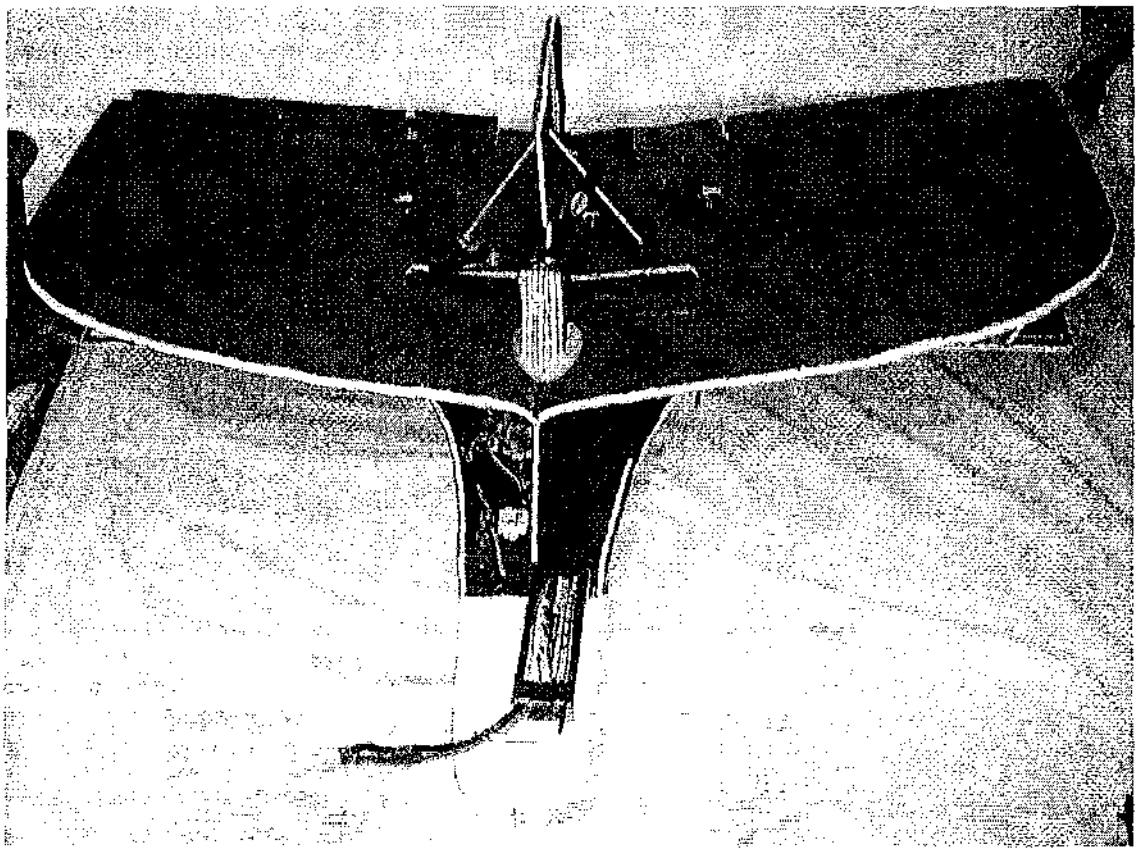
Since then I have repaired the damage to the prototype, and learned more about the autopilot and telemetry electronics and how they work. They are now wired up on the prototype and ready for a test flight which requires good weather. I have had to forego the planned camera system and fiberglass model due the above noted problems. It is now planned to be an ongoing project for the department. I started the project and got the basics down. Assuming the prototype flies and the autopilot works, (which I believe it will in good weather) it can go on as a continual project.

Reflection

Throughout this process, I have learned many things about projects in general, research, and about myself. There are a lot of opportunities out there to help fund academic research if one looks for them. It is very important to keep up a record, preferably daily, as to what is accomplished in what way, and in what order. This includes something like a journal, and more picture taking. If I were to do it again, it would be highly beneficial to have a partner, or a more involved faculty sponsor. Doing things mostly on my own has been quite a challenge.

It is my hope that this project will continue on in the Electronics Engineering Technology program. If the fiberglass version is constructed with the camera and the extra sensors, this could be a really great marketing tool for the department to recruit more students. I always imagined that this plane could fly around the football stadium during the first game of the year where all of the freshmen must attend, carrying a banner that says "EMU COLLEGE OF TECHNOLOGY," or something of the like. So long as the battery is monitored and the way points are set, this is quite highly possible. The plane could also be used to take some stunning videos and pictures from over head of our campus.

Repaired prototype as it sits now, ready for test. Top View:



Repaired prototype as it sits now, ready for test. Front View: