Multi-Rotor Autonomous Payload System

Payload Delivery and Video Reconnaissance via Autonomous Multi-Rotor Drone

Proposal
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Submitted To:

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INTRODUCTION:

Abstract

Cubic Corporation's training solution MILES employs laser transmitters and receivers to provide field training exercise to troops. In order to produce realistic simulation artillery fire, such as mortar rounds and RPGs essential in the drill, a new system must be developed. Current deploying devices are manually performed and indiscreet providing unrealistic simulation. The Multi-rotor Autonomous Payload System (MAPS) will primarily be used for combat live-fire training. System architecture shall be designed for modularity, scalability and expansion. MAPS is composed of a Portable Graphical User Interface computer, Unmanned Aerial Vehicle, and Video Communication System. Together these components will facilitate realistic training simulation through automated remote payload drop-offs.

Project Description

Design a system composed of:

1. **Portable Graphical User Interface that is capable of:**
    a. Calculating a user defined geographical location into GPS coordinates
    b. Allowing emergency/ backup manual override flight control
        i. RC remote control
    c. Communicating bi-directionally to the Unmanned Aerial Vehicle Payload (UAV) system allowing:
        i. A GPS coordinate to be sent
        ii. Real-time UAV video, telemetry data, battery status and deployment status to be displayed
        iii. User to manually deploy payload
2. **Video Communications System that is capable of:**
    a. Wirelessly transmitting composite analog video, through the 5.4 GHz band
    b. An on-ground server wirelessly receiving a composite analog video that is capable of:
        i. Digitizing the analog video signal into MPEG-2
        ii. Wirelessly sending the MPEG-2 data to the Portable GUI
3. **Unmanned Aerial Vehicle Payload system that is a capable of:**
    a. Navigating autonomously to locations using:
        i. Sensors (Sonar, Gyroscope, Accelerometer, Magnetometer)
        ii. GPS
    b. Accurately deploy multiple payloads of 0.25 lbs at each user defined waypoint
    c. 1 mile LOS
    d. Carrying a Video Transmission System
    e. Communicating bi-directionally to the ground station allowing:
        i. Telemetry data to be transmitted
        ii. GPS coordinates to be received
        iii. Manual override

DESIGN:

Background Research

Upon receiving the Request for Proposal from the client, each member worked together to brainstorm possible solutions to comply with the goals and requirements set forth by the customers. Results from the findings and team meetings produced a reiterative process which yielded the following:

- ✓ Research Questions
- ✓ Methods
- ✓ Data
- ✓ Revisions
- ✓ Improvements

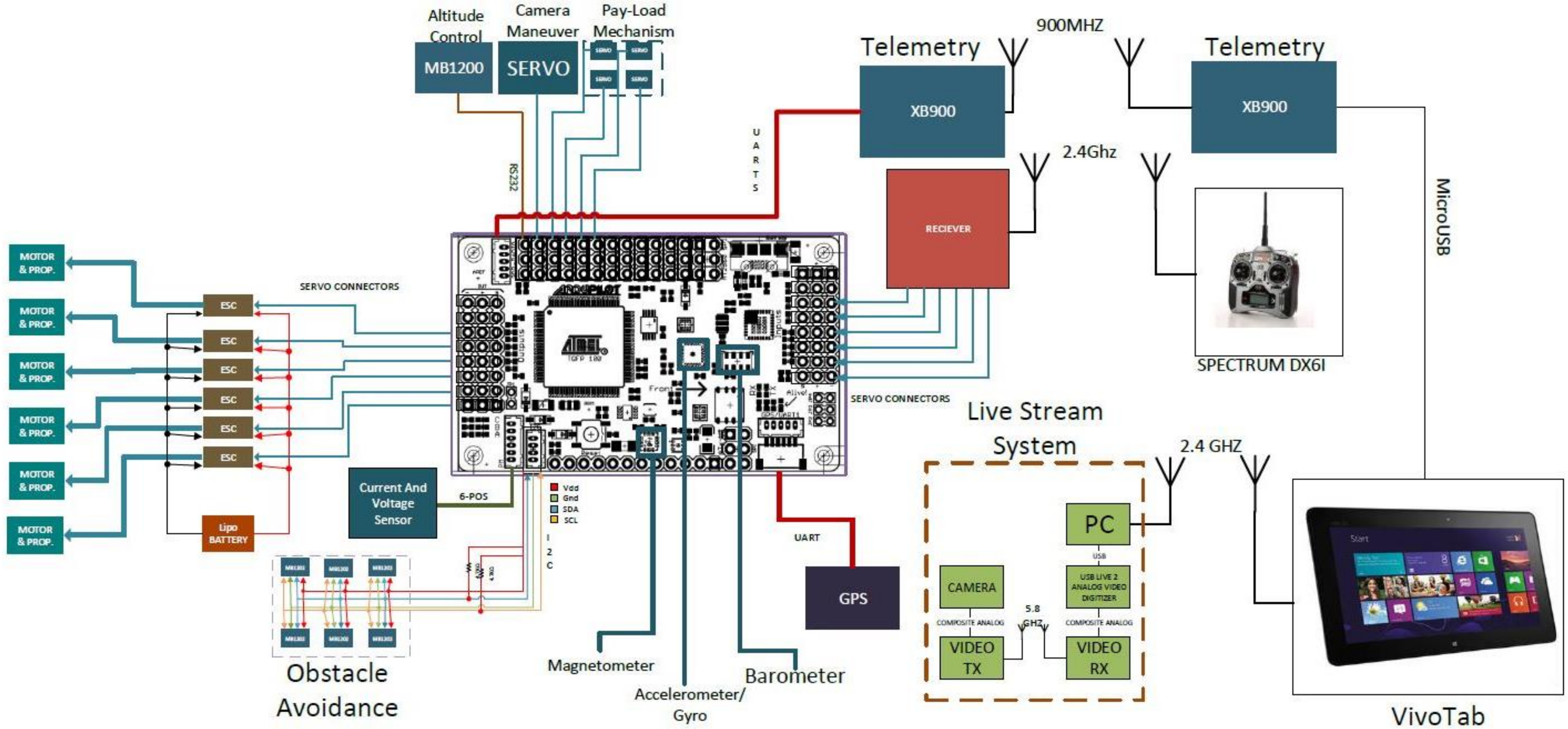
In the first stage of research, the results of the initial research and team meetings allowed the members to narrow down on possible solutions and components.The company advisors guided the team to address any lingering research questions, variables that needed to be omitted, and revisions to be made. The team was tasked to research the different functionalities of the Multi-rotor Autonomous Payload System (MAPS). Each member was assigned a specific aspect of the project:

- ✓ Sensors
- ✓ Tablet
- ✓ Telemetry (Radio)
- ✓ Live Video Stream
- ✓ Autopilot and UAV

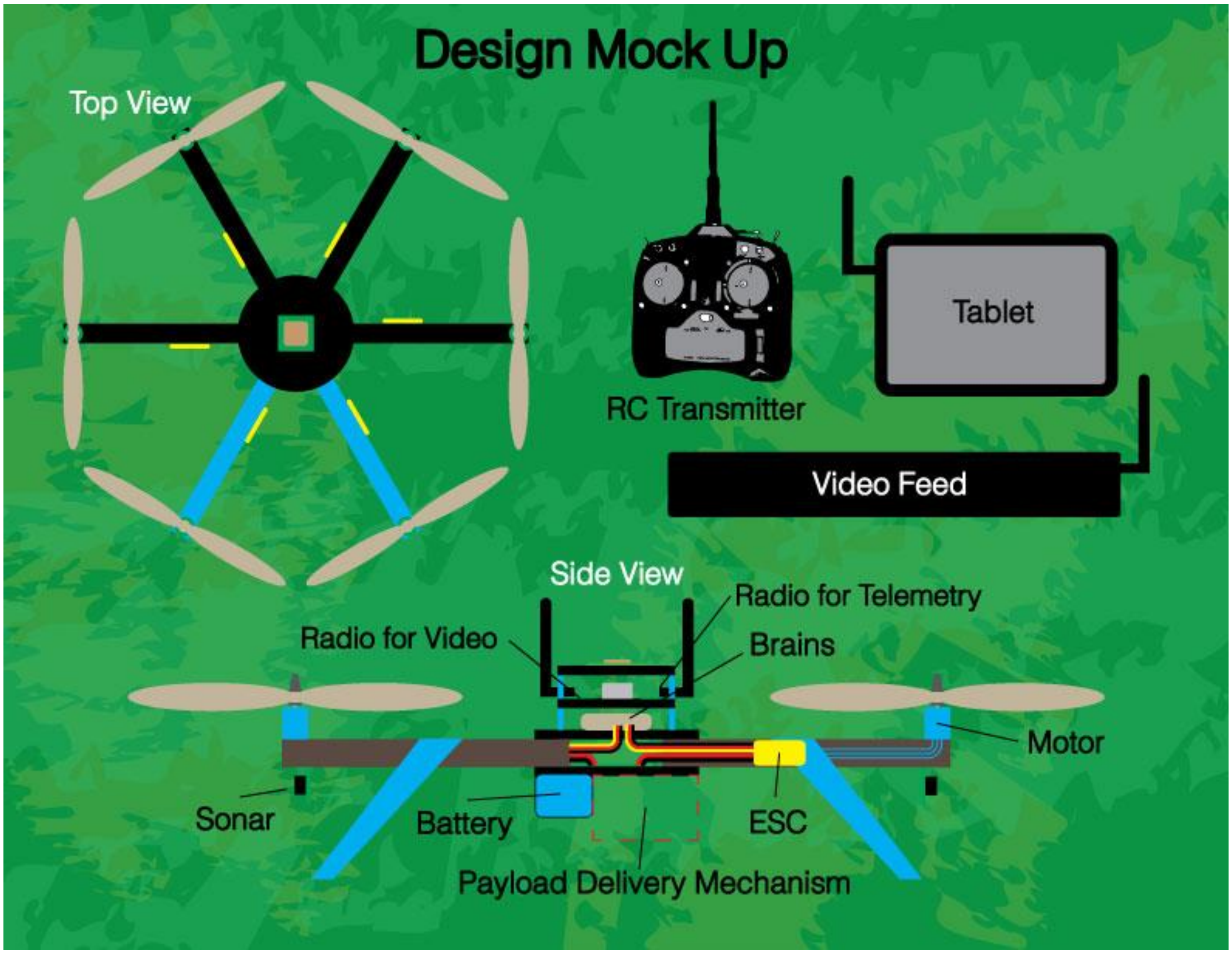
Several members came upon an online resource DIY Drones, and further researched the ArduPilot, an open source Arduino-based autopilot. ArduPilot met most of the needs required for the software and electrical hardware of the UAV. The hardware already included an onboard magnetometer, GPS module, gyroscope, pressure sensor, and accelerometer to aid in autonomous navigation. The only sensor lacking was the SONAR. Members found a compatible SONAR sensor that would be utilized in object detection.

The most important features of the tablet were the platform (Android or Windows based), peripheral ports available, internal GPS, and possible Wi-Fi or Bluetooth connectivity. Along with it, came the need to address communication issues. Telemetry would require a Transmitter and Receiver to interface the tablet and. Members have explored the use of a 900MHz receiver and transmitter. To implement the video stream UAV to the tablet, members explored the use of IP cameras, analog video transmission through radio frequency, and a remote server for the video.

Block Diagram



Mock-Up Illustrations



Constraints

ECONOMIC

The members assessed the financial aspect to meet the requirements. As a result, a budget was produced that outlined the Commercial Off the Shelf (COTS) items to be purchased. These items were chosen such that a pertinent and economic design addressed the needs of the customer.

ENVIRONMENTAL AND SOCIAL FACTORS

The product will primarily be used by the military, but will be designed to use mostly materials that are environmentally friendly and allow proper disposal or reuse of materials to be an option.

The expected location of use will be in remote military training facilities to prevent unintended public safety hazards. This will also adhere to any legal issues relating to privacy and noise ordinances.

STANDARDS AND LEGISLATION

The project requires the flight of a UAV drone that will utilize operating radio frequencies for telemetry feedback and the use of airspace. As such, the FAA Advisory Circular (AC) addresses model aircrafts and flying altitude regulations. The project will ensure regulations are met such as maintaining that the UAV operate within 400 feet above land, and away from airports. Moreover radio communication will only occur on the authorized frequencies designated by the Federal Communications Commission (FCC).

Radios will utilize frequency hopping spread spectrum (FHSS) to transmit signals to minimize the amount of interference to other devices, and will operate within the ISM band limits.

If applicable, the members will look into adhering to the IEEE, ISO, ANSI, IEC, etc. standards and protocols to ensure product interchangeability, compatibility, and interoperability.

MAINTAINABILITY

Members will provide software and hardware maintenance. This entails:

- ✓ Identification of defects and causes
- ✓ Separation and organization of hardware and software defects
- ✓ Verification of requirements being met
- ✓ Simplification of design for easier future maintenance

Several of the parts purchased are COTS items, and are replaceable and/or interchangeable for a similar part. The team also has a direct contact to the San Diego branch of 3D Robotics. Testing will also be a means of improving system maintainability.

SERVERICEABILITY

The project is designed to avoid collisions; however should it fail service should be performed. In compliance with the maintainability, it is necessary to identify exceptions/faults, and incorporate serviceability, which in turn will reduce operational costs and maintain business continuity. Features to be focused on are:

- ✓ Documentation
- ✓ Event logging
- ✓ Technical Support

MANUFACTURABILITY

Focus is made in providing every step in the process required to bring a new product assembly to the market in a timely and cost-effective manner through these processes:

- ✓ Quality Assurance (Q&A)
- ✓ Accounting for Overhead
- ✓ Purchasing low-but efficient products
- ✓ Conducting a well-organized process

The primary goal is to maintain quality, product reliability, cut costs, and shorten production time which will allow room for error revisions, and improvements.

Performance Requirement

Performance Measure	Desired Characteristic
Endurance	7 minutes of flight time
Range	1 mile LOS
Payload Accuracy	within 3 meters of target
Telemetry Data Rate	1 Hz
Payload Requirement	1 lb.

TESTING & VERIFCATION:

Testing Procedures

SOFTWARE

FEATURE

GPS Coordinate Calculation	Verify accurate GPS coordinate is calculated from a geographical location selection through debugger tools Verify UAV receives GPS coordinates by monitoring telemetry channel
Manual Override	Verify manual override by monitoring override channel
Visual Display	Verify transmission of telemetry data, copter location, payload status are accurate on display
Manual Payload Drop Option	Set up test that puts servo arms in an automatic motion pattern, and verify channel overtake is possible
Bi-directional Communication	Test through real-time GUI display, and onboard telemetry data monitoring
Wireless Video Transmission	On ground testing of GUI's ability to display any video

HARDWARE

FEATURE	
Manual Override	Manual radio control tests maneuvering performance, as well as range of radio
Autonomous Navigation	Sensor calibration and testing to verify accurate readings Verification of GUI readings Set up a remote outdoor course to test object detection Run a full mission with payload drops
Wireless Video Transmission	Test the range of the transmitter/receiver pair by viewing video while camera and transmitter pair travel in a 1 mile radius Continue to test capabilities of USB Analog Digitizer, and wireless feed to tablet by setting up the system, and ensuring display on tablet
Accurate Payload Drop	Set up outdoor test to deploy payloads at a certain GPS coordinate. Check payload location by positional comparison, and GPS location through cellular means

Benchmarks

The goal is met once the UAV is fully autonomous capable of deploying a payload. It should transmit telemetry data and video feed

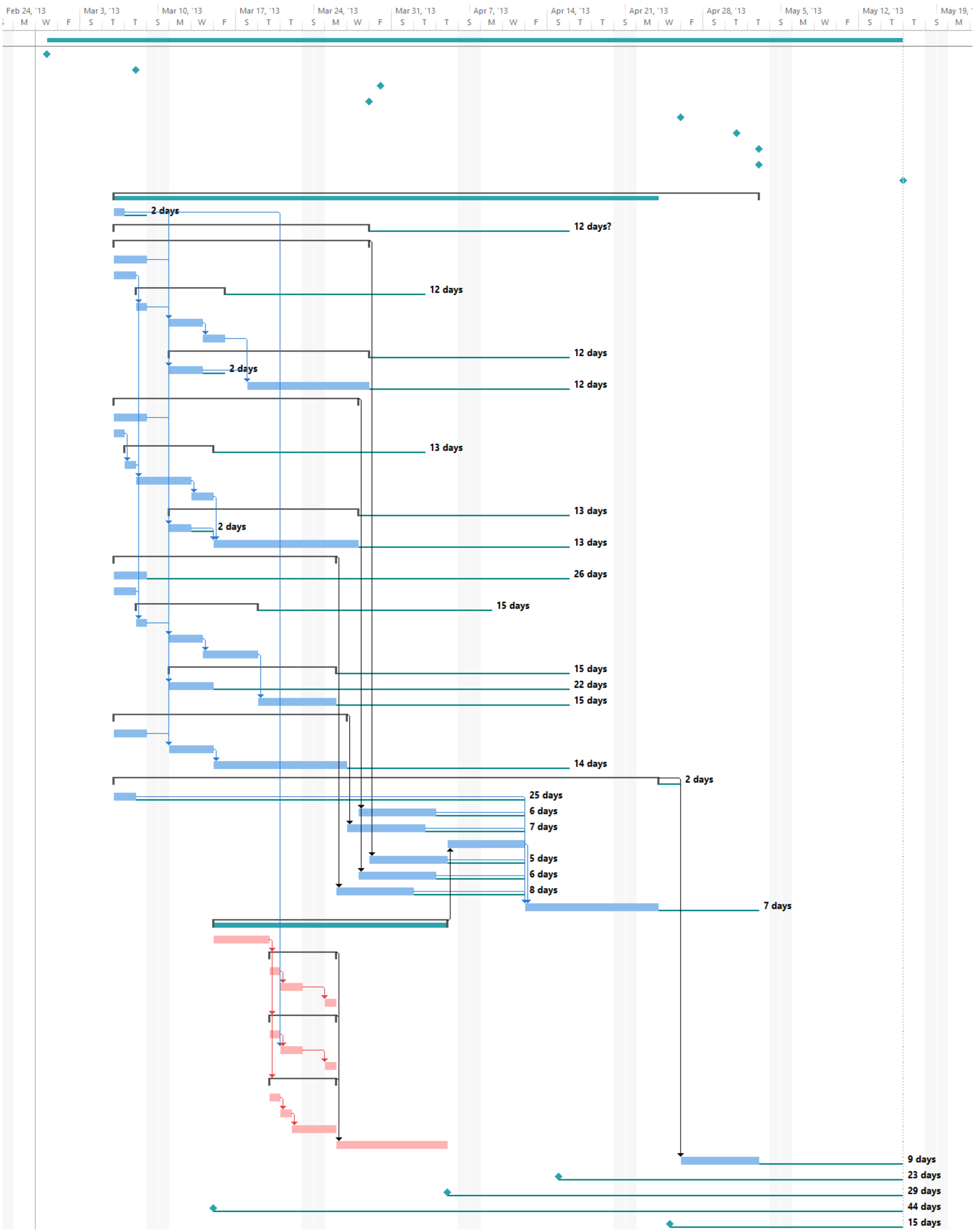
PROJECT MANAGEMENT:

Gant Chart

ID		Task Mode	Name	Duration	Start	Finish	Successors
1			**Important Days**				
2			Submition For Proposal	0 days	Thu 2/28/13	Thu 2/28/13	
3			Oral Presentation #1	0 days	Thu 3/7/13	Thu 3/7/13	
4			Preliminary Website Online	0 days	Fri 3/29/13	Fri 3/29/13	
5			Oral Presentation #2	0 days	Thu 3/28/13	Thu 3/28/13	
6			Practice Final Presentations	0 days	Thu 4/25/13	Thu 4/25/13	
7			Final Oral Presentations	0 days	Tue 4/30/13	Tue 4/30/13	
8			Final Report Outline and Assignments	0 days	Thu 5/2/13	Thu 5/2/13	
9			Final Website Online	0 days	Thu 5/2/13	Thu 5/2/13	
10			Final Report is due	0 days	Wed 5/15/13	Wed 5/15/13	
11			**Hexcopter Flying and Dropping**	**42 days**	**Wed 3/6/13**	**Thu 5/2/13**	
12			Assemble Hexcopter	1 day	Wed 3/6/13	Wed 3/6/13	22,32,42,46,65
13			**Sensors**	**17 days?**	**Wed 3/6/13**	**Thu 3/28/13**	
14			**Gps**	**17 days**	**Wed 3/6/13**	**Thu 3/28/13**	**53**
15			Part Acquisition	3 days	Wed 3/6/13	Fri 3/8/13	22
16			Sensor Calibration	2 days	Wed 3/6/13	Thu 3/7/13	38,18
17			**Software**	**6 days**	**Fri 3/8/13**	**Fri 3/15/13**	
18			Algorithm Design	1 day	Fri 3/8/13	Fri 3/8/13	19
19			Programming	3 days	Mon 3/11/13	Wed 3/13/13	20
20			Algorithm Simulation	2 days	Thu 3/14/13	Fri 3/15/13	23
21			**Hardware**	**14 days**	**Mon 3/11/13**	**Thu 3/28/13**	
22			Integration	3 days	Mon 3/11/13	Wed 3/13/13	23
23			Test part	9 days	Mon 3/18/13	Thu 3/28/13	
24			**Telemetry**	**16 days?**	**Wed 3/6/13**	**Wed 3/27/13**	**50,54**
25			Part Acquisition	3 days	Wed 3/6/13	Fri 3/8/13	32
26			Calibration	1 day?	Wed 3/6/13	Wed 3/6/13	28
27			**Software**	**6 days**	**Thu 3/7/13**	**Thu 3/14/13**	
28			Algorithm Design	1 day	Thu 3/7/13	Thu 3/7/13	29
29			Programming	3 days	Fri 3/8/13	Tue 3/12/13	30
30			Algorithm Simulation	2 days	Wed 3/13/13	Thu 3/14/13	33
31			**Hardware**	**13 days**	**Mon 3/11/13**	**Wed 3/27/13**	
32			Integration	2 days	Mon 3/11/13	Tue 3/12/13	33
33			Test part	9 days	Fri 3/15/13	Wed 3/27/13	
34			**Sonar**	**14 days**	**Wed 3/6/13**	**Mon 3/25/13**	**55**
35			Part Acquisition	3 days	Wed 3/6/13	Fri 3/8/13	
36			Sensor Calibration	2 days	Wed 3/6/13	Thu 3/7/13	38
37			**Software**	**7 days**	**Fri 3/8/13**	**Mon 3/18/13**	
38			Algorithm Design	1 day	Fri 3/8/13	Fri 3/8/13	42,39
39			Programming	3 days	Mon 3/11/13	Wed 3/13/13	40
40			Algorithm Simulation	3 days	Thu 3/14/13	Mon 3/18/13	43
41			**Hardware**	**11 days**	**Mon 3/11/13**	**Mon 3/25/13**	
42			Integration	4 days	Mon 3/11/13	Thu 3/14/13	
43			Test part	5 days	Tue 3/19/13	Mon 3/25/13	
44			**First Person Video Camera**	**15 days**	**Wed 3/6/13**	**Tue 3/26/13**	**51**
45			Part Acquisition	3 days	Wed 3/6/13	Fri 3/8/13	46
46			Integration	4 days	Mon 3/11/13	Thu 3/14/13	47
47			Test Part	8 days	Fri 3/15/13	Tue 3/26/13	
48			**GUI**	**35 days**	**Wed 3/6/13**	**Tue 4/23/13**	**72**
49			GUI Layout Design	2 days	Wed 3/6/13	Thu 3/7/13	56
50			Get Data From Accelerometer	5 days	Thu 3/28/13	Wed 4/3/13	56

51	Get Data from FPV	5 days	Wed 3/27/13	Tue 4/2/13	56
52	Implement Unloading Mechanism	5 days	Fri 4/5/13	Thu 4/11/13	56
53	Implement Target Selection	5 days	Fri 3/29/13	Thu 4/4/13	56
54	Integrate Battery Readings	5 days	Thu 3/28/13	Wed 4/3/13	56
55	Integrate Sonar	5 days	Tue 3/26/13	Mon 4/1/13	56
56	Redifine GUI and Finalized Layout	8 days	Fri 4/12/13	Tue 4/23/13	
57	**Unloading Mechanism**	**15 days**	**Fri 3/15/13**	**Thu 4/4/13**	**52**
58	Desing Loading Mechanism	3 days	Fri 3/15/13	Tue 3/19/13	59,63,67
59	**Software**	**4 days**	**Wed 3/20/13**	**Mon 3/25/13**	**71**
60	Algorithm Design	1 day	Wed 3/20/13	Wed 3/20/13	61
61	Programming	2 days	Thu 3/21/13	Fri 3/22/13	62
62	Algorithm Simulation	1 day	Mon 3/25/13	Mon 3/25/13	
63	**Hardware**	**4 days**	**Wed 3/20/13**	**Mon 3/25/13**	**71**
64	Microcontroller	1 day	Wed 3/20/13	Wed 3/20/13	65
65	Integration	2 days	Thu 3/21/13	Fri 3/22/13	66
66	Testing	1 day	Mon 3/25/13	Mon 3/25/13	
67	**Mechanical**	**4 days**	**Wed 3/20/13**	**Mon 3/25/13**	**71**
68	Design	1 day	Wed 3/20/13	Wed 3/20/13	69
69	Part Acquisition	1 day	Thu 3/21/13	Thu 3/21/13	70
70	Parts Assembly	2 days	Fri 3/22/13	Mon 3/25/13	
71	Integration and Testing	8 days	Tue 3/26/13	Thu 4/4/13	
72	Test and Redife Final Integration	5 days	Fri 4/26/13	Thu 5/2/13	
73	Obstacle avoidance	0 days	Mon 4/15/13	Mon 4/15/13	
74	Finish Unloading Mechanism	0 days	Thu 4/4/13	Thu 4/4/13	
75	Wireless streaming to Tablet	0 days	Fri 3/15/13	Fri 3/15/13	
76	Have The Gui fully Functioning	0 days	Wed 4/24/13	Wed 4/24/13	

Milestones are outlined above in items 73 through 76.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Resource Allocation

Software

- Senior Design Lab computers access to:
  - Visual Studio 2012
- Members will utilize software on individual computers:
  - Visual Studio 2012
  - Microsoft Viso
  - Arduino Software IDE

Equipment/Tools

- Senior Design Lab access to:
  - Soldering/de-soldering station
  - Oscilloscope
  - Power Supply
  - DMM
  - Electrical Components
    - Resistors, Capacitors, Inductors, etc
- Part requisition for ordering

Information

- Use of online academic databases
- DIYDrones
- Datasheets
- Cubic Sponsors
- SDSU Computer &Electrical Engineering Department

BUDGET:

Cost Analysis

DESCRIPTION	QTY	UNIT PRICE	TOTAL
Asus - VivoTab Smart Tablet with 64GB Memory - Black	1	$ 499.99	$ 499.99
USB-Live2 Analog Video Digitizer	1	$ 49.99	$ 49.99
5.8GHz 400mW plug and play transmitter/receiver/antenna combo	1	$ 190.00	$ 190.00
KX-1 Micro Color CMOS Camera	1	$ 50.00	$ 50.00
Turnigy 500mAh 3S 20C Lipo Pack	1	$ 15.00	$ 15.00
I2C MaxSonar EZ0	10	$ 44.95	$ 349.00
3DR Arducopter Hexa-B Frame + Motors + Full Electronics Kit	1	$ 605.99	$ 605.99
3DR GPS uBlox LEA-6	1	$ 75.99	$ 75.99
SERVOS (TBD)	5	$ 15.00	$ 75.00
12V Voltage Regulator [TBD]	1	$ 20.00	$ 20.00
Copter Battery (5000mAh 3s 30C)	2	$ 100.00	$ 200.00
Spektrum DX6i (Tx/Rx)	1	$ 210.00	$ 210.00
BEC (Battery Eliminator Circuit) [TBD]	1	$ 25.00	$ 25.00
xbee pro 900	2	$ 54.95	$ 109.90
antenna	1	$ 20.00	$ 20.00
xbee usb adapter	1	$ 14.99	$ 14.99
xbee board adapter	1	$ 9.99	$ 9.99
cable	1	$ 1.50	$ 1.50
PC	1	$ 200.00	$ 200.00
Router	1	$ 20.00	$ 20.00
		$ -	$ -
Extra Parts	1	$ 500.00	$ 500.00
		SUB	$ 3,242.34
		TAX RATE	8.750%
		TAX	$ 283.70
		S&H	$ 100.00
REQUEST FOR BUDGET $3650		TOTAL	$ 3,626.04

REFERENCES:

[1] Gageik, Nils, et al. *Obstacle Detection and Collision Avoidance Using Ultrasonic Distance Sensors for an Autonomous Quadrocopter*.Universitaet Wuerzburg. September 2012. 20 February 2013.