MRSD **Project 1**

Conceptual Design **Review**

UAV/UGV **Collaboration System**

Team **Zaphod**

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1. User Need

Our UAV/UGV collaboration system is meant to act as a platform for remotely detecting and handling explosives. This is particularly useful when the area of the site under attack/threat is vast or has a complex structure, and bomb squads need to search a large area in a short amount of time. More specifically, our system will be able to cover the following needs and tasks when deployed on a bomb site.

＊The operator needs to use a system to gain immediate access to data on the surrounding area in a short amount of time.

＊The operator wants to manipulate and move objects, which include suspicious bags or explosive devices, weighing about 1 lb.

＊The system used should be reliable and easy to pick up by untrained users.

2. Use Case Scenario

Things were going well for all the people who were at the concert listening to famous local bands. There was decent congregation of people, with a mix of people from all ages including older citizens and kids, but mainly younger people. Just a bunch of everyday people getting together to have a peaceful and quiet time. But disturbing the tranquility, was a huge thundering noise from one of the corners near the podium, followed by fire and smoke.

It becomes apparent that there has been an explosion near the stage, and a few of the people are hurt, police and emergency crews are called upon to the scene immediately. There is chaos and confusion filled around the place, and even though the emergency personal take a short amount of response time to get there, they have no definite intel/info regarding the situation to take a definite action. The first course of action is to find out if there are any other explosives or bombs nearby. Also, there is an immediate need to gather the necessary and significant data as soon as possible. Checking if there is any other potential explosive is the actions that need to be taken.

The Operator from the emergency unit deploys his UAV/UGV collaborative unit in the arena and takes up a workspace at a convenient distance, with video feeds flashing onto the screen in front of him. The UGV is teleoperated by the operator using a joystick and moves about in the field at 0.7 m/s, with the UAV tracking and following it, with the height of 10 feet above the UGV, with a camera on the bottom side of the drone, giving a view from the top. The operator gets live feed from both the robots, of 720p resolution, and the one from the UAV covers a large area in a short amount of time at the speed of 5m/s. The unit raises alarms duly when the ground unit is about to hit any obstacle, thereby helping the operator to maneuver them safely. Once he notices an object of interest or a potential bomb in and around the vicinity, the UAV hones onto that object and flies towards the object and hovers over it, giving instructions to the operator how to go to that place as effectively as possible.

The object is now inspected by the use of the cameras onboard the UGV and by using the 4 D.O.F. manipulator on the UGV which he controls using controller/or a GUI. The operator now has an idea whether the object is safe or not. If the object is safe, he can continue with his job for checking for more objects, or landing the UAV onto the UGV platform and returning if the job is done.

If in case the operator is able to detect the potential bomb, he now uses the arms to pick up the object safely and place it onto the platform of the UGV, and takes it to another location where they can safely dispose of the bomb. The UAV can follow them to help them in the path planning, or land onto the UGV while it goes upon completing the task. He also sees on the screen the continual monitoring of the power levels and the data that is being transmitted via Wifi.

Now that he has the idea as to how to traverse in the area in a duration of less than 10 minutes, he immediately tells the remaining personal how to go about and which places to avoid, thereby helping his companions and all the people over there in safely.

3. System-level Requirements & Performance Measures

Our UAV-UGV collaboration system will be divided into 3 main parts: UAV, UGV, and manipulator mounted on UGV.

3.1 UGV Requirements & Performance Measures

	Description	Performance Measure	Priority
Travelling distance/ Communication Range	The farthest distance UGV can travel without losing communication to the operator.	The distance should be 100m at min.	High
Terrain	The terrain that UGV should be able to travel across.	UGV should be able to cross a 5cm step or shallow water, as well as other rough surface such as grass.	High
Payload	The payload of UGV, including UAV, manipulator, and explosive.	The payload of UGV should be 40kg at max.	High
Battery Life	The battery life of UGV.	UGV should sustain continuous operation for at least 2 hours.	High
Area of Helipad	The area of the helipad for UAV to land on.	The area of the helipad should be at least 1ft*1ft big.	High
Slope	The slope that UGV can climb.	UGV should be able to climb a 15 degree slope.	Medium
Weight	The weight of UGV without payload or manipulator.	The weight of UGV should not exceed 12kg.	Medium
Maximum Speed	Maximum Speed of UGV moving.	The speed should maintain at 1m/s.	Low

3.2 UAV Requirements & Performance Measures

	Description	Performance Measure	Priority
Video Quality	The resolution of video captured by the camera on UAV.	The ideal resolution of video is 720p.	High
Frequency of Camera	Better frequency gives better accuracy. Measure number of frame per second.	The FPS should at least be 24.	High
Weight	The weight of UAV. It should be light enough to land on UGV.	The weight should be less than 500g.	High
Flight Control	Measure difference of given command and executed value.	When given commands to reach a designated point, UAV should not deviate for more than 10cm from that point.	Medium
Sensor	The sensors mounted on UAV.	The UAV should be mounted with IMU and ultrasonic sensors.	Medium
Payload	The payload of UAV.	The UAV should sustain at least 300g of payload.	Medium
Processor Speed	The speed of onboard processor. Better processing speed and frequency is desired	The MIPS rating should exceed 1000.	Medium

3.3 Manipulator Requirements & Performance Measures

	Description	Performance Measure	Priority
Maximum Payload	The lifting capacity of manipulator.	UGV should be able lift and carry 1 Lb. of load.	High
Maximum Reach	Reach of manipulator at full extension.	30 cm reach is required to pick up an explosive efficiently.	High
Shoulder Yaw	Manipulator base rotation.	180 degrees is desirable.	High
Shoulder Pitch	Rotation of the1st joint of manipulator.	180 degrees is desirable.	High
Elbow Pitch	Rotation of 2nd joint of manipulator.	180 degrees is desirable.	High
Wrist Pitch	Rotation of wrist of the manipulator.	180 degrees is desirable.	High

Gripper Opening	Opening of gripper.	Minimum 10 cm is required.	High
Interface	Software control of manipulator.	Each link should be controlled with minimum 1 degree resolution.	High
Manipulator Weight	Weight of manipulator.	The weight of manipulator should not exceed 4 lb.	Medium
Linear Arm Speed	Speed of manipulator.	10 cm/sec is appropriate.	Medium
Power	Power requirement to operate the manipulator.	6 volt and 5 amps are required to operate all servo motors.	Medium

4. System Validation Experiment

Demo Time	Task	Measure
Fall 2013	Rapid Deployment	Both UAV and UGV in starting state and the central control station up and running under 3 minutes
	UAV Takeoff	UAV takes off the platform and hovers over the UGV at a height of 2 meters from the ground on operator's instructions
	UGV Locomotion	UGV is able to traverse a real-world-like demo track as per operator's instructions avoiding 98 % obstacles in its path
	UAV Auto-Mode	UAV to follow the UGV autonomously at around 2 meters from ground and provide bird’s eye view of the UGV's progress
	UI Info Display	The UI will display both video feeds and a number of sensing data on a single window.
	Manipulator basic task demonstration	Stand alone manipulator test to show manipulator precision of 1 degree and reach of end last linkage till 30cm
Spring 2014	Auto Detect Targets	Detect 80% of the potential targets automatically and put a box around them in an image to help the operator
	UAV Auto-Landing	When given command, UAV will land itself on top of UGV. When it’s running out of battery, UAV will also perform auto-landing on UGV.

	UI Input Control	The UI window will have buttons and sliders for basic command input. UI will also allow keyboard command in addition to controlling with joypad.
	Manipulator integrated task demonstration	Manipulator positioning upto 1 degree precision, 30 cm reach potential target and lift 2lbs with gripper as per operator's commands
	Overall task performance	The overall performance of UAV-UGV collaboration.

5. Trade Studies

The following tables are trade studies for our system. We will assign to each performance a score on the scale from 1 to 5, 5 being the highest/closet to requirement. Each feature will also have a weighting number from 1 to 3, where 3 means the highest priority, and 2 &1 are medium and low, respectively.
(The assessment with an asterisk attached to it indicateds that while we can’t find a official spec sheet to prove the performance, it is reckoned to be possible based on videos on the Internet.)

5.1 UGV Trade Studies

The candidates for our UGV are Pioneer 2-AT, MMP-40, KUKA YouBot, and SuperDroid 4WD. One noteworthy point is that since Pioneer is the only one available right now, and commercial UGV is generally expensive, we’ve rated the availability of Pioneer robot much higher than all the other choices. After comparison, Pioneer 2-AT is our most suitable choice for UGV.

		Pioneer 2-AT		MMP-40		KUKA YouBot		SuperDroid 4WD	
Battery Life	**3**	2-3 Hours	**5**	2 Hours	**5**	1.5 Hours	**3**	1.5 Hours	**3**
100m Travelling Distance	**3**	Possible*	**5**	Possible*	**5**	Possible*	**5**	Possible	**5**
Maximum Speed	**1**	0.7m/s	**4**	0.75m/s	**4**	0.8m/s	**4**	1.5m/s	**5**
Terrain (5cm step)	**3**	Possible	**5**	Possible*	**5**	Clearance 2cm, Otherwise okey	**3**	Possible	**5**

Slope (15 degrees)	**2**	21.8 degree	**5**	Possible*	**4**	Unknown	**1**	Possible*	**4**
Payload	**3**	40kg	**5**	13.5kg	**3**	20kg	**4**	6.8kg	**2**
Weight	**2**	14kg	**4**	18kg	**3**	20kg	**2**	13.6kg	**5**
Wireless Comm.	**3**	On-board modem	**4**	R/C in advt	**4**	Will need to implement it using Switchport. Need major work.	**1**	On board wi-fi	**4**
Availability	**3**	Yes	**5**	No	**1**	No	**1**	No	**1**
Overall Score (Total: 115)		**109**		**87**		**65**		**83**	

5.2 UAV Trade Studies

There are only 2 viable options for our UAV: Parrot Drone 2.0 and Arducopter. Again, since Parrot Drone is readily available, it will be our choice for UAV even though Ardcopter has some superior features.

		Parrot Drone 2.0		Arducoptor	
Video recording and transmission	**3**	HD camera onboard drone, 2 in number. Connect and collect date via Wifi using Ros Nodes., Range = 50 meters	**5**	can use external camera, not onboard	**2**
Frequency of camera	**3**	30fps	**5**	30fps	**5**
Processor	**2**	ARM cortex A8 processor onboard, with 1GB RAM ; 2,000 MIPS at 1.0 GHz	**5**	APM boards; Atmega 1280 @16 MHz, 32 Mips	**3**
Sensors	**2**	3 axis Gyro, 3 axis accelerometer, 3 axis magnetometer, Pressure sensor, Ultrasonic	**4**	6 DOF IMU, GPD, Magnetometer, Barometer, IR sensor, Sonar	**5**
Weight	**3**	carbon fiber tubes, 420 g with indoor hul	**5**	1.22 Kg	**1**
Flight Control	**2**	4 brushless motors, 14.5 W , 28,500 RPM	**5**	4 motors, 850 Kv	**5**
Power	**3**	3 elements 1000mA/H Lipo	**5**	LiPo battery	**4**

Payload	**2**	250g	**2**	800g	**5**
Interface	**3**	via Ros nodes through Wifi	**3**	GUI available, with basic PID controls , etc.	**5**
Size	**1**	52.5x51.5cm with hull	**5**	46.99 x 46.99 cm	**5**
Availability and cost	**3**	Yes	**5**	No	**1**
Overall Score (Total: 135)		**121**		**95**	

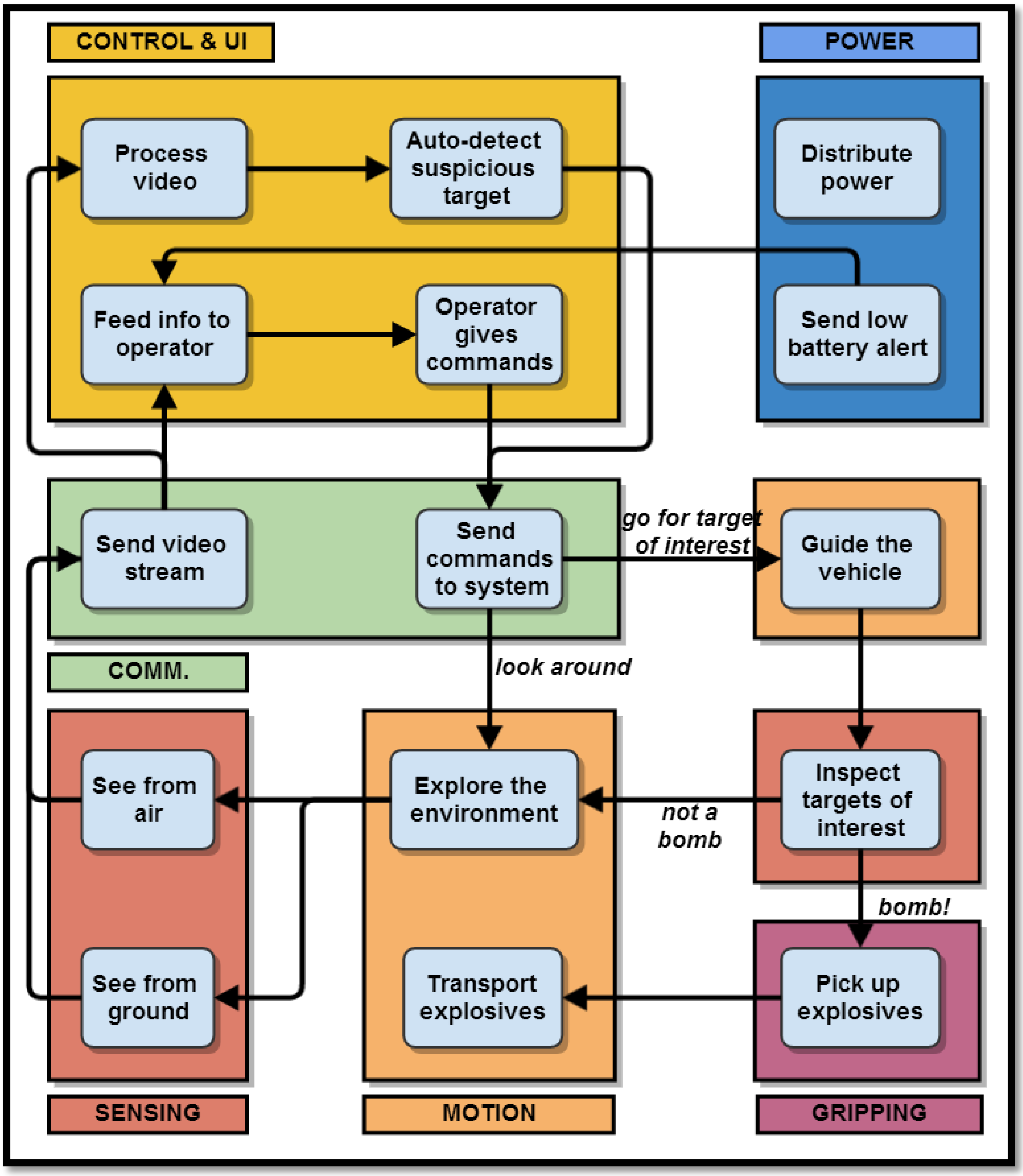
5.3 Manipulator Trade Studies

Because we will design and build our own manipulator arm, we'll do the trade study of motor needs for the manipulator.

One of the major design considerations is accurate position control for our manipulator design. For that, we considered three alternatives for the kinds of motor: Servo – Hitec HS – 805BB, Stepper- ROB – 10847 and High torque DC motor. There is neither feedback nor position control available in DC motor, so we eliminated that option. Stepper motor is suitable for the application, but due to lack of feedback, the position of the shaft cannot be accurately determined. Hence, we finalized Servo motor for our application because it fits in all above mentioned criteria.

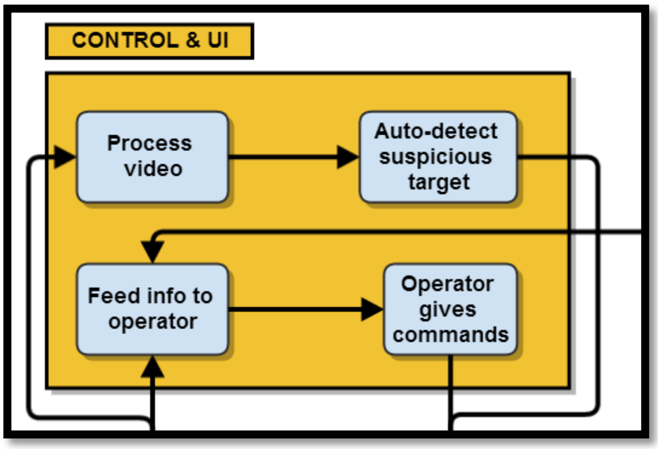
		Servo - Hitec HS-805BB		**Stepper Motor- ROB-10847**		**High torque DC Motor**	
Feedback	**3**	Yes	**5**	No	**1**	No	**1**
Position control	**3**	Yes	**5**	Yes	**5**	No	**1**
Torque (Kg-cm)	**3**	24.69	**5**	9.17	**3**	12	**4**
Weight (gm)	**2**	152	**4**	196	**3**	125	**5**
Size (mm)	**2**	66 x 30 x 57	**3**	56 x 56 x 75	**3**	25 x 25 x 69	**4**
Overall Score (Total: 65)		**59**		**39**		**36**	

6. Function Architecture

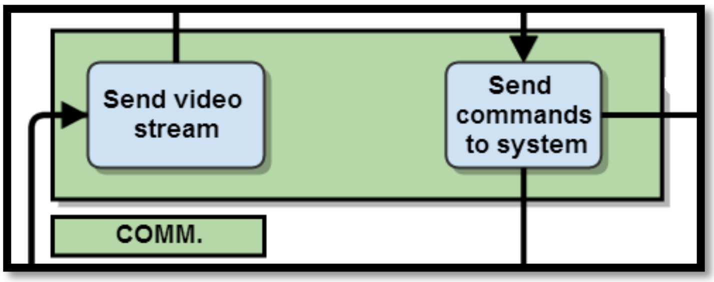


The function architecture for our system can be divided into 6 subsystems: User & UI, Communication, Sensing, Motion, Gripping, and Power.

6.1. Control & UI Function Architecture



This part of the system includes the operator, the control system and the user interface. Once the operator obtains the info sent back from the video feeds and sensors, her or she can either actively sending various kinds of commands to the system, or monitor the system as it carries out certain tasks by itself, such as auto-detecting suspicious bags or packages.

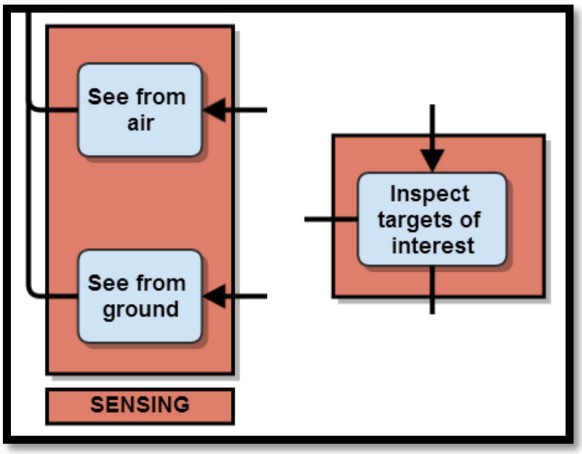


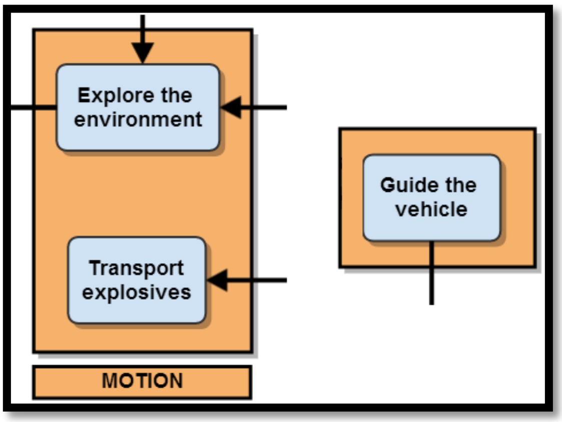
6.2. Communication Function Architecture

This subsystem deals with sending all the data back and forth between the remotely-operated system and the operator.

6.3. Sensing Function Architecture

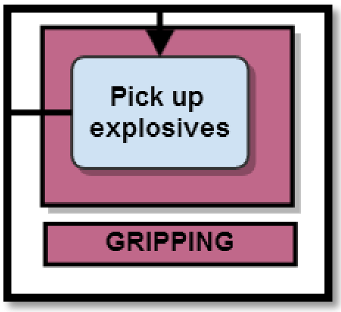
The sensing part of the system consists of a pair of cameras and onboard sensors. When surveying the environment, the operator will have a bird's eye view from UAV. Once the system is near the suspected explosive device, the operator will further inspect the device with sensing data and video feed from UGV.





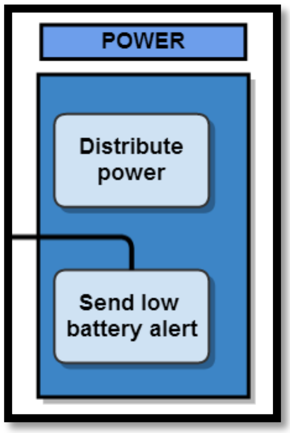
6.4. Motion Function Architecture

The motion part enables the whole system to move around. The UAV will have the ability to follow the UGV around closely, and the UGV needs to be able to traverse different kinds of terrain and minor obstacles.



6.5. Gripping Function Architecture

The gripping subsystem is a manipulator arm capable of picking up the explosive and either holding it with the gripper or placing it in a basket on the back of the UGV.



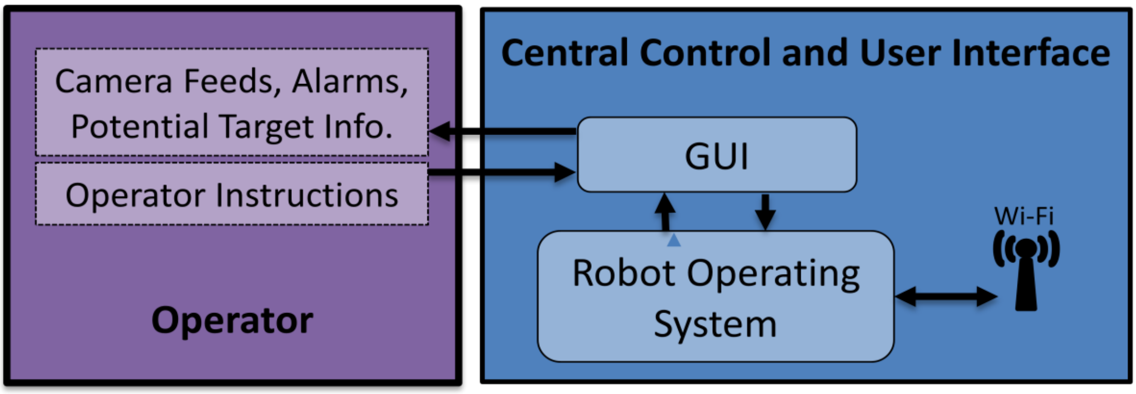
6.6. Power Function Architecture

The last subsystem, power, is simply the part of providing power. The power system also has a minor but crucial function that it would send out a warning signal to the operator when the battery of UAV is running out, so the operator can make the UAV land on top of UGV.

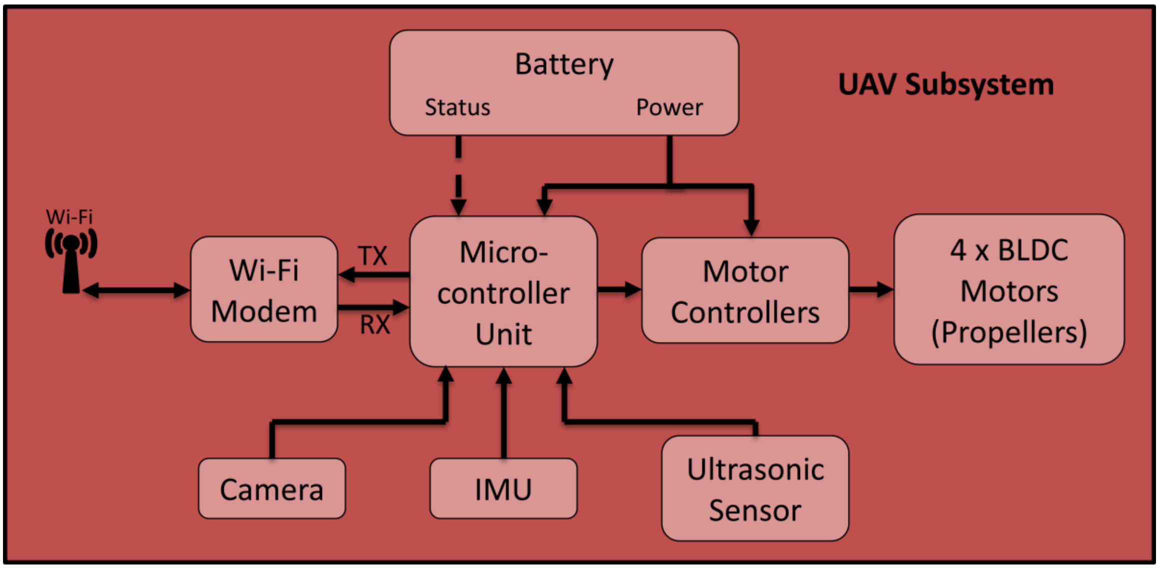
7. Physical Architecture

There are four parts to our system's physical architecture: operator, central control & UI, UAV, and UGV & Manipulator.

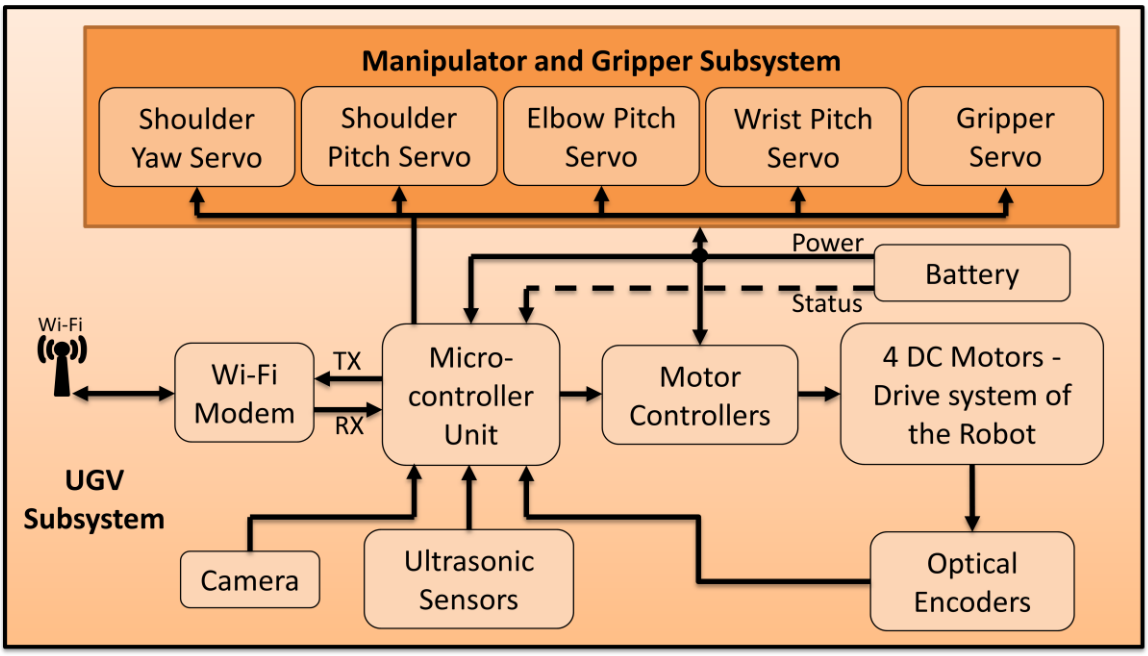
7.1 Operator, Central Control & UI Physical Architecture



7.2 UGV & Manipulator Physical Architecture



7.3 UAV Physical Architecture



8. Work Breakdown Structure

	UAV	UGV	Manipulator	User Interface and Intelligence
Week 1	Basic communication link establishment through ROS	Basic communication link establishment through ROS	Grasping mechanism finalization	(A) Get the infrastructure ready, familiarize with ROS and required packages. (B) Basic connection establishment with UAV and UGV
Week 2	Basic Flight testing with commands given through ROS nodes	Basic locomotion testing with commands given through ROS nodes		
Week 3	Video stream interfacing	Video stream interfacing	Design of linkages and base	Stream videos from UAV and UGV on the monitor
Week 4	(A) Battery monitoring and alarm (B) Operator -assisted emergency landing	Ultrasonic sensor array testing	Finalize the servomotor	Display sensor data from on the monitor in an accessible form
Week 5	Hovering of UAV at given fixed distance from ground using ultrasonic sensor	Positioning of UGV at a fixed distance from Target with help of Ultrasonic sensors	Manufacture the linkages, mount the motors and test the joint movement	Make simple test utility for manipulator control

Week 6				Add basic GUI features for controlling the robots
Week 7				
Week 8			Testing of manipulator with actual servomotors	Implement algorithm for tracking UGV in UAV's feed and accordingly instruct UAV to follow UGV
Week 9				
Week 10	Automatically follow UGV			
Jan ‘14	UAV automatic emergency landing		Design and Manufacturing of Gripper	Use UGV tracking algorithm for emergency landing
Feb ‘14		Integration of manipulator with UGV	Integration of manipulator with UGV	Implement algorithm for detection of potential targets and highlight them in the UAV video feed
Mar ‘14				
Apr ‘14				Refine the GUI

9. Parts List & Budget

Part	Subsystem	Approximate Price (USD)
1 Pioneer 2-AT	UGV	4995 (Available)
1 Parrot ARDrone 2.0	UAV	300 (Available)
1 Webcam	UGV	90
Helipad	UGV	20
Manipulator links - material and manufacturing	Manipulator	200
6 x Servo Motors	Manipulator	240
Gripper - material and manufacturing	Manipulator	300

10. Responsibilities of Each Team Member

	UAV	UGV	Manipulator	UI & Intel
Primary	Vamshi	Akshay	Swapnil	Kevin
Secondary	Kevin	Swapnil	Vamshi	Akshay