# ABES Aerial Robotics Team (AART)

# Technical Design Paper for AUVSI SUAS, 2017

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# ABSTRACT

This paper presents the engineering approach carried out in the development of Unmanned Aerial Systems (UAS) of ABES Aerial Robotics Team (AART). The team consists of undergraduate Engineering students from multiple domains. To meet the requirement of this competition our team has developed and designed an H frame Quadcopter with a Pixhawk autopilot for flight control and an on-board Odroid XU4 processor for image processing related tasks.

# SYSTEM ENGINEERING APPROACH

This section involves several approaches that were taken into consideration while developing the UAS for the competition. The team analysed the tasks and requirements of the competition, based on the analysis the tasks were subdivided into major disciplines of engineering where the team developed a conceptual solution for the problem and later developed a practical design for the same.

Testing and evaluation was done at each module level and upon successful evaluation each individual module was integrated to the system, onto which continuous testing and evaluation is being made so that our system compliances with the requirements of this competition.

## Mission Requirement Analysis

The first and foremost task is to identify the requirements of the mission. After an extensive reading of rules of AUVSI SUAS 2017 competition mainly following requirements were obtained.

| Tasks | Description |
|---|---|
| Autonomous Flight | • The UAS should takeoff and land autonomously and should fly for at least 3 minutes in auto mode. Transition into Stabilize/Manual mode needs to be avoided.<br>• The UAS have to navigate through a sequence of waypoints and get within 100ft of each waypoint. Also to improve the accuracy of the navigation, UAS can attempt to capture the waypoint multiple times.<br>• Flight bounds - 100 ft. MSL to 750 ft. MSL. |
| Obstacle Avoidance | • To avoid virtual stationary and moving obstacles. |
| Search Area Task | • Characterisation of the objects on the basis of background shape, background colour, alphanumeric, alphanumeric colour and alphanumeric orientation.<br>• Also provide Geolocation of each object.<br>• The result can be submitted manually or autonomously. It is preferred to submit it autonomously through interoperability. |
| Airdrop | • A 8 oz. water bottle to be dropped from at least minimum altitude level (i.e. 30m) such that it retains at least 80% of the water.<br>• Our objective is to drop the bottle autonomously at the given GPS location.<br>• An additional equipment/casing can be attached to prevent the bottle from any damage. |
| Interoperability Task | • The telemetry data have to be uploaded to the interoperability system to verify the waypoint accuracy of at least 1 Hz rate. |

| | |
|---|---|
| | • To upload detected image and its characteristics and fetch the position of the off-axis target. |

**Rationale behind System selection –**

The mission requires an aircraft capable of flight of 45 minutes having high ground speed, so that maximum distance could be travelled in minimum span of time.

Following parameters were discussed prior to the selection of type of aircraft-

- Complexity
- Average flight Time
- Degree of Support for Image Processing related tasks.
- Degree of Support for Air Delivery

Right now, team is developing a quadcopter rather than fixed wing aircrafts, because our search algorithm is working almost fine over quadcopters. So at the cost of speed we are utilizing stability of multirotor aircrafts so that maximum results can be obtained from image processing.
Similarly in case of Air Delivery, multi rotors can provide stability to the system and has the ability to maintain a constant position in air, so Air Drop can be done easily, removing all the hustles of projectile motion that were imposing blocks in case of fixed wing aircrafts.
Obstacle Avoidance task is currently at the lowest stack of our bags, and is still under development process. However autonomous air drop system is ready and tested successfully.

## Design Rationale

AART (ABES Aerial Robotics Team) consists of 12 team members from various disciplines having 0-2 years' experience of developing & testing various platforms of UAS and 1 faculty advisor. All the team members are at bachelor level of education and the team is majorly divided into three sub divisions consisting of Electrical & Electronics division, Software Development & Aero-mechanical division. Each sub team work according their specialization and also help other team at minor level in need.

**Airframe Selection**

| **Airframe type (available)** | **Advantage** | **Disadvantage** |
|---|---|---|
| Ranger ex 757-3<br>(Fixed wing) | • High Cruising Speed<br>• High endurance& flight time<br>• Easily repairable due to foam and EPO | • Waypoint hit accuracy very less<br>• Larger operating area required<br>• High control skills required<br>• Difficult to operate in cross & gusty winds |
| Tarot X6<br>(Hex copter) | • High manoeuvrability<br>• Works even on single motor failure<br>• Can perform VTOL<br>• Can carry large payload in compact size | • Less cruise speed<br>• Less flight time<br>• No Gliding feature<br>• Not easily repairable |
| H-Quad<br>(Scratch Build) | • High manoeuvrability<br>• Can perform VTOL<br>• Waypoint hit accuracy high | • Will crash on a single motor failure<br>• Less cruise speed |

| | | |
|---|---|---|
| | • Easily repairable | • No Gliding feature<br>• Hinders radio waves due to material |

From the above at the early stage our team went through selection phases.

At first, the team worked on fixed wing aircraft but soon realized that it requires a very large clear area to operate and as the college is in high density population area, the team's major time period was being wasted in travelling to clear testing sites which also start making an impact on timelines.
Then the team started working on Tarot X6 HexCopter with good results, until it suffered a severe crash. The spare parts of Tarot X6 were very costly and soon the team realized that to develop a successful UAS system requires lots of R&D and more than 100 test flights which may results in crashes.
So finally, the team decide to build rotorcraft from scratch with considerations of crash and easy availability of material and parts. The team build an H-shape Quadcopter of aluminium alloy which is easy to manufacture and the team can build multiple frames easily for backups.

Advantages with our H-frame-

- Waypoint hit accuracy
- Less cost of frame
- Easily repairable on crashes & multiple backup frames at low cost
- Can operate, practice & test in smaller fields
- Can operate in cross & gusty winds

Challenges with our H-frame-

- Low cruise speed and flight time which can be challenging during object detection/classification/localization task.

But the team has planned to reduce the weight of UAS least as can and to change the batteries for high endurance missions.
Our choice of using GoPro Hero 5 action camera was also an outcome result of change of airframe because we now require larger photo footprint area so that maximum area could be covered in a single frame. Prior to it, our team worked with some digital cameras like Nikon Powershot and Canon 760D with 50mm lens. Results from Nikon Powershot were not up to the mark, however another camera Canon 760D with 50mm lens was giving accurate results, but we were bounded to the limitation of payload, hence a heavier camera choice was ruled out and also we could not afford any chances of damage of these cameras during mission testing.

## Programmatic Risks & Mitigations

There are many types of risks associated during operation of Unmanned Aerial system. To perform the operation successfully and without any hindrance it is necessary to identify the risks and problems that may slow down the operational processes or may lead to crash or harm the surrounding.
So, for proper flow and functioning of team towards the competition goal, a set of risks were identified and proper mitigation methods were adopted

| Risk Description | Impact probability | Mitigation Methods |
|---|---|---|
| Not able to meet competition Deadline | Low | Proper planning regarding working of team and an inspection at the end of every week is made regarding work progress. |

| | | |
|---|---|---|
| A sever crash or damage to critical system | Medium | Backup frames and system components are always kept in reserved. Quick actions regarding repair or parts addition. |
| Change in design, software or any other avionic component | Low | Thorough study, simulation & discussions done before implementing any system on UAS. |
| Short of Team members | Low | The team members are regularly consulted regarding their work, so that they don't lose their attitude towards work |
| Less experience or skill | Medium | Multiple missions on small frames were performed with proper De-briefing |
| Unable to operate UAS properly | Medium | Proper pre-flight check-up and Post flight analysis with log study is performed |

# SYSTEM DESIGN

## Aircraft

**Airframe-** The airframe performing all the tasks is a scratch designed and manufactured Quadcopter of H-shape configuration. The frame is made of Aluminium alloy (6063-T1). The material is selected keeping the Budget of team, skills on machinability and considering accidental consequence.

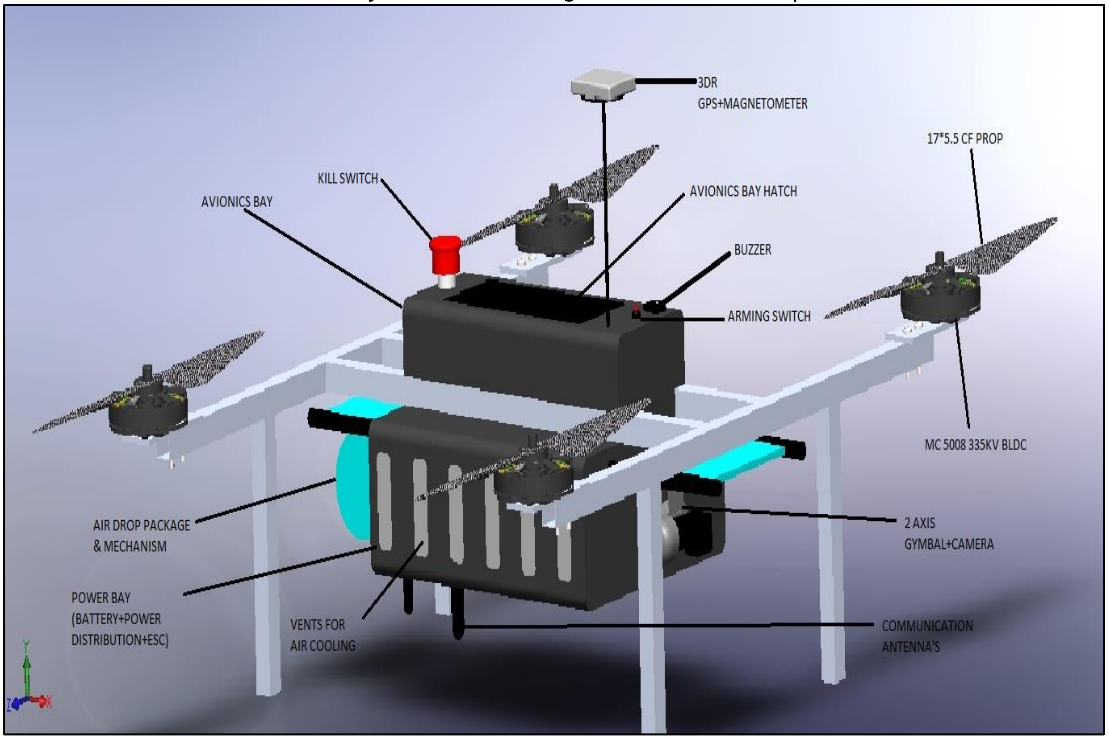



*Fig.1- 3D Model of UAS*

**H-frame**-The quadcopter configuration is H-shape. This configuration allows easy construction of the chassis of frame as no external plating, mounting hinges is required which reduces the weight of frame considerably. At first the team made an X configured quad from scratch, but its self-weight was considerably high as compared to H-Shape. It also allows mounting various type of payload on the frame without addition of extra support in the frame.

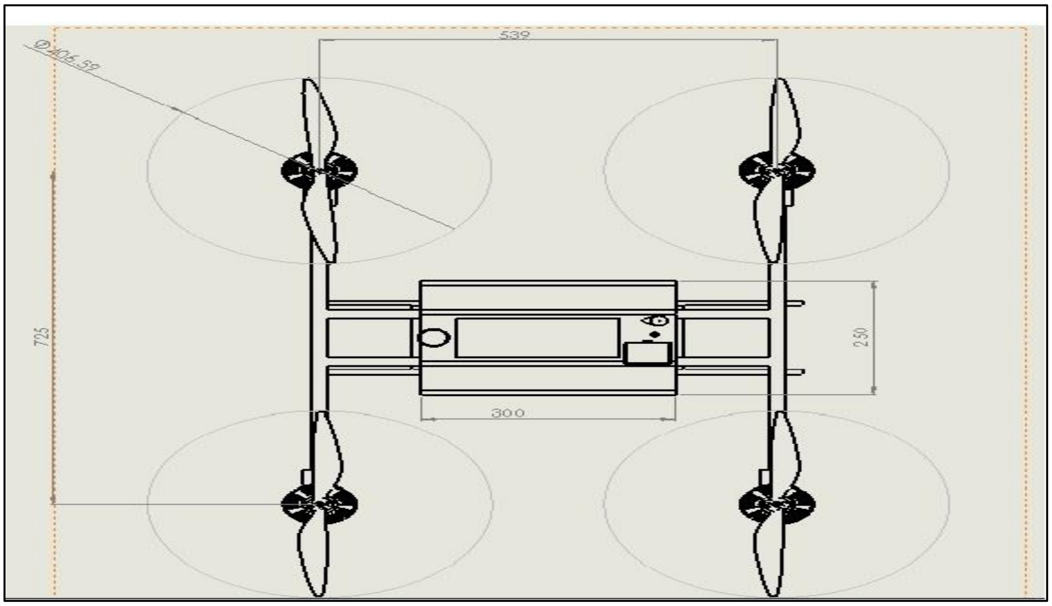



*Fig.2- Dimensions of UAS*

**Material**-The airframe chassis is made up of aluminium alloy (6063-T1). The reasons to select this material are as under-

- Low cost of the material and easy availability in the market.
- Easy machinability and weldability.
- Ductile nature prevents generation of debris in crash.
- Less Damage to avionics in crash.
- Requires less advance manufacturing process as compared to other composites or carbon fibre etc.
- Light weight and aircraft grade material with high tensile strength.

**Calculations and Analysis**- Proper calculations regarding the dimension of aircraft; e.g.

- The arm length of rotors.
- The clearance between propellers spin.
- Check for area under prop wash and prevention of any hindrances.

The structural static and dynamic simulations both FEM (Finite Element Methods) and CFD (Computational Fluid Dynamics) methods are used to identify defects and changes in structure and selection of proper propeller size and pitch for aerodynamic flow and propulsion.

The results helped team to find the following-

- Defects in weldments,

- Proper propeller size,
- Prop wash area, structural damage and effects in simulation under different extreme forces situation

With the above simulation and calculations team were able to optimize the size and material of aircraft after complete simulation under *Ansys 17.0* which helped them to grow their knowledge in practical applications of fem. The CFD analysis helped the students to select the proper prop size even with the comparison available in the datasheet provided by motor manufacturers which helped them to optimize and generate an efficient propulsion system for our aircraft. The bending of frames and behaviour of material under high stress material were also observed and many changes were made to minimize structural failure under.

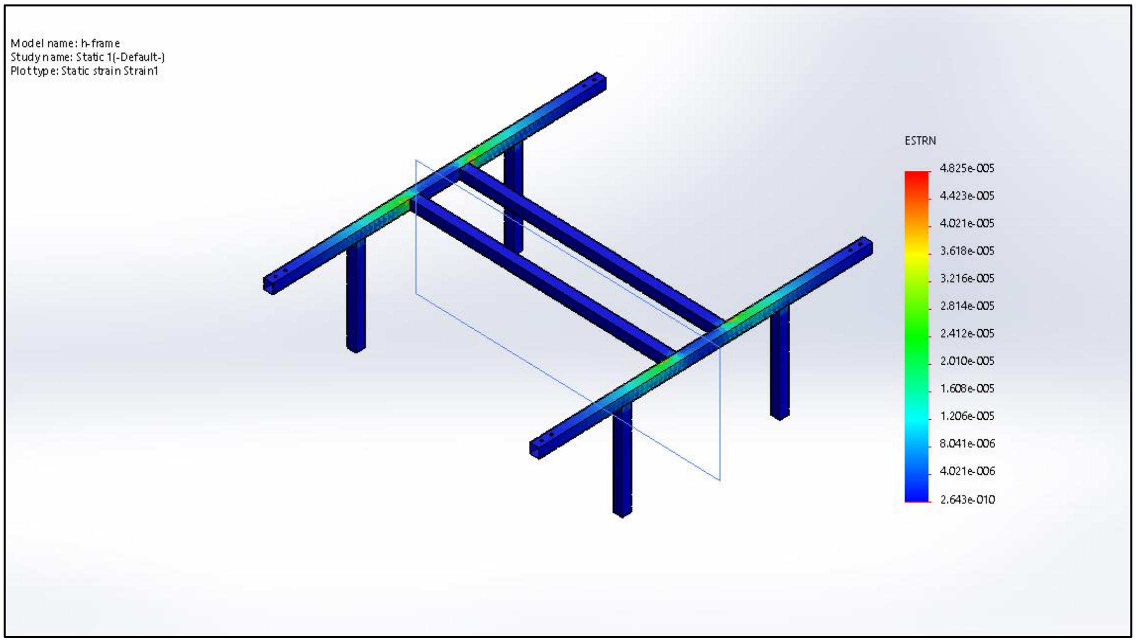



*Fig.3- Strain on weldments and joints and their minimized value for optimization*

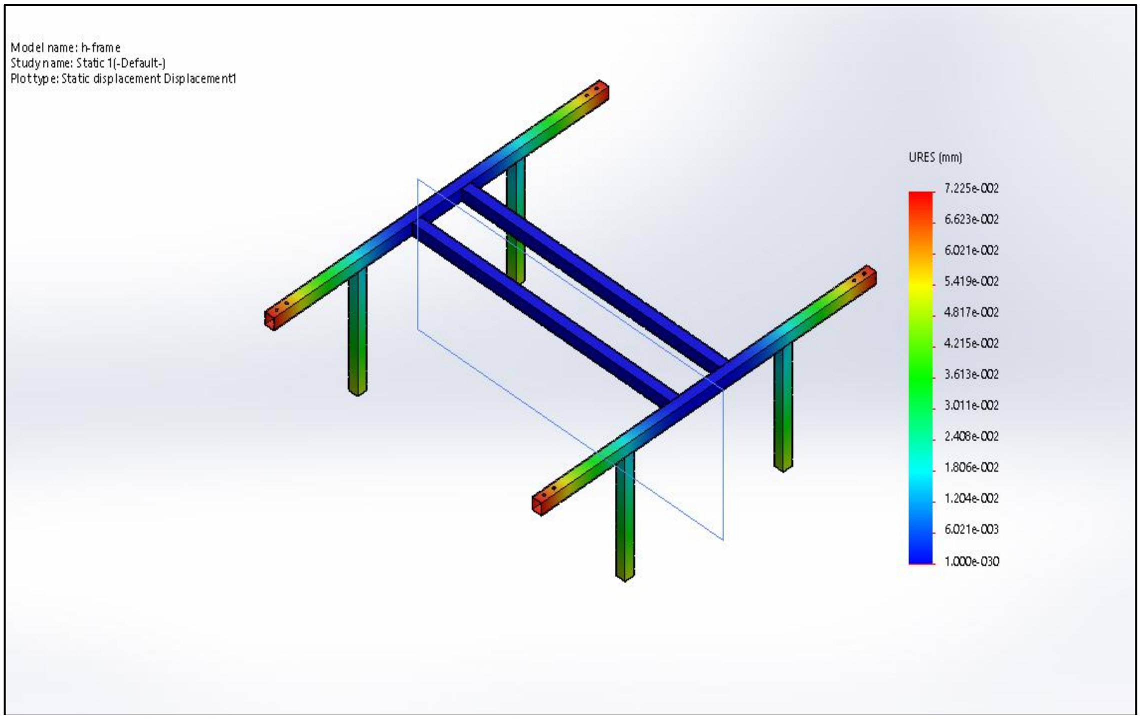
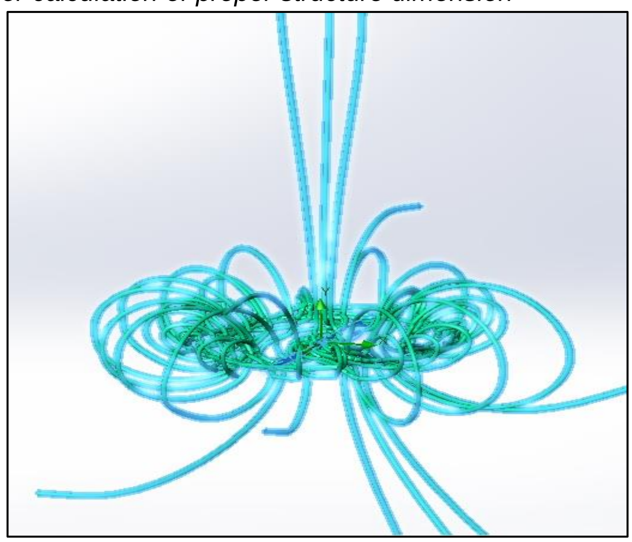



*Fig. 4- Maximum deformation stresses for calculation of proper structure dimension*

**Propulsion System-**

Number of Rotors-4
Propeller-17*5.5" Carbon fibre
Motor-FPV MC-5008
KV Rating-335 kv
Operating voltage-22.2 V
Battery-16000mAh 6s LiPo & 2*10000mAh LiPo
System cruise current-19A
System max current-30A
Max speed-10m/s



*FFig. 6- CFD Analysis of thrust and airflow*

After a deep search for optimize motor and prop selection and CFD analysis the above given propulsion system was selected. The current consumption of the complete system is 19 A which gives a good flight time and endurance.

- Flight time at 16000mAh-35 mins
- Flight time at 20000mAh-50 mins

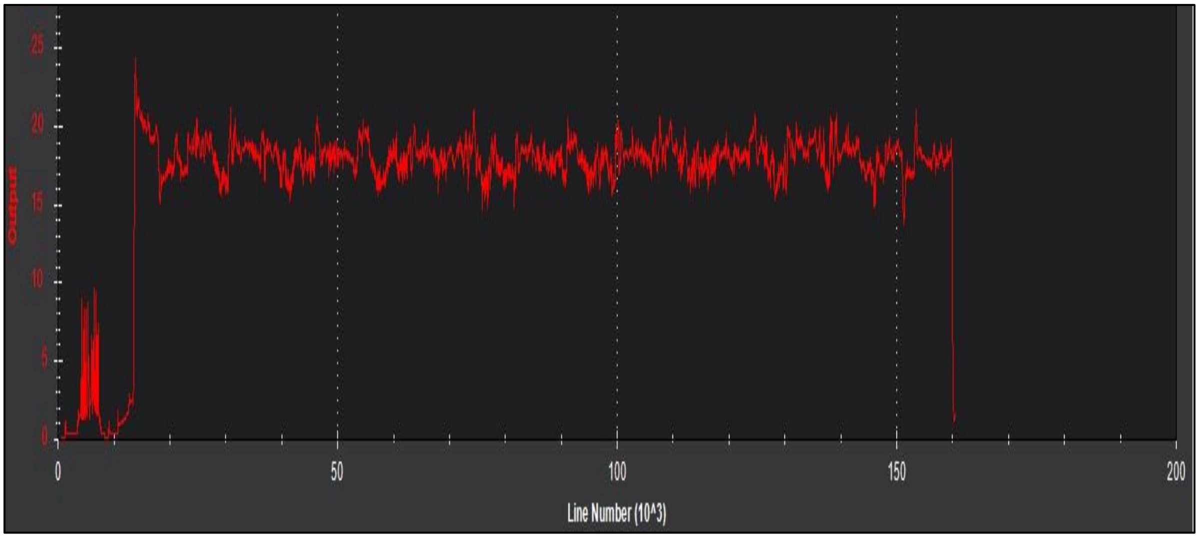



*Fig. 5- Average Current consumption during flight*

Above is the graph plotted by the data log from the autopilot regarding consumption of current by the complete system during the mission. By the above we can observe the average current being consumed is 19 A.

## Autopilot

Competition requirement is fulfilled by using Pixhawk Flight Controller due to its reliability; it is highly optimized to provide control and automation for Mission Planner software with high performance and capacity.
Pixhawk autopilot gives better stability than other used autopilots by our team.
Pixhawk uses PID (Proportional Integral Derivative) controller to control the position, heading and altitude of aircraft in flight. Pixhawk Flight Controller also uses EKF (Extended Kalman Filter) which is generally used for optimal estimation of position and orientation, taking guidance with past data readings of sensors. The use of EKF in flight controller allows it to work on most accurate data from sensor and thus accuracy in navigation and control of aircraft is obtained.

Pixhawk autopilot is capable enough of-

- Autonomous Take-off and landing capability
- Autonomous Waypoint Navigation
- Autonomous Navigating in a search area in through grids
- Autonomous Airdrop at any GPS location
- Configuring failsafe parameters
- Allowing addition of many sensors.

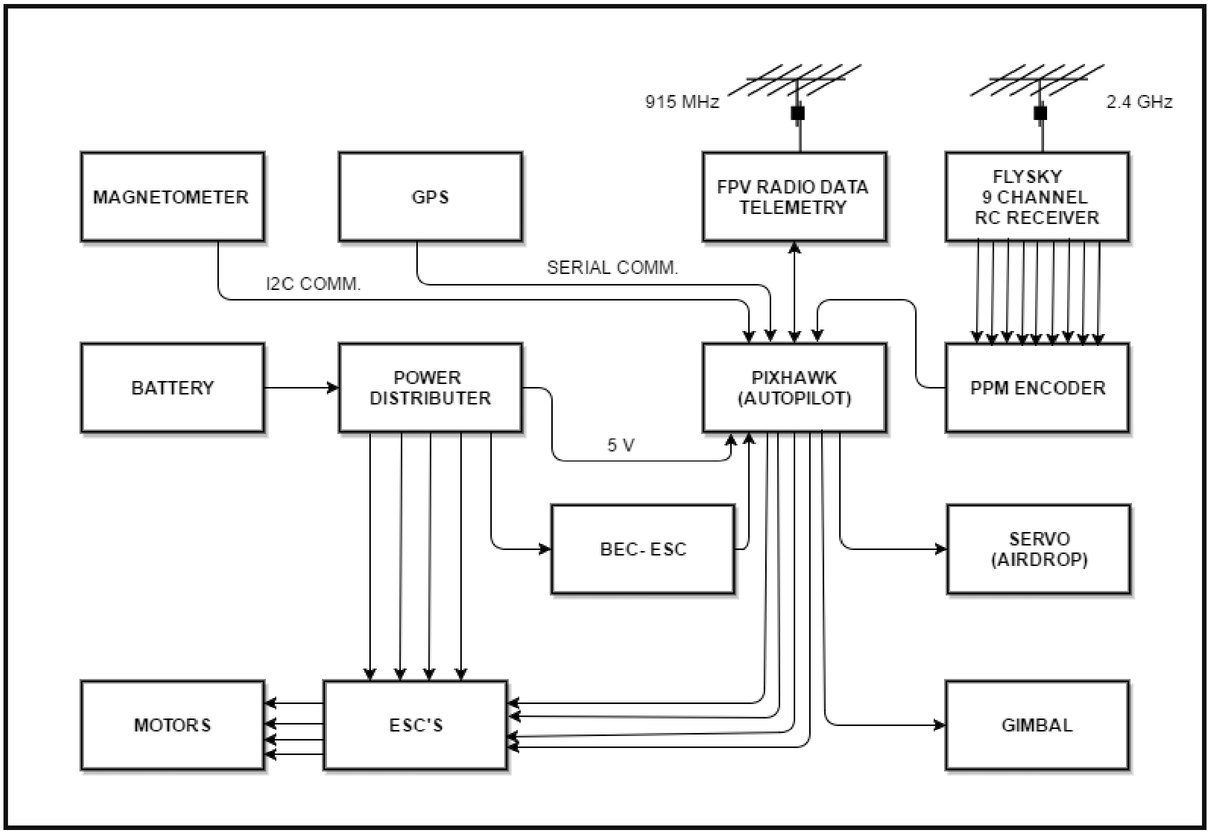



*Fig. 6-UAS System Schematic Diagram*

**Ground Control Station-** We are using combination of Pixhawk as autopilot and Mission Planner as GCS. One of the features of the Mission Planner is that it can run Python scripts, which is an easy way to extend the functionality of the program beyond its built-in functions which will help us to integrate Interoperability with Mission Planner. Tasks related to Interoperability like Obstacle Avoidance, etc. can be attempted by use of python scripts of Mission Planner.

Our Ground control Station consists of a HUD (Heads up Display) monitor for feasibility of safety pilot for better control over Unmanned Aerial vehicle.


*Fig. 7- Ground Control Station Setup*

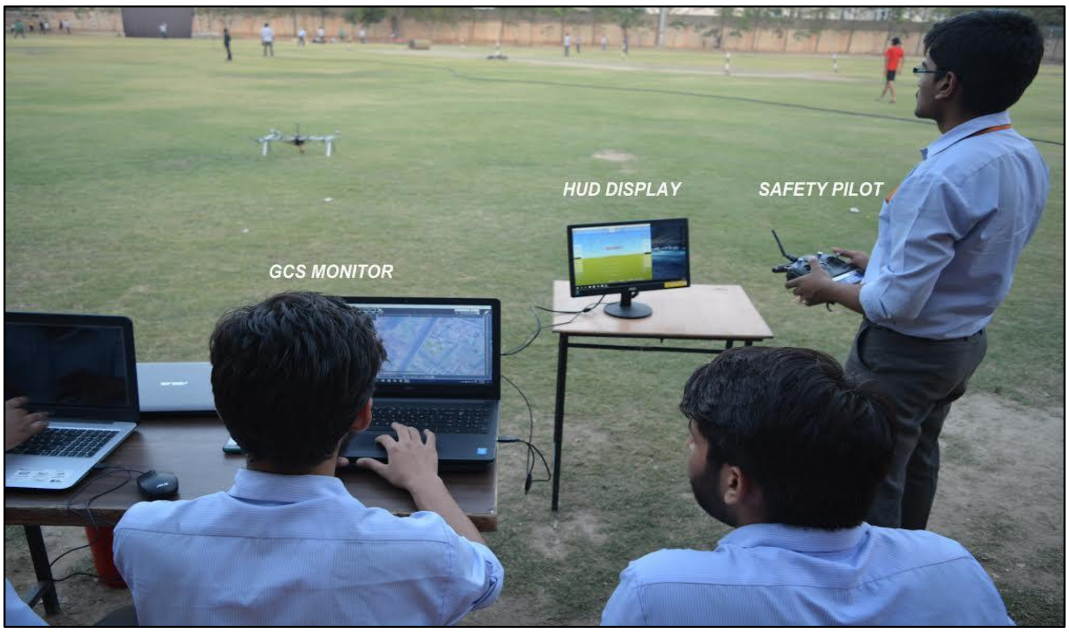



*Fig. 8- Ground Control Station Setup with HUD for safety pilot*

Ground Control Station has a display which always shows a map showing live flight statistics including important parameters like UAS speed, MSL Altitude, Battery Voltage, Current Consumption etc.

## Obstacle Avoidance

By far, we have not fully developed the obstacle avoidance intelligence algorithm for the Autopilot to avoid any stationery or moving obstacles by getting its feed from Interoperability server. We are continuously striving hard to develop a working algorithm for the same. For the time being, our GCS operator will manually update flight path if any obstacles comes in between, to avoid collision.

However, this type of updating flight path of UAS will not be efficient in case of moving obstacles.

## Imaging System

An analysis was done by the team which focussed on factors such as resolution, field of view etc. to choose the best camera for the competition tasks. Also the team preferred the camera to have some protective casing, to prevent any kind of damage to the camera.

For imaging system, we have decided to use an action camera, because any chances of damage to the camera from occurrence of any crash flight are ruled out because of its high withstanding capability. In action camera, especially GoPro Hero 5 camera was chosen because it is said to be the best camera of GoPro. GoPro Hero 5 Black 4k has been chosen as the preferred camera for the imaging platform as it can shoot 4K videos at 30 frames and can take 12 Megapixel stills supporting auto-upload even when camera is charging.

It has GPS for automatic location tracking and it also has built in active noise cancellation and built in auto stabilization.

The GoPro Hero 5 Black 4k camera supports many modes for photography with different FOV (Field Of View) namely, Wide, Medium, Narrow etc. So there exists a trade-off between GSD (Ground Sample Distance) or resolution/pixel and Photo Footprint, among which we are using it in wide mode where GSD comes out to be 3.196 cm/pixel from an altitude of 35 meter.

The method used for calculating GSD (cm/pixel) is computed as follows-

GSD horizontal= Distance captured on ground horizontally / Horizontal Pixels

Where,

Distance captured on Ground horizontally=2*Altitude*tan (Radians (Horizontal FOV÷2))

Similarly, GSD vertical is calculated using Vertical FOV and vertical pixels of camera.

| **GoPro Hero 5 Wide Mode** | | | **GoPro Hero 5 Narrow Mode** | | |
|---|---|---|---|---|---|
| Horizontal Field of View (deg) | 122.6 | | Horizontal Field of View (deg) | 64.6 | |
| Vertical Field of View (deg) | 94.4 | | Vertical Field of View (deg) | 49.1 | |
| Horizontal Pixels | 4000 | | Horizontal Pixels | 2016 | |
| Vertical Pixels | 3000 | | Vertical Pixels | 1128 | |
| Altitude (m) | 35 | 50 | Altitude (m) | 35 | 50 |
| GSD horizontal (pixel/cm) | 3.19 | 4.56 | GSD horizontal (pixel/cm) | 2.19 | 3.13 |
| GSD vertical (pixel/cm) | 2.52 | 3.59 | GSD vertical (pixel/cm) | 2.83 | 4.04 |

So, the average resolution of about 2.5 cm/pixel is sufficient enough for detecting target features of size as mentioned in rulebook from an altitude of 35 meter at flying speed of about 10 m/s.

## Object Detection, Classification, Localization

The object detection/classification/localization task is one of our high priority task. Various methods were used to determine the best approach for this task.

### Selection of possible target

The first task was to find possible target regions or regions of interest in our image. We considered three approaches for blob detection, namely k-means clustering, thresholding methods and colour quantization. For all the three methods first the image was downscaled, this substantially decreased the processing time while keeping the results fairly accurate. This was very helpful especially for k-means clustering, which was impractical to use on normal image due to its large processing time. For this task we first down sample the image to 100th of original size. Then we apply k-means clustering to find region of interest. The image is then thresholded and converted to binary. Contours are found using find contours function in OpenCV that is based on Topological Structural Analysis of Digitized Binary Images by Border Following by *Suzuki, S and Abe, K*. The ROI are then cropped from original image. The ROI are then filtered based on size and contents. The selected crops are then used for further processing.

**Pre-processing of targets**

The images are blurred with a bilateral filter to remove noise. Then watershed algorithm is used to black out the background of image.

**Extracting shape**

Clustering was done to find three prominent regions in the image, the background, the shape and the character. The shape was easily extracted simply by appropriately thresholding the image. Morphological gradient was applied to find shape outline. The contours of this shape were found and were approximated using *approxpolydp* function in OpenCV based on *Douglas Pecker algorithm*.

**Shape recognition**

The contours received from previous stage were compared with previously fed shape templates to decide the shape. The shapes which did not match any template were discarded.

**Character extraction and recognition**

Characters were extracted only from shapes that were selected. Character extraction was achieved by appropriately thresholding the image. The character recognition was done using *Tesseract OCR*. It was used for its fast and accurate results. The character was rotated various times by fixed amount and passed to the OCR. The result with highest accuracy was considered as the final character and its angle was taken as 0 degree. The character's orientation was then determined from this. The results with very less confidence result were discarded as false negatives.

**Colour detection**

For both the shape and character the HSV values of the pixels were found from the original image and then averaged .The HSV value was compared with previously fed values and the colour was determined.

All these object detection/classification/localization related image processing tasks are done on an on-board processor *Odroid-XU4*.

All the results obtained after these processing are transferred wirelessly from on-board computer to Payload systems at Ground Control Station, where data is further processed and then uploaded in designated format to the interoperability server.

## Communications

Hardware used for communication between UAS and GCS are –

- FPV Radio Data Telemetry 1(915 MHz) between Pixhawk and GCS for exchange of Mavlink data
- FPV Radio Data Telemetry 2(915 MHz) between Odroid XU4 and Payload station for transmission of JSON and target images from on-board processor memory to Payload station
- 5.8 GHz Video Telemetry to transfer live video feed in the NTSC/ PAL format from FPV camera to GCS for display purposes.

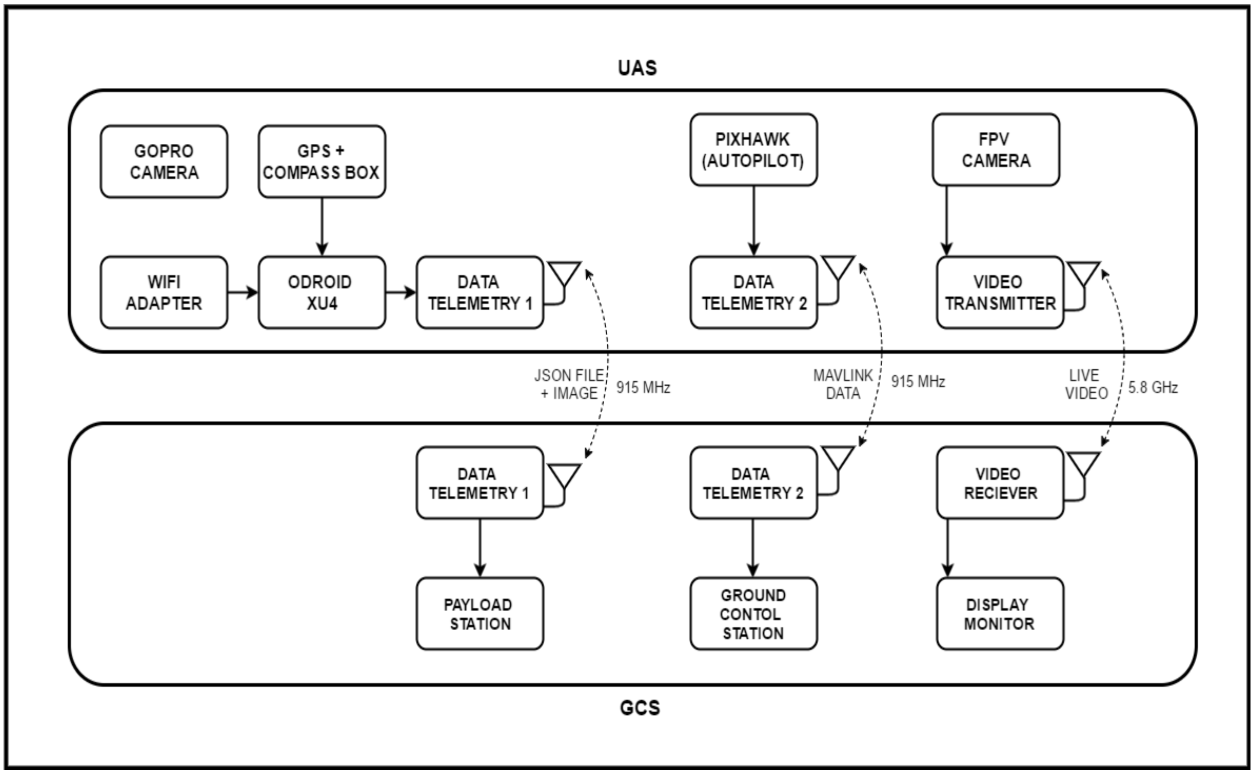



*Fig. 9- Communication System between UAS and GCS*

## Air Delivery

Performing airdrop from a rotorcraft gives an advantage as we can perform the airdrop as free fall on reaching the delivery site precisely. There is no issue of projectile motion of delivery package and aircraft speed calculations. The only problem we expect is the drift by wind during free fall.

Our team has planned to let our UAS to reach the drop location and decent to minimum competition allowed altitude with some threshold altitude in case of altitude error and then perform the airdrop.

The mechanism consists of a bottle attached by a net strap which is hooked by thin shaft triggered by a servo. Due to less height airdrop the final position of package has less bounce and deviation from the drop point.

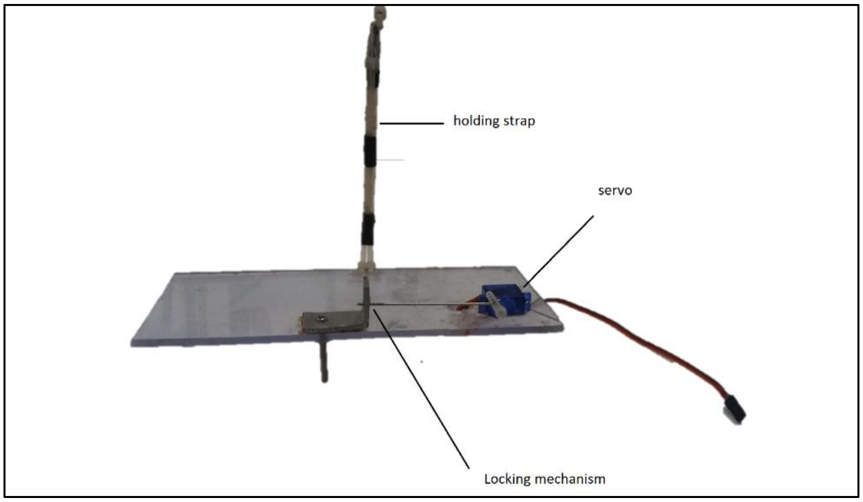



*Fig. 9- Bottle drop mechanism*

## Cyber Security

In cyber security we are using hybrid algorithm of RSA and AES encryption technique which is a public key encryption technology. RSA encryption is based on use of a public and a private key. Typically RSA technique is use to encrypt the keys to make secure exchange of keys and AES encryption is used to encrypt the data.

Now for data exchange between UAS and GCS, first we have to create a secure connection between UAS and GCS with the help of RSA. Secure connection provides strong authentication and secure encrypted data communications over an insecure communication channel such as the wireless communication. After establishing the connection between them, we have encrypted the data received by system by using AES technique and then through the secure connection the encrypted data reaches at GCS. GCS then converts that encrypted data or cipher text into plain text by decryption process. This whole process is contribution to the security in our system. Through it, we can protect our information or data from any kind of theft or damage from the other system.

# TEST & EVALUATION PLAN

## Developmental Testing

During the construction of UAS, we conducted various tests which helped us to choose the various components used in the UAS.

**Air frame material**: Aluminium was chosen after a few tests and safety considerations. Different materials were tested and taken into considerations and after thorough brainstorming, taking economic limits, aluminium was chosen.

| **Parameters /criteria** | **Carbon Fibre** | **Aluminium** | **Injection Moulded Plastic** |
|---|---|---|---|
| Frame | Tarot X6 | Scratch Build | Robomart quadcopter |

| | | | |
|---|---|---|---|
| Cost | (USD 400) (INR 25700) | (USD 7) (INR 500) | (USD 63) (INR 4000) |
| Pros | It is highly stable, light weight, can carry large payload, more speed than Quadcopter, can even work when one motor fails | Aluminium is very cost efficient and easily available. Aluminium does not shatter away into debris due to its ductile nature. In most cases we are able to repair aluminium frames easily. | It is a easily available and is good for testing purpose |
| Cons | Carbon fibre parts and components are expensive and cannot afford frequent crashes | It is heavier than carbon fibre and it may hinders to radio waves | Cannot carry heavy payload |

## Individual Component Testing

Individual components of this UAV were tested separately and then combined into a whole integrated system.

a) **Autonomous Flight:** Autopilot was chosen after going through thorough comparison between two popular autopilots. Many small sized frames were made and autopilots were tested on them for various functions. Autonomous flight was done of various frames and it worked almost perfect.
b) **Imaging:** people's review over the internet and those from professional photographers formed the base for the choice of camera. Then the camera was tested for durability, endurance, water resistance, etc. It did survive a fall from 30 meters.
c) **Air Delivery:** The mechanism of air delivery system is as simple as possible. During testing phase, the bottle was dropped from a height of 50 metres. Not only it survived the fall but also it bounced off only 20 feet from the point of drop. We are still testing it and accuracy is improving. The air delivery system is both manually and autonomously controllable.
d) **Communication:** For the safety of communication from GCS and RC transmitter, various spots were identified on the frame for fixing RC Receiver so that there is no interference from any other components like ESCs.
e) **Object Detection/Classification/Localisation:** The module is tested on ground till now. We are successful in completing the task on ground.

## Mission Testing Plan

Mission has been tested for a few times in recent without Object detection, classification and localisation. Every time it has been successful and we are able to complete the mission in 30 minutes. We are doing it step by step. First we completed the task of waypoint navigation. This task was quite easy. Then we moved to next task of air delivery. First we did this task manually i.e. we controlled it from RC transmitter. Then we tried and are successful in doing it autonomously. Now we are focusing on Autonomous Object detection, classification and localisation and updating grid to the autopilot.

**Backup Strategy:** Till now we are able to perform waypoint navigation, autonomous air delivery under 30 minutes. If we can't do Autonomous object detection, classification and localisation and update grid to autopilot before the time limit, we will be doing these tasks manually from GCS. Also, if we found out that the grid we will get there is larger than that we are designing here, it will be too slow according to us. So in that case we will increase the speed and decrease the efficiency. This will be like a trade off in the code.

# SAFETY, RISKS, & MITIGATIONS

## Developmental Risks & Mitigations

| Risks | Description | Mitigations |
|---|---|---|
| Development Risks | A change in critical Design component which may lead to wastage of time with no output. | A considerable amount of time is given before implementing or changing a system subset. |
| Failure of developed products | Desired output is not obtained | Continuous troubleshooting |

## Mission Risks & Mitigations

| Risks | Description | Mitigations |
|---|---|---|
| Loss of data communication | A communication link between the aircraft and the GCS setup at the base of the mission during flight time. | Best position for the radio device was chosen on the UAS after many attempts, so that interference can be minimized between different types of signals. If there is a communication loss for more than 30 sec. between UAS and GCS, the autopilot automatically initiates RTL/RTH. And if communication loss is for more than 3 minutes, the flight gets terminated. |
| RC Connection lost | A communication link between the aircraft and the safety pilot setup at the base of the mission during flight time | For RC connection problem, we have decided to wait for the connection to be re-established for 15 second. If the connection does not re- establish within the given time frame, we will execute a Return to Launch (RTL) command and look into the problem. |
| Air Frame Damage | In case of harsh landing, if by any reason, our frame gets distorted or damaged. | For any damage to the frame, we have kept two backup frames ready to be used in any emergency. |
| Any unexpected behaviour | Any unexpected behaviour of our autopilot or other avionics during autonomous flight may occur. | If any such incident occurs, our Safety pilot will take the manual control and minimize the danger. |

| | | |
|---|---|---|
| | | We have decided to use Aluminium as the primary material of the frame as it would bend or deform without breaking into small shrapnel. |
| Geo – Fence breach | If by any reason or malfunction in GPS module, the Unmanned Aerial System breach the Geo Fence. | In any case of Geo Fence breach by the air frame, a Return to Launch (RTL) Or Return to Rally Pointcommand would be executed. |

## Operational Risks & Mitigations

| **Risks** | **Description** | **Mitigations** |
|---|---|---|
| Communication gap among team members | The new members of the team may not be able to communicate well the existing team members | We have frequent and regular discussion sessions to help team members interact with each other and get better outputs from the team. |
| Error in uploading mission or waypoints to the autopilot | We have ruled out this possibility, but every team member knows how to tackle this. | Every member has a basic idea of how to feed the waypoints to Mission Planner. |
| Misinterpretation by team members | Accustomed to a certain accent, there is possibility of communication error with the judges. | For avoiding any misinterpretations, we are trying to become habitual to the accent there. |
| Unable to handle any unexpected situation | Occurrence of any unexpected error or glitch can delay the project to a great length | We are planning to conduct a simulation of the mission and competition so we can deal with every possible error that might occur. |

# CONCLUSION

Development for the SUAS 2017 presents a steep learning curve for our team. As this is our first competition our team learns many things. A number of algorithms were explored for the development of the image processing. We were able to manufacture our own Quadcopter. The system engineering approach ensures a safe and reliable unmanned aerial system. Staying true to the team's dedication to safety and reliability team members are suitably trained to ensure the success of the mission. With continuous testing and practice, ABES Aerial Robotics Team is prepared to compete at SUAS 2017