SRM - UNMANNED AERIAL VEHICLE

Journal Paper for AUVSI SUAS 2017

SRM University, India

Figure: SRM-UAV ACE-GT

Abstract

SRM-UAV is a student-led research team at SRM University, India. We have a multidisciplinary team that consists of undergraduate students from various branches of engineering which has helped us to push beyond boundaries to create a state of the art system AUVSI SUAS 2017 Competition. To realize the rationale of this competition, we will be using *ACE-GT* from the *SRM-UAV ACE* series. In order of priority, the system that has been developed to satisfy competition requirements, flight, and overall safety. We have incorporated a high degree of autonomy and on-board processing with a prime focus on the safety of personnel and property on the ground as well as that of the aircraft itself. All flight related operations such as take-off, landing, and cruise are autonomous; these are controlled by the flight controller. As a majority of our operations happen on-board, the flight controller is considered as a low-level computer that works in coordination (depending on flight situations) with higher level computers such as Machine Vision Computer, Flight Termination System, and Master Computer. The Flight Termination System was developed by the competition requirements. It also takes into account other significant risks that could pose a threat to people, property and the aircraft itself. All aspects of the mission can be monitored and controlled from the Ground Control Station. Our results from multiple test flights and individual subsystems testing have been promising.

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1. Systems Engineering Approach

1. a. Mission Requirement Analysis

Over the past two years, SRM-UAV has been developing the ACE series to meet the requirements of the AUVSI SUAS competition and have evolved by a generation in our knowledge and expertise.

We have segregated the tasks or requirements at SUAS 2017 as follows:

- Interoperability System (requirement)
- Autonomous Take-off
- Waypoint Navigation
- Autonomous Landing
- Stationary Obstacle Avoidance
- Moving Obstacle Avoidance
- Object Detection, Classification, Localization
    - Standard Object
        - Search Area
        - Off-axis
    - Emergent object
- Air Delivery

Every task has a threshold and an objective. Threshold indicates the minimum performance which a team has to present to get graded for the respective tasks. Objective indicates the performance which a team has to present in order to score maximum points for a task. We plan to accomplish the objective of Autonomous Take-off, Waypoint Navigation, Autonomous Landing, and Standard Objects in the Search area and Air Delivery. However, we shall attempt and try to achieve the Threshold for Standard Object Off-Axis target and Emergent Object. Obstacle Avoidance does not have a threshold, and since it is graded all or nothing, we shall achieve Stationary Obstacle Avoidance and attempt Moving Obstacle Avoidance.

We have taken the objective of accomplishing all the above tasks and requirements for designing our systems and introspecting our performance.

1. b. Design Rationale

By analysing the requirements of SUAS 2017 and combining the experience gathered from SUAS 2015 and Medical Express Challenge 2016, we have narrowed down into the following design goals:

- Requirement of lighter and portable airframe
- Shift to a more reliable autopilot system
- Optimisation of on-board systems to enable full utilisation and elimination of extra components.
- Isolation of crucial systems to ensure flight safety in case of failures
- Development of efficient algorithms for Image processing and Obstacle avoidance
- Improved algorithm and release mechanism for Air Delivery

These design goals were addressed by implementing a lot of developmental changes from previous years. The major changes include

- Use of a reliable airframe
- New autopilot system, APM: Pixhawk 2 which has reductant sensors and proven algorithms for very stable flight dynamics

- Dedicated GPU powered embedded computer for image processing on the ground
- Single on-board computer for all communications, obstacle avoidance, air drop calculations etc.
- Single encrypted communication system for interoperability, autopilot telemetry, and imagery data
- New machine vision camera mounted on an image stabilisation system will facilitate high quality images for Object Detection, Classification, and Localisation.

1. c. Programmatic Risks & Mitigation

Programmatic risks that could delay/jeopardize the project were assessed on the basis of our experience from Medical Express Challenge 2016, and SUAS 2015. The risks are enlisted in the following table:

Risk	Description	Impact	Probability of Occurrence	Mitigation
Funding Delays	A majority of our funds come from the university. Due to a large number of research groups in the campus, funding delays are unavoidable.	High	High	Application for funding was made well in advance. To make the team more sustainable, efforts were made to obtain more resources through sponsorships.
Testing Constraints	SUAS requires a fixed-wing aircraft with high payload capacity. Hence, a runway is necessary for testing. Unfortunately, availability of a runway in the vicinity is low.	High	Medium	Permissions from a private airfield was sought in order to conduct frequent flight tests.
Fabrication Facilities	Limited facilities and high fabrication costs in the country, especially for composite materials	Medium	High	Almost-Ready-To-Fly aircraft was purchased and modified as per the system requirements.
Crash during Testing	Unfortunately, crashes are an inevitable part of testing in the aviation industry and often cause irreparable damage to the aircraft and payload.	High	Medium	A backup aircraft similar to the main airframe was fabricated.
Shipping Delays	As a lot of components are imported, shipping and custom clearance delays are inescapable.	Medium	High	Components were ordered well in advance. Also, paperwork was prepared beforehand to minimize delays.
Unavailability of Components	The import of LiPo batteries in India is restricted up to 95 Watt-hours	Low	High	IC Engine was chosen as the power plant over an electric propulsion system.

2. System Design

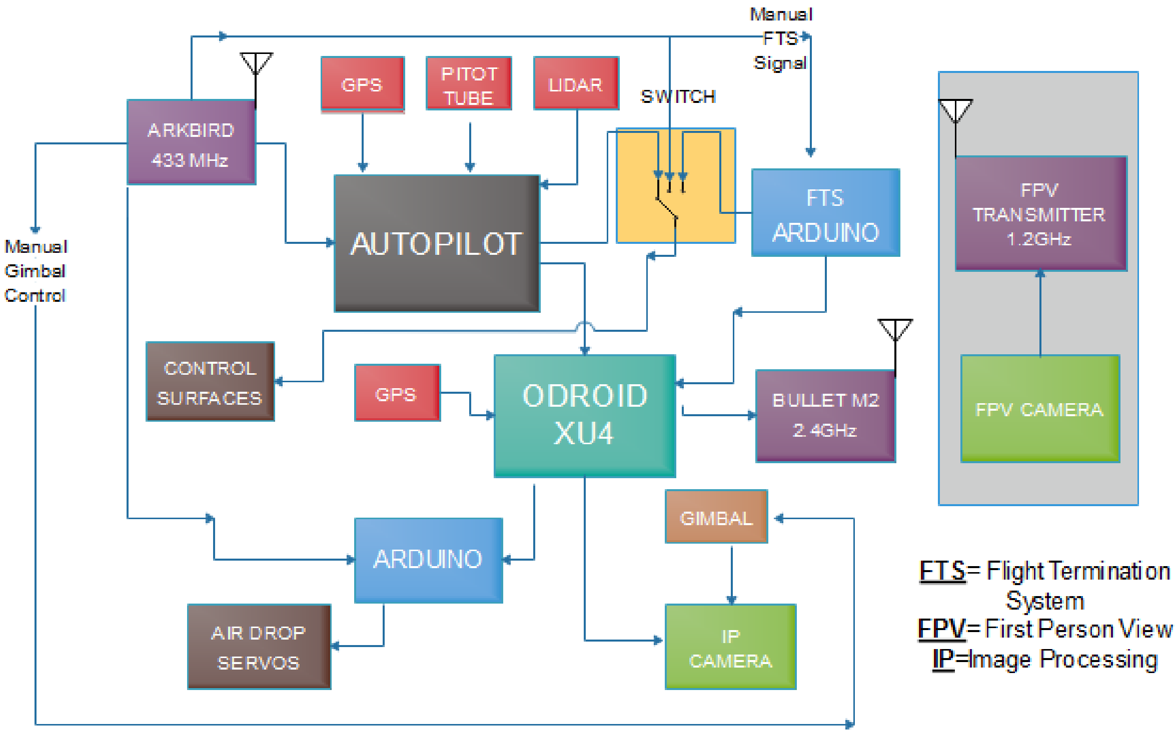


Figure: On-board Systems

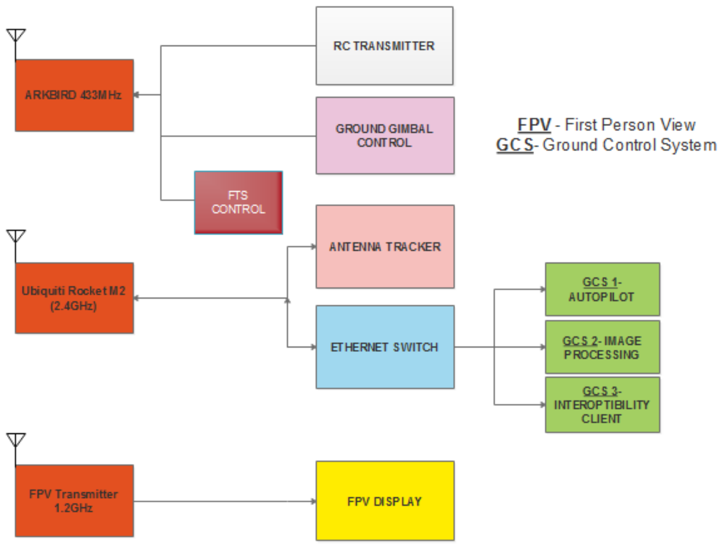


Figure: Ground Control Station Systems

2. a. Aircraft Description

Multiple airframes such as Aero Works GT, Mini Mugin 2.6, and Swallow 2.6m were considered for the competition based on the following parameters:

- Empty weight / Max Take-off weight (MTOW)
- Propulsion type: Internal Combustion Engine / Electric
- Ease of access / modification
- Flight characteristics
- Cost

Parameter	Mini Mugin 2.6m	Aero Works GT	Swallow 2.6m
Empty Weight	6.5 kg	4.1kg	3.3 kg
MTOW	15 kg	6.2 kg	9 kg
Propulsion Type	IC Engine	IC Engine	Electric
Ease of Access/Modifications	High	Medium	High
Flight Characteristics	Medium	Easy	Medium
Cost	High	Low	Medium

A gasoline IC Engine was preferred over electric as we get better power to weight ratio and longer endurance. Moreover, there is a restriction on the import of LiPo batteries in India due to which an electric system was not feasible. Considering the trade-offs between the above listed parameters, *Aeroworks GT* airframe was chosen.

Figure: ACE-GT Airframe

Custom modifications such as reinforcement of high stress regions with carbon composites, cutting of access doors, and laser cut wooden payload component mounts were made to suit the requirements of the *ACE-GT* system.

Specifications of the airframe are as follows:

Parameter	Value
Wingspan	2.23 meters
Wing area	0.85 sq. meters
Wing chord length	0.39 meters
Fuselage Length	1.87 meters
Empty weight	4.1 kilo-grams
Maximum Take-off weight	6.2 kilo-grams
Engine capacity	30 cc
Stall speed	11 m/s
Cruise speed	15 m/s

The aircraft has a high wing configuration which gives it additional stability as a clockwise moment is created due to the distance between the CG and Aerodynamic Centre. This clockwise Moment reduces the effective Angle Of Attack during stalling conditions, thereby giving the aircraft a natural tendency of stabilizing itself.

Its Rectangular Wings give it a better stalling characteristic as the effective angle of attack for rectangular wings is more towards the root. This avoids tip stalling thereby, preventing unnecessary and uncontrollable rolling. The wing has Hoerner Wingtips. These wingtips are such that the upper surface is longer than lower surface of wing. The lower pressured region sucks air from the high pressured region, thereby leading to the formation of wingtip vortices. The curved lower side of the Hoerner Wingtip extends the suction of the high pressured region of the wing to the side of the wingtip. This moves the centre of the vortices outwards, on the side of the wingtip, thereby increasing the effective wingspan and aspect ratio of wing which improves the gliding characteristics.

The Aerofoil used is Clark-Y (11.7%). The reason for use of this Aerofoil is the fact that it gives the best lift-drag ratio for wings of aspect ratio of 6. Another reason is that it has a large leading edge radius. This is very important for low-subsonic airspeeds as it keeps the flow attached which makes the stalling more gentle. With a large Drag Bucket, this Aerofoil also provides a better gliding performance and gliding ratio.

The CG of the Plane lies at 12.7cm from the Leading Edge. This is 17.5%MAC forward of the Aerodynamic Centre. This Forward CG gives the Flight additional stability and easier to fly for the pilot during harsh weather conditions. The Vertical and Horizontal Stabilizers have a taper ratio of 0.5 thereby reducing weight while still leaving enough chord lengths at the tips for adequate trimming purposes, as the tips of stabilizers are the most effective parts for generating lift.

It is equipped with a tricycle landing gear which gives it a stable and safe landing. It has a wheel base of 450mm with a wheel track of 520mm.Tricycle landing gears are easy to land because the altitude of main gear and nose gear is the same and they are less vulnerable to crosswinds. Another advantage that a tricycle landing gear possesses over other is that it reduces the possibility of ground loop because the main gear lies behind the centre of gravity of the aircraft.

The Aircraft is made of Aeroply which makes the aircraft lighter, sturdier and more durable. These features make the *GT Trainer Aeroworks* the most suitable option for the completion of the tasks.

2. b. Autopilot and Flight Control System

The Autopilot is the heart of the UAS, and will be responsible for all flight controls in autonomous mode. As most our operations happen on-board, the flight controller is considered as a low level computer that works in coordination (depending on flight situations) with the higher level on-board computer. The Pixhawk 2 autopilot is a highly tested and reliable open-source system, a feature which is very important for its integration with our systems. Our team has considerable experience with the APM: Pixhawk 2, APM: Pixhawk and Ardupilot Mega autopilot systems on the basis of which we have come to a conclusion of using APM: Pixhawk 2 for the competition. It is a very powerful flight control unit which uses isolated Inertial Measurement Unit (IMU) and Flight Management Unit (FMU), effectively reducing interference to sensors. It also contains a Triple redundant IMU system which consists of 3 x Accelerometer, 3 x Gyroscope, 3 x Magnetometer, 2 x Barometer which enhances the safety and reliability of the system. The selection of Pixhawk was based largely on the following hard points:

- Open Source, Highly flexible and trusted autopilot
- Abundant connectivity options for peripherals
- Integrated backup system for in flight recovery and manual over ride via hardware (not involving any electronics)
- Redundant power supply and automatic failover
- Powerful Cortex M4F processor for running complex algorithms for stable flight dynamics and navigation.
- Affordability
- Open-source Ground Control Station called Mission Planner for programming all parameters, waypoints, geofence etc.

2. c. Obstacle Avoidance

Stationary Obstacles:

The latitude and longitude of waypoints as well the obstacles are converted into Universal Transverse Mercator in order use them as 2D coordinates. To check whether the obstacles are obstructing the path of the aircraft, intersection points between the obstacle (circle) and the current trajectory (first waypoint to second waypoint – straight line) are computed. If the obstacle is indeed obstructing the aircraft's path, a small detour is planned using the intersection points and the midpoint of the shorter arc (in order to minimize change in original trajectory) formed by the intersection points and the obstacle. The coordinates are then converted back into latitude and longitude and then fed into the aircraft's flight in order to avoid obstacles.

Moving Obstacles:

For avoiding moving obstacles, the above algorithm will be iterated at a frequency of 1Hz with the elapsed time from spawning of the moving obstacle to current time for determining the obstacles' current position. The final flight plan is updated when the distance between the upcoming obstacle and the aircraft is at a distance, D where,

$$D = radius\ of\ obstacle + safety\ circle\ radius + aircraft's\ turning\ radius$$

2. d. Imaging System

ACE-GT uses two types of imagery systems; a primary machine vison camera for Object Detection, Classification & Localization of all types of objects, and a First Person View (FPV) camera for the safety pilot.

UI-3880CP color camera from IDS Imaging Development Systems with Tamron, 25 mm, 1/1.8" lens is being used on the primary vision system. The camera will be mounted on a 2-axis (roll and pitch) stabilized gimbal to keep its principal axis perpendicular to the ground during the flight.

Figure: Imagery System

This imaging system was found to be ideal for the following reasons:

- USB 3.0 interface which is fast and can easily be integrated with the on-board computer
- High frame rate of 58 FPS
- High resolution of 3088 X 2076 for a low Ground Sampling Distance (GSD) of approximately 1.1 cm/pixel at 120 metre flight altitude
- Wide aperture range of f1.6 – f16 to accommodate for varying lighting conditions

2. e. Object Detection, Classification, Localization

All imagery from the machine vision camera will be sent to NVIDIA Jetson TK for image processing using OpenCV on Python 2.7. For Optical Character Recognition (OCR), Tesseract is used.

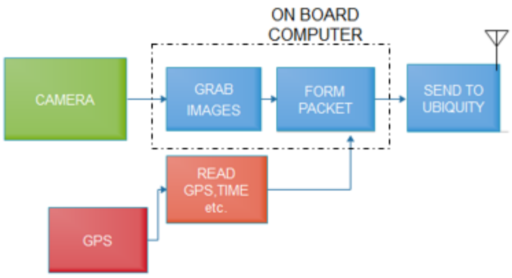


Figure: On-board instance for grabbing frames from camera

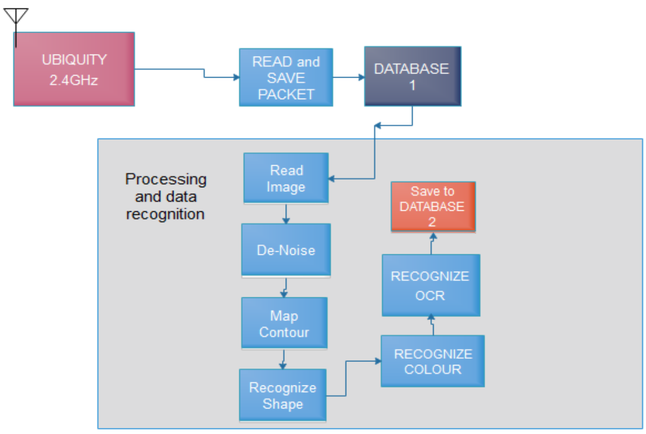


Figure: Denoising and Manipulation

Contour Detection
Images are denoised for processing using a custom algorithm. Manipulations are made to highlight the 8 most abundant colours to define boundaries along coloured objects. The contours are extracted after Laplace and Canny transformations.

Shape Detection
Vertices of the contours are sorted in clockwise order after which angles are calculated to identify the shapes.

Filtering and Finding colours

The cropped images are passed through an algorithm called as k-means, which is a clustering algorithm, for finding the two most abundant colours in the image. The most abundant one is considered as background, and the other as the colour of the alphanumeric.

Recognizing Alphanumeric Character

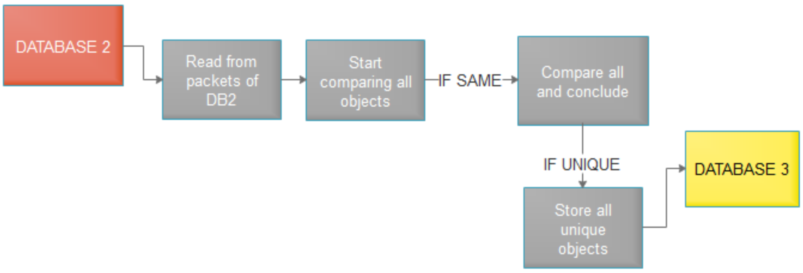
The alphanumeric colour is masked on the cropped image and a binary image is formed. Image is converted to PIL format and fed into Tesseract which reads from a data set on the disk and recognizes the character. The alphanumeric is iteratively rotated while comparing with the data set to find its orientation.

The object is also processed in parallel using the K-NN algorithm, using trained data of alpha numerals in different ambient conditions. The image is passed repeatedly with iterative rotations and compared with the data set for finding its orientation.

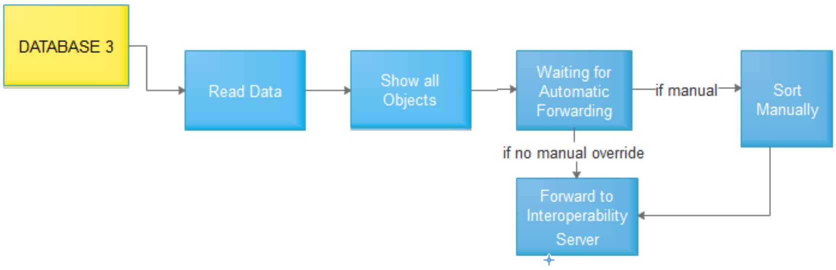
For final results, both outputs are compared on the basis of degree of similarity.

Selection of best Sample

After termination of scanning of the search area, images maybe partially queued in the system for processing, after which the objects are then compared to each other and hence similar and unique objects are classified to remove replica images of the same objects.



Target review
The processed targets are passed through an operator on GCS 2 and are sent to the judges through the Interop server. The operator may interrupt this, and manually identify the targets in case of any discrepancies.



2. f. Communications

We are using three communications in total for telemetry, pilot RC control, and FPV.

The autopilot control link and imagery data will be sent and received through a 2405-2475 MHz Ubiquity module. A 16 dBi Sector antenna with a Rocket M2 mounted on an antenna tracker will be used on the ground; whereas, a 5 dBi dipole antenna with a Bullet M2 will be used on the aircraft.

The pilot RC signals will be sent at 2.4 GHz from the transmitter to an Arkbird 433 MHz repeater station which will send them to the aircraft. The Arkbird has a 10 channel frequency hopping to prevent interference.
For FPV video link, a 1.2 GHz, 1500mW video transmitter will be used.

Please refer to page 5 for a block diagram of the communications system.

2. g. Air Delivery

The water bottle to be dropped will be placed in a custom fabricated capsule. The capsule comprises two interlocking parts which will be filled with Styrofoam or similar impact absorbing material to protect the bottle.

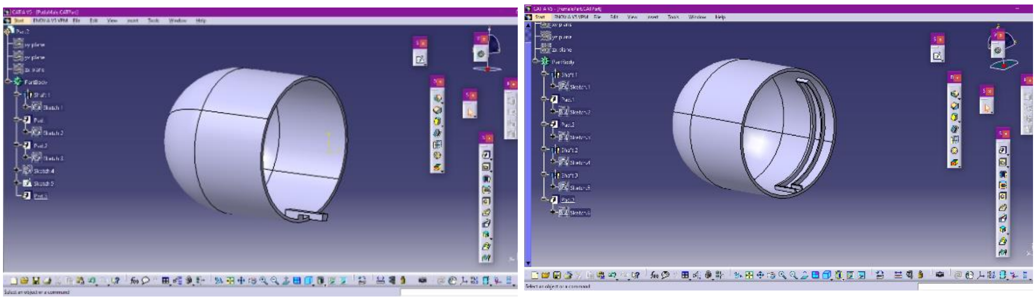


Figure: Two halves of the capsule

Aerodynamic testing, and flow visualisation of the capsule were performed on an Open Subsonic Wind Tunnel to calculate the drag coefficient which was calculated to be 0.94. The pressure distribution was found over a range of angles of attack and is shown in the graph below. The coefficient of force was found by finding the area under the curve.

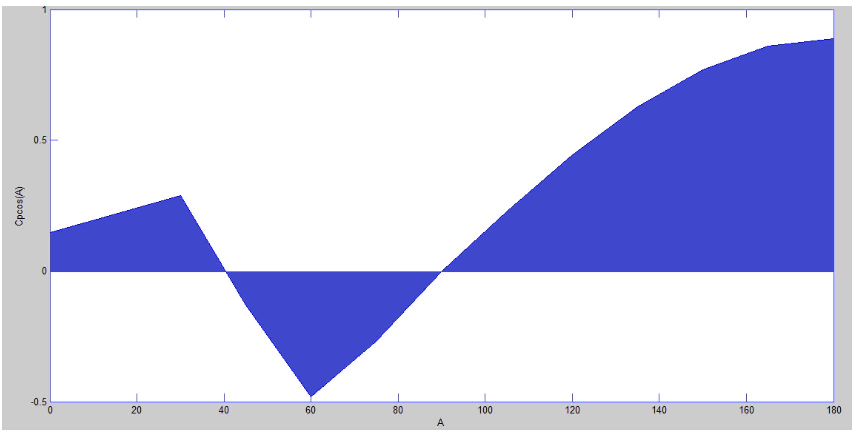


Figure: Pressure Distribution vs Angle of Attack Plot

A trap door mechanism made of laser cut balsa will be used to drop the capsule. A software interlock will be provided to obtain safety clearance from a ground operator before initiating the drop. The system is completely autonomous and calculates the drop trajectory on-board on the basis of wind velocity and direction, aerodynamic characteristics of capsule, heading of the aircraft, and launch altitude.

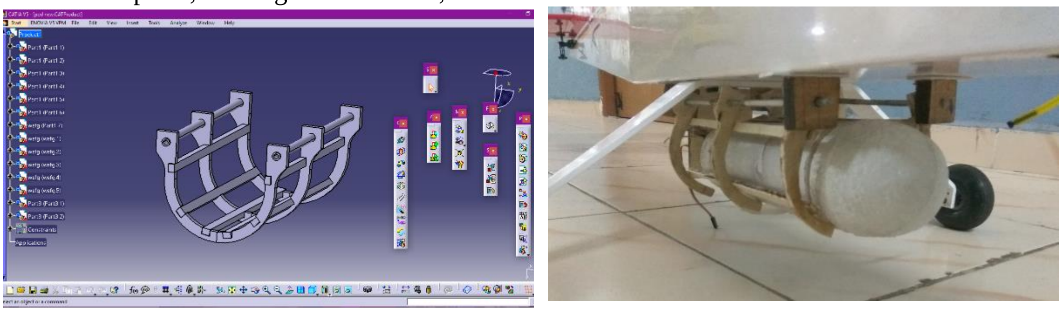


Figure: Release Mechanism

2. h. Cyber Security

The communication link uses Ubiquiti Rocket on the Ground Station and a Bullet M2 in the air. The firmware provided by the manufacturer supports WPA2 security. Moreover, to further strengthen our communication link, AES 256-bit algorithm is used on both the ends for encrypting and decrypting the data.

2. i. Flight Termination System (FTS)

The Flight Termination System is designed as per the specifications mentioned in the problem statement and other major risks that might endanger the aircraft, lives or property on the ground. The system has its independent power supply system that can keep it running for around 2 hours that is more than twice of our maximum flight time.

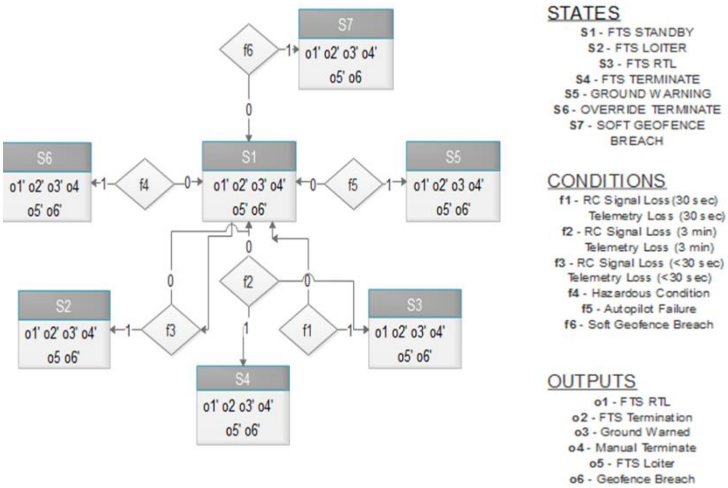


Figure: State Machine Diagram of FTS

FTS is activated if any of the following conditions occur:

- RC signal loss
- Telemetry signal loss
- Manual FTS request

Apart from FTS, warning systems to warn the ground station have also been incorporated in the system. These are:

- Soft Geofence
- Autopilot Failure

There is exclusive communication channel for the pilot to override in such cases to achieve complete manual control over the aircraft.

If FTS is activated, the aircraft will loiter in a 20 meter radius at the same spot. If communications are not regained within 30 seconds, it will initiate RTL. If communication loss goes on for more than 3 minutes, flight termination as per competition rules will be initiated.

3. Testing & Evaluation Plan

3. a. Developmental Testing

3. a. I. Communication System

In order to optimize the on-board systems, a comparison was made between the old communication system comprising of Digi Xstream 2.4 GHz and the new Ubiquity system. As it was decided to perform image processing on the ground, Ubiquity was found to be more suitable due to latency issues with Digi Xstream.

3. a. II. Airframe

The airframe used in SUAS 2015 was used as a hybrid aircraft in Medical Express Challenge 2016. Due to frequent use and structural modifications, the aircraft had started to wear out due to which a new airframe was required. Considering the costs and overall efficiency, *Aeroworks GT* was found more suitable for the competition.

3. a. III. Autopilot Selection

During some flight tests, abnormal behaviour was observed from APM: Pixhawk that also led to a few crashes. On investigation, the reason behind this was found out to be the rebooting of flight controller or Flight Management Unit (FMU). This caused the team to have second thoughts about shifting to the older, more reliable ArduPilot Mega. Unlike APM: Pixhawk, we did not face any issues with APM: Pixhawk 2. This being the latest version was chosen as the autopilot for the competition.

3. b. Individual System Testing

3. b. I. Autonomous Flight

As APM: Pixhawk 2 is a relatively new autopilot in the market, extensive flight testing was conducted to check its reliability and to familiarise the team with its setup. For this purpose, small electric fixed-wing test aircraft and also *Dabang*, the airframe from SUAS 2015 were used.

During these tests, flight stability was studied to identify optimum settings for the autopilot, and switching between different flight modes was checked. A LiDAR sensor has been added to the system to measure altitude during landing. Autonomous landings were conducted and it was found that the landings with the LiDAR were much softer as the aircraft could calculate the flare altitude more accurately.

Figure: Autonomous Flight of *Dabang*

3. b. II. Imaging

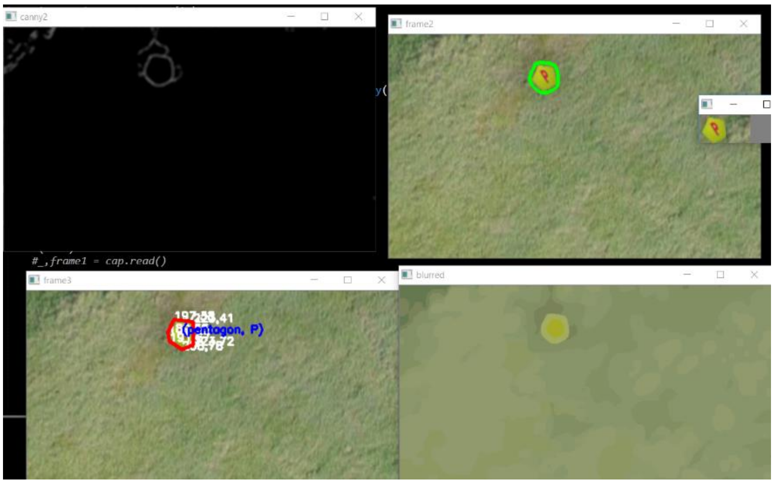


Figure: Original Image with Contour Detection **Figure: Final image after iterations**

For testing, images of competition like targets were clicked at different altitudes using VTOL aircraft. These were processed using the custom algorithms.

3. b. III. Communications

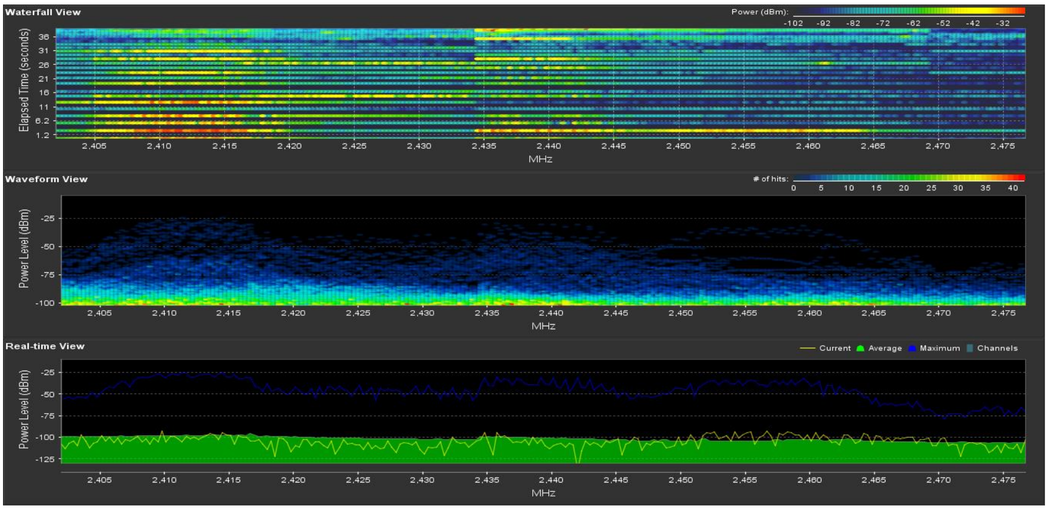


Figure: Range Test Data from Ubiquity Rocket M2

Real world range tests were performed almost Line of Sight (LOS) conditions up to a range of 4.5 Km (approx.).

Range test on the Arkbird repeater was performed up to a range of 6 Km using a quadrotor aircraft.

3. b. IV. Air Delivery

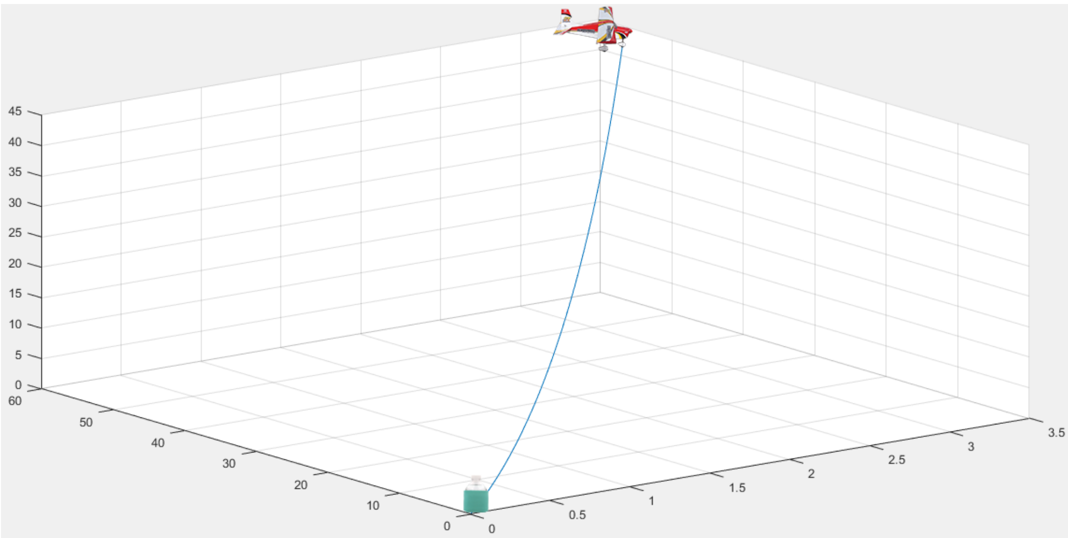


Figure: Air Drop Trajectory Calculation (Speed of aircraft: 20 m/s, Wind Velocity: 5.15 m/s, Wind Direction: 15º towards port side from aircraft heading, Launch height: 45 m)

The trajectory of the capsule has been simulated and tested considering the velocity of the aircraft, the altitude at which the drop is taking place, the wetted area of the capsule, coefficient of drag of the capsule, crosswind velocities, and crosswind direction. Variables such as the velocity of the UAS, its altitude, crosswind velocity, crosswind direction, etc. are instantaneously measured by GPS and IMU data on the autopilot. This data is extracted and fed to the on-board computer. The range, location of launch site, and time of flight of the capsule are instantaneously calculated every 0.2 seconds.

3. b. V. Obstacle Avoidance

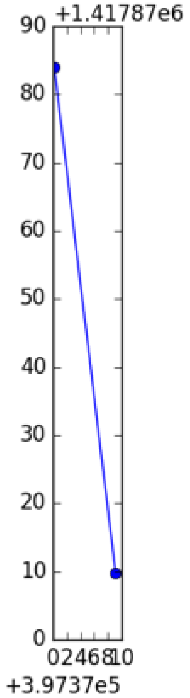


Figure: Original Flight Path

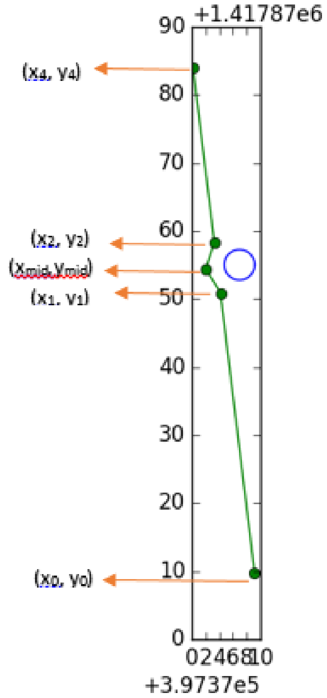


Figure: Altered Flight Path

Obstacle Avoidance algorithms were simulated and tests were conducted using quadrotor aircraft. Tests for fixed wing aircraft are yet to be conducted.

Assuming $A = (m^2 + 1)$, $B = 2(mc - mq - p)$, $C = (q^2 - r^2 + p^2 - 2cq + c^2)$, where m is the slope of line, c is the y intercept, r is the radius of obstacle, and p and q are the coordinates of the centre of obstacle

$$x_1 = \frac{-B + \sqrt{B^2 - 4AC}}{2A}$$

$$x_2 = \frac{-B - \sqrt{B^2 - 4AC}}{2A}$$

$$y_1 = mx1 + c$$

$$y_2 = mx2 + c$$

$$x_3 = \frac{x_1 + x_2}{2} - p$$

$$y_3 = \frac{y_1 + y_2}{2} - q$$

$$\theta = atan2(y_3, x_3)$$

$$x_{mid} = radius_{safe} * \cos(\theta) + p$$

$$y_{mid} = radius_{safe} * \sin(\theta) + q$$

3. b. VI. Cooling System

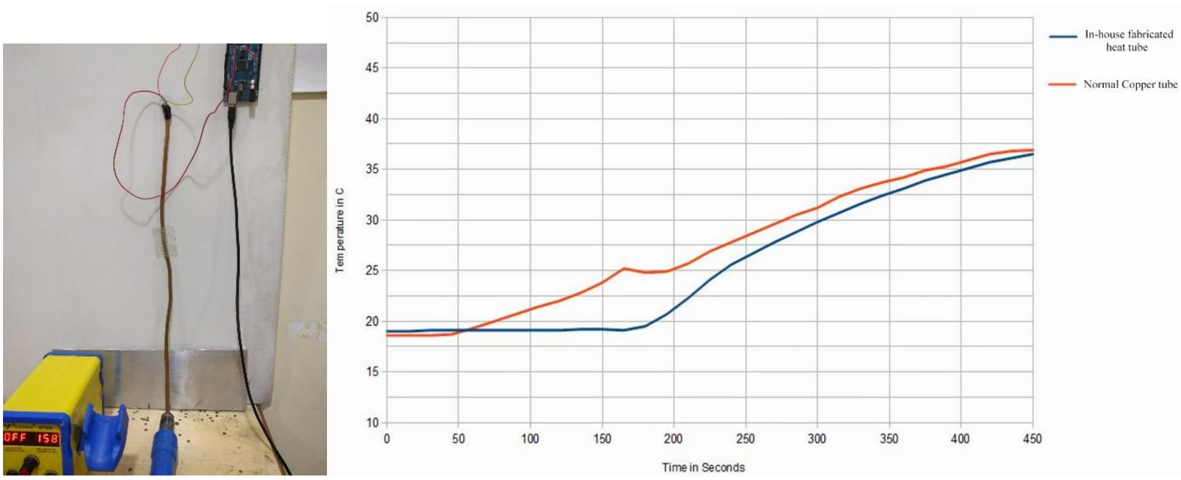


Figure: Cooling System Testing

A major cause of failure of UAV systems that often goes neglected is overheating. To avoid this, in-house fabricated heat tubes are used on the *ACE-GT* system. The copper tubes have a capillary structure inside and are filled with ethanol. The tubes are vacuum sealed and are passed over all major electronics. The heat is released to the atmosphere by the airflow on the outside of the fuselage.

Figure: Heat Tube Capillaries

3. c. Mission Testing

Task	Expected Outcome	Possible Failures	Backup Strategy
Waypoint Navigation	Navigation within 5 m radius of given waypoints	Overshooting of waypoints due to GPS interference and aircraft flight characteristics	• Change in position of GPS to reduce interference • Retuning of autopilot PID values
Auto Take-off	Smooth run and climb to desired altitude	• Insufficient or too high throttle • Insufficient or too high pitch rate	• Reset autopilot parameters
Auto Landing	Flare at proper time interval before touch down and soft landing	• Landing speed too high or too slow	• Reset autopilot parameters
Obstacle Avoidance	The aircraft should calculate and follow the new flight path accurately. The transition between the original and new flight path should be smooth.	• Violent transition to and from new flight path • Not following new flight path accurately	• Retune aircraft parameters in the Obstacle Avoidance algorithm

Object Detection, Classification, and Localization	Click high resolution images and determine object characteristics autonomously	• Too high GSD of images • Unstable images due to vibrations in gimbal • Inaccurate detection of targets	• Fly at a lower altitude • Use vibration damping gels/foams • Train the data set
Air Drop	To drop the capsule at bull's eye and keep the bottle intact	• The bottle breaks on impact • Inaccurate drop	• Change impact absorbing material in capsule • Change capsule material • Change capsule design • Recalculate capsule aerodynamics

4. Safety, Risks, and Mitigations

4. a. Developmental Risks, and Mitigations

RISKS	MITIGATION
Test flights in cities pose a safety risk to people on the ground	All test flights are conducted at a private are field with no habitation in the surrounding areas
Personnel hazard while operating power tools	All members are required to wear safety goggles and gloves while using proper tools. Moreover, proper training from university labs is provided to avoid any mishaps
Accidents while starting the engine	Electric starter is used to start the engine and an emergency kill switch is placed in an easily accessible part of the fuselage
Software and Autopilot Bugs	Multiple software simulations, subsystems tests and tethered tests were conducted to ensure system safety

4. b. Mission Risks, and Mitigations

Risks	MITIGATION
Autopilot Failure	FTS monitors the output signals from the autopilot and sends a warning message to the ground in case of any failure
GPS Failure	Redundant GPS on Flight Controller
Autopilot Telemetry Failure	FTS is activated
Failure of Flight Termination System	FTS can be manually activated
Breach of Geofence	Soft geofence is incorporated to give a warning signal in advance
Accidental launch	The system is unable to take-off until the emergency switch is released and the arming switch is activated
Take-off on low battery	The autopilot will deny the arming command if it detects that the battery is low during take-off Propeller

4. c. Operational Risks, and Mitigations

Risks	MITIGATION
Injury to personnel around the aircraft due to unintentional actuation of engine	An emergency is switch mounted on the exterior of the fuselage which will always be engaged while the aircraft is on the ground and personnel are working around it
Burn injuries due to hot surfaces around the engine	Attachment of an engine cowling
Damage to electronics due to electrostatic discharge from engineers	All personnel working on ESD sensitive equipment are required to ground themselves by wearing electrostatic wrist bands
Rescue of lost aircraft	Flight logs on the ground can be monitored from the ground station to predict flight path and trajectories
Wrongly entered geofence coordinates	The GUI used to enter the coordinates shows all geofence vertices and the geofence polygon. This reduces chances of this risk
Misinterpretation of AMSL and AGL while feeding waypoints	Our members have tremendous experience in their respective fields which prevents such errors. This risk can further be eliminated by using a GUI to visually display locations of waypoints

5. Conclusion

The capability of our aircraft and subsystems to satisfy competition requirements and complete mission tasks at the SUAS 2017 has been tested and demonstrated. We are confident that our system would be able to give the expected performance.

Our pre-flight checks and other safety procedures that have developed from risk assessment of each and every component and our four years of experience have played a vital role in ensuring aircraft and personnel safety in our flight tests.

Our progress so far for the competition has been as per our expectations apart from a few unexpected delays. We are confident that we will be able to integrate all our subsystems to give an unnerving performance at Maryland.

Aim High. Fly Higher.