**Aurora**

***Indraprastha Institute of Information Technology, Delhi***

Journal Paper - SUAS 2016


***Abstract***

Aurora, established in early 2015, is a group of students from Indraprastha Institute of Information Technology, Delhi (IIITD) coming together with a common interest in research and with a zeal to develop innovative products, in the field of Unmanned Aerial Vehicles (UAVs).

We identify ourselves as "Aurora", symbolic of the majestic and transcending aurora lights of the Arctic Region and our institute IIITD. The team has been working since the past one year, with an aim to incorporate innovative technologies in the UAVs, to bring multifunctional capabilities in it.

As part of the 'Infosys Centre of Artificial Intelligence' at IIIT-Delhi, Aurora aims to design industry-level UAVs which would solve real-life problems. The team comprises of a diverse group of students having expertise in computer vision, aeromodelling, computer networking, autonomous and embedded systems.

This is Aurora's first participation in AUVSI SUAS, thus the team has been doing a lot of R&D over the past year, to make the system cost-effective, yet making it robust and multi-functional. Safety, both of the system and the members, is the team's prime concern. All pre-flight checks and safety considerations are taken into account before every flight. The team has also set a high bar for a person to become the Safety Pilot of the team.

The team has quite a large inventory of off-the-shelf planes (about 8) and video systems. The team is also in the process of making its own custom plane which should be ready for the next edition of SUAS.

# Content

## 1. System Engineering Approach

### 1.1 Mission Requirement Analysis

After a meticulous examination and analysis of the mission requirements in the SUAS rules, the team identified key subparts necessary for successful mission execution:

1. **Autonomous Flight:** Auto-Takeoff, Waypoint Navigation, Search Area, Auto-Landing
2. **Image Acquisition:** On-Board Camera for the video feed to the GCS
3. **Image Processing:** Computer Vision algorithms to perform intelligent tasks like extracting target characteristics, decoding QR code, etc.
4. **Data Exchange and Communication:** Telemetry and Imagery Data exchange between the UAS and GCS (Ground Control Station); Required data exchange between GCS and Interoperability server.
5. **SDA:** Path Planning algorithms to avoid virtual objects in space while the UAS is in flight
6. **Air-Drop:** Specialised actuator system for dropping-off the payload at the required GPS coordinate.

The team prioritized the mission tasks on the below parameters:

- Grade - Weight/points allotted to the particular task in the rules
- Complexity - Difficulty level of the mission task
- Team's Experience - Keeping in mind the team's expertise to execute the task successfully
- Additional Budget - Any additional hardware requirement to execute the task, keeping in mind the budget constraints (Not including the autopilot and image acquisition system)

Accordingly, the mission tasks were classified:

| Task / Parameter | Autonomous Flight | Search Area | ADLC | Actionable Intelligence | Off-Axis | Emergent Target | SRIC | Airdrop | Interoperability | SDA |
|---|---|---|---|---|---|---|---|---|---|---|
| Grade | High | High | High | High | Medium | Medium | Medium | Low | High | High |
| Complexity | Low | Low | High | High | High | Medium | High | High | Medium | High |
| Team's Experience | High | High | Medium | Medium | Low | Medium | Low | Low | High | Medium |
| Additional Budget | NR | NR | NR | High | High | NR | High | Medium | NR | NR |

**TABLE 1 MISSION REQUIREMENT**

| Low | Medium | High | NR - Not Required |
|---|---|---|---|

## 1.2 Design Rationale

Considering *Aurora*'s first participation in such a competition, the team decided to use an off-the-shelf plane. The team experimented with a lot of standard airframes, keeping in mind the following parameters:

1. **Payload Capacity:** Large payload volume to accommodate more systems.
2. **Stability (Preferably Glider):** Keeping in mind the image acquisition of the targets placed on the ground, the team preferred to have a glider for a stable flight.
3. **Maintenance:** Airframe is easily repairable after minor crashes.
4. **Durability:** Material of the airframe is strong enough to withstand harsh landings.
5. **Cost:** The airframe is within the budget of the team.
6. **Ease of Transportation:** Plane can be packed in a small package for ease of transportation.
7. **Safety:** Plane is aerodynamically stable to ensure the safety of the payload.

One of the most crucial decisions the team had to make was the choice of an airframe. Without a versatile and rugged frame, the system would not be able to achieve the requirements that we set out for it above. Key parameters that must be looked at, for any airframe are lifting capacity, power requirements, skills required for construction, cost and ease of transportation. After doing an extensive study, the team has decided that the essential requirements for any airframe are its cost and ease of construction.

| Name of Plane / Parameter | Skywalker 1680mm FPV | CloudSurfer | Ronin (Kit) - 2.5mts FPV glider | Parrot (2000mm) 5Ch glider | Ranger EX Professional |
|---|---|---|---|---|---|
| Wingspan (mm) | 1900 | 2000 | 2500 | 2000 | 1900 |
| Max Speed (kph) | 104 | 82 | 98 | 98 | 100 |
| Min. Thrust (gm) | 2000 | 2800 | 2800 | 3000 | 3200 |
| Takeoff Method | Hand/Catapult Launch | Hand/Catapult Launch/Runway | Hand/Catapult Launch/Runway | Hand/Catapult Launch | Runway Required |
| Wing Loading (g/dm2) | 31.7 | 29.2 | 31.9 | 29.2 | 32.3 |
| DSLR Carrying Capability | Yes | No | Yes | No | Yes |
| Configuration | T Tail | T Tail | T Tail | Conventional | Conventional |

TABLE 2 - PLANE SPECIFICATIONS

For this edition of SUAS, *Aurora* will be using the **Skywalker 1900**, which provides us with a versatile and robust platform on which to develop our mission capabilities. It has proved itself more than able to carry the increasingly complex systems that are being developed over the past year, both in terms of lifting the extra weight and allowing for each new piece of equipment to have its own space in the cargo bay.

The airframe has been tested extensively over the last one year with:

1. Different Amounts and Types of Payload
2. Different Motor Setups
3. Different Launching Mechanisms
4. Different Autopilot settings

This large base of knowledge led us to keep this airframe for this year's competition since the rules have not changed enough to necessitate a different selection. This knowledge has been further built upon and applied to this year's entry to guide our choices of system components and our testing regime. It has also allowed us to spend more time testing the individual subsystems without having to worry about unknown factors in our airframe. Details about the airframe are presented later.

### 1.3 Target Types for Autonomous Detection

In order to simulate the real environment of the competition and also to achieve best results for autonomous detection, the team had printed the targets and the QR code on flex sheets, in accordance with the dimensions specified by the SUAS rules.

FIGURE 1 - TARGET TYPES

## 2. UAS Design Description

### 2.1 Airframe Description

The skywalker 1900 has a T-tail configuration which is kept well out of the disturbed airflow behind the wing and fuselage, giving smoother and faster airflow over the elevators. This configuration also gives more predictable design characteristics and better pitch control. The Aircraft also boasts a wingspan of 1900mm that help in providing a stable flight.

It is constructed with EPO foam, which is both lightweight and flexible. The airframe has ample space inside to support all our payload systems . It has also got a window on the side of fuselage to allow easy installation and removal of equipments. The airframe has a dry weight of 1050g and the ability to carry payload up to 4Kg.

The airframes propulsion system is made up of 505W, 1050kv brushless DC outrunner motor and a 9 x 6 propeller which draws power from a 5000mAh 4S LiPo battery.

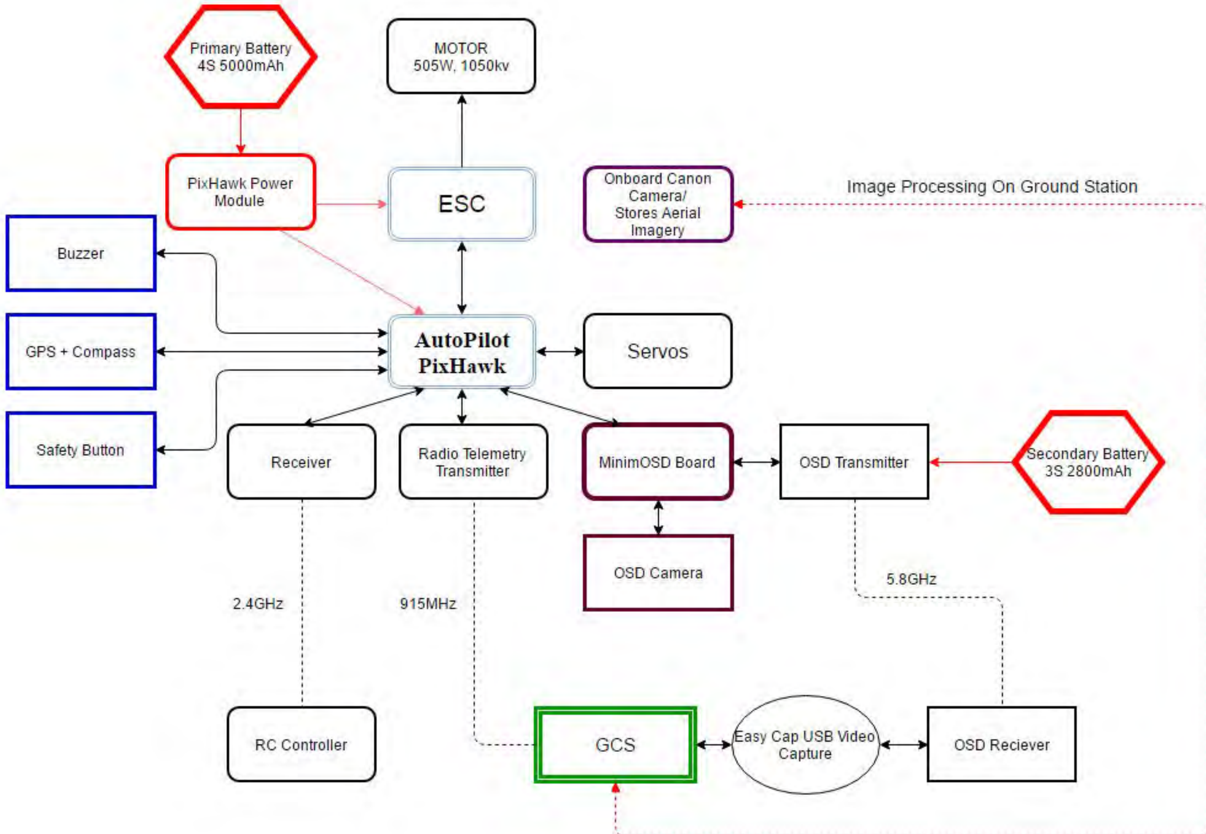



FIGURE 2 - UAS DESIGN

## 2.2 Power System

In order to get the maximum flight time, the team used 5000mAh 4S LiPo Battery as it's primary source of power. It powered the motor, autopilot system and the 4 servos, giving a maximum flight time of 35 min. A separate power module was used for pixhawk, connected to the battery,
The maximum current drawn from the system was 36A , of which the motor drew 34A at full throttle and the servos a maximum of 2A. We used a 60A ESC and a 4A UBEC to distribute power across our primary system

**Auxiliary:** As secondary power source, a 2800mAh 3S LiPo battery was used to power the video systems. We also used an OSD kit for First Person View ( FPV ) which used a datalink at 5.8GHz and operated at a power supply of 7 - 12 V

## 2.3 Autopilot System

The team used 3DR autopilot system. It is an advanced autopilot system designed by the PX4 open-hardware project and manufactured by 3D Robotics. It features advanced processor and sensor technology from STMicroelectronics and a NuttX real-time operating system. The system is also accompanied by the following array of specialised sensors, assisting for the autonomy of the UAS :

- MEAS MS5611 barometric pressure sensor for determining altitude
- UBlox GPS + Compass Module
- MicroSD card for storing the mission log files

## 2.4 Ground Control Station

The GCS comprises systems for controlling and coordinating on-board systems and processing the acquired data for achieving good performance. The GCS is responsible for autonomous flight, telemetry, real-time imagery and processing the imagery data generated during the flight. A basic description of these ground station systems is as follows:

- A powerful system running Mission planner (for Autonomous flight and navigation)
- Video Telemetry receiver for real time aerial imagery (for Actionable intelligence)
- OpenCV(Open Source Computer Vision Library) based software for the processing of the imagery data and the telemetry logs, waypoint generation for obstacle avoidance (for ADLC, Emergent target task and SDA)

### 2.4.1 Navigation Control

The autopilot team used GUI based Mission Planner software to control autopilot PIXHAWK. The 915 MHz is used for planning, monitoring and retasking mission. The autopilot operator constantly monitors the UAV's location and navigation accuracy. It is also responsible for computing flight paths for mission tasks. The Navigation Unit is interfaced with interoperability server for transmitting and receiving data.

## 2.5 Payload

### 2.5.1 Imagery Unit

The imagery system is responsible for locating targets and classifying them. There will be 2 image acquisition system payloads on the UAS:

1. **Video Telemetry Transmitter (5.8 GHz) with a Sony CCD Camera**
   This system uses a minimOSD board which pulls the telemetry data from the PIXHAWK flight controller and overlays it on the video captured from the camera.This video feed is captured at the ground station dedicated to Actionable Intelligence using a USB Video Capture.
2. **High Resolution Visual Sensor(Canon Camera)**
   This imagery system is used to acquire aerial imagery data required to perform the Automatic Detection/Localization and Classification task. The rationale behind capturing images instead of shooting is as below
   Disadvantages :
   - Videos have a lower resolution with the same camera

   Advantages :
   - Possibility of Target tracking
   - Possibility of Background Subtraction

   As video has no specific plus in the terms of ease of target detection or classification, we have decided to click images at the rate of about 1 image/second. At the height of 150-200 ft and a maximum speed of about 20 m/s, this frequency is enough to capture the whole search area with some overlap in between the images.
   Once the aircraft has surveyed the search area and landed, the aerial imagery is downloaded and input to the ground station dedicated to image processing.

## 2.6 Communication Systems

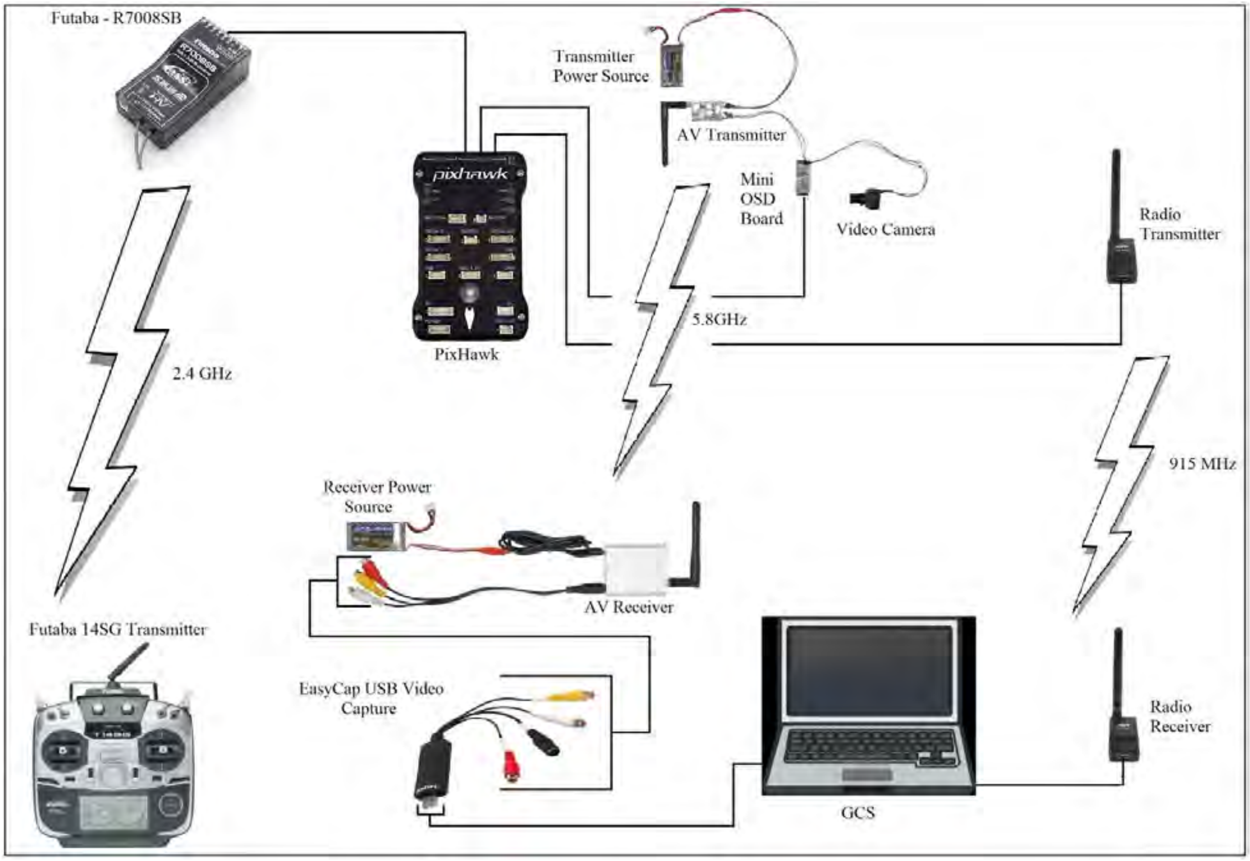



FIGURE 3 - COMMUNICATION SYSTEMS

Communication with the Ground Control Station was established over 3 independent data link:

- The Command and Control includes a 2.4 Ghz Remote Control link which uses Fasttest Technology providing a bidirectional communication link between receiver and transmitter.The System also supports SBUS2 technology which allows multiple servos, gyros and telemetry sensors being installed with a minimum amount of cables.
- The OSD kit relays information over a 5.8GHz data link to transfer the captured imagery to the Ground Control Station embedded with autopilot telemetry data.
- The radio telemetry data link was established at 915 MHz , between the ground control station and the autopilot which uses Mavlink protocol framing, Frequency hopping spread spectrum (FHSS) and Adaptive Time Division Multiplexing.
- We have also used a Clover Leaf Antenna with the Radio Transmitter as it gives a high gain of 5dBi and is circular polarised so the orientation change while in flight won't affect the signal strength.

FIGURE 4 - CLOVERLEAF ANTENNA

## 3. Expected Task Performance

More than half of our members are electronics students. Some of our team members also, have considerable experience in the field of computer vision and robotics. We have been performing these tasks for some time now with rare failure. As described above, we are adept to attempt the following tasks Autonomous Flight task, Search Area Task, ADLC, Actionable Intelligence, Emergent Target Task Interoperability and SDA.

In accordance to the Table 1, the team has decided to not attempt the following tasks: SRIC, Off Axis Task and Air drop.

## 4. Programmatic Risks and Mitigation Methods

For successful deployment of the UAS and accomplishment of the mission tasks, a comprehensive risk assessment was carried out at every stage, to identify the risks and formulate the mitigation plans accordingly. We have always been vigilant about the safety of the equipments and the personnel. All the systems were bought and designed, taking into account any likelihood failure. The wirings of all on-board components and spare parts of the airframe were bought in double quantity, to prevent any delay of operation in case of a crash or despotic landing. Also, a post-flight analysis is carried out every time, to check any component failure and overall running status of the UAS. The team characterised the following risk factors and strategised the mitigation methods consequently:

| Risk | Cause | Likely Delay in Operation | Mitigation Method |
|---|---|---|---|
| Structural Damage | Despotic Crash | No Delay/1 day | 1) Two backup airframes<br>2) Any structural damage repairable in 1 day |
| Slight Damage to Airframe | 1) Harsh Landing<br>2) Careless Transportation | 3 hrs/ No Delay | 1) Perform the required repairs<br>2) Replace with spare parts<br>3) Use backup airframe |
| Avionics Failure | 1) Servo Malfunction<br>2) Motor Failure<br>3) Faulty wiring | 1 hr | Replace with the redundant parts |
| Autopilot Failure | 1) High voltage spikes<br>2) Crash | 10 days | 1) Ordering of new pixhawk<br>2) Using APM as backup and doing all the required calibrations |
| Network Failure (Interoperability) | 1) Bug in the code<br>2) Power failure | 1-2 hrs | 1) Fixing the required bug in the code<br>2) Replace the access points to restore power |
| Imagery System Failure | 1) Plane crash<br>2) Noise Interference<br>3) Vibration from airframe | 3 days | 1) Ordering new video system<br>2) Using a backup imagery system of lower quality |

| | | | |
|---|---|---|---|
| | With other equipments | | 3) Better design mounts to reduce the impact durign crash<br>4) Insulating the video system with rest of the payload |
| Absence of some crew members | Bad Health | No Delay | There is redundancy for each member, in every module |

| | | | |
|---|---|---|---|
| Probability of the Risk | Low | Medium | High |

TABLE 3 - PROGRAMMATIC RISKS AND MITIGATION MEASURES

# 5. Image Processing

## 5.1 Search Area Task and ADLC task

In order to be able to do the search area task, we require high resolution images given the size of the targets and the height at which a fixed-wing UAV flies. Also, required are the telemetry logs from the flight controller for localisation of the targets. Hence, we will be downloading the aerial imagery data captured by the high resolution camera and then, using the additional information provided by the telemetry logs from the Mission planner, localisation will be done.

The ADLC task requires us to develop algorithms which perform automated imaging detection of potential targets and then cue the imagery judge. The algorithm shall localize the detected targets and automatically determine the target characteristics. These algorithms are then applied to the acquired high resolution images to get some of the characteristics.

The image processing ground station is a fairly powerful laptop running Ubuntu, a linux based operating system. The image processing software is based on C++. It is primarily based on the libraries, OpenCV and ZBAR.

## 5.2 Computer Vision Algorithm

The images acquired by the imagery unit are given as input to the ground station system dedicated for Computer vision. Following algorithm is used to report the required characteristics.

1. **Blob Detection**: This is used for image segmentation and ROI extraction. Basically, after applying this technique, time taken reduces and ease of further processing increases manifold.

FIGURE 5 - DATASETS

2. **Preprocessing**: The potential targets were then passed through a series of preprocessing steps to make the targets more suitable for detection.

    2.1. Target images were *sharpened* by using an *Unmask Blurring* technique.
    2.2. A *median blur*, with *kernel size '7'* was then applied to remove grain noise from the background grass.
    2.3. Specular reflections were removed by first generating a specular map of reflections using thresholding at higher values and then applying neighbour based interpolation.
    2.4. This was then followed by a series of *Morphological Opening and Closing operators* with *kernel size 15*, to further reduce reflections and fill holes.

3. **Clustering** : Next, we assumed that the images obtained after preprocessing will have 3 prominent colors for the 3 different regions. Based on our assumption, we clustered each of the pixels on the basis of their color and applied an average color to the clustered pixels. This technique is often called *k-means clustering*. Clustering gave us clear and distinct boundaries between each of the clusters, which proved very useful in the next steps.

4. **Edge Detection + Contour Detection:** In the previous step, we got distinct boundaries between every cluster. Now, we generate an Edge Map by applying canny edge on the clustered target to get a distinct edge for the shape and for the alphanumeric character within the shape. This edge map is then used to find contours. The largest contour belongs to the shape and the next largest contour, whose area shows significant deviation belongs to the alphanumeric character.

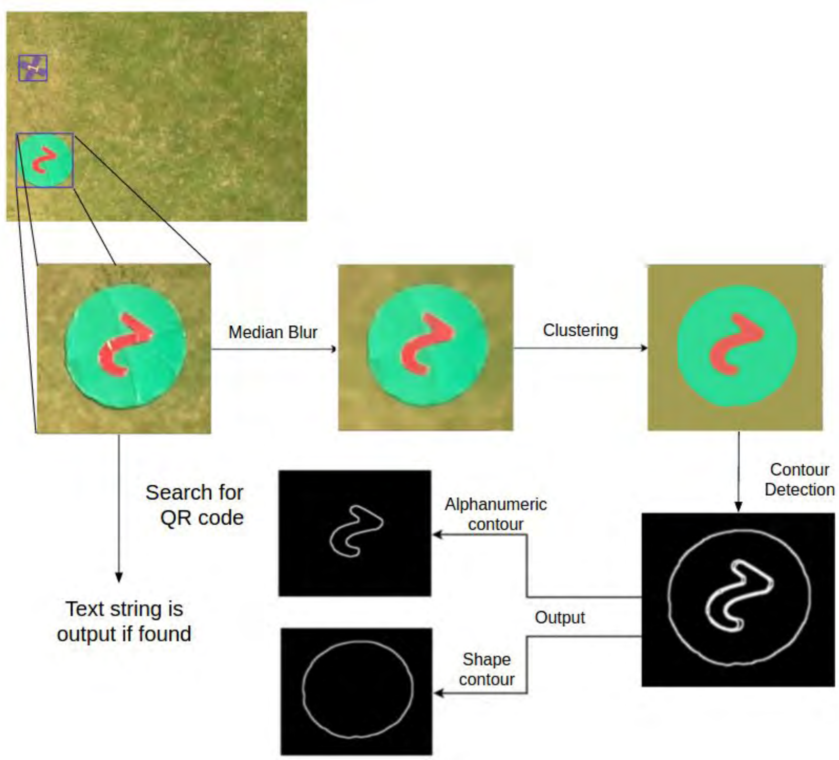



FIGURE 6 - EDGE AND CONTOUR DETECTION

**Shape Determination**: The shape of the contour is determined by applying the Douglas-Peucker algorithm to the shape contour obtained earlier. It approximates the contour curve/polygon with another curve/polygon, having less number of vertices. The resulting number of vertices help determine the shape of the contour. Eg. a circle always gives '13+' vertices, whereas a pentagon will give '5', a triangle gives '3' etc.

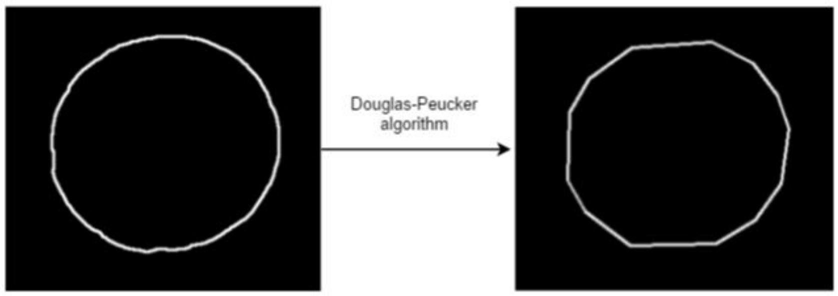



FIGURE 7 - SHAPE DETERMINATION

5. **Color Determination:** Now, we segment out the shape from the clustered image obtained in step 3, by using the contour end points of the shape contour. Traverse the segmented shape and count the number of pixels belonging to different clusters, by maintaining a bucket for each of them. The largest value bucket gives the shape color and the bucket with the second largest value gives the alphanumeric character's color. Since initially, we arranged the pixels into a total of 3 clusters, we maintain an additional bucket to accommodate points belonging to a 3rd cluster. This is done to reduce error, since only in an ideal image, would we get exactly 2 clusters inside the segmented shape,

6. **Alphanumeric character Recognition**: The alphanumeric character is further segmented out using the shape contour and undergoes a set of preprocessing steps, after which, it is passed as input to the *tesseract library* for character recognition.

## 6. Path Planning

The SDA task, given the waypoints, coordinates, sizes and velocities of the obstacles, requires us to plan a path for the UAS such that the obstacles, stationary and moving, are avoided while maintaining minimum possible distance from the straight path connecting the given waypoints. Hence, the problem can be reduced to, given a list of waypoints, {W1, W2, W3,...., Wn}, reach from Wi to Wi+1, avoiding all obstacles obstructing the path from the two waypoints in question.

Avoiding stationary obstacles is a comparatively simpler path planning problem. This year we plan to use a simple algorithm, Bug2 adapted for 3 dimensions. Avoiding moving obstacles is a tougher task but since, the velocity of each moving obstacle is constant, we can easily predict the approximate position and time at which the obstacle is encountered by the UAS.

The Bug2 algorithm can be summarised as follows:
1) Assuming the UAS heads toward the next waypoint along a straight path
2) If the UAS is expected to come closer to an obstacle, than a preset threshold, the UAS will follow the boundary of the obstacle maintaining some distance until the straight path connecting the start and goal waypoints is encountered again.
3) Once, the straight path is encountered, it shall continue towards the goal.
The Bug2 algorithm will be adapted to 3 dimensions by assuming the trajectory of the plane lies in a 2d plane defined by 2 vectors, namely, one joining the start and goal waypoints and the other pointing out from the right wing. This will ensure minimum roll of the UAS at any point in the trajectory.

This path will be generated in the form of many closer waypoints by a program running on the ground station. These waypoints will be stored in a file, which will be input to the Mission Planner and hence, the obstacles, stationary or moving, will be avoided.

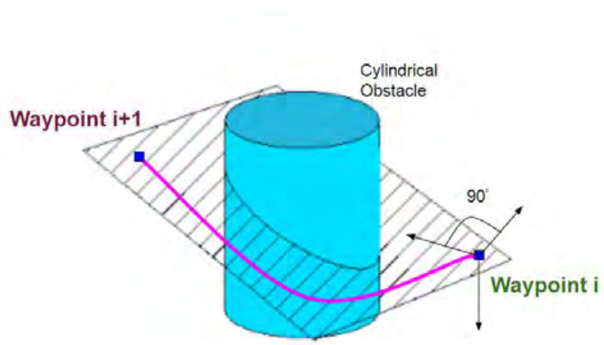



FIGURE 8 - PATH PLANNING

## 7. Mission Planning

One of the most important part of a mission before the flight day is the *Mission Planning*. The tasks to be accomplished in the mission is decided at least 1 day prior to the flight. Accordingly, the flight path is designed and burnt on the autopilot firmware. Also, with the help of HITL (Hardware-In-The-Loop) simulation, the validity and accuracy of the flight path is tested.

### 7.1 Geofencing

In order to ensure that the aircraft does not go beyond the no-fly zone, a virtual fence was created around waypoint path of the mission. In case of a fence breach, the plane will enter GUIDED mode and will return to the nearest waypoint and continue the mission. This will not only ensure the safety of the UAS (by not allowing the plane to go beyond the set area) but also ensure that the mission is continued.


FIGURE 9 - GEOFENCING

# 8. Test and Evaluation Results

## 8.1 Autonomous Flight Task Performance

### 8.1.1 Auto-Takeoff

Autonomous takeoff is one of the most pivotal component of a fully autonomous flight. The basic idea of automatic takeoff is to set the throttle to maximum and climb until a designated altitude is reached. As a safety measure, it was ensured that the distance between the takeoff and the first waypoint is at least 60m, so that the climb of the plane is not very steep, thus preventing situation of a stall. Also, when doing a hand launch for autonomous takeoff, the minimum hand speed after which the throttle will get on, is set to a decent 5m/s, with an added delay of .4 msec, for the safety of the crew member.

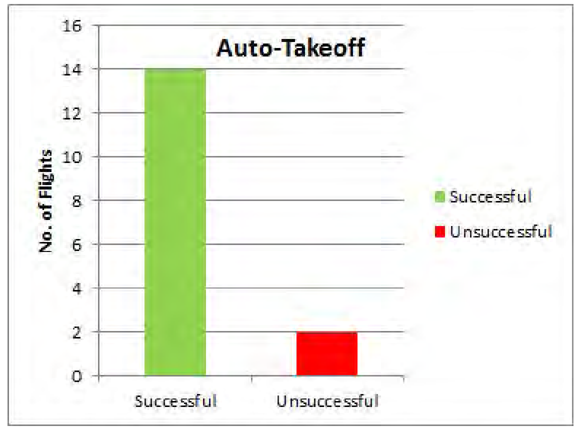



FIGURE 10 - AUTO TAKEOFF

### 8.1.2 Waypoint Navigation

As one of the primary tasks, the UAS needs to capture the waypoints within 50 ft of accuracy and the waypoint flight path within 100 ft of accuracy. Navigation tuning of the airframe was performed rigorously, to achieve the best possible accuracy.

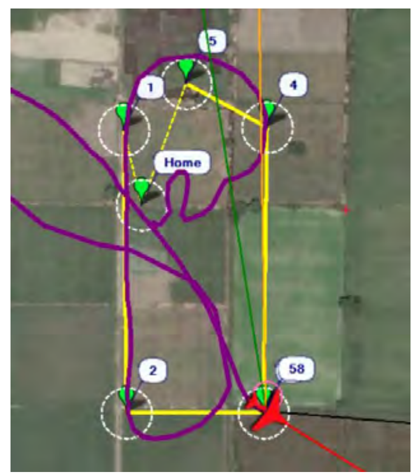



FIGURE 11 - WAYPOINT NAVIGATION

### 8.1.3 Survey Grid - Search Area

For the search area task, the UAS had to cover a closed area in a lawnmower pattern, such that there is sufficient overlapping to avoid any misses of targets lying on the ground but at the same time, optimising the flight time because if there is too much overlap, the battery consumption will increase and the UAS had to be landed to replace the battery, thus increasing the mission time.

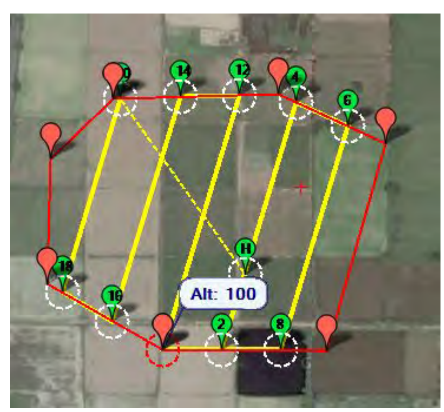



FIGURE 12 - SURVEY GRID

### 8.1.4 Auto-Landing

As part of a full autonomous mission, the team also achieved autonomous landing of the UAS. Similar to the auto-takeoff, it was ensured that the distance between the last waypoint and the landing position is at least 50m, to prevent stalling. An important point to note during autonomous landing is the *glide ratio,* which is the ratio between the distance between the last waypoint and landing point, and the height between last waypoint and the landing point. An ideal glide ratio is 10%. As an added safety feature, the motor is disarmed automatically after 10 sec of the landing.

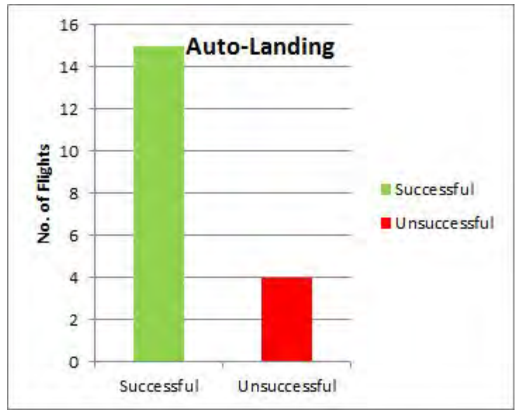



FIGURE 13 - AUTO LANDING

## 8.2 Vision based Task Performance

The targets which are to be detected, classified and localised in the acquired imagery data were printed on flex. This was done to cut on costs. These targets were quite reflective, thus giving us an opportunity to test our algorithms on a difficult dataset.

The image sensor was put on the UAS as a payload and a mission identical to the one used for the Search Area Task was input to the mission planner.After a safe autonomous landing the acquired aerial imagery and the telemetry logs were input to the image processing ground station for the ADLC task.

The blob detection segments the ROIs with high recall but bad precision. This is intended as this ensures that the input for further processing is considerably smaller while almost no target is missed. The various filtering and clustering techniques work quite reliably too. Hence, for this year we aim to report the characteristics, shape, shape color and alphanumeric color. The False Alarm Rate was below the required threshold. The localisation of segmented blobs is done using the telemetry logs received from the autopilot. The location of targets are well within the permitted error limit. The QRC targets were detected and decoded with good accuracy.

## 8.3 Interoperability Task Performance

Interoperability requirement has been met by transferring HTTP packets in JSON format. We have used python as our language of choice as it easier to run Python scripts with Mission Planner. The connection to the interoperability server and the UAS telemetry data(UAS lattituddе, longitude, altitude and heading) upload is made by running the two scripts: *clientproxy.py* globally and *auvsi_mp.py* from inside the MissionPlanner. The rate of data upload was found to be 12Hz , which was above the mission objective of 10Hz. At the same time, we were able to download the information of stationary and moving obstacles from the server, for SDA task.

| Test No | Medium used | Duration(sec) | Packets Sent | Speed(Hz) |
|---|---|---|---|---|
| 1 | WLAN Router | 673 | 4050 | 11..657 |
| 2 | Lan Cable | 608 | 5083 | 12.045 |

TABLE 4 - INTEROPERABILITY TESTS

## 8.4 Path Planning Task Performance

The sample file containing waypoints, obstacle coordinates and velocities was downloaded from the interoperability server and input to the motion planner software created by the team. A file containing all the waypoints which the UAS must pass through in order to avoid the obstacles was output. This file was input to the Mission Planner software. Now, as the autonomous take-off was successful, the UAS entered into the autonomous navigation mode and passed through the waypoints as generated by the motion planning software. Because these waypoints are very close to each other, navigation through these internal waypoints is well-tuned.

For further practice, arbitrary waypoints, obstacle coordinates and velocities were put on the interoperability server in the form of a text file in the prescribed format. This text file was downloaded on the ground station and input to the motion planning software. Similar results were observed.

# 9. Safety Considerations and Measures

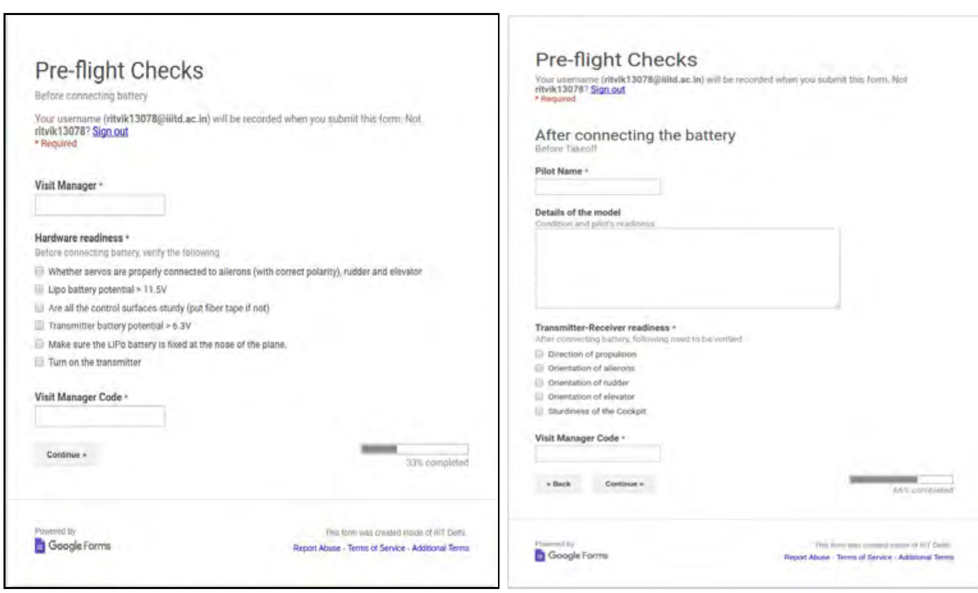
Safety has always been the team's priority. *Aurora* has taken several precautions and carried out continuous risk assessments during the design of the UAS to ensure a safe flight. In order to successfully and *safely* execute the mission tasks, the team had adopted the following mitigation measures:

## 9.1 Pre and Post-Flight Checklist

### 9.1.1 Pre-Flight Checklist

A Google form was made for the pre-flight checks, which was filled before every flight to ensure that safety risks are minimized and each flight goes through a well-structured and formal procedure. Some of the special features of the pre-flight checklist include:

1. **Visit Manager:** Each flight has a visit manager (person heading the field visit, Captain/Team Advisor/Most Experienced in the team) who signs all the safety checks. The manager also enters an ***encrypted code***, to prevent any spoofing/malpractice.
2. **Pilot**'s name and his 'readiness' before the flight.
3. Covers all the minute checks of airframe readiness.



Pre-flight Checks
Before connecting battery
Your username (ritvik13078@iiitd.ac.in) will be recorded when you submit this form. Not ritvik13078? Sign out
* Required

Visit Manager *

Hardware readiness *
Before connecting battery, verify the following
- Whether servos are properly connected to ailerons (with correct polarity), rudder and elevator
- Lipo battery potential > 11.5V
- Are all the control surfaces sturdy (put fiber tape if not)
- Transmitter battery potential > 6.3V
- Make sure the LiPo battery is fixed at the nose of the plane.
- Turn on the transmitter

Visit Manager Code *

Continue »
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Pre-flight Checks
Your username (ritvik13078@iiitd.ac.in) will be recorded when you submit this form. Not ritvik13078? Sign out
* Required

After connecting the battery
Before Takeoff

Pilot Name *

Details of the model
Condition and pilot's readiness

Transmitter-Receiver readiness *
After connecting battery, following need to be verified
- Direction of propulsion
- Orientation of ailerons
- Orientation of rudder
- Orientation of elevator
- Sturdiness of the Cockpit

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FIGURE 14 - PRE FLIGHT FORMS

### 9.1.2 Post-Flight Checklist

A crashless flight doesn't mean that the mission is successful. The team performs various post-flight checks to assess the following:

- Assessing slightest of the damage caused to the airframe after the flight (mostly during landing) and checking all the control surfaces.
- Analysing the pilot's control over the plane and providing him the feedback accordingly.
- Visit manager's comments about the entire flight which includes team coordination on the field, flight readiness and each members' on field presence.


FIGURE 15- POST FLIGHT FORMS

## 9.2 Design Safety

Being *Aurora*'s first participation on such a platform, the team decided to use one of the most *stable gliders*, Skywalker 1680. This ensured safety both of the equipments and the personnel, yet executing the mission tasks to the full capability.

Also, a lot of thought process had gone into placing of the autopilot system, video system, batteries, antennas on-board. This was to ensure that they give optimal results, efficiently use the payload space and most importantly, least damage is caused to the systems during a crash. Explosive equipments like batteries were covered with *foam* to reduce the shock in case of a crash. All the systems were attached with a velcro (and many with a zip tie, to provide a second layer of security), to ensure that they remain in place during a turbulent flight or in a crash.

## 9.3 Operational Safety

*Aurora* also follows a structured protocol to overcome unforeseen circumstances during flight. The plane is declared flight ready once the pre-flight check forms has been completed. It also includes a basic testing of all the payload on the craft.

Apart from ensuring safety against any hardware malfunction, proper measures have also been exercised to mitigate any software problems also. The safety pilot is capable of taking control of the plane in midst autopilot flight using the safety switch on the transmitter.

Listed below are the failures that can occur during flight and the mitigation measures that would be undertaken:

- Telemetry Link Loss:
    - Indication: Link Indicator in mission planner goes below 60%
    - Effect: Control over UAV hindered
    - Response:Wait for Link signal to increase, if it doesn't then switch to manual and troubleshoot
- Mission Control Centre computer problem:
    - Indication: Main GCS compute hangs or shuts down
    - Effect: No control over Autopilot
    - Response: Safety Pilot takes control of the plane while the GCS team readies the backup laptop
- Image relay failure or Terminal Crashes:
    - Indication: No or slow video feed available
    - Effect: Image processing hindered
    - Response: Perform Emergency Landing via R/C and do quick repair.
- Motor cut-off:
    - Indication: Airplane quickly loses speed
    - Effect: Loss of proper control on the airplane
    - Response: Perform Emergency Landing via R/C and use backup plane.
- Structural Failure or Component Disintegration:
    - Indication: Visible damage assessment; falling parts
    - Effect: Aircraft no longer suitable for Flying
    - Response: Perform Emergency Landing via R/C and either do quick repair or use backup plane.

## 9.4 Safety Pilot Standards and Simulator Practise

*Aurora* has set high standards for a person to become the safety pilot. The person should have clocked minimum of 30hrs of manual flying (on various airframes), and do regular flying practice on a *flight simulator (Realflight 7.5)* set to one of the most difficult levels, regularly. The safety pilot is required to do at least 1hr of piloting practise on the simulator, before flying an actual plane on the field. These standards are based on the recommendations of our advisor. Because, it has been only limited time since we started training, only our advisor could match up to the aforementioned criteria so this year he has generously accepted our request to be our safety pilot.

FIGURE 16 - REALFLIGHT SIMULATOR

## 10. Conclusion

*Aurora,* over the past year, has evolved into an established team aiming to make a difference in the unmanned systems technology. The team tested various airframes for this edition of AUVSI SUAS, with various combination of payload systems and different combination of their position in the airframe. The team had a steep learning curve, implementing advanced image processing algorithms for automatic and actionable intelligence tasks. *Safety* and *Cost Optimisation* were the team's priority while designing the UAS, with no compromise on the mission capability of the system. The team have been punctilious in its efforts to perform the mission tasks to the best of its ability and is confident of giving a sublime performance at SUAS 2016.

## 11. Team Members

- Parikshit Maini — *Team Advisor (Safety Pilot)*
- Ritvik Agarwal, Team Captain — (*Pilot,Computer Vision*)
- Aditya Jain, Vice-Team Captain — (*Autopilot, GCS Operator, Data Communication*)
- Himanshu — (*Flight Readiness, Hardware Support*)
- Mandeep Singh — (*Pilot, Hardware Support, Autopilot*)
- Purusharth Dwivedi — (*Computer Vision*)
- Sidharth Sharma — (*Hardware Support, Data Communication*)
- Syesha Girdher — (*Hardware Support*)
- Vijay Sharma — (*RF Communication*)

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