Mavericks UAS

Deliverable 2 Report

UAV Challenge Medical Express 2018

Table of Contents (D2:2)

Statement of Originality and Accuracy (D2:3)

We declare that this report is entirely the work of the team members listed below, and has not previously been submitted by us, or others for this challenge or any other similar event.
We have acknowledged external material with appropriate references, quotes or notes to indicate its source.

We declare that this report is an accurate record of activities carried out by us in preparing for this specific challenge. The events, data and other material contained within this report occurred and have been fully detailed.

List of Team Members:

- Igor Monteiro (Captain)
- Yash Turkar
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- Davina Pinto
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Compliance Statement (D2:4)

Team Name: Mavericks UAS

We declare that this report and the entry that it describes complies with the rules of the 2018 UAV Challenge, and that we enter with the intention of competing in the spirit of the challenge. Specifically, we declare that our entry is compliant with the following topics and provide reference to within our Deliverable 2 document were our method of compliance is described:

Rules Reference	**Topic**	**Compliance**	**Deliverable 2 Reference**
1.6	Maximum of two aircraft for the mission	**Compliant**	**D2 : 5**
3.1.1	Must not be a commercial off-the-shelf complete system	**Retrieval aircraft Compliant**	**D2 : 5**
3.1.1	Must be capable of autonomous flight	**Retrieval aircraft Compliant**	**D2 : 5, video**
3.1.1	Must have a maximum gross weight of less than 100 kg (rotary) or 150kg (fixed wing)	**Retrieval aircraft Compliant**	**D2 : 8.2**
3.1.1	Must have continuous telemetry radio communication with the UAV Controller	**Retrieval aircraft Compliant**	**D2 : 8.1**
3.1.1	Must have an easily accessible E-Stop to render the aircraft deactivated	**Retrieval aircraft Compliant**	**D2 : 5, D2 : 8.1, video**
3.1.1	Must have an external visual indication of state (armed, inert, disarmed)	**Retrieval aircraft Compliant**	**D2 : 5, video**
3.1.1	Must have an arming switch	**Retrieval aircraft Compliant**	**D2 : 5, video**
3.1.3	Must implement automatic (on-board) detection of crossing a Geofence boundary	**Retrieval aircraft Compliant**	**D2 : 8.5**
3.1.4	Must include a flight termination system meeting all conditions	**Retrieval aircraft Compliant**	**D2 : 8.4, D2 : 8.3a**
3.1.5 & 5.3.2	Flight termination method described, and analysis provided of maximum distance outside Geofence	**Retrieval aircraft Compliant**	**D2 : 8.4**
3.1.6	All criteria for flight termination must result in immediate activation of flight termination	**Retrieval aircraft Compliant**	**D2 : 8.4, D2 : 11**
3.2.1	Flight outside the Base area must be autonomous	**Retrieval aircraft Compliant**	-
3.2.2	Must have a ground control station that provides a graphical display	**Retrieval aircraft Compliant**	**D2 : 5**
3.2.2	Must provide an NMEA data feed from the ground station	**Retrieval aircraft Compliant**	-
3.2.3	Communication equipment must comply with ACMA regulations	**Compliant**	**D2 : 8.6**

3.3.2 & 5.3.2	AMSL altitudes will be measured and reported as pressure altitudes	**Compliant**	**D2 : 8.5**
3.3.3 & 5.3.2	Correct aeronautical units used	**Compliant**	**D2 : 5**
3.3.3	Description of how aircraft will be maintained within its airspeed envelope	**Retrieval aircraft Compliant**	**D2 : 5**
3.4.5	Pyrotechnic mechanisms have safety mechanism implemented and safety manual provided	**Not applicable**	-
5.2	Disclosure of sponsors and funding sources	**Compliant**	-
5.3.2	Statement of originality and accuracy included	**Compliant**	**D2 : 3**
5.3.2	Executive summary provided	**Compliant**	**D2 : 5**
5.3.2	Introduction and design approach provided	**Compliant**	**D2 : 6**
5.3.2	Landing site analysis strategy provided	**Compliant**	**D2 : 7**
5.3.2	System Diagram provided	**Compliant**	**D2 : 8.1**
5.3.2	Flight termination system design, state machine diagrams and transitions provided	**Compliant**	**D2 : 8.3a , D2 : 8.3b, D2 : 8.4**
5.3.2	Geofence system design provided	**Compliant**	**D2 : 8.5**
5.3.2	Radio frequencies to be used and relevant licenses provided	**Compliant**	**D2 : 8.6**
5.3.2	Updated risk assessment provided	**Compliant**	**D2 : 8.10**
5.3.2	Assessment of the risks associated with autonomously taking off and landing provided	**Compliant**	**D2 : 8.10**
5.3.2	Risk Management provided	**Compliant**	**D2 : 8.11**
5.3.2	Details of the system response to loss of data link provided	**Compliant**	**D2 : 8.11.1**
5.3.2	Details of the system response to loss of GPS provided	**Compliant**	**D2 : 8.11.1**
5.3.2	Details of the system response to lock-up or failure of autopilot provided	**Compliant**	**D2 : 8.11.1**
5.3.2	Details of the system response to lock-up or failure of the GCS provided	**Compliant**	**D2 : 8.11.1**
5.3.2	Details of the system response to loss of engine power provided	**Compliant**	**D2 : 8.11.1**
5.3.2	Details of fuel and/or battery Management provided	**Compliant**	**D2 : 8.11.2**

5.3.2	Details of the management of other risks provided	**Compliant**	**D2 : 8.11.3**
5.3.2	Flight tests results provided	**Compliant**	**D2 : 12**
5.3.2	Conclusions provided	**Compliant**	**D2 : 13**
5.3.2	Video provided showing the retrieval aircraft autonomously landing and taking off	**Compliant**	**D2 : 5**
5.3.2	Video provided showing the teams pre-flight set up and checks	**Compliant**	**D2 : 5**
7.2	“Soft Geofence”	**Not Implemented**	**D2 : 8.5**
5.3.2	Deliverable 2: Max 23 pages.	**Compliant**	**-**

Printed name: Igor Monteiro

Date: 11th April 11, 2018

Executive Summary (D2:5)

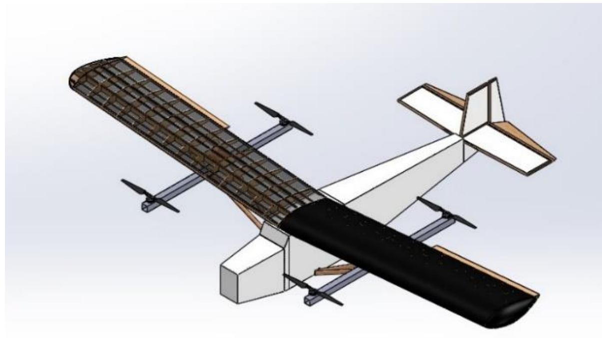
Team Mavericks UAS aims to deliver UAVs for long haul flights which are used in rigorous test environments. Our goal is to help people through our research and simultaneously contribute to the world of UAVs. Our system design ensures that the UAV is completely autonomous and makes sure that it satisfies all the requirements of the competition without compromising on safety, efficiency and standards compliance.

We have one vehicle i.e. only the retrieval aircraft that is a custom design that has been carefully designed and tested under the guidance of our advisor. We have chosen to not implement a support aircraft. The UAV has an advanced autopilot to implement features like autonomous takeoff and landing, GPS hold, way-pointing, loiter etc. This UAV is a hybrid of a fixed wing aircraft and a multirotor and hence provides efficiency in long range flights. The IMU and the GPS together provide a speed estimation of the UAV and ensure that the UAV maintains the speed that was specified while uploading the mission.

There is a failsafe system implemented in case any of the safety standards are violated. The failsafe system is completely independent from other systems, ensuring the safety of the flight and the people as can be seen from the Sections D2:8.3a, 7, 10, 11. A ground control station will be used to monitor the onboard systems of the UAV and take necessary actions if required. Also, all the flight data of the UAV will be available in the units specified in section 3.3.3 of UAVC Medical Express 2018 Rules.

The requirements of an arming/safety switch, E-stop switch, External visual indicator of the safe/unsafe to approach state of the aircraft, preflight checks and autonomous take off and land have been demonstrated in the video titled ‘Mavericks UAS Medical Express 2018 Deliverable 2’. The video has been uploaded on YouTube and the link for same has been provided in the Email. **With permission from the organizers, the model that is showcased in the video is a scaled down version of the final model that we plan to make. The final model will have the same design as mentioned in the section D2: 6 and will only be up-scaled in size with no design changes**.

Introduction and Design Approach (D2:6)



The UAV is a slow stick trainer model which gives us maximum stability at the price of speed. We have chosen a high-wing model because of various reasons mainly including:

- Increased ground clearance thereby increasing safety during take-off and landing on hazardous terrain.
- Increasing ground visibility for photography, object detection and ground reference navigation.
- As the center of lift is higher than the center of mass, more stability is provided.
- If the UAV rolls to the right, the airflow will act on the wings from the right side thereby increasing the local angle of attack which results in levelling of the UAV.

The wing is made of two halves joined by 4 braces, having a dihedral angle of 4.96 degrees to prevent fluttering of the wing. There are 34 ribs in total with 2 ribs to the central ones for imparting strength to each part of the wing. The aspect ratio is 8.436 and wing loading is 9.241 kg/m^2.

There are two main spars having dimensions of 145.34 x2.87x2.87 cm and 5 notch spars having dimensions 142.02x0.72x0.64 cm in each wing to form the airfoil. The total area of the wing is 20812.5 centimeters^2.

Actual wingspan is 299cm, fuselage length is 179cm and the maximum thickness of the fuselage is 18cm.

The notch spars along the wing provide resistance to bending forces due to the lift produced, while the main spar provides strength against shearing forces due to drag and the thrust. The airfoil is a custom airfoil having the closest similarity with the Rhode St. Genese 36 (rhodesg36-il).

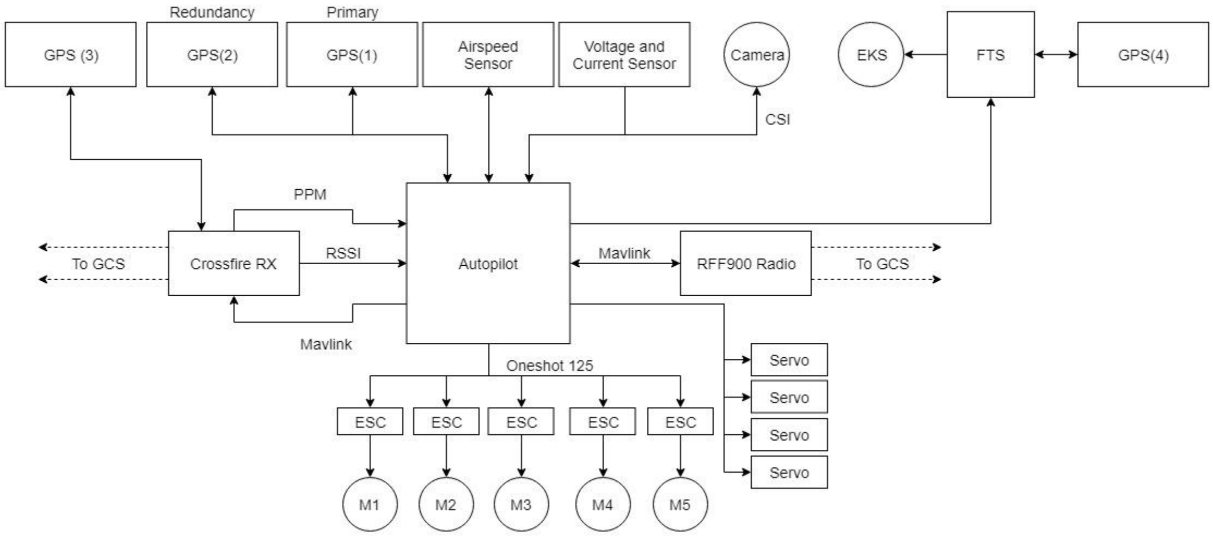
Landing Site Analysis (D2:7)

The Emergency landing target will be chosen in a way that it is easily visible from the onboard camera. The camera will look for the emergency landing target, detect it based on its high contrast as compared to its surroundings and flag it as an interest. The onboard computer will then attempt to recognize the emergency landing target out of all the flagged objects. Once recognized, the computer will then verify the recognized object and proceed to apply photogrammetry to find out its coordinates. The algorithm will divide the image into quadrants such that the origin coincides with the coordinates of the UAV, the camera will be mounted at a nadir angle 0 °. The algorithm will check every quadrant for the emergency landing target and once found will divide that quadrant into four more quadrants, which will be done recursively until the algorithm cannot proceed due to pixilation.

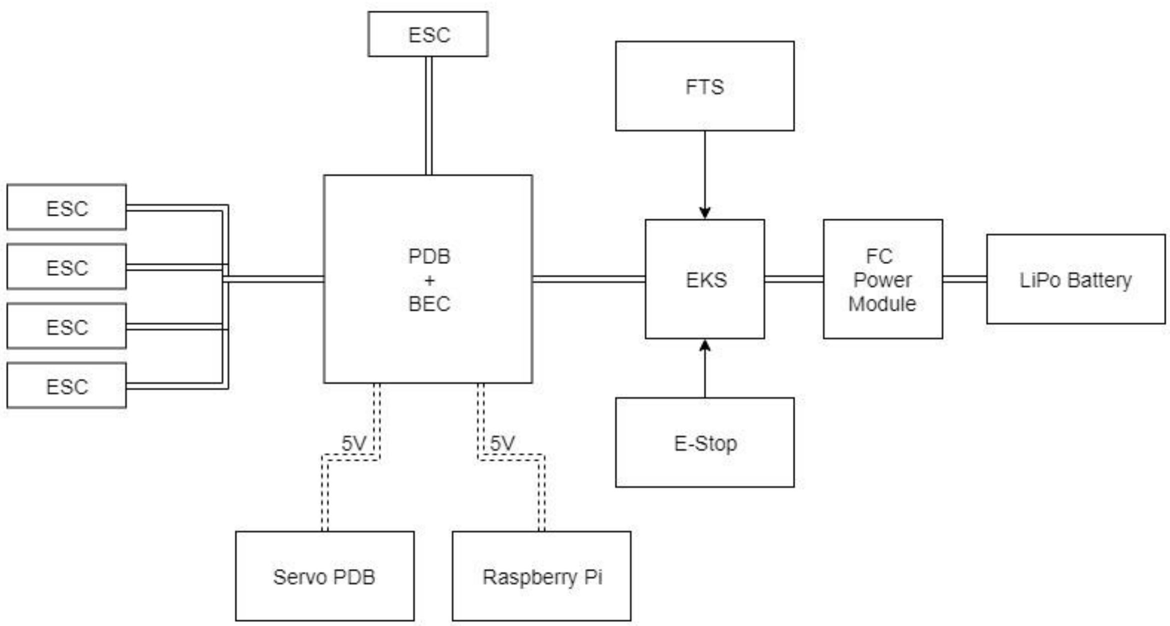
The mission will end once the UAV has scanned the area for the emergency landing target after which it will loiter in the multirotor mode until further action is specified.
Once the emergency landing target has been located the co-ordinates will be reported to the Ground Control Station (GCS). Upon confirmation with the authorities the GCS will give the UAV a command to “Go To” the specified coordinates. When the UAV is at the specified location the GCS will give the Land command.

System Design (D2:8)

System Diagram (D2:8.1)



(Main System + FTS)



(Power System)

Aeronautical Requirements (D2:8.2)

During a banked turn of 60 degrees a stalling speed of 22.725 m/s or 44.1738661 knots is found with our aircraft which weighs 10kg having a load factor of 2 and aspect ratio of 8.3122 with sea level density of 1.225 kg/m^3 having wing area 1.08 m^2 with maximum coefficient of lift of 0.6 and aspect ratio reduction factor of 0.9.

The airfoil is a custom airfoil having the closest similarity with the Rhode St. Genese 36 (rhodesg36-il).The rhodesg36-il has a maximum thickness of 16.25% at 30% chord while our airfoil has 14.28% at 30%.By using the rhodesg36-il as a reference, the aircraft is assumed to travel at 33 knots (60kmph) having a chord width of 14 inches and kinematic viscosity of 1.3324x10^-5 m^2/s we find the Reynolds number to be 444,820 which approximately corresponds to a CL of 0.65 and CD of 0.02 at an angle of attack of 0 degrees where the maximum CL/CD is 70.5 at angle of attack of 5.5 degrees. The reason for choosing a derivative of the rhodesg36-il is that the airflow and the base chord of the airfoil are co-incident.

Lifting force acting on this airfoil having area 1.082023 m^2 having speed of 33 knots (60kmph) is 12.23 kg.

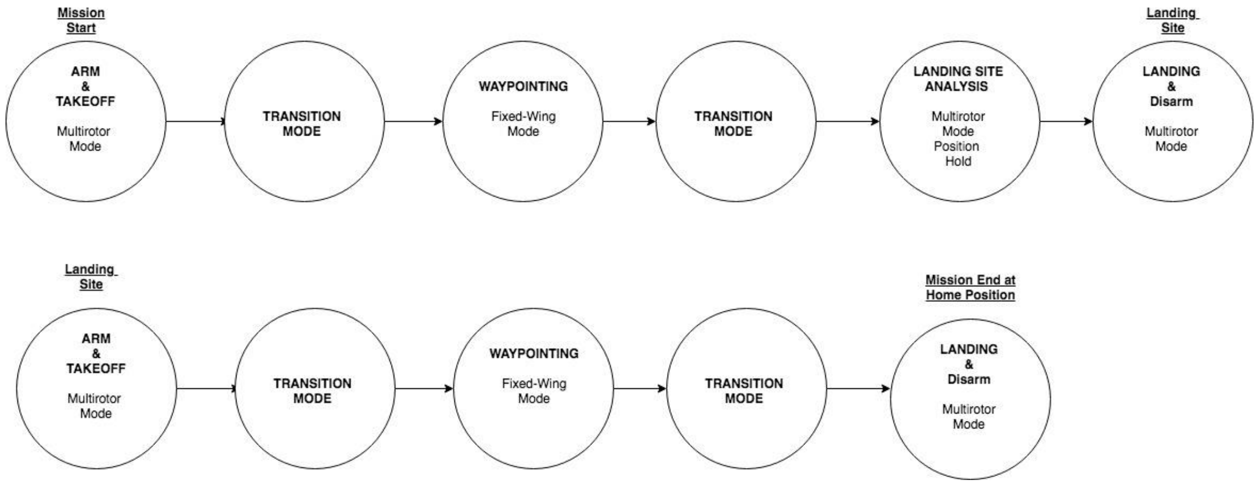
Assuming a T/W ratio of 0.35, the maximum angle of climb of an aircraft is approximately 20.5 degrees

Maximum stalling angle is 15 degrees. Assuming true airspeed to be 33 knots (60 km/h) which remains constant and maximum banking angle of 60 degrees, the turn has a radius of 49m.

Flight Termination System Design (D2:8.3a)

The flight termination system (FTS) will consist of the computing module such as a Raspberry Pi Zero. It will have its own discrete power supply and will be concealed in a hard case like a black box, this will prevent any damage to the system as the FTS is a critical system. The FTS will be at the highest level and will be prioritized over any other flight system such as the autopilot or the imaging system.

State Machine Diagram(D2:8.3b)



Flight Termination System Analysis (D2:8.4)

The Flight termination system will be connected between all the propulsion and power systems. It is a Raspberry Pi Zero that is connected to the flight controller for GPS data and has its own redundant independent GPS. The Raspberry Pi Zero will have its general-purpose input output pins connected to the electronic kill switch (EKS) and the servos of the control surfaces of the quad plane.
When a condition to activate the FTS is met the python script running in the raspberry pi will set the control surfaces to the positions mentioned in the version 2 of the rules section 3.1.5 and then operate the EKS to kill power to all propulsion systems.

Providing a post FTS analysis is not possible as the way the FTS is implemented will make the UAV spiral nose down and crash and thus destroy it. If the FTS is engaged, none of the electronics would survive making the post FTS analysis impossible. However, we have done mathematical estimations and have deduced that should the FTS be engaged the, the UAV will crash in a radius of 10-12 meters from the point of activation of FTS.

Also, it can be seen from the risk management section (D2:10) that the FTS will activate in all the scenarios mentioned in section 3.1.6 of UAVC Medical Express 2018 Rules V2.

Geofence System Design (D2:8.5)

The geofence will be specified while uploading the mission to the autopilot.
The autopilot is connected to a Raspberry Pi that has a ground station running in the terminal (mavproxy). The onboard GCS will then get all the mission parameters including the geofence from the autopilot. If the GCS detects a geofence breach it will signal the FTS to engage.
Soft Geofence has not been implemented as it is not mandatory as mentioned in section 7.2 of the UAVC Medical Express 2018 Rules V2

Radio Equipment and Frequencies (D2:8.6)

An Ultra High Frequency (UHF) radio module will be used to ensure stable connectivity at long distances. Two redundant UHF radios will be used to ensure that the system is reliable, and the GCS has command in case one radio fails.

Both the UHF radio modules use the 915mhz radio band as it gives high penetration due to the relatively high wavelength (compared to 2.4ghz). Both the radio links will provide full telemetry to the GCS and one of them will also carry PPM signals for manual control in case the UAV pilot has to take over. The frequency band complies with the ACMA regulations and is an open band.

Extension Autonomy Challenge Design Brief (D2:9)

Implementation Approach (D2:9.1)

The ground control station features a command “Go To” that pauses the current ongoing mission and directs the aircraft to a waypoint not specified in the primary mission. The mission can then be continued from that waypoint.

The data of a virtual event is received from the radar as mentioned in section 1.6 of UAVC Medical Express 2018 rules. Using the location, size and velocity of the virtual event as well as the UAV, the Ground Control Station will estimate the area where a possible collision could occur. The Ground Control Station will then add a series of sequential “Go To” waypoints around the predicted area of collision. The UAV will select these “Go To” waypoints in such a way that it will also avoid any Static no fly zones.

Scenarios (D2:9.2)

Case of Dynamic No Fly Zone Being added

A) Creates an obstruction in the current flight path of the UAV

The System will update the new GO TO points to which the UAV must fly to avoid the DNFZ based on the size and shape of the defined region.

B) Doesn’t Create an obstruction in the calculated path of the UAV

The mission will continue as usual since no alteration in course is required for handling such a situation.

Case of UAV Flying into DNFZ

The system would continue as normal as the flight termination system would be oblivious of such a problem taking place as the DNFZ would not be updated into its No- Fly Zone risk table. Hence termination of flight wouldn’t be affected in the case of such a violation.

Case of addition of Highly Demanding/ Taxing No Fly zones

A) Highly demanding

In the Case of DNFZ being added which create extreme bank angles or maneuvers which the on-board computers would find to be unfeasible the DNFZ would be ignored and mission would continue ignoring all DNFZ.

B) Highly taxing and extreme mission delaying

If the DNFZ introduced might cause the UAV to come to a halt and reposition due to proximity to the DNFZ or high computational requirements of new paths being feasible, the DNFZ will be dropped and mission would continue ignoring all DNFZ.

Risk Assessment (D2:10)

Update of Deliverable 1

In the deliverable 1 report it was mentioned that mobile network will be used as back up if the primary means of communication (RFD900) fails. Instead of mobile network, the crossfire telemetry will be used because of better reliability.

List of Assessed Risks

- **Failure of IMU**
  The internal sensors of the autopilot i.e. the accelerometer, gyroscope, magnetometer, barometer fail.
- **Failure of Primary GPS**
  Primary GPS fails to give a value / stops working
- **Failure of Secondary GPS**
  Secondary GPS fails to give a value / stops working
- **Failure of Both the GPS**
  Both GPS modules connected to the UAV stop working
- **Noise in the sensors**
  Vibrations in the frame of UAV due to motors can cause noise in the sensors.
- **Lockup or failure of GCS**
  The GCS hangs or stops responding
- **Loss of Data link**
  Radio link between the telemetry radio and UAV breaks
- **Failure of autopilot**
  The autopilot stops working in flight
- **Loss of Engine power**
  The main front motor of the UAV stops functioning
- **Waypoint system failure**
  The UAV does not follow the waypoints in the mission and goes off the route.
- **Loss of radio link**
  The link between the transmitter and UAV is lost

- **Sensor malfunction**
  GPS – The GPS gives a wrong value
  Gyroscope – The gyroscope data is inconsistent or wrong
  Accelerometer – The accelerometer data is inconsistent or wrong
  Magnetometer – The Magnetometer data is inconsistent or wrong
- **Failure of Multi-copter motor**
  The motors used for vertical takeoff and land fail
- **ESC Burnout**
  Electronic Speed Controllers for the VTOL or the forward flight propulsion system burn out due to overdraw of current causing haphazard movements.
- **PDB Burnout**
  The main power distribution board burns out causing the propulsion system to lose power which in turn will lead to a crash.
- **LiPo Battery Burnout**
  The Lithium polymer (LiPo) batteries are prone to catch fire or leak if not charged or discharged properly.
- **Battery voltage Management**
  If the battery voltage drops under a certain value, this can lead to loss of power to systems as the BEC cannot handle voltage under a certain value.
- **High Speed Crosswind**
  Strong crosswinds that the UAV is not able to provide enough thrust to respond to. This will result the aircraft to drift in the direction of the wind. This risk is especially applicable to take off and land and the aircraft can drift while in either modes considerably depending on how strong the wind is.
- **Bird Attack or Bird Flocks**
  In event of a bird attacking the UAV or a flock of birds flying in the path of the UAV (across or parallel)
- **Flapping of the Wing**
  Due to innate material bending and forces on the wing the wing experiences flapping motion which causes reactionary forces affecting the effective lift produced.
- **Fluttering of the wing**
  Vibrations generated by the moving parts of the plane.

- **Downwash**
  Turbulent forces created by the forward motor and the wind being redirected by the body of the fuselage and the wings.
- **Vortices**
  Turbulence created due to erratic regions of contact between high pressure air and low-pressure air.
- **Efficiency**
  Drag created due to shape of the wing reduces effective performance and efficiency of the aircraft.
- **Structural Damage**
  The craft might experience heavy impact forces at certain regions leading to the probability of breaking or damage or internal impact of components within the craft causing errors in readings and failure of systems.
- **Heating of internal components**
  Increase in the temperature of internal electronic components can result in malfunction and incorrect data transmission and causes irreversible damage.

Risk Management (D2:11)

Response to System Failure (D2:11.1)

Lockup or Failure of GCS

The UAV will be connected to 2 different GCSs via different telemetry modules. The GCS connected via the RDF 900 telemetry module will be the primary GCS and the other connected via the Crossfire Telemetry will be the secondary GCS

If the primary GCS locks up the mission will be paused by putting the aircraft in loiter mode using the switch on the transmitter / secondary GCS. If the GCS is not running and has established not communications with the aircraft in 1 minute the aircraft will be returned to launch position using the RTL switch on the transmitter.

If the secondary GCS locks up the mission will continue for a duration of 2 waypoints. If in this duration the secondary link is not recovered the UAV controller will initiate return to launch

Loss of data link

Dual telemetry for redundancy has been used. The primary telemetry will be by using the RFD 900 telemetry module and the secondary telemetry will be through the crossfire radio.

If the primary data link is lost the mission will be paused by the putting the aircraft in loiter mode using the switch on the transmitter/or the secondary GCS connected to the Crossfire telemetry.

If the primary GCS has not established communications with the aircraft in1 minute, the aircraft will be returned to launch position using the RTL switch on the transmitter.

If the secondary telemetry data link is lost the mission will continue for a duration of 2 waypoints. If in this duration the secondary link is not recovered the UAV controller will initiate return to launch

Loss of GPS / Failure of Autopilot

Loss of GPS refers to the case where both GPS connected to the autopilot stop working

The Flight termination system will wait stop receiving the GPS data from the autopilot. It will then wait for 10 seconds before engaging.

Loss of Engine Power

The loss of Power for the Front puller motor will be identified with the data of the relative airspeed and the altitude. Both these parameters will drop rapidly letting the UAV controller identify this occurrence.

i) The UAV is out of line of sight

The UAV controller will pause the mission and have the aircraft transition to multirotor mode and auto land at then current location.

ii)The UAV is in line of sight.

The UAV will be put in manual mode and the Pilot will take control and have it land safely.

Waypoint system failure

If the vehicle goes off the route the UAV controller will manually initiate return to launch. In case the vehicle does not respond to this command FTS will be manually engaged from ground.

Failure of IMU

The autopilot has triple redundant IMU system. It has 3 sets of accelerometer and gyroscope and compass and 2 sets of barometers.

Failure of one of the 2 GPS

The autopilot will have 2 GPS for redundancy. In case one fails the flight will continue using the other GPS.

Noise in the Sensors

sets of IMU are vibration-isolated by built-in pieces of foam, reducing the effect of frame vibration to state estimation.

Loss of radio link

If there is a loss of radio link the UAV controller will pause the mission and have the UAV loiter at its then current location.

If the link is reestablished in 10 sec the mission will be resumed. Otherwise the UAV controller will initiate a return to launch.

Multi-copter motor failure

If the multi-copter mode of the quad-plane that is used for vertical take-off and land fails, the UAV controller will have the UAV transition to fixed wing mode.

If the UAV can recover and stabilize itself the UAV controller will have it land as a fixed wing aircraft. If the UAV cannot stabilize itself, then the kill switch will be engaged.

Sensor Malfunction

The sensors will be calibrated in the preflight checks. A set of preflight checks in the autopilot will check for abnormal values or biases in the sensors. Only if the all the sensors give a consistent value the mission will be started.

If any of the sensors fail mid-flight and give abnormal values the UAV controller will infer this from the data available at the GCS and the abnormal behavior of the UAV due to inconsistencies in the sensors. For example, if the compass gives an abnormal value the UAV will start heading in a wrong direction letting the UAV controller know of this abnormality. The UAV controller will then Engage the kill switch since the UAV will not be able to land or RTL safely if the sensor data is inconsistent. If the GPS gives a wrong value, then the UAV controller will notice the abnormal location and immediately engage the kill switch because an inconsistent GPS will not let the UAV RTL or land safely. In case GPS reports that the UAV is in a no flight zone or that it has voided the geofence FTS will be deployed.

Battery Management (D2:11.2)

Heating of the LiPo battery

An air cooling system will be implemented along with an internal cooling system. The voltage of the LiPo battery will be constantly monitored and an internal cooling system will be implemented in case of over drainage.

Voltage management

High discharge Batteries will be used to reduce voltage sag in batteries.

Physical Stress

To protect the LiPo Battery against physical forces, it will be encased with an immobile porous sponge padding.

Other Risks (D2:11.3)

Highspeed Crosswinds

To counter the powerful crosswinds and improve stability the surface area of the vertical and horizontal stabilizers will be increased.

Flapping of the wing

Struts have been attached to the bottom of the plane and fixed to the wing to reduce oscillatory motion of the wing.

Fluttering of the wing

4 Sets of plywood braces installed at the interface between the two wings.

Downwash

To avoid downwash created, the empennage is raised above the neutral plane.

Drag and efficiency

An angular wing has been constructed to produce a parabolic lift distribution thus reducing drag, improving efficiency and negating flapping.

Structural damage

The landing gear has been angled and reinforced to allow max of up to 20 kg impact load.

PDB/ESC Burnout

The soldering for the ESCs and the PDB will be done by expert electronics faculty to ensure a reliable system

Flight Test Results (D2:12)

Flight tests were done for both Multirotor and Fixed wing mode before attempting a VTOL flight with transitioning. Both the flight modes were first independently put through numerous flight tests (both manual and auto) till both flight modes could satisfactorily loiter, hold altitude and perform an autonomous mission.

Back Transition (Fixed wing to multirotor)

When a VTOL performs a back-transition (transition from fixed wing mode to multirotor) it needs to slow down before the multirotor can take proper control. The back transition is considered complete when the horizontal speed has reached multirotor cruise speeds or when the back-transition duration has passed. During this period the VTOL will shut down its fixed wing motor and slowly ramp up its multirotor motors while gliding.
The caveat of this behavior is that the vehicle will only control altitude and not position during this period, so some drift can occur.

- **Initial flight tests**
  The back-transition time was set too high, so the vehicle glided for more time while slowing down resulting in a noticeable drift. While this drift did not affect the way pointing as the UAV would correct its heading if it drifted, this is certainly posed a risk of accidentally entering a no flight zone while transitioning. Reducing this parameter resulted in much less drift. However, this caused an issue in a mission as the set value of the expected deceleration was not in tune with this lower transition time and caused the UAV to complete its transition quite far away from the landing site and quite abruptly. This is quite inefficient in terms of power as 4 motors would take more power and time as the speed in multirotor mode is much less than that in fixed wing mode
- **Intermediate flight tests**
  These flight tests were spent in finding the perfect sweet spot between the back-transition duration and the expected deceleration parameters.

- **Final flight tests**
  Smooth back transition was observed. Also, the UAV started back transition at an appropriate distance from the landing site such that it did not complete the transition too early and did not have to travel most of distance for that waypoint in multirotor mode.

Forward Transition (Multirotor to Fixed wing mode)

The transition from fixed wing to multirotor involves gradually increasing the speed of the front motor and reducing the speed of the multirotor motor. This increase must be perfectly coordinated and the blending(mid-transition) and final complete transition depends on the airspeed value and the parameter transition throttle i.e. the throttle value for front motor will be attempted. This value had to be perfectly tuned as our tests showed that required airspeed for transition was not reached if this value was too low and if it was too high it led to a significantly higher power consumption

- **Initial flight tests**
  The initial value set for transition throttle value was too low which resulted in not reaching the set transition airspeed. After tuning this parameter, the UAV achieved transition.
  However, it tended to go nose up and stall as the front motor directly started at the transition throttle instead of slowly ramping the speed up. Fixing this issue gave a smooth transition with a dip in altitude.
- **Intermediate flight tests**
  The mentioned dip in altitude was caused because the speed at which the multirotor control turned off and the UAV became a complete fixed wing aircraft was low. This was fixed by increasing the speed at which complete transition took place. Doing this reduced the dip significantly.
- **Final flight tests**
  The final test flights for front transition showed smooth transition from multirotor mode to a fixed wing mode with minimum acceptable dip in altitude and no stalling. The UAV was able to fly in a perfectly satisfactory manner after the transition.

Conclusion (D2:13)

The following aspects of the UAV have been tested and confirmed to be working satisfactorily

- Autonomous take off and land
- Transition between fixed wing and multirotor
- Fully autonomous missions involving take-off, land, transitioning and way pointing.
- Loiter in multirotor and fixed wing mode
- The E-stop switch
- Location of landing site

We also understand that the blood might coagulate if kept out of the body for a long time at an elevated temperature. Thus, we will be looking into the solutions for this problem such as an internal cooling system.

The team not only aims to deliver a completely autonomous UAV but also beget a major contribution to the field of robotics and set high standards for the future competitions.