



Short Technical Report (Deliverable 1)

UAV Outback Challenge 2016 (Medical Express)

Team Overview

SRM-UAV is a collegiate research team of SRM University, with its prime focus on Unmanned Aerial Vehicles. It comprises of undergraduate students from various branches of engineering viz. Aerospace, Mechatronics, Mechanical, Electronics & Instrumentation, Electrical & Electronics and Information Technology. The team comprises of 15 members and has been researching and developing end to end solutions to real civilian and military problems which can be solved using unmanned aerial systems since two years.

Summary

The team's approach for UAV Outback Challenge 2016 is to use a type of hybrid aerial vehicle which the team has been working on. The reason behind this selection is the long distance from the Base to the Remote Landing Site and the unavailability of a runway at both the locations. Moreover, in order to perform an accurate landing within the required distance from Joe requires an aircraft with VTOL (Vertical Takeoff and Landing) capability.

The team's main focus is to design a fully autonomous, long range, robust and highly maneuverable UAV platform with all the safety measures required by the competition such as GeoFencing, Flight Termination System and Flight Controller Overrides in order to successfully complete the mission tasks.

The team will be developing and testing two designs and will be using the most suitable one for the competition.

Design 1: Hybrid Quadcopter

The first design is a hybrid of a quadcopter and a fixed wing aircraft combining the advantages of both. This design is known as SRM-UAV X-2 and has been developed after extensive research and development both in the field of aerodynamics and control systems by our team over the past two years.

The aircraft is capable of performing Vertical Takeoff and Landing as a quadcopter and transitions itself into a conventional fixed wing during cruise. In this, the fixed wing aircraft uses an IC engine with midair electric starting capability.



Figure: Hybrid Quadcopter

Design 2: Hybrid Tilt Rotor

The second design is a tilt-rotor aircraft with three electric motors and no control surfaces. The aircraft is controlled by using thrust vectoring. The tilt mechanism comprises of two single degree of freedom gimbals for wing mounted motors and a two directional gimbal for the tail rotor.

This aircraft behaves like a Tricopter during takeoff and landing and as a fixed wing during cruise. The control of the aircraft is achieved as follows:

- Roll: Tilting wing mounted motors in opposite directions
- Pitch: Tilting tail motor along the horizontal axis
- Yaw: Tilting tail motor along the vertical axis

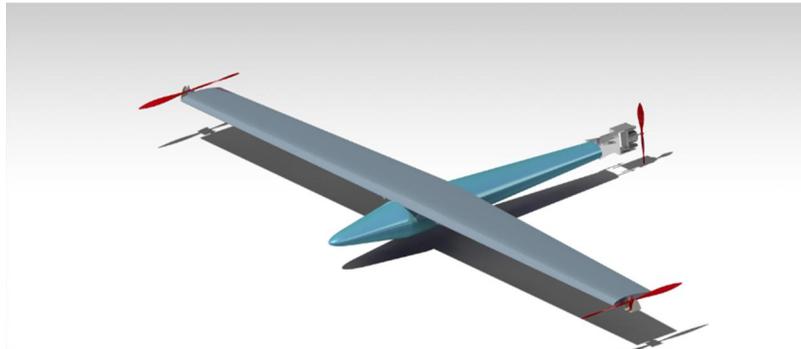


Figure: Tilt Rotor

GeoFence System

The aircraft will be using an independent onboard computer running on Linux along with the inbuilt geofence system in the autopilot for GeoFencing and flight termination system.



Figure: GeoFence System

The GPS coordinates of the geofence will be fed in to this computer by which it will generate a geofence polygon. The computer will have an onboard GPS and will activate the flight termination sequence if at any point of time the coordinates of the onboard GPS match those of the geofence polygon.

For the vertical geofence, the onboard computer will be equipped with a barometric pressure sensor.

As soon as the computer detects that the geofence has been breached, it will physically (by hardware) override all the signals to the actuators and initiate flight termination sequence.

Mission Description

The sequence of tasks for completion of the mission is as follows:

Sr.No	Operation	Task	Configuration
1	Takeoff From Base	Takeoff	*VTOL
2	Transition	Transition to fixed wing configuration for cruise	-
3	Cruise	Cruise along Transit Corridor towards Remote Landing Site	Fixed Wing
4	Enter Remote Landing Site	Initiate Search Sequence	Fixed Wing
5	Transition	Transition to VTOL configuration for slower and more efficient search	-

6	Search	Initiate Thermal Image Processing Algorithms and search the site for Joe's Location	*VTOL
7	Land	As soon as Joe is located, landing sequence at that location is initiated	*VTOL
8	Throttle Cut	Cut throttle to all engines/motors and wait for Joe to load sample and give takeoff clearance signal	*VTOL
9	Takeoff from Remote Landing Site	Takeoff	*VTOL
10	Transition	Transition to fixed wing configuration for cruise	-
11	Cruise	Cruise along the Transit Corridor towards Base location	Fixed Wing
12	Transition	Transition to VTOL configuration	-
13	Land	Land at Base location and deliver the sample	*VTOL

*VTOL refers to Vertical Takeoff and Landing

System Description

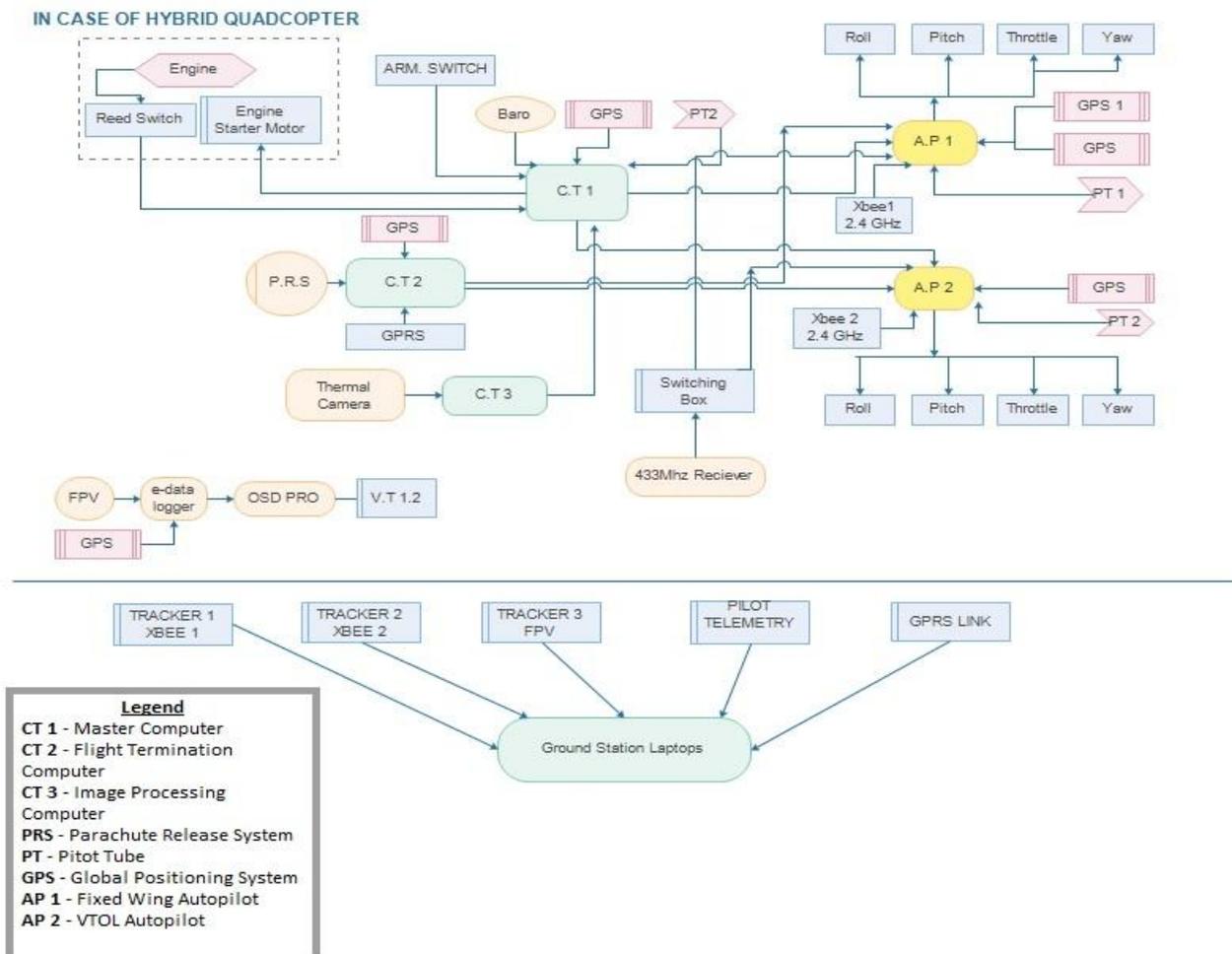


Figure: System Block Diagram

- Autopilot: Each of the above mentioned designs uses 2 APM: Pixhawk autopilots as their flight controller and navigation system. These autopilots are integrated using a master-slave architecture with a master embedded computer. This is a highly reliable and tested autopilot with thousands of users and developers around the world. Team SRM-UAV has developer experience with both the older Ardupilot as well as

Pixhawk. Both these autopilots proved to be user friendly and easy to modify. Pixhawk was chosen because of its faster ARM processor over the Arduino based Ardupilot. Pixhawk also has support for redundant sensors which enhance its reliability and system safety.

- **Onboard Computers:** The UAS consists of an embedded computer for GeoFence and Flight Termination System, one for image processing and one for the master control of all subsystems. These embedded computer run on ARM Cortex A7 processor with 2 GB of RAM.
- **Ground Control Station:** The ground control station was designed for easy transportation and lightest possible and minimal equipment required for a high performance, long range UAS. The UAS is designed to be fully autonomous and thus requires almost negligible human interference during flight. The ground station equipment consists an autopilot terminal, a payload terminal, a radio transmitter for pilot control, a LCD monitor, two antenna trackers and two antenna stands.
- **Imaging:** The system consists of a thermal and an electro optic CCD camera for collecting imagery. The thermal camera is used to detect Joe by searching for human body temperature in the Remote Landing Site using onboard image processing. The electro optic camera is used to provide First Person View telemetry at the ground station for flight monitoring and pilot override in emergency situations.
- **Communications:** The UAS uses 4 communication links in total at different frequencies to avoid interference. The system is designed in order to provide a communication range of up to 10 kilometers. The details of the communication system are shown below:

Link	Frequency	Module	Ground Station Antenna Tracker (Yes or NO)	Ground Station Antenna	Onboard Antenna	Power	Direction of Link	Purpose
Autopilot Telemetry	2.4 GHz	XBee Xstream	Yes	Parabolic Grid 24 dBi , Whip 15 dBi	Whip 5 dBi	50mW	Uplink and Downlink	To get live data from autopilot, send mission specific commands.
First Person View	1.2 GHz	Video Transmitter	Yes	Patch 14 dBi	Whip 5 dBi	800mW	Downlink	For First Person View to pilot and off-axis task.
Pilot Telemetry	433 MHz	Arkbird Repeater	No	Whip 5 dBi	Whip 5dBi	1400mW	Uplink	For long range pilot control.
Flight Termination Manual Override	GPRS	3G	No	N/A	N/A	N/A	Uplink and Downlink	For manual override of flight termination system.

Flight Termination System

The flight termination will operate on the same onboard computer as the geofence system. The system includes an independent power supply and a GPRS based ground communication system for manual override.

The termination system for each design would vary. The system design is as follows:

- For Hybrid Quadcopter:

If the termination sequence is activated in VTOL configuration, the computer would immediately cut throttle to all motors and deploy a parachute for a safe landing of the aircraft.

If the termination sequence is activated while the aircraft is in fixed wing configuration, the computer will activate the fixed wing flight termination sequence which is:

- Throttle closed
- Full up elevator
- Full right rudder
- Full down on the right aileron
- Full up on the left aileron

A pitot tube connected to this computer will constantly monitor the airspeed and deploy a parachute as soon as the airspeed reaches below stall speed.

- For Tilt Rotor:

When the flight termination sequence is activated, the motors would reverse direction of rotation and decelerate the aircraft. This helps reduce the distance the aircraft traverses outside the geofence if termination is activated through geofence breach.

A pitot tube connected to this computer will constantly monitor the airspeed and cut throttle and deploy a parachute as soon as the airspeed reaches below stall speed for safe recovery of the aircraft.

Flight Termination is activated under the following circumstances:

- Geofence Breach: As soon as the onboard computer detects a GeoFence breach, it overrides the flight controller and initiates the flight termination sequence.
- Manual Termination Request: The onboard computer communicates with the Ground Control Station using a GPRS link which can be used to manually initiate a flight termination sequence.
- Failure of Flight Controller/Subsystems: The subsystems embedded computers and flight controller will be sending a "healthy state" signal to the master computer. Absence of flight controller signal for more than 10 seconds or that of the flight termination computer for more than 30 seconds will initiate the flight termination sequence.
- Engine Failure (In case of Hybrid Quadcopter only): Engine RPM is monitored using a reed switch mounted on the crank shaft. If an engine stall is detected, the onboard computer will initiate the electric start sequence and will attempt to restart the engine twice. If the engine is unable to restart, the flight termination sequence is initiated.
- Loss of GPS: The flight controller system uses a redundant GPS system which switches from a receiver with a lower number of satellite links to a receiver with a higher number of satellite links if the difference in the number of satellites is more than 2.

Risk Assessment and Management

Risk	Mitigation
Mid flight engine failure (Design 1)	Mid-flight electric starter mechanism is used to restart the engine
Low Fuel (Design 1)	If sufficient fuel is available, a return to launch location is activated or else flight termination is activated
Uneven surface at Remote Landing Site	High ground clearance prevents the fuselage from damage
Maintaining geofence	Using redundant GPS system along with a dedicated Geofence system
Rains during flight	Waterproof motors and sealed casings for electronics prevent them from damage due to moisture
AutoPilot Failure	The flight controller will be sending a "healthy state" signal to the master computer. Absence of flight controller signal for more than 10 seconds will initiate the flight termination sequence
GPS Failure	Redundant GPS on flight controller and Geofence system
Low Battery	An alert is sent to the Ground Control Station and a return to launch location is initiated. If the battery is not sufficient, flight termination is initiated
Software and Autopilot Bugs (During testing)	Software and Hardware in the loop testing to prevent crashes and loss of equipment
Parachute Failure and Entanglement	Special training will be provided to team members for folding and packaging of parachute to ensure proper activation
Autopilot Telemetry Failure	Built-in failsafe to return aircraft back to launch location if link is not established within 20 seconds
Mechanical and structural failure	High strength composite airframe along with rigorous preflight inspections
Failure of Flight Termination System	Throttle to all motors is cut and parachute will be deployed electronically
LiPo Battery Protection	LiPo batteries are kept in a carbon fibre case to isolate explosion of batteries in case of a crash