Multifunctional Uav to Assist Police

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***Abstract*—The main motive of this project is to assist Police personnel in the field of their missions by designing and fabricating a Multifunctional Unmanned Aerial Vehicle (MUAV). In order to reduce the efforts, workload and also to increase the security and intelligence of the Police personnel the MUAV should be capable of completing their required mission which is meant for a user friendly manner as an aerial policeman. The missions of Police department are such as Highway Patrolling, Crowd monitoring, Aerial Surveillance, Target Tracking, Accident Monitoring, Emergency Response and Disaster Response Operations. To accomplish this type of missions the aerial vehicle should require a High Definition (HD) video camera with One Way Real Time Video Communication, Two Way Audio Communication, Spot light, Stabilization System, Telemetry and Fail Safe Return to Home or Launch. To stare and scour particular area hover flight is required, for target tracking high speed conventional flight is required. By blending both, the principle of chopper and conventional flight we have designed and developed a tilt wing MUAV. This Tilt-Wing aerial vehicle features a wing in horizontal position for high speed conventional forward flight and tilts vertically for hovering and vertical takeoff and landing.**

Keywords—* *Drone, Multifunctional UAV, Police Drone, Police UAV, Tilt wing, UAV.

I. INTRODUCTION

A. About UAVs

An unmanned aerial vehicle (UAV), commonly known as a drone but also referred as a Remotely Piloted Vehicle (RPV) by the International Civil Aviation Organization (ICAO), is an aircraft without a human pilot onboard. Its flight is controlled either autonomously by onboard computers or by the remote control of a pilot on the ground or in another vehicle. The typical launch and recovery method of an unmanned aircraft is by the function of an automatic system or an external operator on the ground. Historically, UAVs were simple remotely piloted aircraft, but Now-a-days autonomous control is increasingly being employed. They are usually deployed for military operations. At present UAVs are also used in a small but growing number of civil applications, such as policing and firefighting, and nonmilitary security work, such as inspection of power or pipelines. UAVs are often preferred for missions that are too “dull, dirty or dangerous” operations instead of manned aircraft.

B. About police UAVs

Police UAVs are some of the special types of UAVs which are more protective and perfective for their missions. There are some of the UAVs are used now-a-days, which are narrowed to a specific mission. The UAVs are such as dij-naza, camcopter, Aeryon Scout.

II. CONSIDERATIONS

A. Missions

The following are some of the missions in which the Multifunctional Unmanned Aerial Vehicle (MUAV) should complete this missions.

1) Commercial Aerial Surveillance

Aerial surveillance of large areas is made possible with low cost UAV systems. Surveillance applications include wildfire mapping, pipeline security, home security and anti-piracy. The trend for the use of UAV technology in commercial aerial surveillance is expanding rapidly with increased development of automated object detection approaches. VIP Protection & Security is also comes under Surveillance mission.

2) Search and Rescue

UAVs likely play an increased role in search and rescue. Micro UAVs, such as the Aeryon Scout, have been used to perform Search and Rescue activities on a smaller scale, such as the search for missing persons and damage assessment at low altitude.

3) Highway Patrolling

Highway Patrol is overseeing and enforcing traffic safety compliance on roads and highways.

4) Accident monitoring

Gathering evidence to determine the cause of a roadway accident and to analyze the depth of accidents. As well as providing first aid to the injured.

5) Commercial vehicle enforcement

Enforcing highway laws related to commercial transport, including weight limits and hazardous materials rules.

6) Emergency response

Securing the scene of a traffic accident by transmitting the video to analyze the depth of damages or strength of crowd.

7) Traffic enforcement

Enforcing laws and regulations intended to improve traffic safety, such as speed limits. Assisting local police in urban and rural areas, and keeping an eye out for non-traffic violations.

8) Maintenance

Observing and reporting damage to the roadways, electric lines and conducting hasty surveys after disasters or the passage of inclement weather.

9) Target tracking

Following a vehicle [5] in highways and cities by means of aerial ways makes the job easy and there is no option to miss the target.

B. Conditions

MUAV mainly is to assist the police personnel. In order to achieve this, we have decided to use a tilt wing configuration. Because as far as they need to stare and scour some of the suspected areas. For this mission the UAV should be capable of hovering in a particular position for a long while. On the other hand the UAV should also about to capable of target tracking [5] in order to follow a vehicle in high speed. For this features we utilized the concept of a tilt wing. For hovering in a particular position quadrotor is most suitable but in the case of target tracking this fails. For target tracking a fixed wing aircraft is most suitable but this has not the capability of hovering. So what we trying to do is going to blend both, the design of the quadrotor [4] and the design of fixed wing. Finally we came up with an idea of tilt wing, which is about to have more capability of hovering and also have the capability of high speed cruising.

For achieving this the MUAV should capable of withstanding sudden gust, wind storm, cross wind, variation in temperature, pressure and long range operations.

C. Equipment's

In order to accomplish all types of missions the MUAV should have High Definition (HD) camera for capturing and recording as an aerial eye, one way real time video transmission for instant accessing the view at base, search or spot light for scouring in night, payload bay for first aid medical kit and optional thermal imaging devices, two way real time audio transmission for communicating with suspects.

III. PROBLEM STATEMENTS

Even though this model has more sustainability and capability there is some of the draw backs which states that intention should be solved keenly. The main and major problem is maneuvering during hovering and Transition period.

A. Maneuvering during hovering

In tilt wing, while hovering the wing tilts vertically and in this model we have designed in a manner to place the aileron behind the motor in order to achieve the same controls to be controlled for maneuvering during hovering.

On hovering by deflecting ailerons yawing is achieved. By varying the speed of the motor uniquely banking is done. And by controlling the rpm of the propeller collectively pitching is accomplished.

B. Transition period

During hovering the UAVs lift should be greater than its average weight. Transition period is that occurs due to changing the angle of incidence of the wing as in [2]. During transition period there is possibility of sudden loss of lift. To overcome the sudden loss of lift this planes tilting mechanism is designed in that manner that the wing can be tilted and positioned at any angle during transition. Mainly the forces during the transition period is as follows below as a picture in "Fig.1".

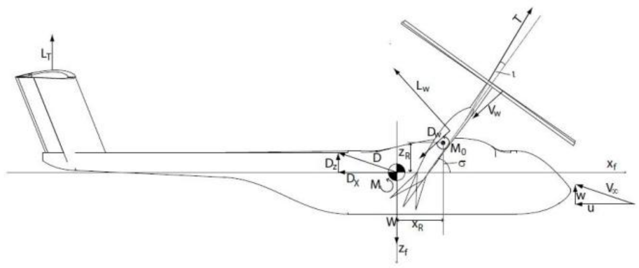

Figure 1. Forces acting during transition period. [1]

IV. DESIGN CALCULATIONS

A. Parameters

No. of wings = 1

Vertical location of wing = mid wing

Configuration of wing = straight wing

Wing span (b) = 0.8m

Wing chord (c) = 0.15m

Airfoil = NACA 2412

B. Average weight

$$W_{avg} = 0.5[W_i + W_f] = 2 \text{ kg} \quad (1)$$

Where,

Wi = initial weight

Wf = final weight

C. Surface area

$$S = b*c \quad (2)$$

$$S = 0.12 \text{ m}^2$$

Where,

b = span length of wing

c = chord length of wing

D. Aspect ratio

$$AR = b^2/S \tag{3}$$

$$AR = 5.33$$

Where,

b = span length of wing

S = surface area of wing

E. Wing loading

$$WL = W/S \tag{4}$$

$$WL = 16.667\ kg/m^2$$

Where,

W = weight of aircraft

S = surface area of wing

F. Lift coefficient

$$C_L = 2\ W_{avg} /(\rho v_c^2 S) \tag{5}$$

$$C_L = 0.1429$$

Where,

ρ = density of air

v_c = cruise velocity

G. Thrust to Weight ratio

$$(T/W) = (T/W*g) \tag{6}$$

$$(T/W) = 1.999 \approx 2$$

Where,

T= thrust

W = weight

H. Lift to Drag ratio

$$(L/D) = \eta p*T/v*W \tag{7}$$

$$(L/D) = 0.3$$

Where,

L = lift

D = drag

ηp = propeller efficiency

V. MODELING AND ANALYSIS

A. Modeling

We have modeled the components of UAV in CATIA V5R20. In CATIA one of the most used designing option is “Mechanical Design Suite” which provides products for intuitive specification driven modeling for Solid, Hybrid and Sheet metal Part design, Assembly design and integrated Drafting. After designing and modeling in the mechanical part design all individual part is imported to the “Assembly Section”. There each single part is assembled according to the specified dimension. In assembly section we can also able to plot the material with its properties. For different parts we can select different colours based on our choice. The parts were designed in part design and assembled in assembly design in CATIA V5. The designed models are as follows below with commands.

In CATIA V5R20 We have selected “Part→Mechanical Design→Sketcher” for each part.

1) Wing design

In that we have imported the desired points of airfoil coordinates of NACA 2412 by using the application “Aerospace Profile Modeler”. Then by using the “Pad” command we have extruded a projection for the required dimension.

Then by using the actual dimension we have sketched and extruded the motors and propellers for one side of the wing. For other side of the wing we have simply mirrored the required part at the respective axis as shown in “Fig.2”.

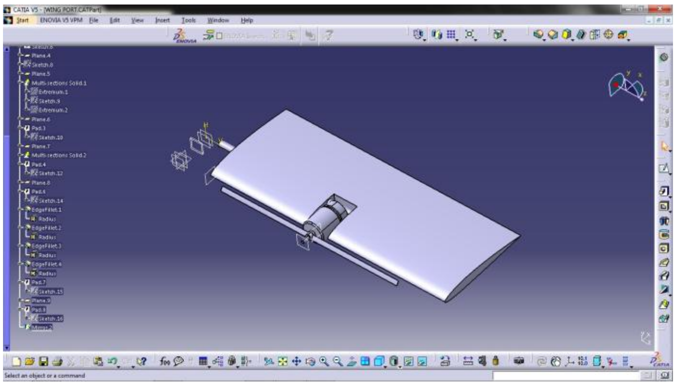

Figure 2. Wing design.

2) Fuselage design

By using the commands line, spline, trim we have designed a 2D model. Then by using pocket command we have made a cutout with the exact dimension as shown in “Fig.3”.

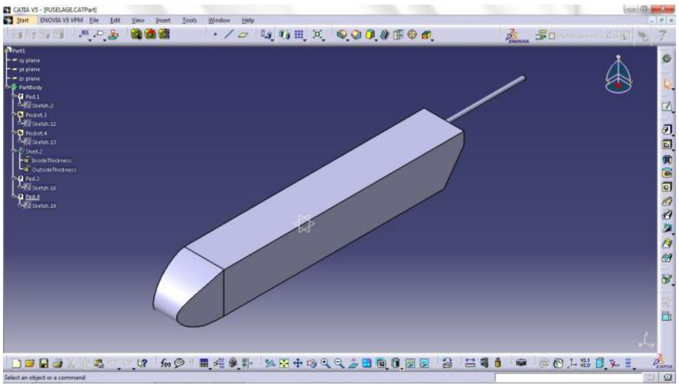

Figure 3. Fuselage design

3) Empennage

For horizontal tail we have imported the desired points of airfoil coordinates of NACA 2412 by using the application “Aerospace Profile Modeler”. Then by using the “Pad” command we have extruded a projection for the required dimension. For vertical tail we have imported the desired points of airfoil coordinates of FX 76 (symmetric airfoil) by using the application “Aerospace Profile Modeler”. Then by using the “Pad” command we have extruded a projection for the required dimension as shown in “Fig.4”.

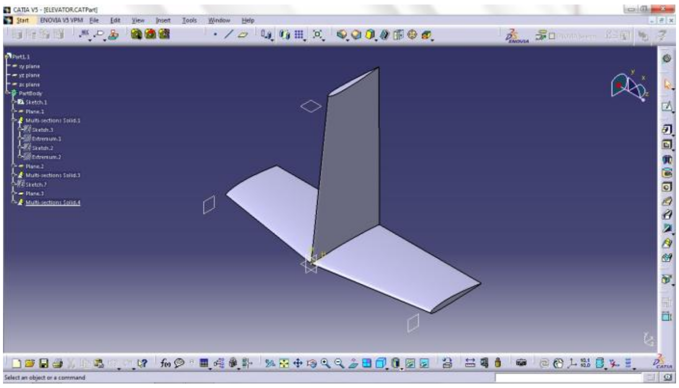

Figure 4. Empennage design

4) Landing gear

By using the commands line, spline, trim we have designed a 2D model. Then by using “Shaft” command we have revolved an extrusion to make a Landing Gear as shown in “Fig.5”.

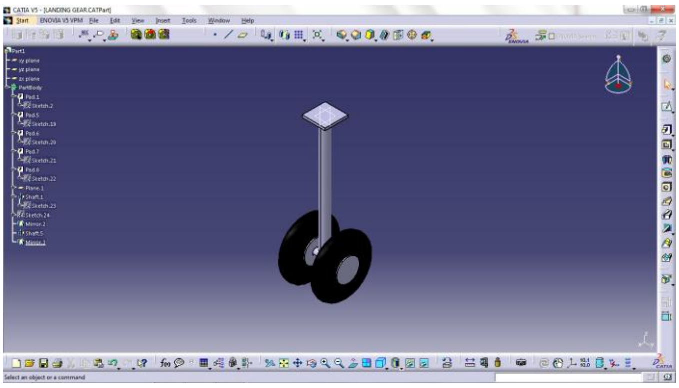

Figure 5. Landing gear

5) Full assembly

In CATIA V5R20 We have selected “Mechanical Design →Part →Assembly”. By importing all the required parts such as Wing, Landing Gear, Fuselage, Empennage to the Assembly we can able to complete this full-fledged model as shown in “Fig.6”.

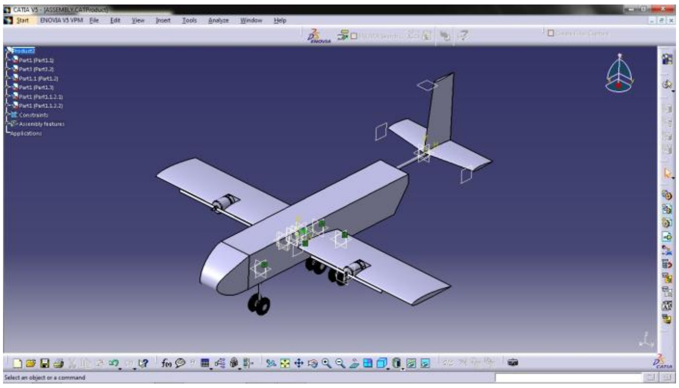

Figure 6. Full assembly

B. Flow analysis

This analysis is done in the Application “XFoil v6.10”. XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils. Given the coordinates specifying the shape of a 2D airfoil, Reynolds and Mach numbers, XFOIL can calculate the pressure distribution on the airfoil and hence lift and drag characteristics. The program also allows inverse design - it will vary an airfoil shape to achieve the desired parameters. A crude design module has been included in XFLR5, which allows the design of Foils either from B-Splines or from "Splined Points". The former gives smoother surfaces, the latter authorizes greater control over the geometry. In that Application XFoil, select “File→Direct Foil Design”. Now in that window select an airfoil. Then go to “File→xFoil Direct Analysis”, in that select “Analysis→Batch Analysis”, then run the Reynolds number analysis. Then goto “File→Wing & Plane Design”, in that select “Analysis→Define an Analysis”. Finally run the analysis according to the required parameters. The following figures “Fig.7,8,9,10”, are some of the flow analysis over the airfoil with constant velocity at different angle of attack in order to observe the behavior of the airfoil at different conditions and to check the values that is capable for this design to keep the plane in air.

1) NACA 2412 at angle of attack 0˚

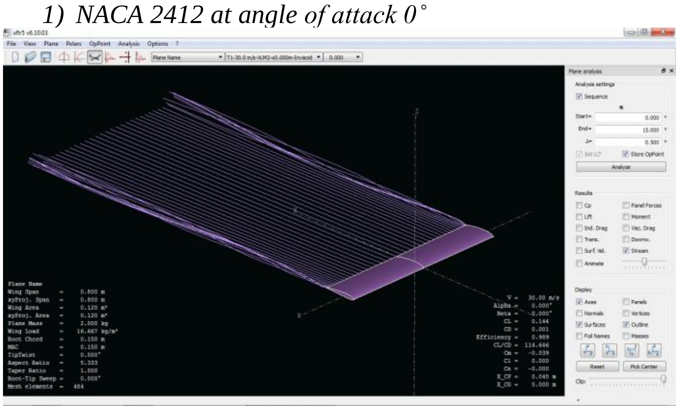

Figure 7. Airflow over the airfoil at v=30m/s, α=0˚.

2) NACA 2412 at angle of attack 5˚

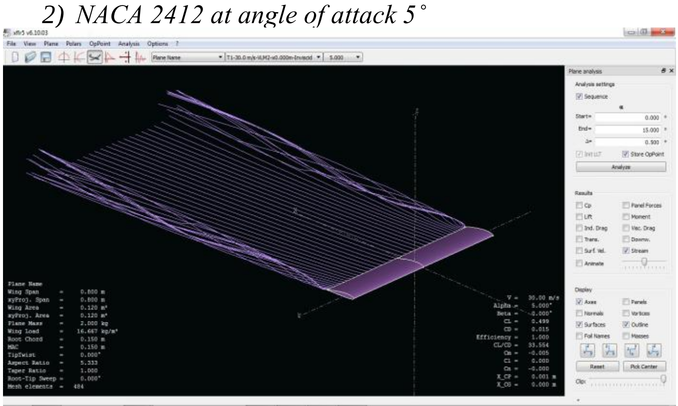

Figure 8. Airflow over the airfoil at v=30m/s, α=5˚.

3) NACA 2412 at angle of attack 10˚

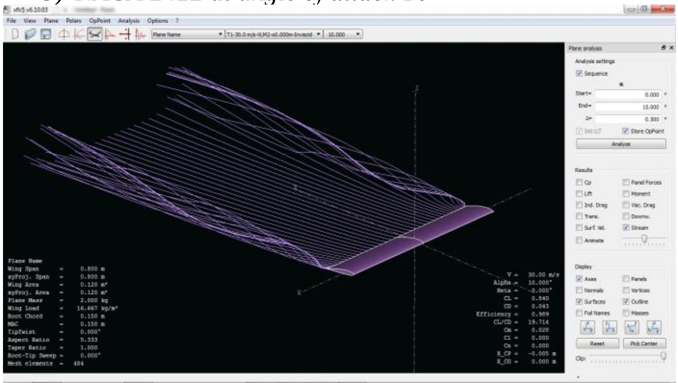

Figure 9. Airflow over the airfoil at v=30m/s, α=10˚.

4) NACA 2412 at angle of attack 15˚

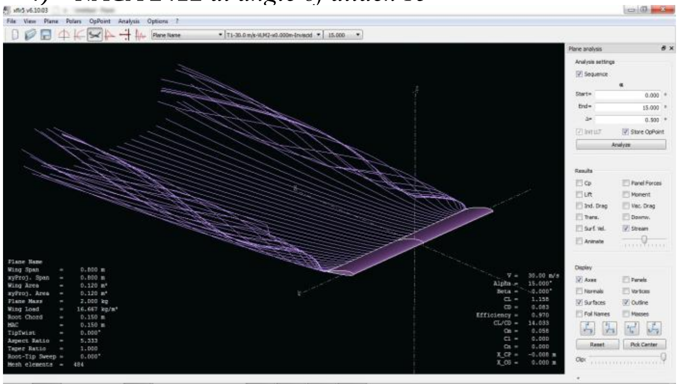

Figure 10. Airflow over the airfoil at v=30m/s, α=15˚.

By observing this analysis it shows that the wing is capable of producing necessary lift which is desired for this flight.

VI. MATERIALS AND EQUIPMENTS SELECTION

A. Avionic equipment selection

1) Necessary for airworthy

The following are some of the electronics which are very essential to keep the flight in air.

a) Propulsive system

In this model we use couple of 1100kv electric DC brushless motor as in "Fig.11", which has the capable of producing a maximum thrust of 2kg per motor. We use Turnigy aerodrive D3548/4 Model motor, the revolution of the motor is 1100 rpm/V. It also have high thrust to weight ratio.

b) Speed controller

It is a device which is used to control the speed of the motor by controlling the power to the motor. In this we use 70 amps Hobbyking blue series programmable Electronic Speed Controller (ESC) which perfectly suits this motor "Fig.12". This device also have the battery elimination current with regulated voltage supply, which is used to operate for other devices like servos.

Figure 11

Figure 12

c) Stability controller

Stability controller is a type of auto pilot with Inertial Monitoring Unit (IMU). In this case we use Ardu Pilot Mega 2.6 (APM), which includes the accessories such as Global Positioning System (GPS), telemetry, power module, On Screen Display (OSD).

d) Battery

For this mission we preferred High discharge battery, which have the discharge rate of 20C. This battery is made up of Lithium Polymer (Lipo) and also have the capacity of 4 amps. This battery consist of 3S Cell, which delivers the voltage of about 11.1V i.e. 3.7V/S. By using this battery the plane may have the endurance of about 40-50 min.

e) Servo

In this we used two types of servos. One is 9g servos for controlling the control surfaces, which can produce the torque of about 1.6 kg. The other one is 25g servos for tilting wings, which have the capacity of producing torque about 6 kg.

f) Radio control

The model of the transmitter is Hitech optic 5. This model have the range for transmission is about 1.5 km. This radio operates in the frequency of 2.4 GHz. This radio acts as a five channel transmitter. The model of the receiver is minima 6, which have the reception range of about 0.5 km. This also operates in the frequency of 2.4GHz.

2) Necessary for mission

a) Camera

For this mission High Definition (HD) video camera with the capability of real time video out function is very necessary. This camera acts as an aerial eye for the police personnel. We used a high zoom high definition camera model for this purpose, which have the capability of live video out function with onboard recording.

b) Video transceiver

The minimum requirement of video transceiver is that it should have the capability of transmitting for long range without any interference. In order to attain long range we have utilized 5db dipole antenna for transmission. For neglecting the interference the transmitter and receiver part should be placed on opposite sides of each other. For this we used Boscam TS832 and RS832 transmitter and receiver respectively.

c) Gimbal

In order to avoid flutter, video shaking, blurring and to attain video stabilization the gimbal with gimbal controller is used. For this we used 2-D gimbal with controller for pitching and tilting. For controlling the pan, tilt motion of the gimbal a secondary transmitter or gimbal controller is very much necessary.

d) Spot light

For searching and tracking in night and dim lights spot light will be more helpful being focusing the high intensity light on the target. For this we took CREE 1800 lux single Light Emitting Diode (LED) light, which have high sustainability and though it is a LED it consumes very low power.

e) Walkie talkie

This walkie talkie enables the conversation between the suspect and any third person with the police personnel's. For this we decided to dedicate a two way radios sport watch mini walkie talkie which covers long range for conversation.

B. Structural frame selection

1) Depron

Depron is a millimeter thin insulation sheet manufactured of fully recycled material, free from Freon and Halogen. Depron is a closed-cell foam which is stronger and denser. In addition to that both sides of the foam is laminated to make it even stronger. The superior closed cell foam takes much less glue and is easier to be waterproof. Its sealed surface adds considerable strength as well as making it very easy to apply non-solvent depron friendly paint or ink finishes.

2) Landing gear

This landing gear should capable of withstanding a maximum weight of 4 kg with spring suspension as shock absorber. So, we used Hobbyking landing gear which also have the capable of nose wheel steering mechanism with spring suspension.

3) Propeller

12*4.5 is the most suitable propeller for this brushless motor. Whereas here 12 denotes the length of the propeller in inch, 4.5 denotes the pitch of the propeller.

4) Accessories

Pushrods, clevis, horns, hinges, these type accessories helps us and most useful as building equipment's.

C. Tools used

Hot wire foam cutter for shaping foam, Hot glue gun for adhesive, Solders, Drillers, Multiple screw drivers, cutters, Pliers…

VII. FABRICATION

A. Wings

Initially as a first step we have made a pattern of airfoil in a cardboard. Then we fixed and glued on both sides of the foam. After that we made a groove of the desired diameter in order to place the shaft for tilting the wing by using hot wire foam cutter. The groove for the shaft is to be made at one third of the wing from the leading edge of the wing where the center of gravity (CoG or CG) is maintained. Then the electric DC brushless motor which gives primary power of thrust for propulsion is also to be mounted in the shaft and servo for aileron is also placed. Then finally by using hot wire foam cutter the foam is shaped along the surface of the airfoil pattern in order to shape the wing. Now the desired wing is ready to make control surfaces.

B. Fuselage

Fuselage is made up of laminated foam sheet, which is also known as depron. It gives a rigid form of structure. Fuselage is box type structure, which is easy to fabricate. Landing gear and gimbal is also to be placed in the fuselage.

C. Empennage

Initially as a first step we have made a pattern of airfoil in a cardboard separately for horizontal stabilizer and for vertical fin. Then we fixed and glued on both sides of the foam. Then finally by using hot wire foam cutter the foam is shaped along the surface of the airfoil pattern in order to shape the stabilizers.

D. Placing avionics

In order to avoid interference between transmission and reception signals both should be placed in the opposite end of the fuselage. So the position of placing avionics also plays a vital role. The electrical signals should not get interrupted with the battery power. Position the avionics item as shown in the "Fig.13".

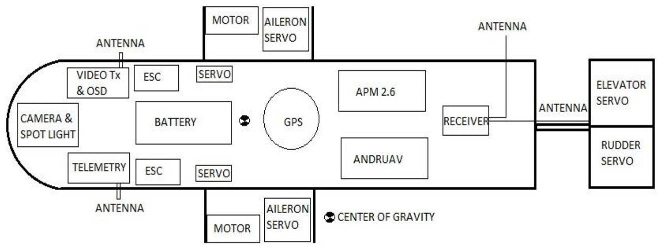

Figure 13. Placing avionics

E. Wiring and connection

Initially before powering the APM check for JP1 jumper is removed. If the board is connected with Battery Elimination Current (BEC) it may lead to fire the board. Before starting the connection make sure that you have calibrated the necessary calibrations. Then connect the receiver to the input of the APM through jumpers. Then connect the servos and motors to the output of the APM appropriately.

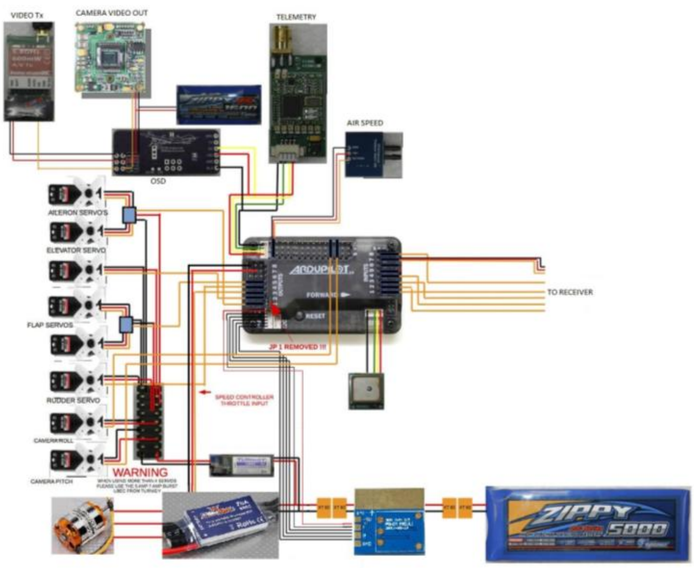

Figure 14. Wiring and connection for APM 2.6

Now connect the GPS and magnetometer to GPS port and 12C port respectively. Now connect the telemetry to OSD and slave radio or Bluetooth module. Make sure that you have connected the video out cable through the OSD to the video receiver. Connect the power module to the respective port. Now before connecting the power make sure that your connections are correct "Fig.14". Finally plug in the battery to the power module and the other end of the power module is connected to the motor through ESC.

F. Ground control station

1) Andruav

Andruav can be implemented in many configurations, it can be mounted on a simple foam plane, and create KML file with its path in off-line mode. The next step is to use it online with an Andruav GCS where you can track your vehicle –or multiple vehicles- online using data connection which give you unlimited range. You can take images by controlling camera from GCS a thumbnail of captured image is sent to GCS online while a high resolution one is saved on vehicle storage and attached to KML file. A more complex implementation is the big-brother configuration. In this configuration you fly your plane using Ardu pilot mega or Multiwii flight controller and use Andruav on board. Andruav will connect to these boards via Bluetooth or USB and make two roles.

The first role is to act as HUB or very long range telemetry and sends data to ground station. The second role is to act as the plane brain, where it can define waypoints based on complex criteria or following other vehicles regardless of the actual flight control boards. i.e. an Ardu can follow a Multiwii and communicate with each other. This Andruav can be connected with both android ground control station as well as with android ground control station. But this needs that the Andruav and GCS should be interconnected with Wi-Fi or Bluetooth. This figure "Fig 15" shows the working and connections for Andruav.

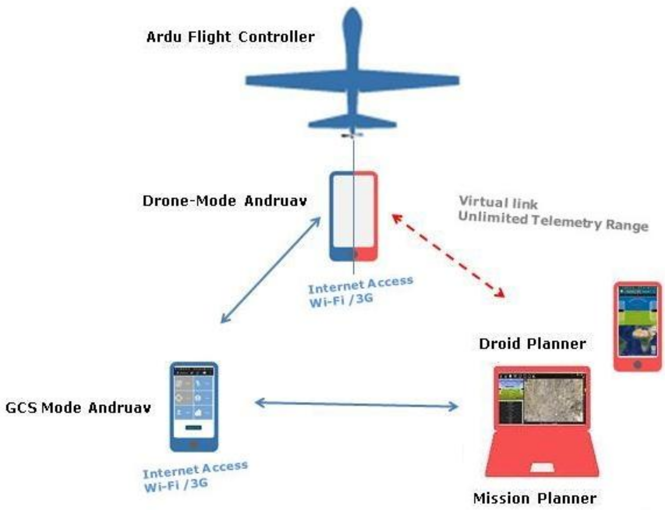

Figure 15. Working and Connection of Andruav

2) Android GCS

Figure 16. Android GCS with telemetry

For android Ground Control Station (GCS) the android device should capable of accessing On the Go (OTG) function. And also the device should be able to connect with Wi-Fi for connection with Andruav. Then just plug the telemetry ground radio to the android device and just connect it with the droid planner "Fig.16" or instead of using telemetry radio use onboard Bluetooth dongle for connecting APM with the droid planner. But in case if you are using beyond the visibility range we would prefer telemetry radio for better signal. For using Andruav the device should have at least 3G data connection to access Andruav server. This Andruav gives unlimited range of telemetry through data connection.

3) Computer or Laptop GCS

For computer GCS just install the mission planner or APM planner "Fig.17" for accessing the real time telemetry. Now connect the telemetry master radio via the specific COM port. And also connect the Audio Video (AV) receiver to the computer through the AV to USB converter. Then check for Andruav connections, that the computer is connected with GCS Andruav by the medium Wi-Fi. By this we can get the unlimited range of telemetry. Finally check all the systems connected and working properly.

Figure 17. Computer as a ground control station.

VIII. CONCLUSION

In this paper We have explained about UAV's, police missions, problems in design, modeling and analysis, materials and equipment's selected, tools required in detail. By this we conclude that this Multifunctional UAV will make the police personnel a strain less job. It will surely help them to analyze the dangerous situation without any interruption.

IX. FUTURE ENHANCEMENT

As a future work for this MUAV we hope to upgrade this MUAV as a solar powered self-rechargeable system for a long range flight and also we hope to install a cargo hook for payload such as medical kits which can be dropped off.

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I'm Gokulakrishnan G, pursuing M.Tech - in Hindustan University with the specialization of Avionics Engineering. This paper shows that how much I'm crazy about drones. Also I have designed and fabricated many of fixed wing aircrafts as a hobbyist.

NAGENDRA PRASAD R

I' m Nagendra Prasad R, pursuing M.Tech - Avionics Engineering in Hindustan University. I know that in future UAVs are one of those who will rule the world. So, I decided to work in to this.

NIJANDAN S

I'm Nijandan S, studying Master Degree in Avionics engineering from Hindustan University. I did my Under Graduate in Electrical so I have special interest in dealing with avionic system of drones.