1. SOFTWARE REQUIREMENTS SPECIFICATION

- Image Processing And Flight Control Software

  A single-board computer with a minimum of 2 GHz or faster processor speed and a minimum of 4 Gb of ram is needed for the necessary transaction speed so that drone can decide and process the data at the same time.
  A flight control card will be used for all the information gathering needed for the main program to decide what is the next move that drones do and do not. So flight control card has to have the necessary sensors. Lastly a camera is needed for video input and one other camera is needed for visual presentation of flight.

- Operating Systems

  In raspberry pie, we will use Linux based operating system. And for autopilot software, we will use ArduPilot or ROS(Robot Operating System) these are works best with raspberry-pie and Emlid-Navio flight card.

- Realtime Telemetry Flight Parameters

  We will need real-time information software on our computers or smartphones so that we will keep track of our drone's real-time information like UAV range, height, speed, GNSS strength, remaining battery power, and warnings.
  We will use Ardu-Pilot for that.

- Mission Planner (Ardu-pilot)
  This software requires windows 10 or newer versions. Integrated mouse , keyboard and at least 2 Gb of ram for minimal usage.

2 . ELECTRICAL & ELECTRONIC REQUIREMENTS SPECIFICATION

1. Thrust System Requirements
   a. **Motor**
      Brushless DC motor selection will be adjusted by considering the weight of the total body and other equipment and the amount of total energy storage. The so-called KV rating of the motor is representing the ratio of the motor's unloaded rpm to the peak voltage. KV will be chosen by the drone's weight.

980KV motor will turn around 10,000 rpm so that four of them will be carrying the drone.

b. **Speed Controller**

To regulate the amount of current which the motor is consumed, an **electronic speed controller (ESC)** is used. ESC provides a motor to control correctly its speed and spin direction.
The normal current provided by the ESC will be 40A.

c. **Power Distribution Board**

Since Quadcopter has 4 motors and 4 ESCs attached to them, a power distribution process is needed. ESC is run by a single battery pack and a single battery pack has only one DC output, i.e. one positive wire and one negative wire. Thus, it needs to be extended into 4 connection wires in order to distribute all the needed energy to the ESCs and then motors.

2. Energy Storage Requirements

a. **Battery**

The main energy source of a UAV is a **LiPo** battery. In almost every aerial application, LiPo batteries are used instead of other lithium variations. LiPo batteries have lesser weight and a high discharge ratio which gives the vehicle a higher capacity for energy usage.

b. **Voltage of Batteries**

Almost every industrial LiPo battery has a standard voltage value which is 3.7 V. They are generally represented by *S.*
3.7 V is represented by 1S.
Therefore, $2 \times (3.7V) = 7.4V = 2S$ and so on.
Batteries, also have *'mAh'* value means *'milliAmp hour'*. This value is used to measure the energy capacity of a battery.
Energy drawn by the motors will decide the amount of S.
A 3S battery will be enough to provide energy for all the drone parts.

c. Flight Controller

The brain of the drone will be chosen by some criteria which are incoming parameters from sensors, handling voltage, telecommunication parts, and other drone equipment.
In addition, control system parameters will be designed on the basis of the automated drive.
The software will be loaded into a flight control card.

d. Telecommunication

Telecommunication requirements will be chosen considering the range between receiver and transmitter. Although there is no need to interrupt the drone with a remote controller due to autopilot, still there will be a GPS antenna, receiver, and telemetry.

3. Environmental Hardware

i. **Connectors**
   Most of the electrical parts of a UAV are several parts that need to be connected to the proper location. ESC, Power Distribution Board, etc. all need to be connected via a connector.
ii. **Battery Charger**
iii. **Multimeter**

3. MECHANICAL REQUIREMENTS SPECIFICATION

3.1 3D Model Requirements

3.1.1 CAD Usage

All components of the quadcopter will be modeled in the CAD program. Autodesk Fusion 360 will be mainly used program, but other programs also can be used. Components will be assemble together included electronic parts. Their fastening method will be properly designed.

3.1.2 Dimensions and Tolerances

The modeled parts need proper dimensions and tolerances in mechanical matter. There is no way to have exact dimension in reality. So, it should be considered that after manufacturing, do the parts fit each other or not. In 3D model session this situation should be mind and proper design should be created.

3.2 Frame Strength Requirements

3.2.1 FEA Usage

Finite Element Analysis will be used to calculate stress and strain levels on the designed parts. Since this method is a numeric and iterative solution method, mesh sensitivity analysis should be done to make sure that the data from FEA is accurate enough. Boundary conditions, mesh type and size should be selected properly, and simulation should be made in a reasonable way. FEA will be done on ANSYS.

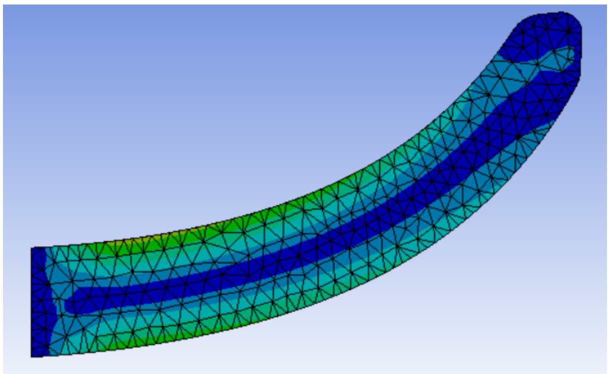

Figure 1) Stress Distribution Example

3.2.2 Material Selection Strength Basis

All the components have different purposes in the design so their material should be selected according to these purposes. The main parameters when selecting material are strength, mass, stiffness, vibration absorption capacity, RC wave permeability.

3.3 Mass Budget Requirements

3.3.1 Total Mass Calculation

After selecting materials of the parts, their density should be multiplied by their volumes so we can list their masses. Mechanical parts' masses will be calculated in the design session and electronic parts masses will be taken from the catalogue data. By this way, total mass will be calculated with a reasonable margin. Maximum mass according to competition is 4kg but also the drone should be light as possible to decrease the cost of the thrust system. Also, the competition's score sheet considers mass as a parameter that lighter drones can get higher scores.

3.3.2 Topology Optimization

Since this project is an aerial vehicle, mass should be considered properly. In a mechanical manner, generally, more mass means more strength. However, with a careful calculation, we can design a lighter but equally tough drone. By doing topology optimization, a wiser geometrical shape which distributes stress more equally can be developed. To accomplish that ANSYS will be used.

Figure 2) After Topology Optimization Example

3.4 Thrust System Requirements

3.4.1 Motor and Propeller Selection

Motor and propeller selection should be done according to mass of the total system. Motor’s thrust weight ratio should be between 2 and 3 so the drone can fly properly. Motors should be attached to a convenient propeller. Greater propeller usually means greater thrust, but the efficiency of the motor can decrease after a point of this size increase.

3.4.2 Vibration Elimination

Cyclic motion of motors creates vibration. This vibration should be decreased to a certain level. So, the electronics, especially sensors, can work properly. Also, vibration have fatigue effect in mechanical manner. This fatigue can cause unexpected fracture. To eliminate vibration necessary damper elements will be used in critical points and propeller balancing operation will be done. To balance propellers, a necessary mechanism will be manufactured by using 3D printer.

Figure 3) Propeller Balancer

3.5 Manufacturing Requirements

3.5.1 Manufacturable Design

There are some designs which are impossible to manufacture. There is no logic on designing a part which can not be manufactured. So, manufacturability should be considered at the beginning. Also, some designs cost so much while manufacturing although there can be a way that the design is simpler but can meet the needs and it can be manufactured cheaper.

3.5.2 Additive Manufacturing

Most of the mechanical parts will be manufactured in 3D printer with proper filament. Creality Ender 3 V2 is used as printer and Cura as software. Designs should be transformed to g code to be used in 3D printer. Process parameters should be selected properly while 3D printing. This is an experimental and iterative procedure. That means many prototype parts should be printed until finding proper parameters.

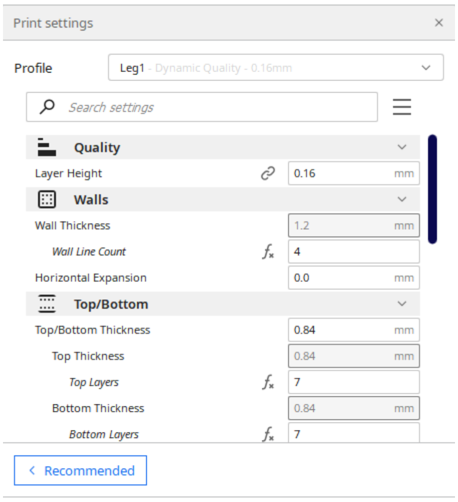

Figure 4) 3D Printing Parameters Example

3.6 P.I.D. Control Requirements

3.6.1 Selection of Parameters

P.I.D. Control Algorithm has three fundamental parameters which are Kp, Ki and Kd. These parameters have different effects on control of the drone. They should be iteratively changed and checked if the system works properly or not.

3.6.2 Manufacturing Test Setup

Parameters will be checked in mechanical test setups. It is not wise to create a complete drone and test it while it is flying. So, some experimental setups which simulate the drone’s flight will be manufactured.

3.7 Test and Verification Requirements

3.7.1 Measurements and Fit Check

After manufacturing 3D models, it should be tested that if the parts are in desired dimensions or not. Parts’ connections will be tested if they fit each other or not.

3.7.2 Strength Test

FEA or hand calculations are just foresight in stress, strain, and safety factor specification. So, experimental results are badly needed. Experimental setups should be created to simulate the real operating process and parts should be tested if they fracture under proper conditions or not.

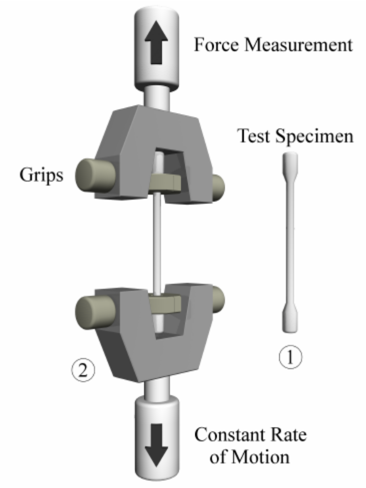

Figure 5) Strength Test (Tensile) Example

3.7.3 Inspection

After manufacturing, there can be some defects on the parts. These defects can degrade surface quality, strength, or they can cause crack propagation. By inspection, it will be tried to see if there are any defects or not.

4. REFERENCES

[1] Santos, Igor & Nieves, Javier & Bringas, Pablo & Penya, Yoseba. (2010). Machine-Learning-Based Defect Prediction in High-Precision Foundry Production.

[2] Moaveni, S., "Finite Element Analysis, Theory and Application with ANSYS", Prentice-Hall, 1999.

[3] Kalpakjian, S., & Schmid, S. R. (2006). Manufacturing Engineering and Technology. Pearson Education.