DESIGN AND FABRICATION OF AUTOMATIC FUEL TRANSFER SYSTEM OF AN AIRCRAFT

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B.Sc. ENGINEERING THESIS

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DHAKA, BANGLADESH

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DESIGN AND FABRICATION OF AUTOMATIC FUEL TRANSFER SYSTEM OF AN AIRCRAFT

DECLARATION

It is hereby declared that the study reported in this thesis entitles "Design and Fabrication of Automatic Fuel Transfer of an Aircraft" is outcome of the investigation carried out by the authors under the active supervision of Air Cdre Md Aminul Haque, Department of Aeronautical Engineering, MIST and Gp Capt Sidhart Sankar Patnaik, Department of Aeronautical Engineering, MIST. This thesis has not been submitted anywhere for any degree or other purpose. Further, we certify that the intellectual content of this thesis is the product of our work and that all the assistance received in preparing this thesis and sources have been acknowledged and cited in the reference section.

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ABSTRACT

DESIGN AND FABRICATION OF AUTOMATIC FUEL TRANSFER SYSTEM OF AN AIRCRAFT

In aviation efficient fuel management is very crucial because it influences stability, performance and control. Manual system will fulfill the needs but for optimal functionality and precision automatic fuel transfer system is required. Otherwise up in the sky managing fuel system is very challenging for the pilot. This thesis introduces the creation of an automatic fuel transfer system for aircraft.

Necessary research is done on existing fuel transfer system and found areas to improve. Drawing from this analysis, the design process integrates sensors to enable precise control and real-time monitoring of fuel transfer operations.

During fabrication stage while integrating these components into the aircraft's fuel system structure compatibility is ensured. To ensure validity of the system thorough testing is conducted to assess performance. Different condition and parameters were given as input for experimental purpose.

Flight safety is very essential issue in aviation sector. Less human intervention is required for safety and reliability. Proposed automatic fuel transfer system represents precise control and enhanced safety.

In summary, this thesis presents an approach towards automating fuel transfer systems in aircraft with emergency and indication system. Future research endeavors may explore for various aircraft models by using this project practically.

সারসংক্ষেপ

DESIGN AND FABRICATION OF AUTOMATIC FUEL TRANSFER SYSTEM OF AN AIRCRAFT

বিমান চালনায় দক্ষ জ্বালানী ব্যবস্থাপনা খুবই গুরুত্বপূর্ণ কারণ এটি স্থিতিশীলতা, কর্মক্ষমতা এবং নিয়ন্ত্রণকে প্রভাবিত করে। ম্যানুয়াল ব্যবস্থা চাহিদা পূরণ করবে তবে সর্বোত্তম কার্যকারিতা এবং নির্ভুলতার জন্য স্বয়ংক্রিয় জ্বালানী স্থানান্তর ব্যবস্থা প্রয়োজন। অন্যথায় আকাশে জ্বালানী ব্যবস্থা পরিচালনা করা পাইলটের জন্য খুবই চ্যালেঞ্জিং। এই থিসিসটি বিমানের জন্য একটি স্বয়ংক্রিয় জ্বালানী স্থানান্তর ব্যবস্থা উপস্থাপন করে।

বিদ্যমান জ্বালানি স্থানান্তর ব্যবস্থার উপর প্রয়োজনীয় গবেষণা করা হয়েছে এবং উন্নত করার অবকাশ রয়েছে। এই বিশ্লেষণ থেকে, প্রক্রিয়াটি জ্বালানী স্থানান্তর ক্রিয়াকলাপের সুনির্দিষ্ট নিয়ন্ত্রণ এবং রিয়েল-টাইম নিরীক্ষণ করতে সেন্সরগুলিকে সংহত করে।

সংযুক্তকরণ পর্যায়ে এই উপাদানগুলিকে একীভূত করার সময় বিমানের জ্বালানী সিস্টেমের কাঠামোর সামঞ্জস্যতা নিশ্চিত করা হয়েছে । সিস্টেমের বৈধতা নিশ্চিত করতে কর্মক্ষমতা মূল্যায়ন করার জন্য পুঙ্খানুপুঙ্খ পরীক্ষা করা হয়। বিভিন্ন পরিস্থিতিতে পরীক্ষামূলক উদ্দেশ্যে ইনপুট হিসাবে বিভিন্ন শর্ত দেওয়া হয়েছিল।

ফ্লাইট নিরাপত্তা এভিয়েশন সেক্টরে খুবই প্রয়োজনীয় বিষয়। নিরাপত্তা এবং নির্ভরযোগ্যতার জন্য মানুষের হস্তক্ষেপ কমানো প্রয়োজন। প্রস্তাবিত স্বয়ংক্রিয় জ্বালানী স্থানান্তর ব্যবস্থা বাড়তি নিয়ন্ত্রণ এবং নিরাপত্তা নিশ্চিত করে।

সংক্ষেপে, এই থিসিসটি জরুরি অবস্থায় করণীয় এবং ককপিটে ইঙ্গিত ব্যবস্থা সহ বিমানে জ্বালানী স্থানান্তর ব্যবস্থা স্বয়ংক্রিয় করার একটি পদ্ধতি উপস্থাপন করে। ভবিষ্যত গবেষণায় এই প্রকল্পটি বিভিন্ন বিমানের মডেলের জন্য ব্যবহার করা যেতে পারে

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

CHAPTER 1

INTRODUCTION

1.1 Background

The operation of aircraft highly relies on efficient and continuous transfer of fuel. Advancement of technology has brought light for automatic fuel transfer system. Now crew members do not have to take pain to control the system manually. Fuel distribution, control and management can easily be done by generating code. It has given opportunity for further efficiency, flexibility, ease, enhanced safety, and sustainability directly influencing flight performance, range, and operational expenses. Fuel sequencing is more important for fighter aircrafts where pilots have to take decision competing with the speed of sound. Where few drops of fuel will change the calculations. That being the case, analysis of fuel sequencing has become a major issue. By designing a universal prototype all challenges can be examined correctly. By this single fabrication we can simulate any kind of sequencing by changing the user data.

1.2 Objectives

The objective of the project is to:

- Design and live simulation of fuel transfer system in an aircraft to understand various stages of automatic fuel transfer.
- Fabricate a working model of the automatic fuel transfer sequence for better appreciation and understanding about the system in an aircraft.

1.3 Scope and Significance

The expected outcome and their significance are described as follows:

- On ground/Inflight refueling of the tanks after automatic fuel transfer.
- Manual override operation in case of failure of automatic sequence.
- Simulation of unserviceability for snag rectification.
- Simulation of emergency situations and associating it with necessary warning system.

1.4 Structure of the Thesis

The Upcoming chapters will delineate and investigate each aspect of the research project in a systematic manner. Chapter 2 will give a guideline of overall project. Chapter 3 will talk about literature review. Chapter 4 is about the method we have followed. Chapter 5 is validating the data. Chapter 6 will illustrate simulation. Chapter 7 will talk about problems and its solution. Chapter 8 will discuss about the results. Chapter 9 will talk about Future scope. Last chapter will conclude the thesis.

1.5 Gantt Chart

Ghantt chart is an essential tool for displaying events or activities against project schedule. It was designed by henry Gantt. A Gantt chart is given below for better understanding. It showcases how the project gradually formed its shape.

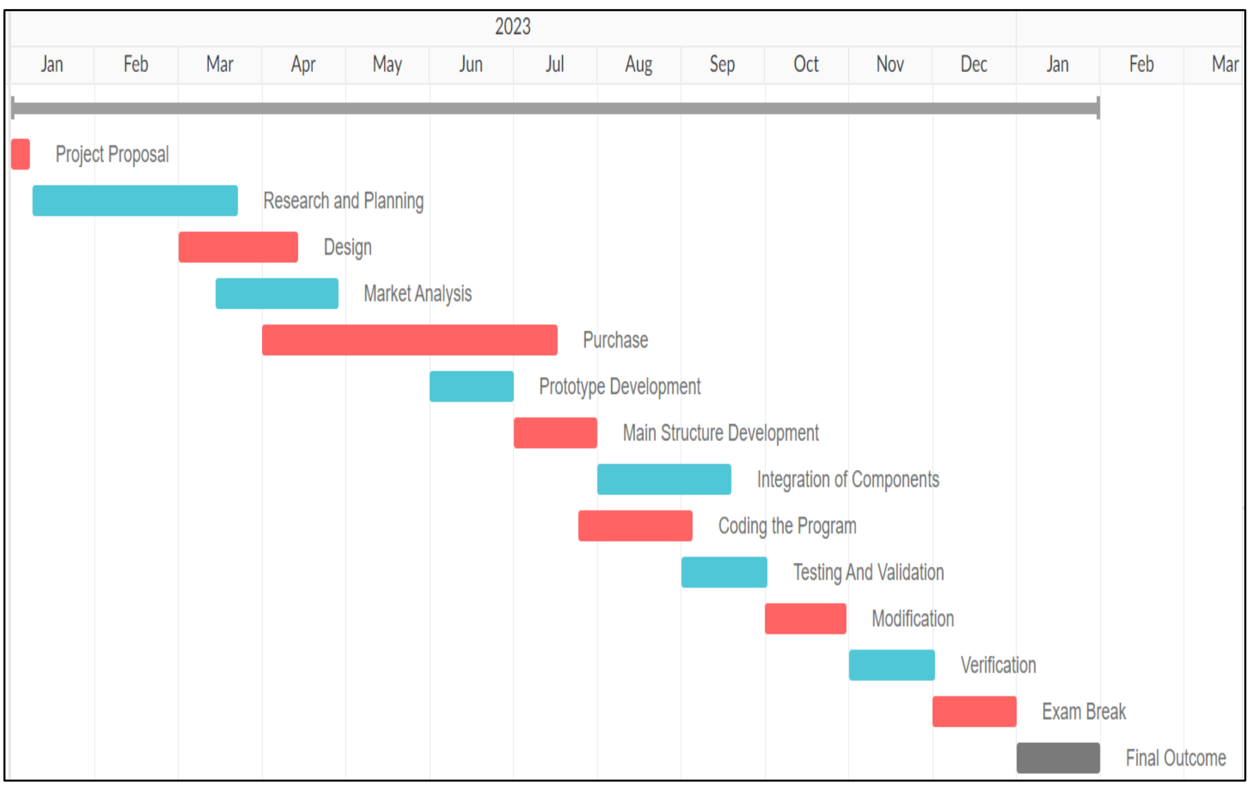


Figure 1.1: Gantt Chart

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Aircraft fuel management system consists of several components and subsystem to ensure healthy fuel supply to the engine. Improved fuel management system is now evolving day by day and it has improved a lot. A general aircraft fuel system has Just fuel tanks, fuel lines, fuel pumps, fuel filters, fuel vanes, fuel quantity gauge, fuel management system, fuel ventilation system, fuel heating system, fuel dump system, emergency system etc. It can be either gravity feed fuel system or pressure feed fuel system. A generic fuel system is shown below

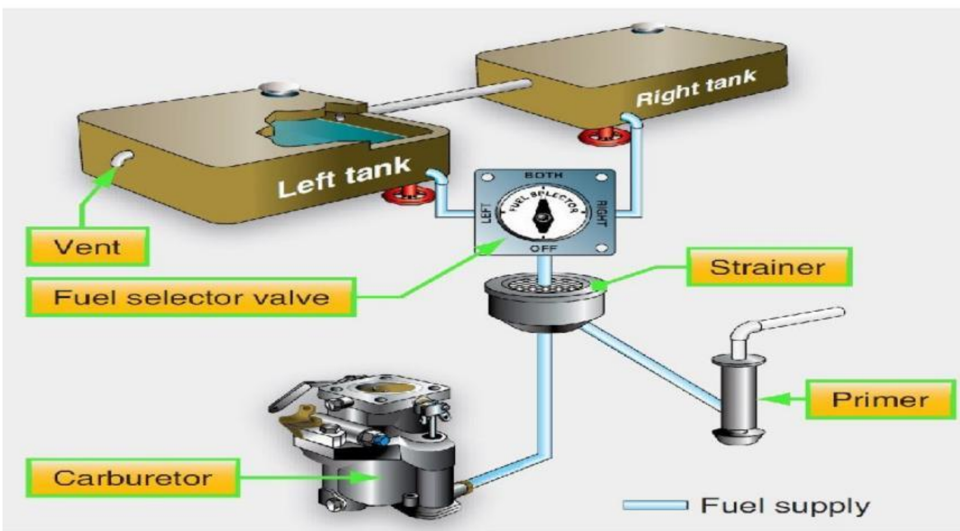


Figure 2.1: Generic Fuel System

Aircraft fuel sequencing is done within Fuel management system for better optimization , weather conditions , aircraft performance, cost efficiency for sustainable aviation initiatives. Fuel sequencing may differ from aircraft to aircraft according to flight needs though the ultimate goal is same for all designs. As technology advanced, semi-automatic fuel transfer systems arose as a compromise between manual and completely automated alternatives. This subsection addresses the improvements in semi-automatic systems and how they affect fuel management efficiency.

2.2 Analytical Studies

Fuel consumption analysis, optimization models and algorithms, sensitivity analysis, cost benefit studies etc are performed to build a complete aircraft fuel management system. Later on, it is synthesis and integrated on aircraft.

(Ting SHEN, Fangyi WAN, Weimin CUI, Bifeng SONG ,2010) Here the application of Prognostics and Health management (PHM) technology in Aircraft Fuel System is analyzed. As aircraft is a complex system so combination virtual instrumentation and computer-based simulation can be used to make fuel system more efficiently. Such as Failure analysis, Identification of failure modes for example looseness, pipe line breaks, Fuel tank leaks can be detected. Thus increases the reliability, accuracy, tolerance.

(Yue Zhang, Guiping Lin, Yi Tu, and Xiaodong Mao,2012) The aircraft fuel system was conceptually developed for sophisticated fighter aircraft. The fuel management sequence avoids an offset of the center of gravity. Numerical simulations were performed to determine system component structure, dynamic flow rate, pressure, as well as to calculate fuel cooling capacity and recirculation under various fuel consumption scenarios. Thus, it assists designers in understanding the different types of components and how the fuel system works overall.

(Nathan Raphael do Nascimento Pinheiro, and Luiz Carlos Sandoval Góes, 2017) Two operations were simulated: refueling and engine feed line pressurization The fuel pump pressurizes the engine feed line at a specific pressure, delivering fuel from the collection tank to the main tank. The fuel level in the wing tanks is unaffected by engine feed line pressurization.

(Irina-Carmen ANDREI, Gabriela STROE, Sorin BERBENTE, 2019) It is A study on fuel management in low bypass turbofan engines focused on numerical simulations. This study highlights improved features such as reduced fuel consumption, adaptability to all operating regimes and flight conditions, and safer engine operation through continuous monitoring and control. At least one health engine monitoring and control system can help to keep the turbofans' dynamic behavior stable.

(Juan F. Jimenez, Jose M. Giron-Sierra, C. Insaurralde, M. Seminario, 2006) Simulation of the Aircraft Fuel Management System Emphasizes the requirement for an aircraft-on-board programmed for fuel system management and reconfiguration that is adaptable in different aircraft and fuel system. Simulates over 80 different flying instances, including regular and malfunctioning operations.

2.3 Computational studies

Computational studies have combined simulation models, optimization algorithms, and real-time data inputs to develop data-driven decision support systems for fuel sequence optimization in an aircraft. These technologies give pilots or mission planners useful data and recommendations for modifying fuel sequencing in response to changing flying conditions or mission needs.

2.4 Experimental studies

Different types of fighter jet aircraft such as Mig-29, F/A-18C, Mig-21, F-15 are observed. Among this four-fuel system fuel tank arrangement are different. Rest all components are similar.

2.4.1 Mig-29 Tank Capacity

Mig-29 aircraft carries total 8 fuel tanks and it is a twin-engine aircraft. Fuel tanks are Internal wing tank, CL tank, Wing drop tank, tank no 1,2,3,3A2, 3A1.

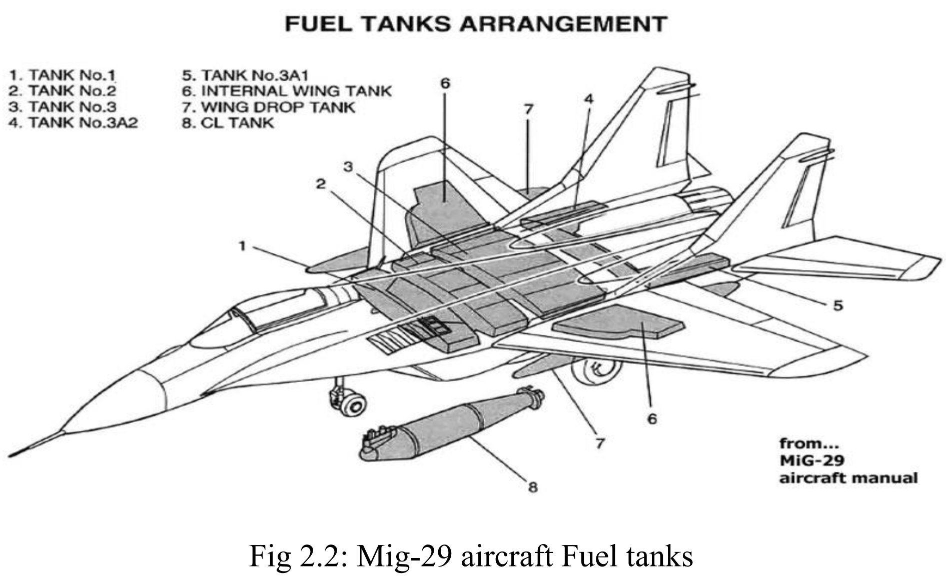


Fig 2.2: Mig-29 aircraft Fuel tanks

Tank Name	**Capacity (US gallons)**
2* Wing Tank	396
Main fuselage Tank (no 1)	870
Centerline Tank (no 2)	396
Drop tank	Attached when range increases
2*wing tip tank(3A1,3A2)	792
TOTAL	2,850 US gallons

Table 2.1: Mig-29 Tank Capacity

There are numbers of models of these aircrafts. Accordingly, capacity will vary models to models

2.4.2 F/A-18C Tank Capacity

F/A-18C has Internal wing tanks & tank no 1,2,3,4 total 6 wing tanks. Fuel weights are based on JP-5 or JP-4 air 6.8 or 6.5 pounds per gallon and a temperature of 15^0.It has two engines

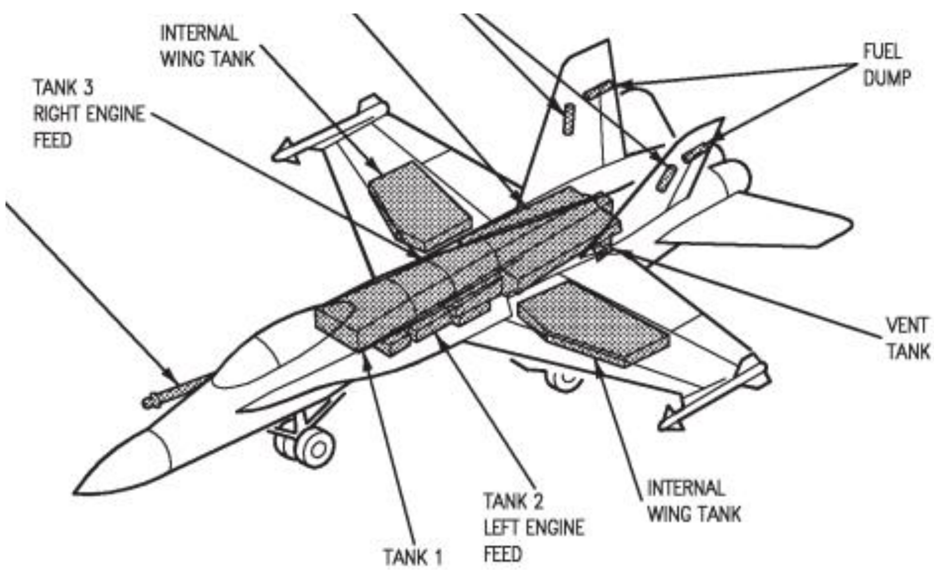


Fig 2.3: F/A-18C aircraft Fuel tanks

Tank Name	Capacity (US gallons)
Internal Fuselage tank	465
2* Wing Tank	2*161
Center Line tank	315
Drop Tank	330
TOTAL	1432 US gallons

Table 2.2: F/A-18C Tank Capacity

There are numbers of models of this aircrafts .Accordingly, capacity will vary models to models

2.4.3 Mig-21 Tank Capacity

Mig-21 has a bit complex fuel system design. It has total nine fuel tanks with one engine. Fuel tanks are two internal wing fuel tank and rest seven tanks are accommodated in fuselage.

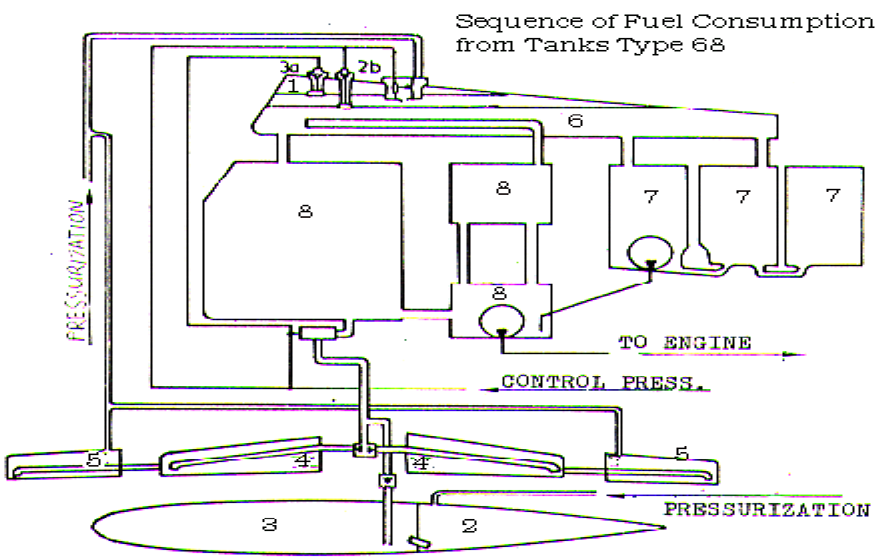


Fig 2.4: Mig-21 aircraft Fuel tanks

Tank Name	Capacity (US gallons)
2* internal Wing Tank	2*422
Internal Fuselage tank	594
Tail Tank	53
Center Line tank	158
Drop Tank	130
TOTAL	1779 US gallons

Table 2.3: Mig-21 Tank Capacity

There are numbers of models of these aircrafts. Accordingly, capacity will vary models to models

2.4.4 F-15 Tank Capacity

F-15 fighter aircraft has Internal wing fuel tank of capacity 13,123 lb , two CFTs with carrying capacity 21,645 lb and lastly up to three drop tanks of 610 us gallon capacity. It is a twin-engine aircraft.

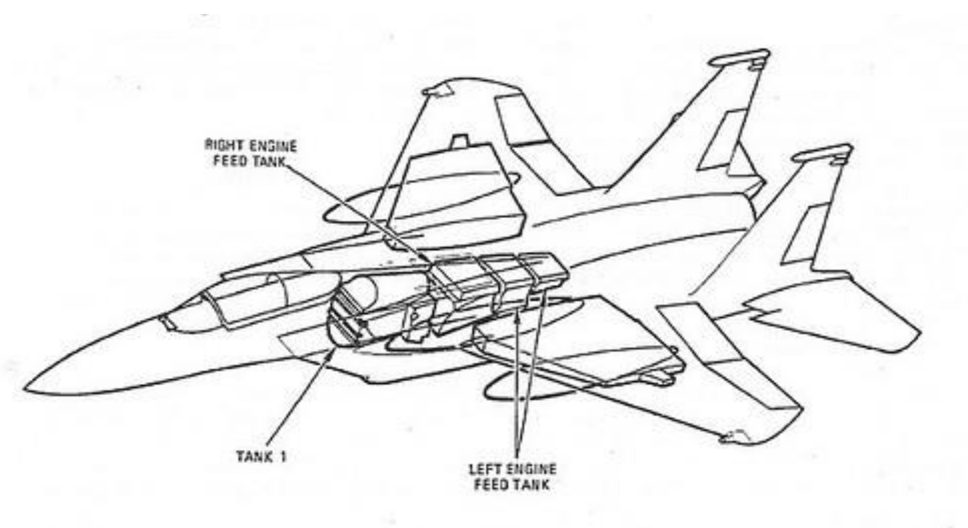


Fig 2.5: F-15 aircraft Fuel tanks

Tank	**Capacity (US gallons)**
Wing Tanks	750
Drop Tanks	3*330
Fuselage internal Tanks (1-8)	13455
TOTAL	15945 US gallons

Table 2.4: F-15 Tank Capacity

There are numbers of models of these aircrafts. Accordingly, capacity will vary models to models

2.5 Summary of literature review

Early study showed several issues with manual fuel transfer systems, including human error, inconsistency in gasoline distribution, and restricted monitoring capabilities. Studies highlighted the need of tackling these issues in order to improve aircraft safety.

Recent research has centered on the design and deployment of completely automated fuel transfer systems. This section delves into the use of modern sensor technologies, data analytics, and automated algorithms to accomplish exact fuel management without human intervention.

CHAPTER 3

PROJECT OVERVIEW

3.1 Fuel System Design Concept

In an aircraft fuel system can be categorized depending on the location of tanks and its use:

a. Main Fuel System
b. Auxiliary Fuel System

Main fuel system is situated on the centerline of the aircraft and the auxiliary fuel system is initiated for extended range flights. Auxiliary system is used to supplement the main tanks.

The main types of fuel system are as follows:

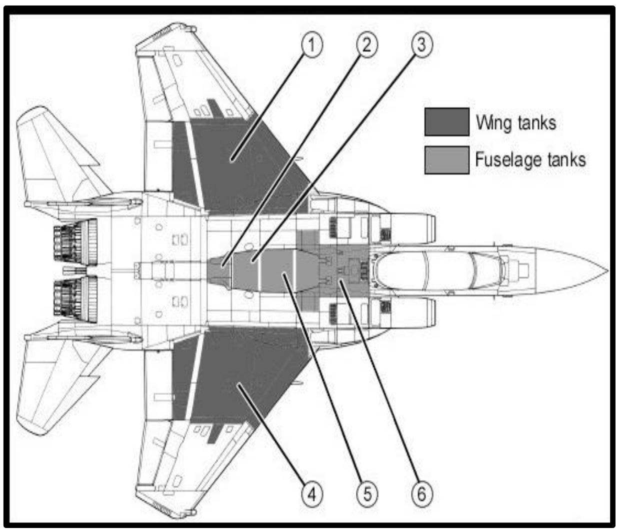
a. Gravity Feed System
b. Pump Feed System
c. Fuel Injection System

In small aircrafts gravity feed fuel system is used. Here the tank is located above the engine. The gravity force is used to transfer continuous fuel to the engine. But for large aircraft pump is needed to transfer fuel to different tanks and engines. The system itself is bigger and flexible. At any orientation the fuel can be delivered to engine. This is more reliable one. Fuel injection system is used in piston engine aircraft. Fuel is sprayed directly into the engine cylinders for combustion.

3.2 Project Description

Fuel sequencing is needed in aircrafts for economy of fuel, engine performance, CG balance, thrust management and maneuvering. The project is designed such a way that one can observe how automatic fuel transfer system work on an aircraft. Though the project is based on fighter aircraft, it can be modified for any aircraft by changing the algorithm and layout.

One aircraft model has been built and automatic fuel transfer is demonstrated. At the same time real time data like flow rate, fuel quantity, overall engine consumption are taken for further use. Though the prime requirement is demonstration of automatic fuel transfer, it can be used as a simulator to train pilots, engineers, under trainees and students in better understanding fuel management system. Its real time feedback will be interactive for users. Here in the figure one conventional fighter aircrafts fuel sourcing is given to gain understanding of the project. One fighter aircraft is considered in this regard.



FUEL SOURCES

1. Left Wing Tank
2. Rear Group
3. Center Group
4. Right Wing Tank
5. Forward Group
6. Service Tank

Figure 3.1 : Conventional Fighter Aircraft Fuel Sources

3.3 Flow Chart

After starting the system, Fuel Control Unit will perform. Pumps will receive signal from Fuel control unit and operate accordingly. Each tank is regulated by the program of FCU. Each tank is supplying fuel to the service tank and service tank will provide to the engine. Sensors are provided after service tank to measure the flow rate and fuel consumption by the engines. Moreover, there are sensors in each tank to measure fuel quantity.

Flow chart provides structured outline of the process. Users can understand the process easily by taking a look at the flow chart and its sequence.

Flow chart of fuel sequencing is as follows:

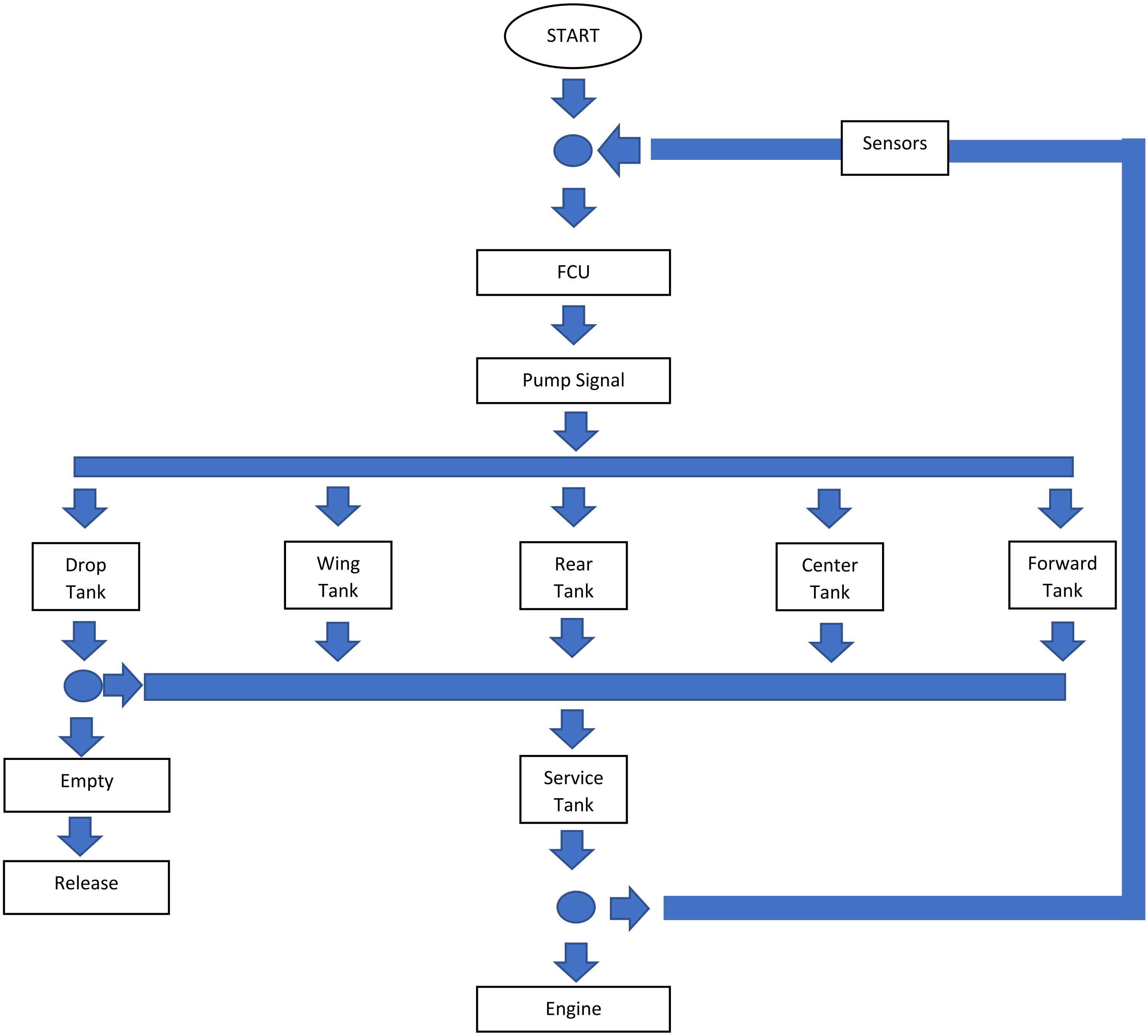


Figure 3.2: Flow Chart

3.4 Tank Locations

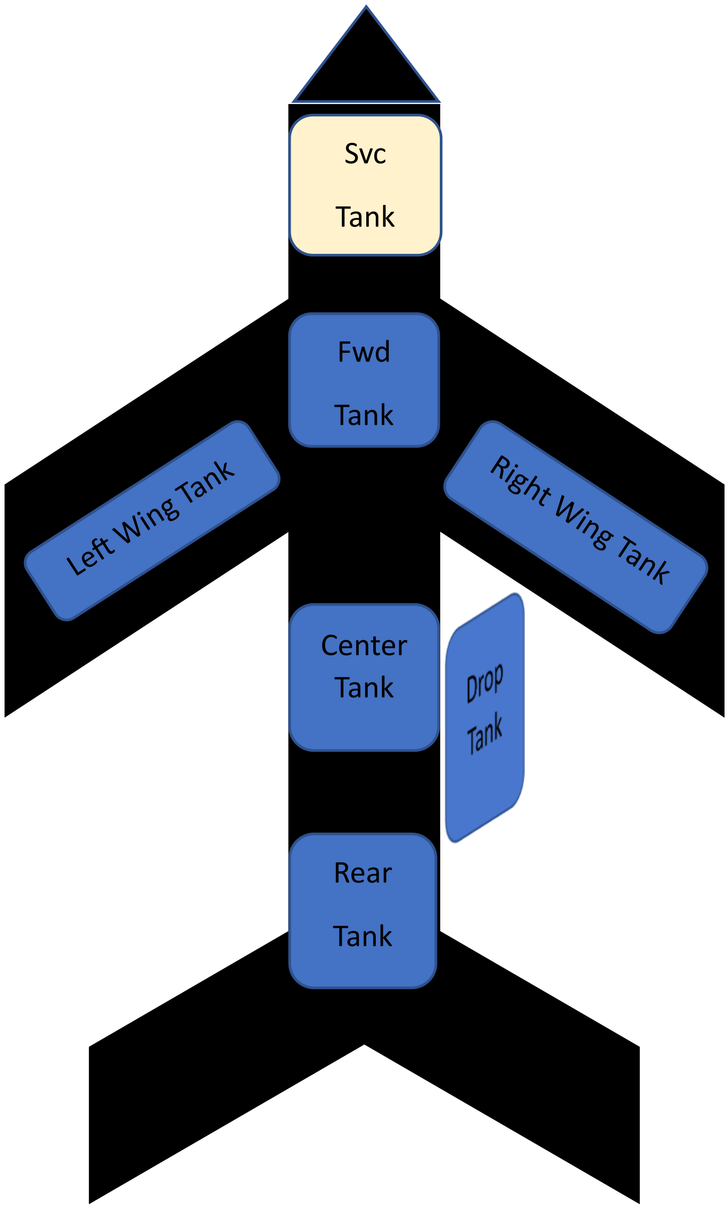


Figure 3.3: Model Tank Location

In the designed aircraft tank locations are very basic two wings containing two wing tanks and a drop tank below. These are auxiliary fuel system. Main fuel system represents the center line where rear, center and forward groups are located. Service tank supplies to the engine at the end.

3.5 Key Features

Key features of the project are as follows:

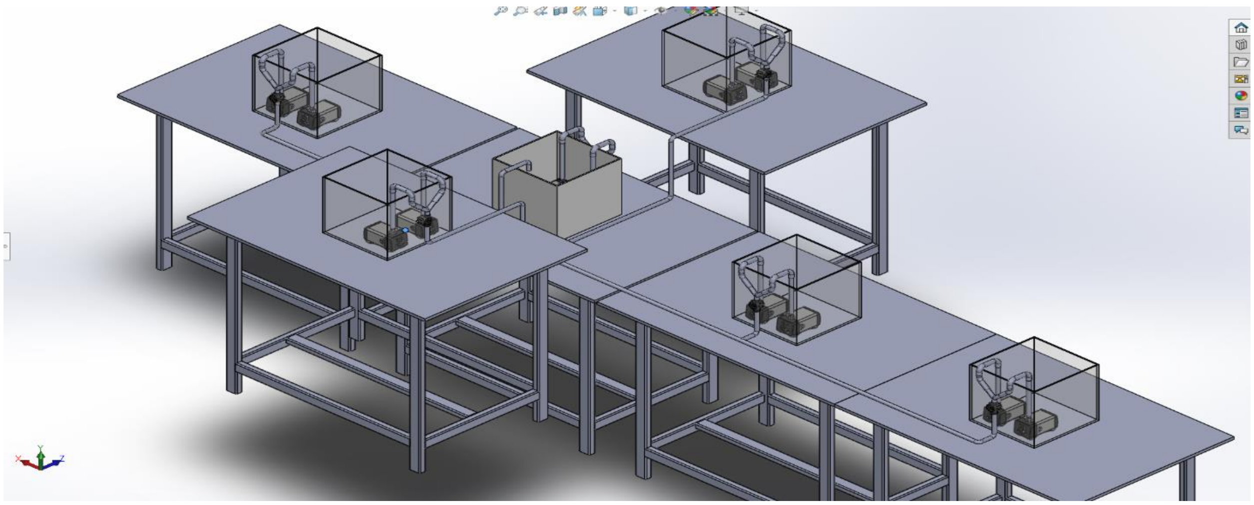
a. **Pump feed system** All the tanks are mainly fed by pumps.
b. **Gravity feed system** Wing tanks are having gravity feed system if pumps fail. It can also be fed while pumps are open.
c. **Automatic shut off valve** Pilot can switch to emergency system by automated valve opening and closing for initiating gravity feed system.
d. **Indication system** There is indication system for the viewer to understand which stage the aircraft is operating on.
e. **Pressure feed drop tank** Drop tank is pressurized by the compressor to supply fuel to the engine.

CHAPTER 4

METHODOLOGY

4.1 Solid-works Design

The project is initially designed on solid-works. A draft 3D computer aided design helped to visualize. Necessary changes were made after feasibility check. Initial designs and final design is demonstrated below:



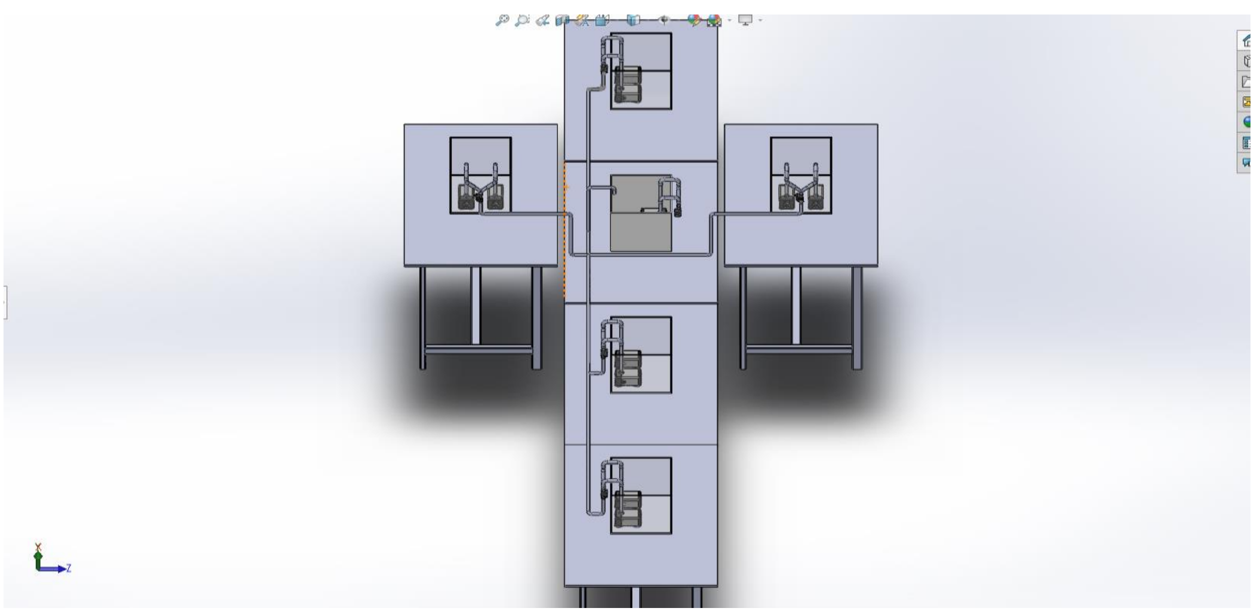


Figure 4.1: Conceptual Model (Initial plan)

Initial plan was to design a table like frame where the fuel tanks will be placed. But it was modified later on where the frame was changed to aircraft shape having extra legs.

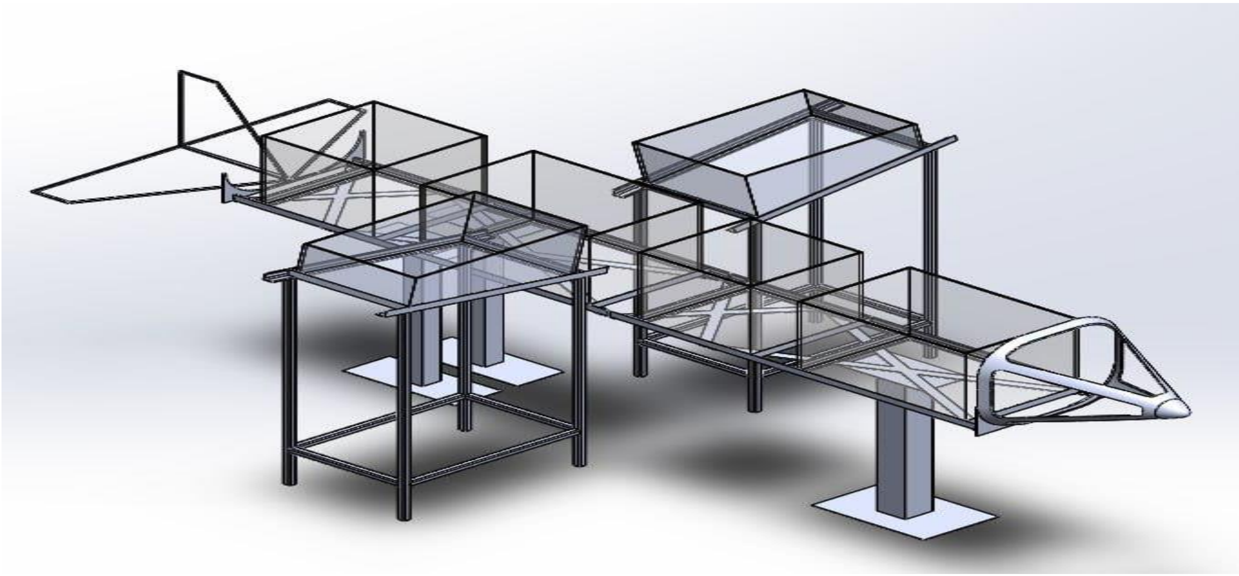


Figure 4.2: Preliminary Model (Second plan)

The aircraft shape is further updated where it has three undercarriage, cockpit and tail portion resembling an aircraft. Virtually CG balance is simulated. It is modular type as every part is joined with nuts and bolts. It can be divided into multiple parts and reassembled. The model is also movable as its undercarriage has wheels.

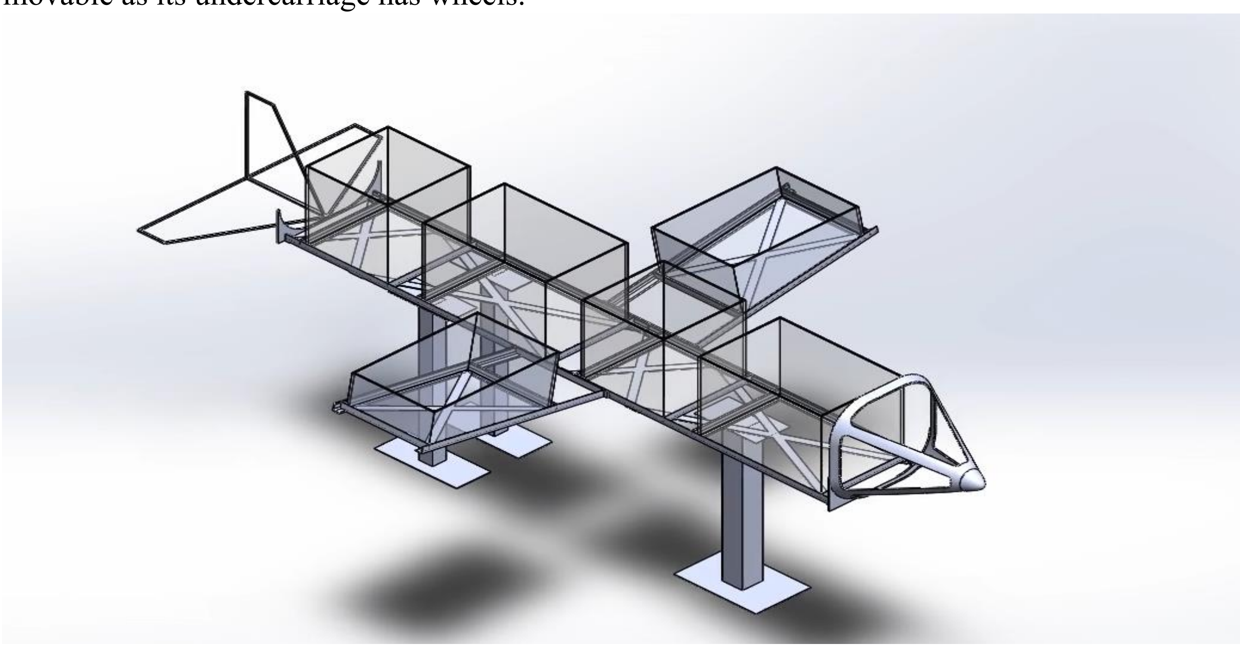


Figure 4.3: Preliminary Model (Modular plan)

4.2 Fabrication

Fabrication is done by shaping, joining, cutting and assembling different components and parts. The steps that were followed during fabrication are as follows:

Figure 4.4: Fabrication Process

a. **Market Analysis.** Initially product availability, pricing, quality and options are checked. Some of the sensors and components are better in oversees than local market. For purchasing the products quality is not compromised. Rather compatibility is checked.
b. **Frame and Base.** Frame and base supports the structure and stabilizes distribution of weight. Physically center of gravity balancing is a tough job to do. Mild steel is used for the structure to hold balance. Strong and thick sheets are used as base, so that it can hold the weight. Total six wheels are used at three landing gears. It has locking system for stability. Wings are elevated so that gravity feed system is functionable.
c. **Drop Tank.** Drop tank is the only pressure feed component used in the model. It has a heavy compressor to generate the necessary pressure to lift the fuel underneath the fuselage and

transfer subsequently to engine.It has one inlet for fueling and one outlet for fuel transfer. One point is connected with compressor. Compressed air is used as power source to move fuel. Initially one compressor of 100 PSI was used. But it could not generate enough force. After testing it is changed to a better and stronger one. After usage pilot can release the drop tank and reduce weight.

Earlier Compressor (0.7 Mpa)

Updated Compressor (2Mpa)

Figure 4.5: Drop Tank

d. **Fuel Tanks.** Fuel tanks are made of crystal glass so that fuel demonstration is easily seen. See through layout gives clear view for observer. In total seven fuel tanks are used. One of these are drop tank which is exceptional. Other than that, all the tanks are made of crystal glass which is suitable for demonstration.

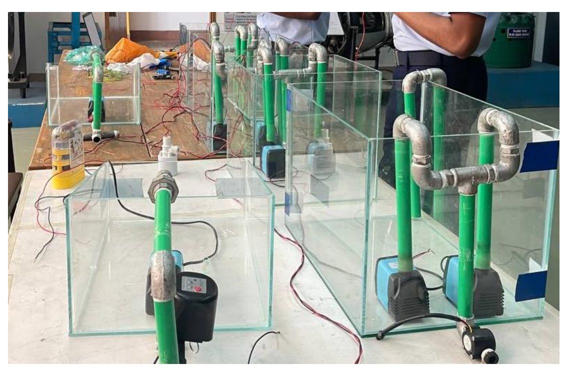


Figure 4.6: Crystal Glass

e. **Fuel Line & Joints**. Fuel transfer lines and joints are carefully chosen as they play vital role. If there is leak than there will be accident. Moreover, the engine will have insufficient fuel.

Same goes for the joints. If the fittings are not tight properly than there will be leakage. Again, over tightening can damage components and under tightening can lead to leakage. Sometime sealing is needed like gaskets thread sealants etc. Aircraft fuel lines are actually made of stainless steel or aluminum which are free from corrosion. It should be also possessing high pressure and temperature tolerance. Otherwise, it may fail. For the project PVC pipe is used mostly. For drop tank flexible line is used so that it is not fixed with the main structure and it can be dropped easily when needed. In real case the joints and pipe lines undergo regular checking and maintenance.

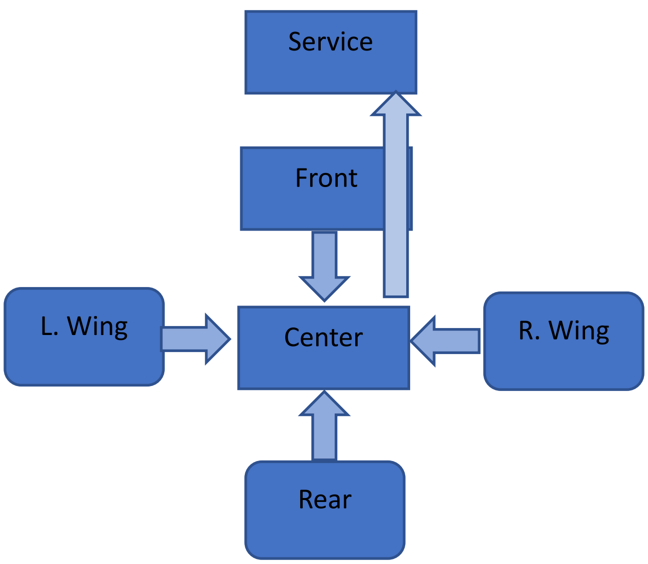


Figure 4.7: Line & Joints

f. **Shut off valve.** Shut off valve is used to stop the flow of fuel. It is also known as cut off valve. In this case one shut off valve is used in the wing tank line. Normally fuel is transferred to center tank from wing via pump. But if the system fails there is redundancy. When emergency occurs pilot can switch to gravity feed system. When pilot will turn on switch, shut off valve will open and start the gravity feed system. Initially this line is closed. But according to pilots desire it can be opened. It allows changing from pump feed to gravity feed system.

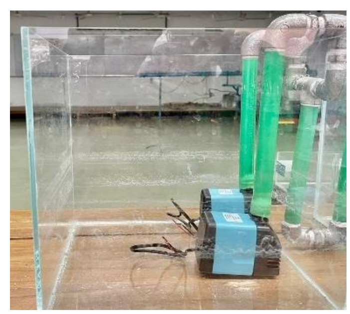
Switch for pilot to configure gravity feed

Shut off valve Controller with valve

Figure 4.8: Shut-Off Valve

g. **Pumps.** There are different types of pumps in aircraft. Among them fuel pumps are the heart of the fuel system as these deliver fuel to engine. There are different sensors to measure as the pump is transferring correctly or not. In this project one additional pump is added in case of failure another will take over and run the system continuously.

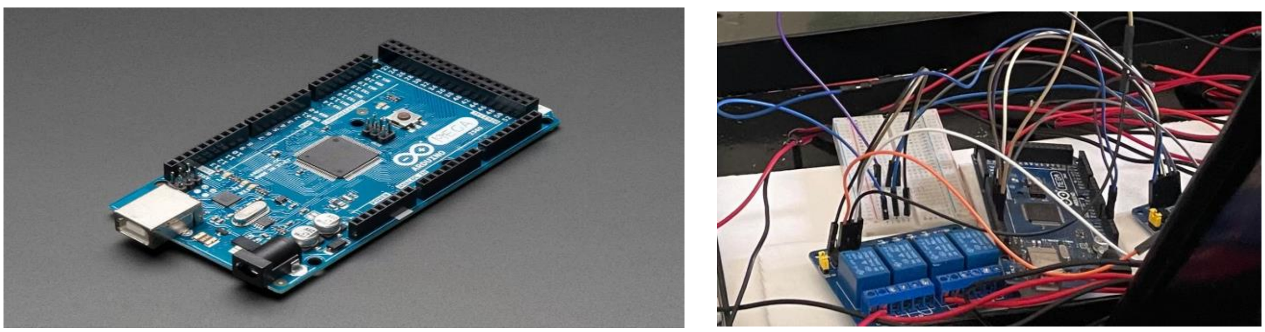
Single pump



Additional Pump for Redundancy

Figure 4.9: Fuel Pump

h. **FCU.** Fuel Control Unit gives command to the overall fuel system. Basically, this particular component regulates the amount of fuel required for the aircraft at particular time period depending on the condition of the aircraft. At different stages of flight different amount of fuel is required by the engine. For instance, during maneuver more fuel is required than cruise flight. This combination is done by measuring different parameters beforehand on ground on the basis of logic and algorithms. Arduino mega is the main processor for the fuel control unit in this project. It controls the relays and relays control the individual pumps. Relays are electromechanical switches which control higher power circuit using lower power signal. Two four channel relays are used for operating six pumps and one compressor. Bread boards are used for connectivity.

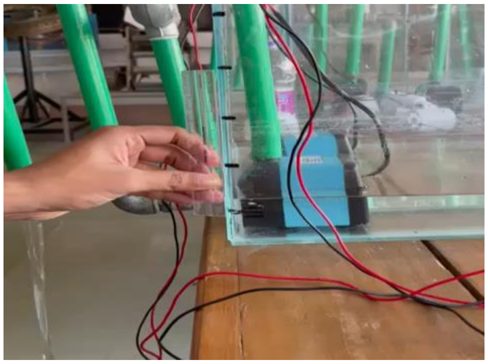


Arduino mega

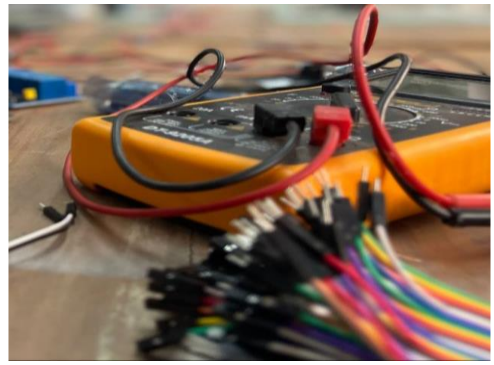
Relay Connection

Figure 4.10: System Controller (Arduino Mega)

i. **Wiring.** Wiring carefully installed and protected to prevent any kind of damage and risk. It is routed in corners; sharp edges are over protected so that discontinuity does not take place. Wiring ensures the signals are passing from each equipment and it is also giving feedbacks. So, it works both ways. While wiring different groups were separated and marketed. Routes are also divided so that one can easily understand and fix in case of any damage. For neat appearance the wiring system is taken below the surface. Heat shrink tubing is used for wire connections. After tubing, electrical tape is used to seal the joint area. It’s because pumps are located underneath the fuel. So, it must be well covered and sealed so that there is no chance of damage. Multimeter is used to check the connection and components when any problem is faced.



Electric Wiring

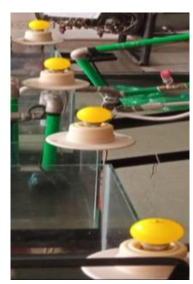


Jumper wire

Figure 4.11: Wiring

j. **Indication system**. There are two types of indication system used. One is for pilot who can see from cockpit. Another one is for observer of the simulation process. For the first one pilot will understand from which fuel tank engine is being fed. If any problem occurs that will be also understood by the pilot and then necessary actions can be taken. On the other hand, it is easier for the demonstration purpose also. These lights are installed over the fuel tanks on light holders. One plain 4-inch x 4-inch plastic sheet is used at the back of the holder for safety. The cockpit lights are decorated on a nice panel. Red color indicates the drop tank, Green color indicates wing tanks and Yellow color indicates the centerline tanks.

Cockpit Indication

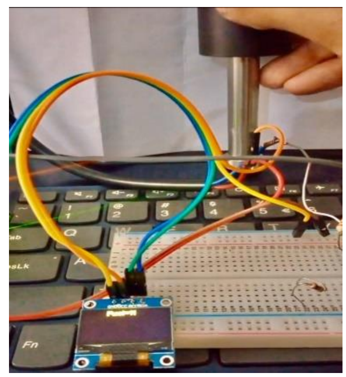


Indication for Observer

Figure 4.12: Indication Light

k. **Display.** OLED or Organic Light Emitting Diode display is used for the necessary reading of the pilot. These readings are important to understand what is going on at real time. The data is projected on the display taken from the sensors. There are four displays. One is bigger than the other three. The bigger one is connected with the service tank sensor. It gives the reading of overall fuel consumption. The rest three displays give reading from other three fuel tanks which are forward, center and rear group. Rear and forward group are having same sensor as service tank. But the center group is having level sensor which measures the level of the fuel. The sensor works based on resistance. When resistance is changed the value is also change. This value is displayed on the OLED display. This display can be changed to bigger or better one according to the requirement.

OLED Display



OLED test Fuel Level sensor

Figure 4.13: OLED Display

l. **Sensors.** Sensors detect and measure physical change in a component and convert them in electrical signal. These signals are sent to the display and Fuel Control Unit for further processing. There are multiple sensors used in fuel system starting from temperature sensor to fuel level sensor. Here fuel flow sensor and fuel level indicator sensor is used. These two sensors work in two different principles. Fuel flow sensors are used at the outlet of the tank but fuel level sensor is mounted on top to take reading.

Fuel level sensor

Fuel Flow Sensor

Figure 4.14:Level Sensor & Fuel Flow Sensor

4.3 Automation

For automatic fuel transfer system Arduino mega code is generated. The algorithm is customizable. By changing the values, it can be updated for any aircraft model. The code is as follows:

Coding For pump operation

```
const int relayPin1 = 7;  // Connect to the first relay

const int relayPin2 = 8;  // Connect to the second relay

const int relayPin3 = 9;  // Connect to the third relay

const int relayPin4 = 10;  // Connect to the fourth relay

const int relayPin5 = 11;  // Connect to the fifth relay

const int relayPin6 = 12;  // Connect to the sixth relay

const int relayPin7 = 6;  // Connect to the seventh relay
```

```
void setup()

  pinMode(relayPin2, OUTPUT);
  pinMode(relayPin4, OUTPUT);
}
void loop() {
  digitalWrite(relayPin2, HIGH);
  digitalWrite(relayPin4, HIGH);
  delay(15000);
  pinMode(relayPin1, OUTPUT);
  digitalWrite(relayPin1, HIGH);
  delay(60000);
  digitalWrite(relayPin1, LOW);
  delay(120000);
  pinMode(relayPin5, OUTPUT);
  digitalWrite(relayPin5, HIGH);
  delay(30000);
  digitalWrite(relayPin5, LOW);
  delay(180000);
  pinMode(relayPin6, OUTPUT);
  pinMode(relayPin7, OUTPUT);
  digitalWrite(relayPin6, HIGH);
  digitalWrite(relayPin7, HIGH);
```

```
  delay(120000);
  digitalWrite(relayPin6, LOW);
   digitalWrite(relayPin7, LOW);
  pinMode(relayPin3, OUTPUT);
  digitalWrite(relayPin3, HIGH);
  delay(60000);
  pinMode(relayPin1, OUTPUT);
  digitalWrite(relayPin1, HIGH);
  delay(120000);
  digitalWrite(relayPin1, LOW);
   digitalWrite(relayPin3, LOW);
   delay(90000);
   digitalWrite(relayPin2, LOW);
  digitalWrite(relayPin4, LOW);
  exit(0);
}
```

4.4 Redundancy

Additional components are added so that these can give back up in case of failure. It gives more reliability for the function to run. Some of the redundancy systems used are as follows:

Back up pumps → Extra one pump is added per fuel tank

Gravity feed → Two wings' tanks are kept higher than the service tank. So that it can

CG Balance → Sensor is taking reading from each tank. Accordingly, fuel is being supplied to engine maintaining CG of the aircraft. It ensures stability and control of the aircraft.

4.5 Sampling Strategy

For collecting sample one single tank was used in controlled environment. The tank was equipped with all the necessary components. Necessary manipulation could be done as it was easy for data collection. Experimental data is used for constructing rest of the tanks.

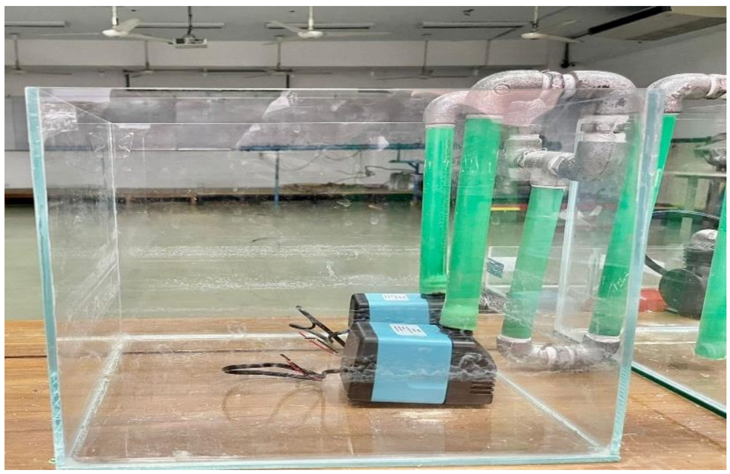


Figure 4.15: Sample Tank

4.6 Operating Sequence

Operating sequence for used algorithm is as follows:

- Initially from service tank will transfer fuel for start up
- Then first tank will send fuel up to a limit
- After that Center tank will initialize
- Gradually drop tank and Wing tanks will feed
- Subsequently Forward and Rear group will start simultaneously
- At the end Center group will feed service tank
- Whole through the sequence service tank will continuously provide fuel to the engine

4.7 Universal Sequencing Process

A comprehensive arrangement is designed where any modification is possible in respect of algorithm, logic and physical modifications.

Structural Modification. As the layout is modular based, any part can be removed to match with targeted aircraft in order to match the sequence.

Algorithmic Alteration. If any logic is changed than the sequence will be changed. Thus any sequence is achievable by adjusting the code reducing resource consumption. It is not even required to remove any part as code will do the same job.

Experimental code. During fabrication and testing one more sequencing is done using same set up and layout.

Existing Sequence

1. Sequential advancement from rear group to forward group
2. It balances CG
3. **Reason.** Tail is heavy, so center group is fed just after rear group. So CG is balanced

New Sequence

1. Sequential advancement rear to forward group skipping center group
2. It hampers CG a bit
3. **Reason**. Tail is heavy as engine is generally considered near tail. As center group is fed after forward group, CG is imbalanced

Figure 4.16: Sequence Improvement

Code alteration process. After defining the pins on the code output control pins are initialized. During this initialization if we declare any certain pin than that particular pin will be activated. Thus that particular pin is working for that declared pump. So by changing the pin number only code is altered. Here is the demonstration:

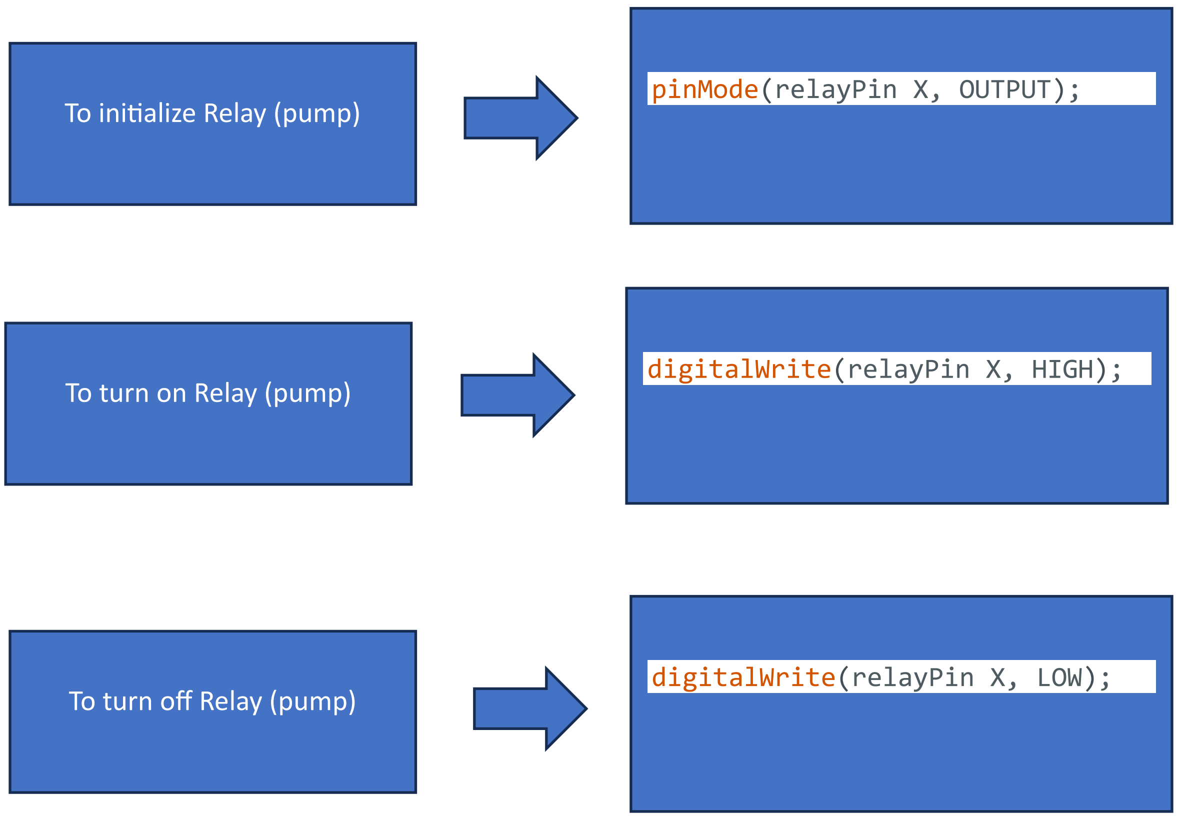


Figure 4.17: Code modification

Let X refers to any of the pumps. Replacing the X with the pump number matching with declared pin this code can be regenerated for any consideration.

CHAPTER 5

MODELING & VALIDATION

5.1 Proposed Model

Modeling and simulation of a single engine aircraft fuel system incorporates total seven fuel tanks and necessary Fuel pump, Fuel filter, Fuel vent system, Fuel management system etc. Seven tanks are two internal wing tanks, one drop tank, four tanks along fuselage.

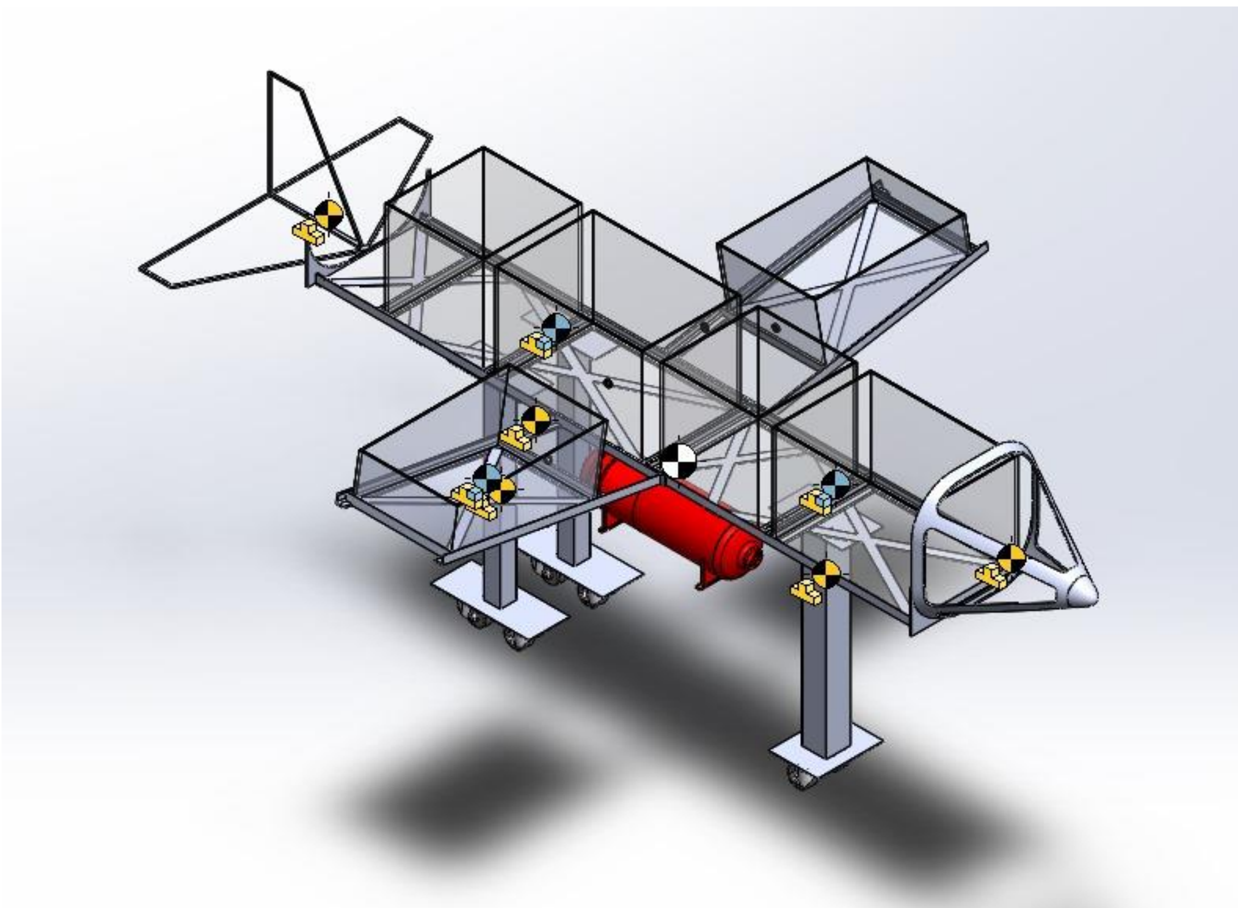


Figure 5.1: Proposed Model

5.2 Schematic Diagram

Below Schematic diagram simulates virtual positioning of fuel tanks & fuel supply pipes with necessary connections.

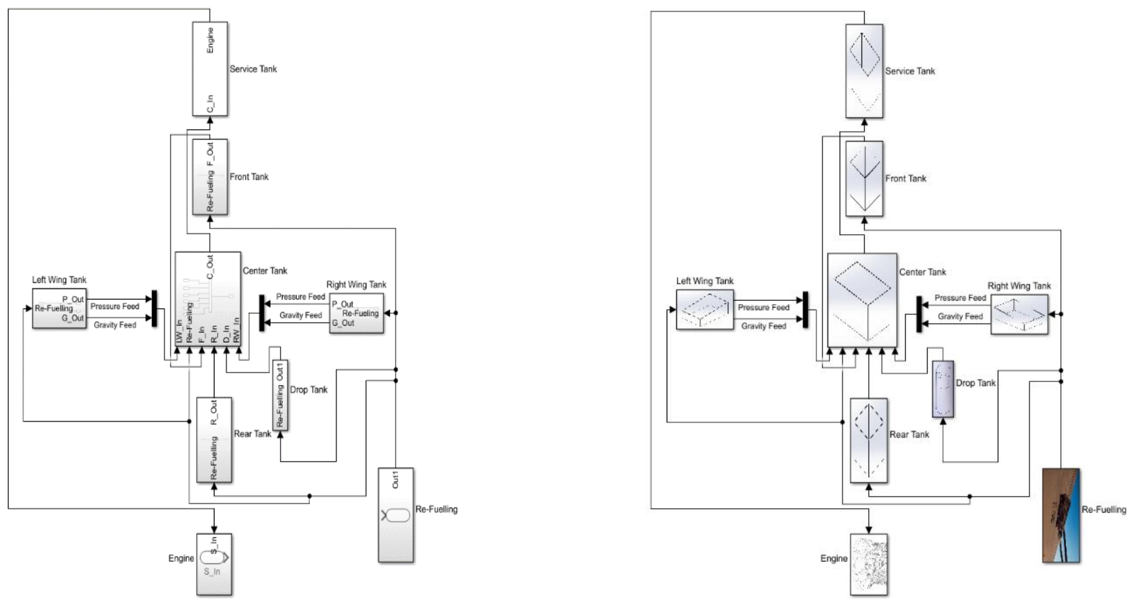


Figure 5.2: Schematic Diagram

5.3 Wiring Diagram

There are total 10 fuel pumps and one compressor to feed fuel from drop tank. To control this AC components relays are used which is made to function by Arduino coding. Six pumps remain always working and rest four pumps are used for redundancy. Only one pump is used in wing tanks as we are incorporating Gravity feed fuel system as backup system. The wiring diagram is shown below.

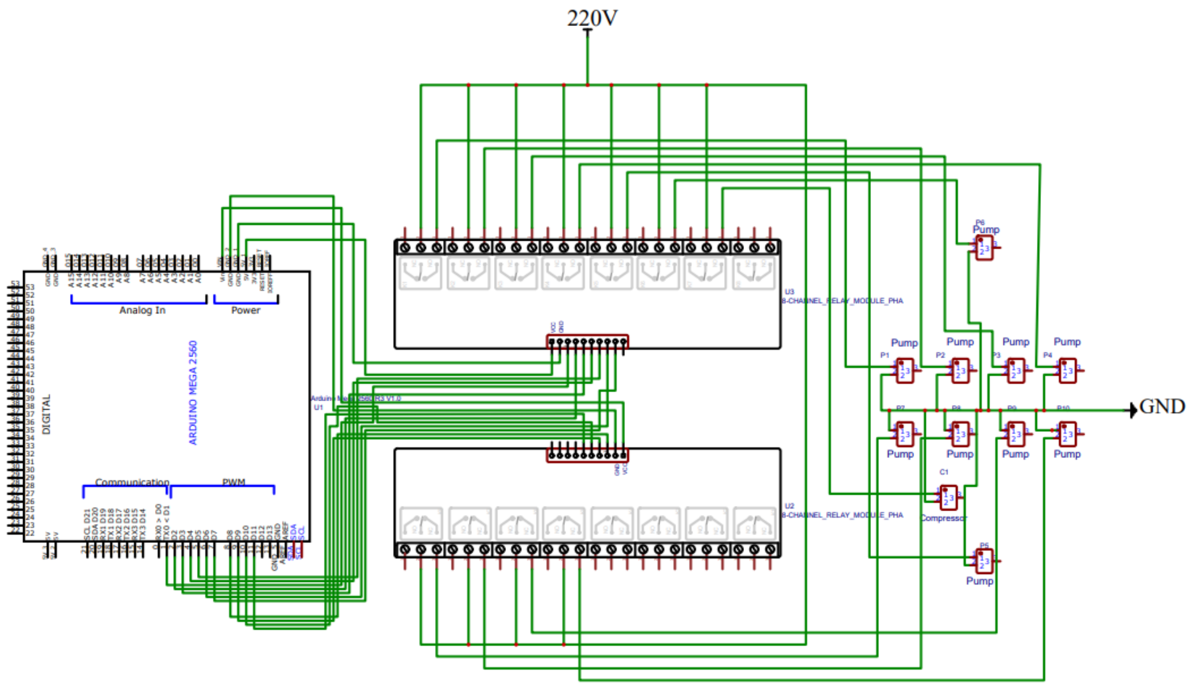


Figure 5.3: Wiring Diagram

5.4 Coding

For the perfect design & fabrication of automatic fuel management system proper controlled system is needs to be manufactured. Mainly Arduino is the control system and Arduino coding runs modeled aircraft.

Coding for Fuel level Sensor

```
#include "SSD1306Ascii.h"
#include "SSD1306AsciiAvrI2c.h"
SSD1306AsciiAvrI2c oled;
#define I2C_ADDRESS 0x3C
int TankValue0;
int TankValue1;

void setup() {
```

```
  Serial.begin(9600);
  oled.begin(&Adafruit128x64, I2C_ADDRESS);
  oled.setFont(Arial_bold_14);
  oled.clear();
}
void loop() {
  int sensorTankValue0 = analogRead(A0);
  int sensorTankValue1 = analogRead(A1);
  TankValue0 = map(sensorTankValue0, 940, 1023, 30, 0);
  TankValue1 = map(sensorTankValue1, 940, 1023, 20, 0);
  if (TankValue0 < 0) {
    TankValue0 = 0;
  }
  if (TankValue1 < 0) {
    TankValue1 = 0;
  }
  if (TankValue0 > 100) {
    TankValue0 = 100;
  }
  if (TankValue1 > 100) {
    TankValue1 = 100;
  }
  oled.print("      Fuel=");
  oled.print(TankValue0);
  oled.println(" ");
  //oled.print("T1=");
  //oled.print(TankValue1);
  oled.println(" ");
  oled.setCursor(0, 0);
  delay(1500);
}
```

Coding for Flow meter Sensor

```
#include <Wire.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SH110X.h>
#include “SSD1306Ascii.h”
#include “SSD1306AsciiAvrI2c.h”
SSD1306AsciiAvrI2c oled;
#define I2C_ADDRESS 0x3C
#define i2c_Address 0x3C // OLED display I2C address


#define SCREEN_WIDTH 128    // OLED display width, in pixels
#define SCREEN_HEIGHT 64    // OLED display height, in pixels
#define OLED_RESET -1       // Reset pin # (or -1 if sharing Arduino reset pin)

Adafruit_SH1106G display(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

#define SENSOR_PIN 2 // Pin connected to the flow sensor

long currentMillis = 0;
long previousMillis = 0;
int interval = 1000;
float calibrationFactor = 7.5;
volatile byte pulseCount;
byte pulse1Sec = 0;
float 34lowrate;
unsigned long flowMilliLitres;
unsigned int totalMilliLitres;
float flowLitres;
float totalLitres;
```

```
long wakeup = 0;

void pulseCounter()
{
  pulseCount++;
}

void setup()
{
  Serial.begin(115200);
  delay(250); // Wait for the OLED to power up
  Serial.begin(9600);
  oled.begin(&Adafruit128x64, I2C_ADDRESS);
  oled.setFont(Arial_bold_14);
  oled.clear();



  // Initialize OLED display
  if (!display.begin(i2c_Address, true)) // Address 0x3C default
  {
    Serial.println(F("SSD1306 allocation failed"));
    for ();;
  }

  // Clear the display buffer
  display.clearDisplay();
  delay(10);

  // Set up pin mode for flow sensor
  pinMode(SENSOR_PIN, INPUT_PULLUP);
```

```
  // Initialize pulse count and other variables
  pulseCount = 0;
  36lowrate = 0.0;
  flowMilliLitres = 0;
  totalMilliLitres = 0;
  previousMillis = 0;

  // Attach interrupt to the flow sensor pin
  attachInterrupt(digitalPinToInterrupt(SENSOR_PIN), pulseCounter, RISING);
}

void loop()
{
  currentMillis = millis();
  if (currentMillis – previousMillis > interval)
  {
    pulse1Sec = pulseCount;
    pulseCount = 0;
    36lowrate = ((1000.0 / (millis() – previousMillis)) * pulse1Sec) / calibrationFactor;
    previousMillis = millis();
    flowMilliLitres = (36lowrate / 60) * 1000;
    flowLitres = (36lowrate / 60);
    totalMilliLitres += flowMilliLitres;
    totalLitres += flowLitres;
    Serial.print("Flow rate: ");
    Serial.print(float(36lowrate));
    Serial.print("L/min");
    Serial.print("\t");
    // Update OLED display
    display.clearDisplay();
```

```
display.setCursor(10, 0);
display.setTextSize(2);
display.setTextColor(SH110X_WHITE);
display.print("Fuel Flow");
display.setCursor(0, 20);
display.setTextSize(2);
display.setTextColor(SH110X_WHITE);
display.print("R:");
display.print(float(37lowrate));
display.setCursor(100, 28);
display.setTextSize(1);
display.print("L/M");
Serial.print("Output Liquid Quantity: ");
Serial.print(totalMilliLitres);
Serial.print("mL / ");
Serial.print(totalLitres);
Serial.println("L");
display.setCursor(0, 45);
display.setTextSize(2);
display.setTextColor(SH110X_WHITE);
display.print("V:");
display.print(totalLitres);
display.setCursor(100, 53);
display.setTextSize(1);
display.print("L");
display.display();
}
}
```

5.5 Subscale validation

Dimensionally this experiment deals with less capacity. To make it fit for actual aircraft an appropriate measurement is taken shown below

Tank Name	**Capacity(liter)**	**Actual Aircraft(liter)**
Service tank	12	240
Front Tank	23	460
Center tank	35	700
Rear tank	23	460
Drop tank	6	1200
Wing tanks	7.9	1580
TOTAL	**114.8 liter**	**6220 liter**

Table 5.1: Fuel Capacity Scale

5.6 Comparison of fuel capacity

Our experimental setups are compared with existing aircrafts in the shown in table below

<table>
<tr><th>Tank Name</th><th>Capacity(ltr)</th><th>Actual Aircraft(liter)</th><th>Mig-29</th><th>F/A-18C</th><th>Mig-21</th><th>F-15</th></tr>
<tr><td>Service tank</td><td>12</td><td>240</td><td></td><td></td><td></td><td rowspan="4">13455 gallons</td></tr>
<tr><td>Front Tank</td><td>23</td><td>460</td><td>870 gallons</td><td>465 gallons</td><td>594 gallons</td></tr>
<tr><td>Center tank</td><td>35</td><td>700</td><td>396 gallons</td><td>315 gallons</td><td>158 gallons</td></tr>
<tr><td>Rear tank</td><td>23</td><td>460</td><td></td><td></td><td></td></tr>
<tr><td>Drop tank</td><td>6</td><td>1200</td><td></td><td>330 gallons</td><td>130 gallons</td><td>330</td></tr>
<tr><td>Wing tanks</td><td>7.9</td><td>1580</td><td>396 gallons
792 gallons(wing tip)</td><td>161 gallons</td><td>422 gallons</td><td>750</td></tr>
<tr><td>TOTAL</td><td>114.8</td><td>6220 liter</td><td>2850 gallons</td><td>1432 gallons</td><td>1779 gallons</td><td>15945</td></tr>
</table>

Table 5.2: Fuel Capacity Comparison

There are numbers of models of these aircrafts. Accordingly, capacity will vary models to models

CHAPTER 6

SIMULATION

6.1 Virtual Simulation of the aircraft fuel system

At first software-based simulation is carried out. After successful completion design and fabrication of automatic fuel management system is constructed

Step-1. Fuselage center tank supplies fuel. Consequently, Service tank feeds engine.

Step-2. Drop tank fuel is passed to center tank. upon finishing the drop tank wing tank starts feeding.

Step-3. Fuel simultaneously feeds from forward tank and rear tank Thus it gives a sustainable design and fabrication of automatic fuel management system.

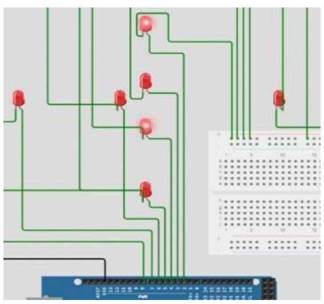


Fig: service & center tanks active

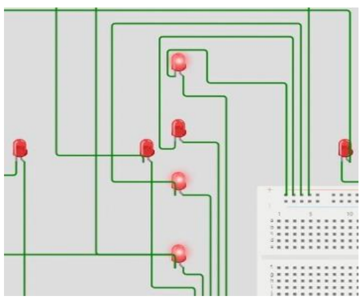


Fig: service, center tank & rear tank Active

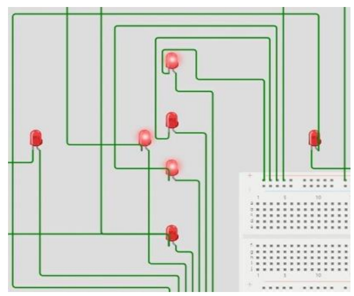


Fig: service,center tank & drop tank active

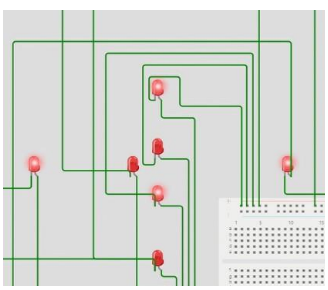


Fig: service, center tank & Wing tanks active

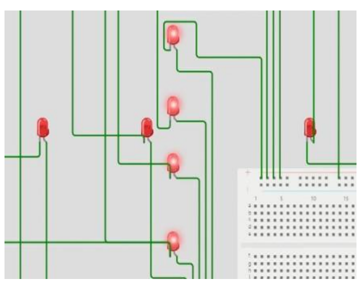


Fig: service, center tank, rear & Forward tank active

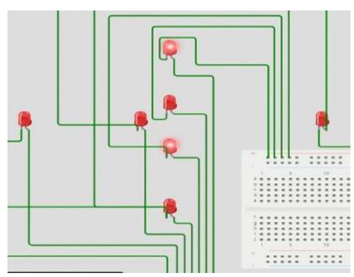


Fig: service & center tank is active

Figure 6.1: Virtual Simulation Model

6.2 Parametric Analysis

6.2.1 Fuel pump parameter

EB-301 is the submersible pump by which fuel is transferred between tanks & ultimately the engine is feed. EB-301 has a flow rate of 1000 L/H, Maximum height reachable is 2m. It consumes 25W power and operating voltage is 220v-240v/50 Hz. It is an AC motor so adequate safety must be ensured. It is small in size and very much energy efficient. This pump is controlled by a motor controller by using machine language programing. Thus, flow rate can be adjusted as per the requirement of Fuel. So, controlling EB-301 is efficient.

6.2.2 Non return Float Valve sensor parameter

Non return Valve significantly used to restrict fuel back flow. It combines with a float valve which is pressure sensitive by which automatically fuel level is controlled in center fuselage tank. In center fuel tank three cylindrical NRV float valve is used to keep balanced fuel flow from both wing tanks & Drop tank. If the flow rate excides the bearable limit, then fuel channel gets open. As consequence catastrophic damage might occur.

Figure 6.2: Non-return Float Valve

6.2.3 Compressor parameter

To feed the fuel from Drop tank compressor is used. It is a 200-220V and 50 Hz compressor. It has a flow rate of 5 L/min.

Fig 6.3: compressor

6.2.4 Flow meter parameter

YF-S201 flow meter sensor is used. General specification of YF-S201 is given below

Model	YF-S201
Working Voltage	5~18
Max current Draw	15mA @5V
Working Flow rate	1~30
Operating temperature range	-25~+80
Operating Humidity Range	35%- 80%
Accuracy	± 10%
Max water Pressure	2 Mpa
Output Duty cycle	50% ± 10%

Output Rise time	0.04 μsec
Pulses per liter	450
Output fall time	0.18 μsec
Outer diameter	20 mm
Intake diameter	11 mm
Outlet Diameter	11 mm
Length	62.5mm
Height	35mm
Width	50 gm
Shipment Weight	0.089 kg

Table 6.1: Flow meter Parameter

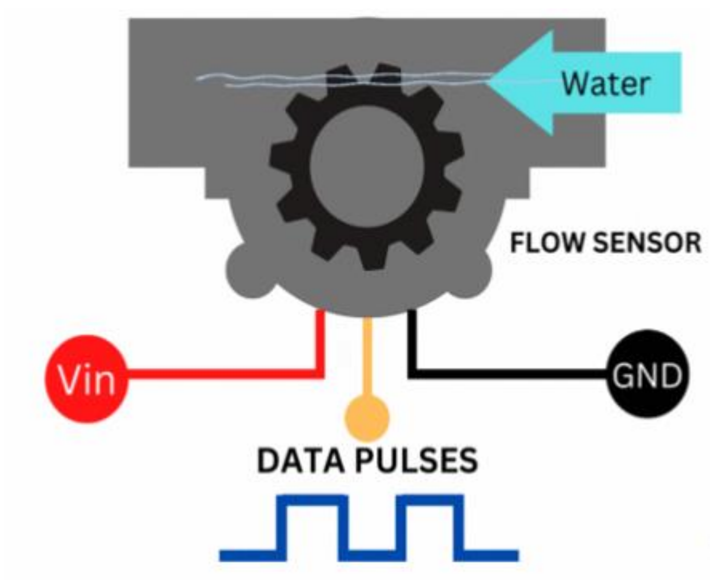


Fig 6.4: Flow meter

6.2.5 Check valve controller

For redundancy gravity feed fuel system Zigbee 3.0 Gas Valve Mechanical Valve Switch controller is used which can be operated manually or automatically via Wi-Fi & Bluetooth. The Schematic diagram is shown.

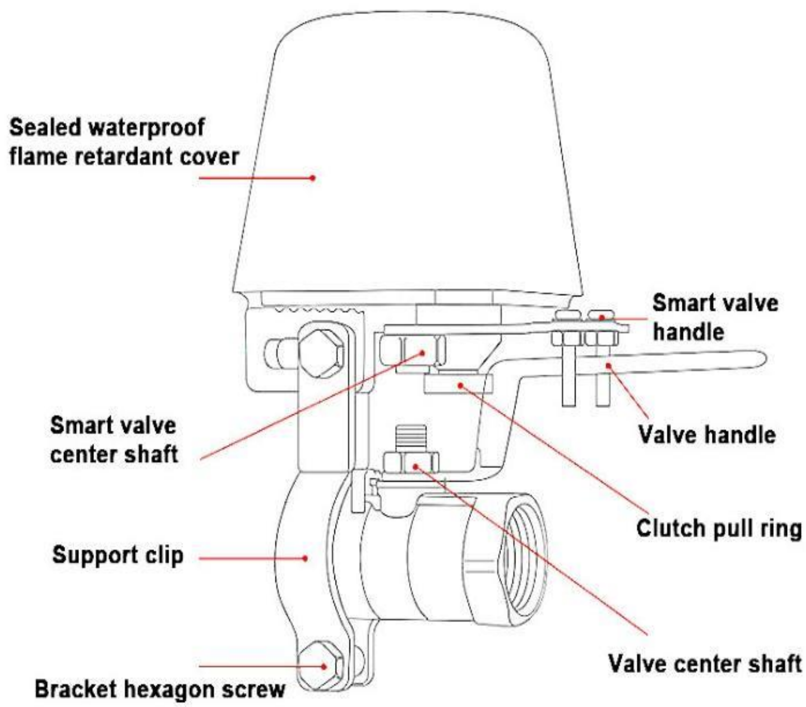


Figure 6.5: Check Valve Controller

6.2.6 Fuel level sensor (AE-E300)

AE-E300 is a fuel level sensor. It works by following transducer principle where Fuel level Which is a analog physical parameter is converted into digital signal that represents in Display section of the cockpit. Movement of the float valve is measured in terms of voltage change. This voltage change is calibrated in terms of fuel level. For measuring voltage change 2.2kohm resistor is used.

Figure 6.6: Fuel Level Sensor

6.2.7 Capacity of fuselage tanks

Tank Name	**Capacity(ltr)**
Service tank	12
Front Tank	23
Center tank	35
Rear tank	23

Table 6.2: Fuselage Tank Capacity

6.2.8 Drop tank parameter

Tank Name	Capacity(ltr)	Actual Aircraft(ltr)
Drop tank	6	60

Table 6.3: Drop Tank Capacity

6.2.9 Wing tanks

Tank Name	Capacity(ltr)	Actual Aircraft(ltr)
Wing tanks	2*7.9	2*395

Table 6.4: Wing Tank Capacity

6.2.10 Fuel Feed mechanism

Generally, aircraft has two types of fuel system gravity feed fuel system and pressure feed fuel system. In pressure feed fuel system external pressure is applied to feed the engine. For gravity feed fuel system fuel is feed to engine due to its weight. Due to advantages of pressure feed fuel system over gravity feed mechanism now adays pressure feed is used. In this design and fabrication of automatic fuel management system both type feed mechanism is applied. Here gravity feed mechanism is used only in redundancy system. It will operate when pump fails to deliver fuel to engine.

6.2.11 Display parameter

OLED display of 0.96” & 1.3” is used for Fuel level display. It has following specifications

Display panel	**OLED**
Size	0.96” & 1.3”
Operating Voltage	5v
Resolution	128*64 pixels
No of pins	4(Vcc, 5v, Ground,
Driver	SSD1315
Color of Display	Yellow, Blue

Table 6.5: Display Parameter

6.3 Actual Simulation of aircraft fuel system

Simulation is done using total seven fuel tanks of different capacity. If the flight envelope has takeoff, cruse & landing phase. It should be completed by following sequences. Initially fuel is supplied from service tank then center tank feeds fuel & feed by rear tank. In the meantime, fuel sequentially feed from drop tank and two wing tanks & fully emptied. Fuel feed from drop tank is 60 liters & wing tanks 2*395 liters. Lastly fuel is feed from forward and rear tank simultaneously.

Time (sec)		Front Tank		Center Tank		Rear Tank		Service Tank		Wing Tank		Drop Tank	Total Fuel
		height (cm)	Volume (L)	height (cm)	Volume (L)	height (cm)	Volume (L)	height (cm)	Volume (L)	Left (L)	Right (L)	Volume (L)	Volume (L)
0		25	23.22543936	25	34.83815904	25	23.22543936	9	12.5417373	7.71	7.71	6	115.2508
15		25	23.22543936	24	33.44463268	25	23.22543936	8.5	11.8449741	7.71	7.71	6	113.1605
75		25	23.22543936	24	33.44463268	19	17.65133391	8.7	12.1236793	7.71	7.71	6	107.8651
195		25	23.22543936	15	20.90289542	19	17.65133391	9	12.5417373	7.71	7.71	6	95.74141
225		25	23.22543936	16.8	23.41124287	19	17.65133391	9.2	12.8204425	7.71	7.71	1	93.52846
405		25	23.22543936	7	9.754684531	19	17.65133391	8.9	12.4023846	7.71	7.71	1	79.45384
525		25	23.22543936	14.2	19.78807433	19	17.65133391	9	12.5417373	1.34	1.65	1	77.19658
585		18	16.72231634	11.6	16.16490579	19	17.65133391	9.1	12.6810899	1.34	1.65	1	67.20965
675		6	5.574105446	9	12.54173725	8	7.432140595	9	12.5417373	1.34	1.65	1	42.07972
765		6	5.574105446	3	4.180579085	8	7.432140595	3	4.18057908	1.34	1.65	1	25.3574

Table 6.6: Experimental Data

6.3.1 Rear Group

The dynamics of flight are a complex interplay of various factors, one of which is the management of fuel. This study presents an analysis of fuel sequencing in combat aircraft, focusing on the relationship between time and volume of the rear fuel tank.

igure

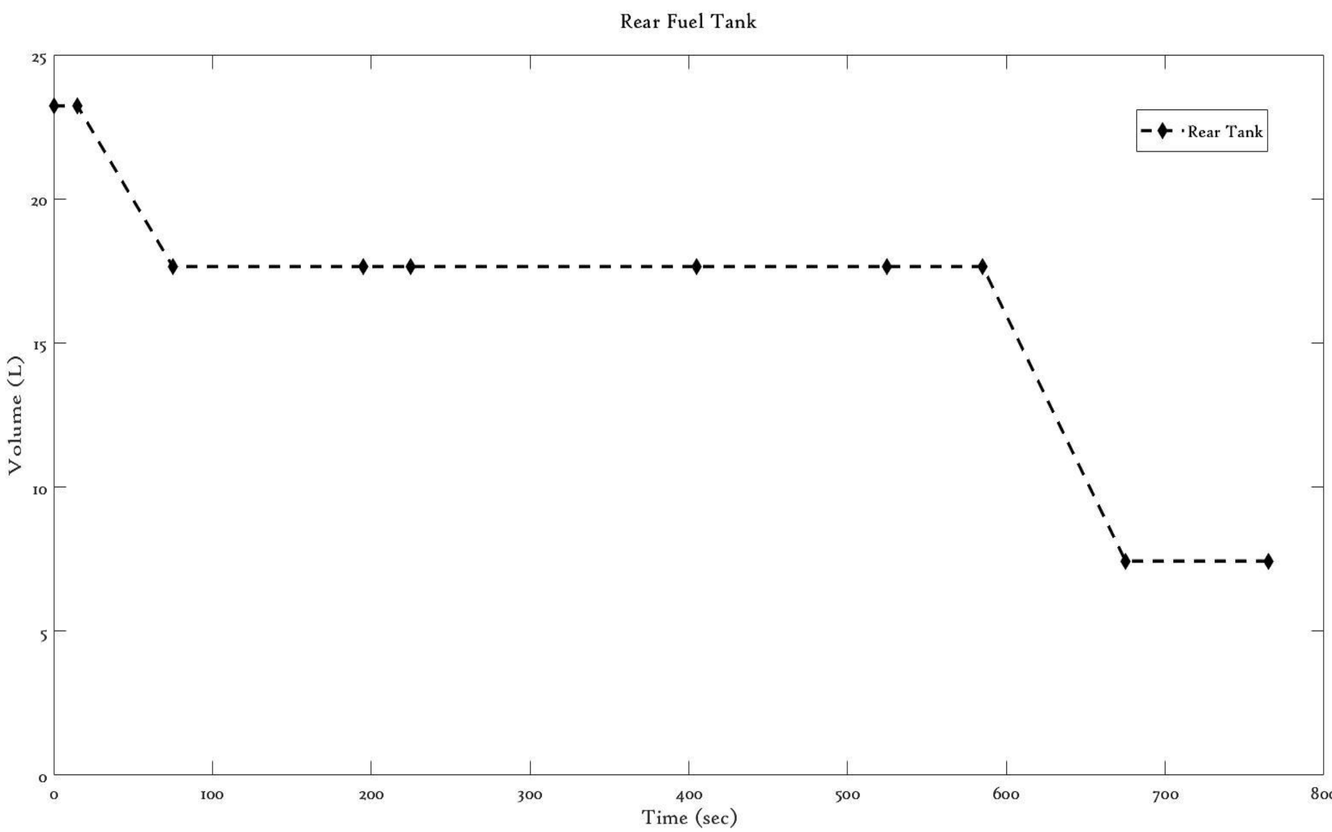


Figure 6.7: Rear Fuel Tank Consumption Graph

The Graph reveals two distinct phases in the volume of the rear fuel tank. Initially, for a duration of 525 seconds, the volume remains relatively stable at approximately 17.65133 liters, a slight decrease from the initial volume of 23.22544 liters at 0 seconds. However, post the 675-second mark, there is a steep decline in volume, dropping to 7.432141 liters by around 765 seconds.

The first phase of fuel drain is a strategic maneuver. Most aircraft are tail-heavy, which can affect their operational efficiency and maneuverability. To counteract this, fuel is first drained from the rear tank, reducing the tail heaviness and improving the aircraft's balance and operation. This strategy is evident in the data, where the volume of the rear tank remains relatively stable for the first 525 seconds.

The second phase, marked by a steep decline in volume post-675 seconds, which supply fuel for center tank collectively along with front tank.

6.3.2 Center Group

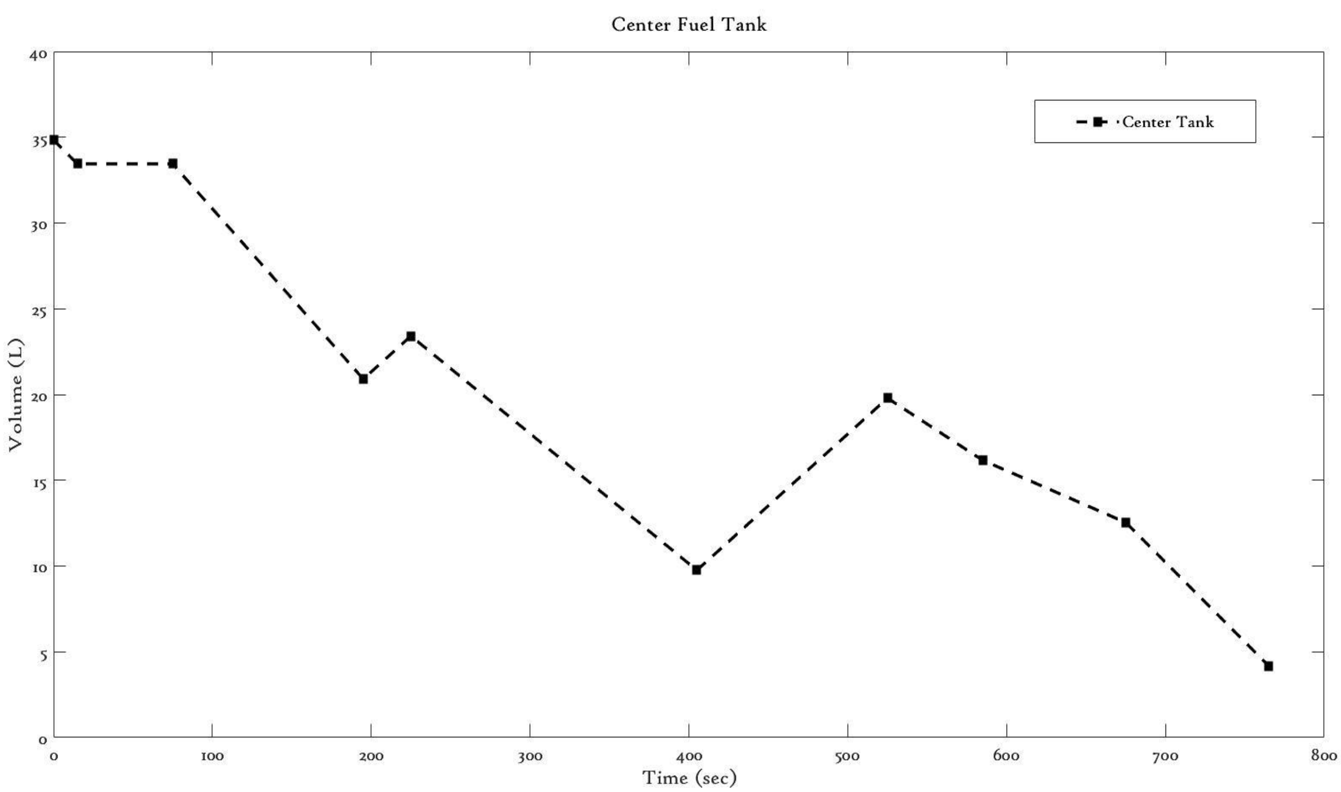


Figure 6.8: Center Fuel Tank Consumption Graph

The data reveals distinct phases in the volume of the center tank over time. Initially, for a duration of 15 seconds, the volume remains relatively stable at approximately 34.83815904 liters. However, post the 15-second mark, there is a slight decline in volume, dropping to 33.44463268 liters by around 75 seconds. This volume remains constant until 195 seconds, after which there is a significant reduction in volume to 20.90289542 liters. Interestingly, there's a minor increase in volume to 23.41124287 liters at 225 seconds, potentially due to a positive spike from the drop tank before it starts declining again reaching its lowest point of 4.180579085 liters at 765 seconds.

The center tank plays a pivotal role in the aircraft's fuel sequencing model. It not only has its own fuel but also collects from various tanks and sources at different time periods. The center tank is always providing fuel to the service tank to run the engines. The initial phase of fuel drain in the center tank is strategic. The slight decrease in volume post the 15-second mark attributed to the transfer of fuel to the service tank to power the engines. The constant volume phase refers to a balanced consumption and refilling mechanism. The sudden increase post-195 seconds could be attributed to increased rate of refilling mechanisms from Drop tank. The major increase in volume at 405 seconds is at first due to a positive fuel spike from the both wing and later on from Front and Rear tank supplying fuel at the same time to Center tank.

6.3.3 Front Group

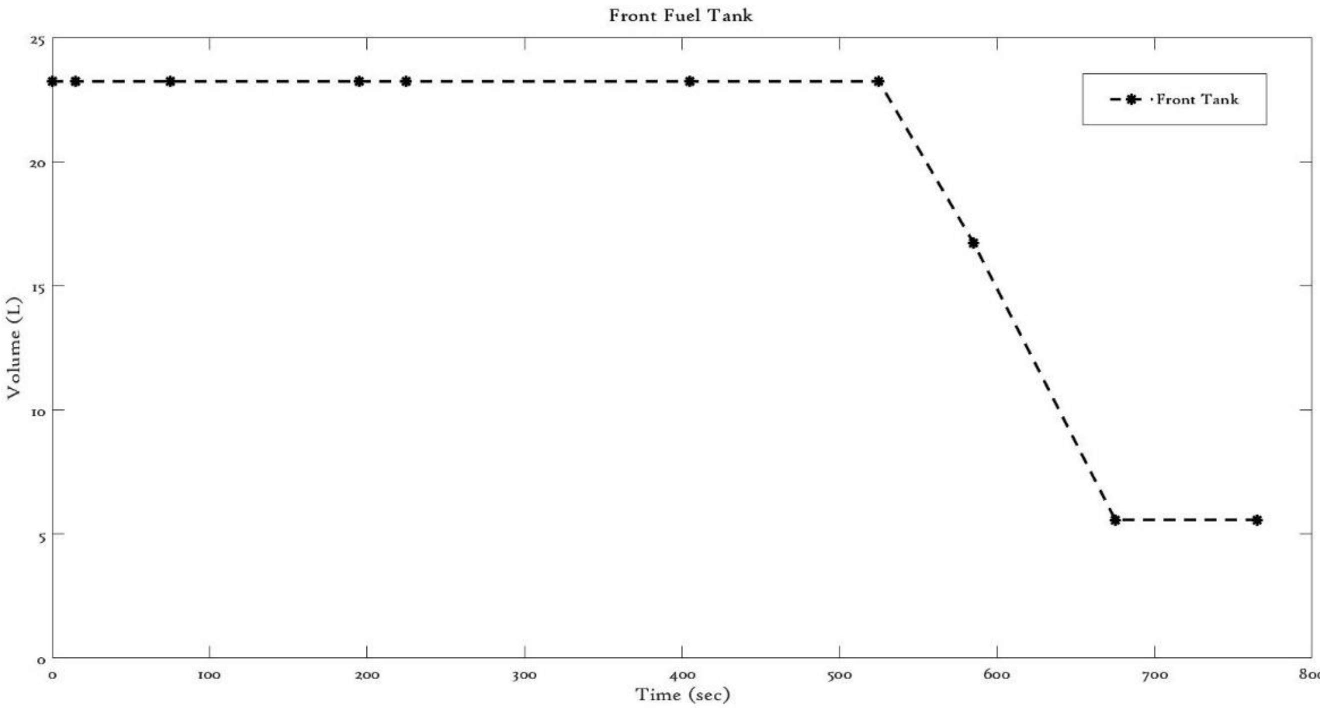


Figure 6.9: Front Fuel Tank Consumption Graph

The data reveals distinct phases in the volume of the front tank over time. Initially, for a duration of 600 seconds, the volume remains relatively stable at approximately 25 liters. However, post the 525-second mark, there is a steep decline in volume, dropping to 5.574105446 liters by around 765 seconds. Front tank keeps supplying fuel to front tank till the end attributed to increased consumption due to the aircraft's operational demands.

Front tank's role in the fuel sequencing model provides valuable insights into the operational strategies of combat aircraft. It underscores the importance of fuel management in maintaining the aircraft's CG balance, enhancing efficiency and safety.

6.3.4 Drop Tank & Wing Group

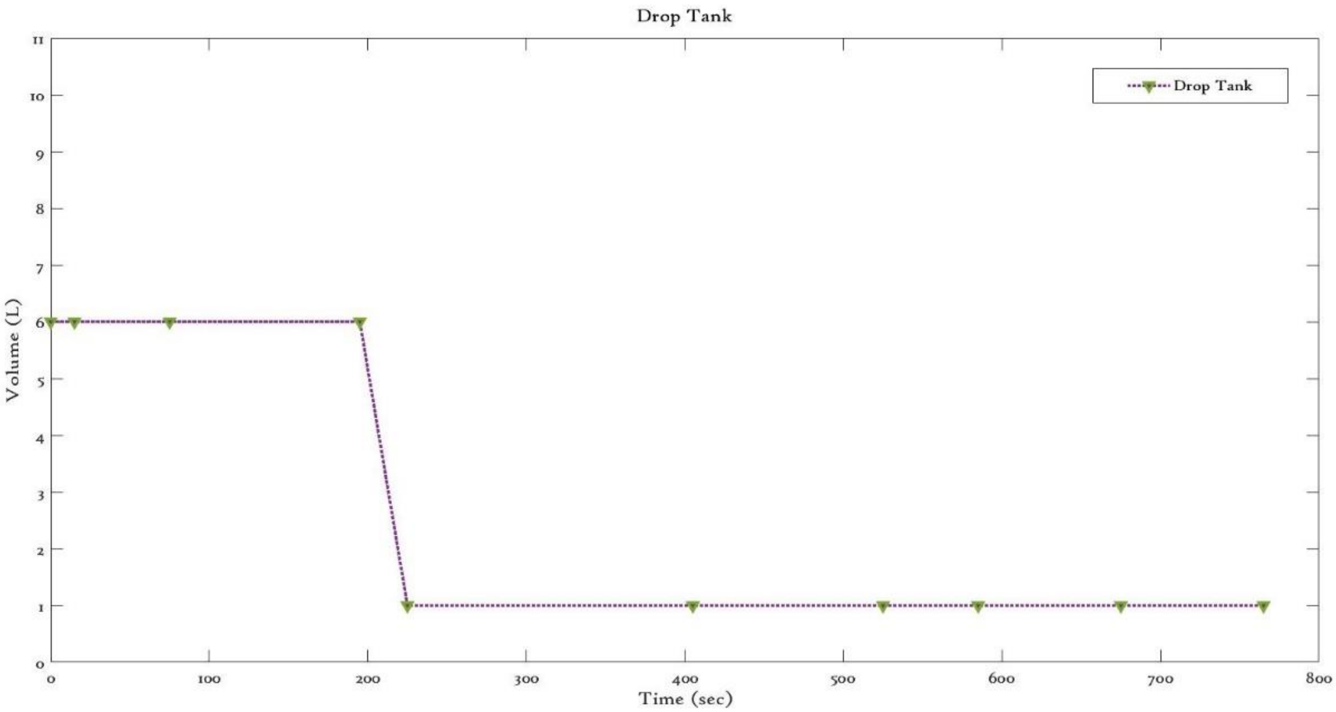


Figure 6.10: Drop Tank Consumption Graph

The data reveals a well-orchestrated sequence in the volume of the drop tank and both wing tanks over time. Initially, the drop tank, with its capacity of 5L and flow rate of 5L/min, provides a steady supply of fuel to the center tank from 195 seconds to 225 seconds.

The drop tank plays a crucial role in the early phase of flight. It provides a rapid supply of fuel to the center tank, ensuring optimal performance during this critical period. Once the drop tank is depleted, the aircraft begins to utilize the fuel reserves in the wing tanks.

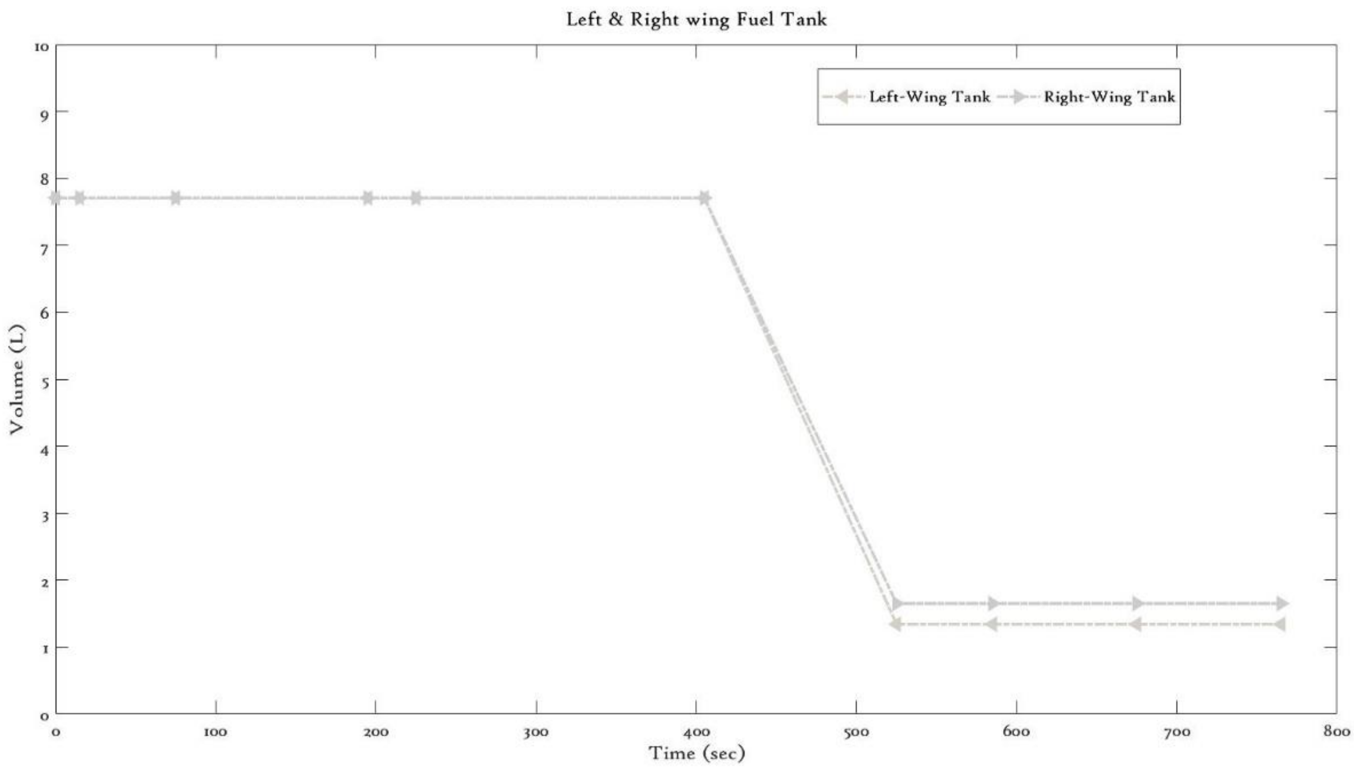


Figure 6.11: Wings Fuel Tank Consumption Graph

However, post the 405-second mark, there is a sharp decline in volume in both wing tanks, indicating the commencement of fuel supply from the wing tanks to the center tank until 525 seconds.

The wing tanks maintain a constant volume for the initial 405 seconds. This phase is not due to constant refueling, but rather a strategic measure to maintain the aircraft's center of gravity (CG) balance. The sudden drop post-405 seconds attributed to the commencement of fuel supply from the wing tanks to the center tank.

The Right- and Left-wing tank indicate different level of residual fuel even though initial level of fuel was equal, it's mainly due to mechanical error on our part of wing group manufacturing.

6.4 Display unit view

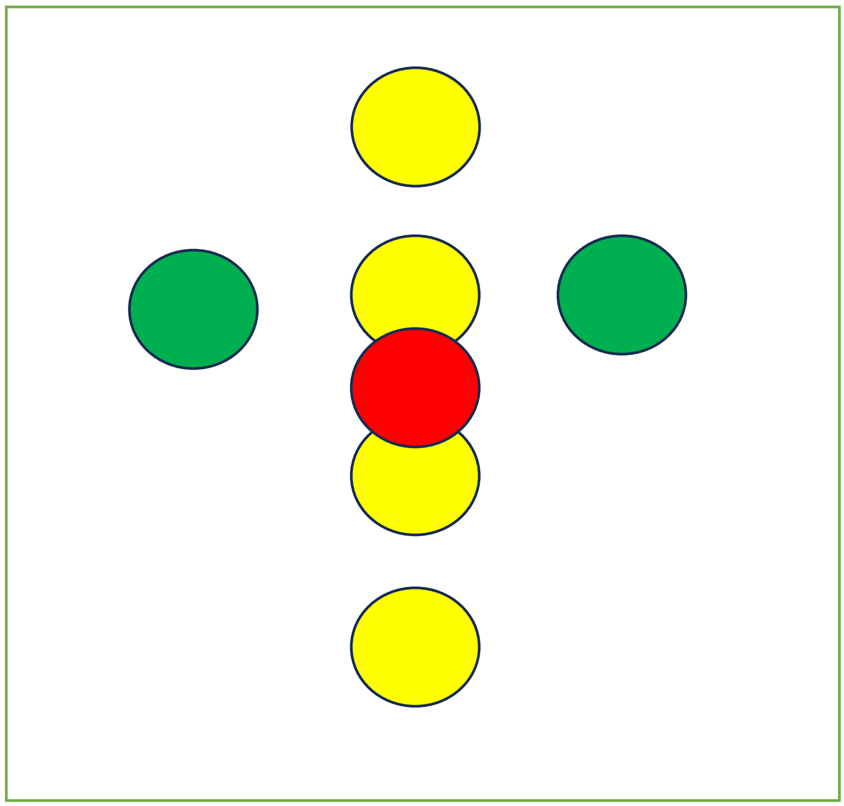


Fig 6.12: Indication of fuel transfer system

Fig 6.13: Actual simulator indications

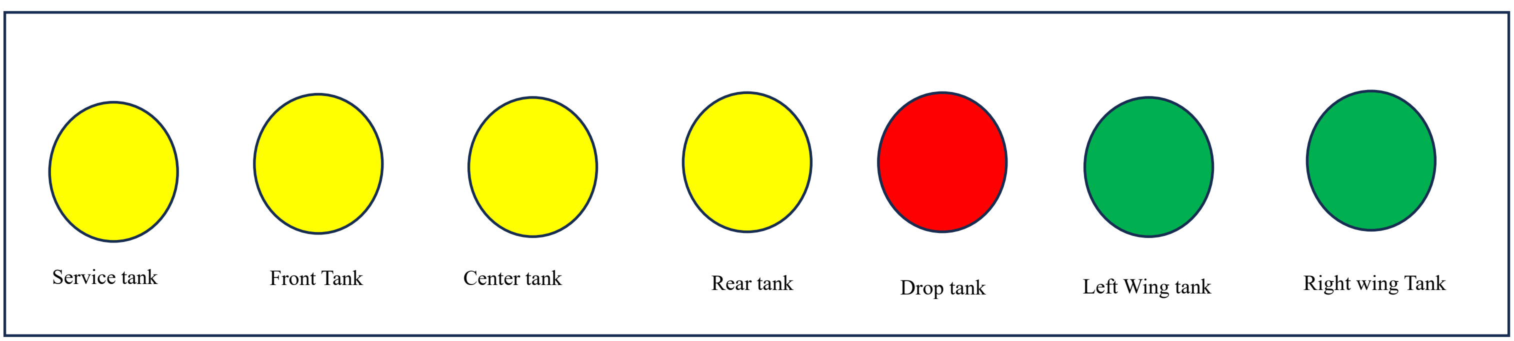


Fig 6.14: Cockpit Indication lights

In display section there will be indications for all seven fuel tanks. Yellow marked are for fuselage tanks. that is service tank, forward tank, center tank, rear tank. Red color indicates drop tank. For left- and right-wing tanks green indications are used.

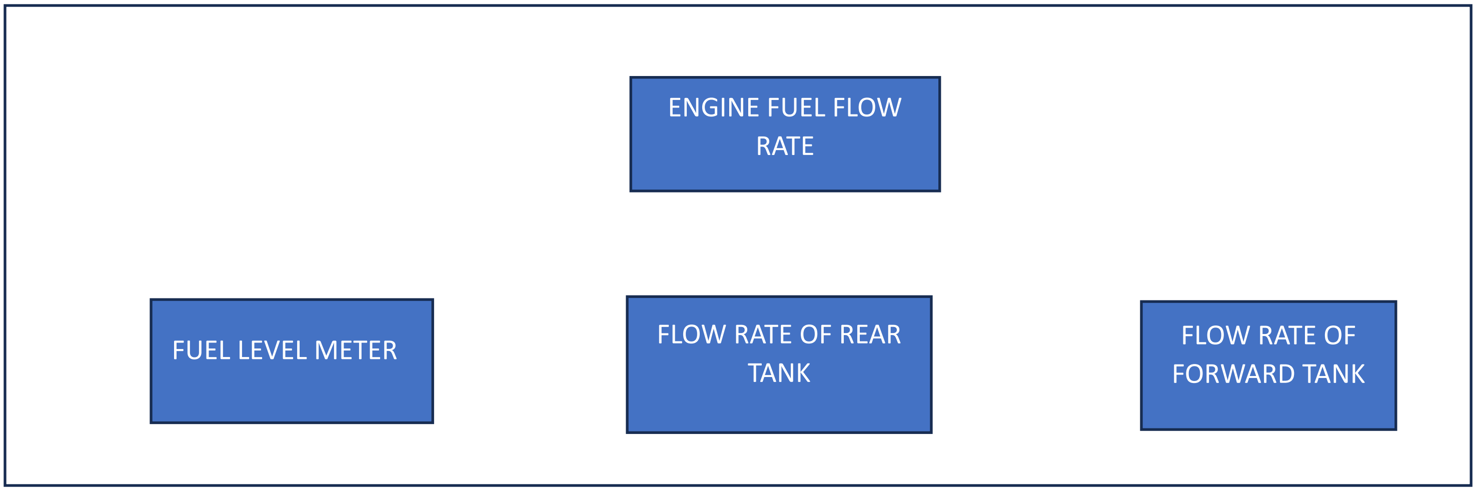


Fig 6.15: Cockpit display units and their functions

Total four OLED is used to show engine fuel flow rate, Fuel Level meter, Flow rate of rear tank and flow rate of forward tank.

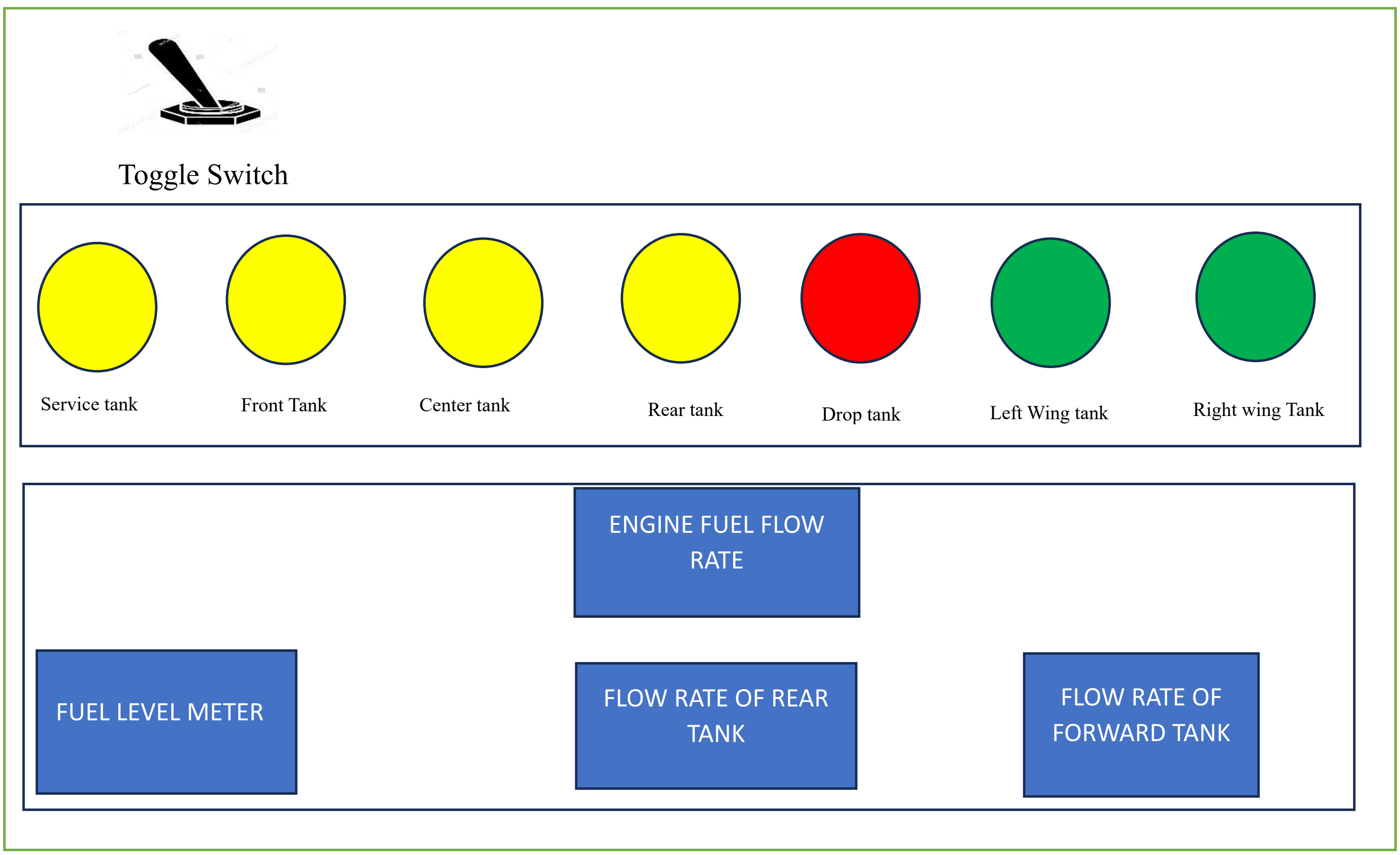


Fig 6.16: Cockpit view

6.5 Simulation Environment & Safety considerations

Proposed fuel management system runs with both alternating current (220-240v) and Direct current (3.3v/5v). Though simulation is kind of approximation top priority is given to safety. NEC (national Electrical Code) & OSHA (Occupational safety & health Administration) should be followed. Simulation must be done under supervision of Qualified Professionals. Proper training & certification needs to be ensured. Before each simulation Startup check is must. Online educational simulations & Opensource simulation software can reduce risk up to some limit. Last but not the list never work alone.

Chapter 7

Problem Specification & Solution

7.1 Problems

The fuel sequencing project we undertook for our thesis has been fraught with difficulties that have put our ability to solve problems and tenacity to the test. The syphon effect was one major challenge we faced, complicating the dynamics of fuel flow inside the system and necessitating a great deal of analysis to counteract. Furthermore, the weight of the fuel and the extended wing arm created moment-induced stress on the wing linkage with the fuselage, which required creative technical solutions. Our design's over-reliance on relays and Arduino components raised the likelihood of a system failure, underscoring the necessity of simplifying our control procedures to ensure reliability. Moreover, the late-stage revelation of defects in the drop tank design constituted a significant setback for the project and highlighted the importance of rigorous prototyping and testing procedures from the outset. Throughout the process, our team demonstrated resilience and resourcefulness in the face of these daunting challenges, ultimately acquiring significant insights into fuel system design and implementation.

7.2 Solution

In order to prevent or lessen the influence of the syphon effect, the aviation fuel sequencing project must carefully evaluate and use a number of strategies. The following are a few methods to avoid the syphon effect:

- Install Anti-Siphon Valves: To stop fuel from running backwards, anti-siphon valves can be put in the fuel system. By limiting fuel flow to the intended direction, these valves efficiently prevent the syphon effect.

- Employ Check Valves: Also referred to as one-way valves, check valves only permit fluid to flow in a single direction. Fuel syphoning out of the tanks can be avoided by carefully placing check valves in the fuel lines.

- Maintain Appropriate Ventilation: To avoid creating a vacuum that can start the syphoning process, make sure the fuel tanks are adequately vented. Air can enter the tanks through proper ventilation, balancing the pressure and preventing fuel from being pulled out.

- Optimize Tank Design: By adding baffles or partitions to the fuel tank layout, you can prevent fuel from syphoning out by erecting obstacles that obstruct the fuel's flow. By doing this, the fuel system's exposure to the syphon effect may be reduced.

- Control Fuel Pump Operation: One way to help avoid excessive fuel flow that could cause the syphon effect is to put in place a system that bases fuel pump operation on certain factors, including fuel level or pressure.

These techniques can help us avoid or lessen the siphon impact in the airplane fuel sequencing project, which will guarantee the fuel system's dependable and secure performance.

By maintaining the closed pipe system's outlet above the fuel level at the source and in the environment, we have employed the fundamental concept to avoid the problematic siphon effect.In order to ensure that the wing will have the room and rigidity to hold the necessary fuel and transfer system in place, the proper design and stress study on the wing connection has been done.

In order to improve the system's reliability and solve the issue of our design's excessive reliance on relays and Arduino components, we must streamline our control processes. By keeping Arduino components' burden to a minimum and making sure they are only handling necessary activities, we can maximize our utilization of them. This can be accomplished by breaking up functions into distinct components and using careful programming and modular architecture to more effectively divide the task. Furthermore, the danger of a total system failure can be reduced by including redundancy and fail-safe features in the control system. Through the simplification of our control procedures and the implementation of these steps, we can enhance the design's reliability and reduce the probability of unforeseen malfunctions.

A significant setback was experienced when flaws in the drop tank design were discovered later in the project, underscoring the vital necessity of rigorous prototyping and testing protocols from the outset. We have taken proactive steps to solve this problem, such as tilting the drop tank to maximize fuel flow and guarantee the simulation's effective presentation. Through the implementation of these modifications and the prioritization of thorough prototyping and testing over the course of the project, our goal is to proactively detect and address any potential design problems, ultimately improving the overall dependability and efficiency of our solution.

Chapter 8

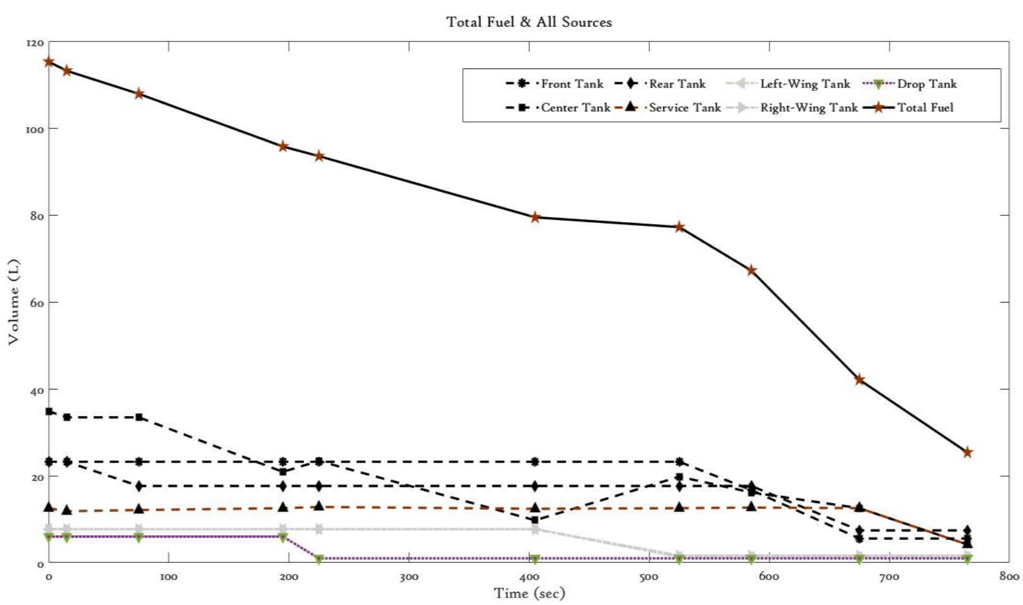
Result & Discussion

The provided data and graph offer a comprehensive view of the total fuel consumption in an aircraft fuel sequencing model.

The data reveals a steady decline in the total fuel volume over time. Initially, at 0 seconds, the total fuel volume is 115.250775 liters. As time progresses to 765 seconds, there is a noticeable decline in the total fuel volume to 25.35740421 liters. This indicates the consumption of fuel from various tanks including the front tank, center tank, rear tank, service tank, wing tanks, and drop tank. The drop tank plays a crucial role in the early phase of flight. It provides a rapid supply of fuel to the center tank.

This well-orchestrated sequence ensures that there's always an adequate supply of fuel being fed into crucial systems at all times while maintaining balance across different sections of the aircraft for optimal performance and safety.

In conclusion, the total fuel consumption data provides valuable insights into the operational strategies of combat aircraft. It underscores the importance of fuel management in enhancing efficiency and safety.



Chapter 9

Future Scope

9.1 Indication

A certain indication system has been arranged with indication light, but a better and more sophisticated indication system could be implemented.

9.2 Display

There is only display to indicate flow rate and fuel volume of different fuel tank. Now 0.96-inch display is being used for getting these data, but a much more integrated and user-friendly display panel can be implemented.

9.3 Fuel Filter

As of now no fuel filter has been incorporated. Fuel filter are essential and can be used for much accurate and fail free system.

9.4 Variable pump

The system is currently manufactured using a single speed AC submersible pump, but it can be adjusted and made more capable of simulating different fuel requirements based on the manoeuvre being performed and the different speeds at which the aircraft is being flown by using a variable speed and controlled pump.

CHAPTER 10

CONCLUSION

10.1 Findings

The project consisted of seven different fuel tanks, pumps, fuel control unit and a panel to showcase the automatic transfer of fuel system. Main conclusion is that modeling and simulation approach can be applied to determine fuel system behavior and its sequence.

10.2 Applications

- Troubleshooting test investigation for actual aircraft.
- Fuel management system can be improved by changing algorithm.
- Fuel gauges can undergo testing using this system.
- Ensure automatic fuel transfer without affecting CG balancing.

10.3 Strength and Limitation

The robustness of the system is, it gives crystal clear demonstration of automatic fuel transfer system which can be visualized in naked eye. This automatic system can be used in many different airplanes for real time monitoring or fault detection.

Although the system has promising results it is necessary to acknowledge the challenges faced during the work. Air to air fueling system can be incorporated and further investigation can be done.

10.4 Recommendations

The whole project is modular and component based. In case of difficulties any part can be replaced. For demonstration purpose user manual can be used for safety. As 220V is used, to avoid accident necessary precautions should be taken. Advanced software and improved method will reconfigure the whole system.

10.5 Conclusion

This fabrication and simulation results hold immense potential in reshaping fuel management system for more efficient, safer and reliable aircraft operations.

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