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## Aircraft Health Management Network: A User Interface

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# Aircraft Health Management Network: A User Interface

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## ABSTRACT

Network management is one of the most discussed topics in the networking fraternity. The efficiency of the network management suit is measured by the number of parameters/components handled by the application while making decisions. In the case of internet-enabled aircrafts, along with network security, even aircraft safety needs to be considered as a factor while designing the Network Management suit. This requires the Network Management suit to monitor/analyze the aircraft-related data (avionics data, physical security parameters, etc.) while determining the proper functioning of the overall system. Herein, these authors present a framework for Network Management suit that, along with network health, monitors inputs from avionics, video surveillance system, weather monitoring system, and manual pilot alarms, and based on the situation, reconfigures the on-board networking devices to stream appropriate flight-critical data to the ground station. The proposed framework attempts to provide a comprehensive user interface for the flight health monitoring crew with all relevant data.

## INTRODUCTION

Flight safety is one of the most important aspects in today's aviation world. Many safety/security initiatives have been proposed to ensure safe operation of flights. Statistics collected related to aircraft crashes [1] reveal that a large percentage of crashes are due to human error (either due to lack of attention or due to weather/equipment). Most of the crashes result in human life losses along with property damage. Every effort should be made to improve the safety of flights and reduce casualties due to human

error. FAA and DoT have taken several initiatives to improve the safety of flight.

Flight safety depends on several parameters including avionics, weather, passengers, and flight crew. While some of these could be controlled by human beings, others are dependent upon the mechanical components and nature. However, knowing the status of these parameters helps the flight crew in making appropriate decisions during stress situations; thus preventing unfortunate events.

Recent developments in the avionics industry have resulted in deploying more computing power within the aircraft. The availability of additional computing power could be utilized for improving the safety of the flight. The introduction of internet connection within the airborne aircraft provides access to additional resources; thereby improving the safety of the flight. Using the available internet connectivity, the flight crew can access knowledge database that contains best practices for various flight conditions. This helps to reduce the human error factor involved with flight accidents and improves the reliability of the air travel.

### Flight Safety Parameters

Safe operation of an airborne aircraft depends upon several parameters. Parameters like weather conditions, avionics components, and physical safety play an important role in flight operations [2]. While most of these parameters are beyond the control of the flight crew, monitoring these will help in the smooth operation of the aircraft.

### Weather

Weather is one of the most important parameters that control flight operations. Under the umbrella of weather, there are several parameters that affect flight operations.

### Temperature

Temperature is one of the most important parameters that affect flight operations. Temperature affects air density, wind direction, fog formation, thunderstorms, cloud formation, turbulence, and icing. These parameters have direct impact on the stability of the aircraft. Variation of temperature affects the visibility range when the flight is airborne.

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Variation in atmospheric temperature must deal with compensative measures to maintain aircraft stability.

#### *Atmospheric Pressure*

Atmospheric pressure varies depending upon the altitude and the temperature. As the altitude increases, the pressure decreases. The atmospheric pressure is also affected by the atmospheric temperature as, with higher temperature, air expands increasing the pressure. The change in atmospheric pressure affects the altitude readings (altimeter) as in most implementations altimeter measures the altitude using the atmospheric pressure.

#### *Wind*

Wind speed and direction are two major parameters that affect the flight operation along with other parameters. Change in wind patterns may result in an uneasy ride for the aircraft.

#### *Moisture, Cloud Formations, and Precipitation*

Aviation weather reports normally express moisture or dampness in terms of dew point and relative humidity. The temperature at which the air becomes saturated by the water vapor is called the dew point. The spread, i.e., the difference between the actual air temperature and the dew point temperature, leads to cyclic changes of states of water. The changing of water to water vapor, or ice to water, and the reverse processes involve the exchange of heat energy with the surroundings, termed as latent heat of fusion. If these parameters attain high values, it affects the flight adversely.

Relative humidity is the deviation of the actual humidity to the normal and acceptable humidity. The higher the temperature, the more moisture (or water vapor) in the air. Warm air rises through the cool air due to convection, and continues to rise higher and is called unstable air which leads to cloud formation. Cooler temperature on flight surfaces, sometimes due to cold fuel in the tanks, chills the external humidity which leads to high aerosol conditions such as cloud formation, or other forms of precipitation. This not only leads to icing on aircraft wings but also affects the visibility in fog or snow.

#### *Icing*

Icing is full of hazards for aircraft. Icing once started, conglomerates and severely affects aircraft efficiency by adding weight and drag, eventually stalling lift and thrust. Icing effects subsume false indications of flight instruments, distortion of the antenna shape resulting in the loss of radio communications, and loss of operation of control surfaces, brakes and landing gear, and inefficient engine performance.

#### *Air Density*

Air density directly affects the flight take-off and rate of climb. The density of the air is inversely proportional to temperature, altitude, moisture and humidity. When the air density is low, aircrafts requires more runway length for take-off with a poor rate of climb, and a faster landing approach with a longer landing roll.

#### *Visibility and Sky Condition*

Sky conditions predominantly affect the visual ranges of the flight. Minimum values of ceiling and visibility determine visual flight rules. Continuing VFR into adverse weather, where the pilot is primarily or exclusively responsible for *see-and-avoid* practices, results in easy chances of aviation accidents. Lowering ceiling or visibility requires accurate Instrument Flight Rules (IFR).

The sky conditions such as air masses, fronts, low clouds, haze, snow, fog, dew, and frost should be intricately monitored in order to prevent any icing and zero visibility of the aircrafts. Moreover, unstable air lifted to high altitude by fronts, sea breezes, and mountains sometimes cause thunderstorms and lightening which are always dangerous to aircrafts. Increased lightening frequency indicates thunderstorms. Planes flying in or adjacent to an active cumulonimbus cloud will have high chances of lightening strikes.

Nearby lightening can blind the pilot, impairing him momentarily, unable to navigate either by instrument or by visual reference. Lightening has been suspected of igniting fuel vapors causing explosions. Also, it introduces permanent errors in the magnetic compass, disrupt radio communication, and damage electronic navigation equipment. Hail is also a major weather condition which can cause direct physical damage to the airplane.

#### **Avionics**

The control system of the aircraft can be widely categorized into Electronic Control Systems, Mechanical Control Systems and Hydro-Mechanical Control Systems [3].

The primitive mechanical flight control systems used a collection of mechanical parts such as rods, cables, pulleys, and sometimes, chains to transmit the forces of the cockpit controls to the control surfaces. The need for performance and support for larger size has increased the complexity of these mechanical control systems by a large extent. An addition of hydraulic power to this system has overcome these limitations.

In a hydraulic control system the important instruments in addition to the rods, cables, pulleys and chains are the hydraulic pumps, pipes, valves and actuators. All of the factors affecting the proper functioning of these parts such as hydraulic pressure, materialistic challenges of the parts, and friction, should be carefully considered for smooth functioning of the entire control system.

Finally, the Electronic Control System is introduced in all new aircrafts today. They are software-driven systems which are not limited by mechanical constraints. The advent of fly-by-wire and electro-actuated flight surfaces has improved the flight safety by a large extent. One major requirement for electronic control systems (including software) is reliability. The system design reliability is expected to be 100%; i.e., no failures – example: Autopilot. The introduction of Electronics systems has improved the flight safety and has reduced fatal events due to human error. Moreover, these systems are easy to upgrade by adding new features.

## Aerodynamics

Theoretically, all the variables of *Bernoulli's Principle* as well as *Newton's Air Deflection Principle* are the major parameters of aerodynamics. However, practically, four forces; i.e., thrust, drag, weight, and lift are considered and categorized as major entities defining the aerodynamics of the flight [4]. Thrust should be equal to drag, and lift should be equal to weight. If drag is greater than thrust, then the plain will slow down and if weight is greater than lift the plain will descend. Also, there are three more vital factors studied in aerodynamics to control the direction of flight.

- **Pitch** – Upward/downward movement of the nose,
- **Roll** – Rotation around the longitudinal axis, and
- **Yaw** – Swinging turn, such as change of heading direction of the aircraft.

All of the factors affecting the major forces, such as performance of the propellers, gas turbine engines, rocket engines, coefficient of air pressure, coefficient of lift, aircraft velocity, airspeed, angle of incidence, angle of attack, and angle of sideslip, etc., and the major movements such as pitch, roll, and yaw should always be carefully considered and taken care of.

## Structure

The structure of the airplane and the total area of the lifting surface of the flight is the actual lift factor of the airplane. The body of the aircraft and the shape of the cross-section of the wing are carefully shaped as an aerofoil, which experiences enough controllable lift when passed through the atmosphere. All the movable control surfaces such as aileron, elevator, flap, vertical stabilizer (rudder), and the propeller are smoothly shaped to reduce the frictional forces and are designed to control the motion and direction of the flight.

## Passenger Profiling

Passenger profiling means collecting passenger's data related to his or her identity, character, or attitude. It also includes comparing the information given by the passenger (i.e., flight information data) with the information in government and commercial databases. It is an enhanced security measure whose factors are invisible to the public. The profile data may include nationality, but airlines insist that race, religion, and national origin are not screening factors. Many published reports show that factors widely include frequency of travel to certain destinations, passenger's travel history, whether the passenger is a member of the airline's frequent flyer program, and if the ticket was bought with cash or credit card. This profiling of passenger

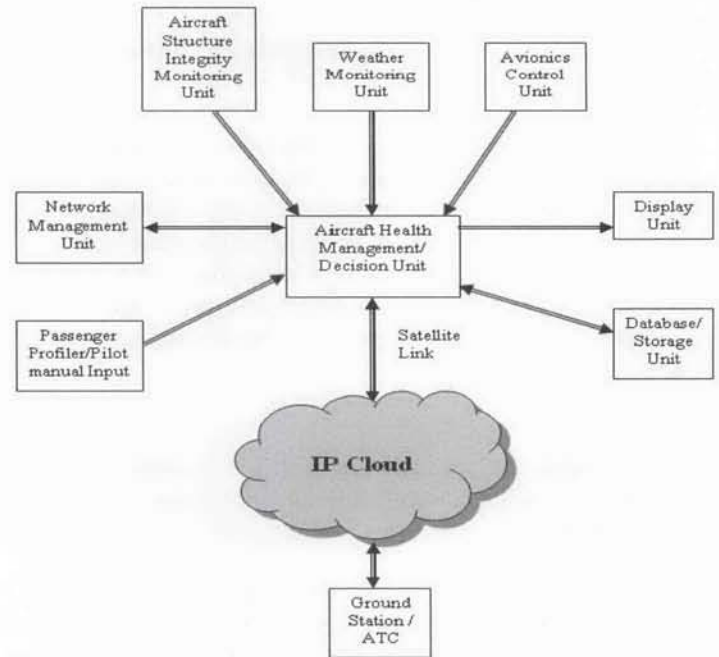


Fig. 1. Aircraft health management tool architecture

information helps identify threats and determining, in advance, which passengers pose the greatest risk.

## FLIGHT CRITICAL PARAMETER MONITORING

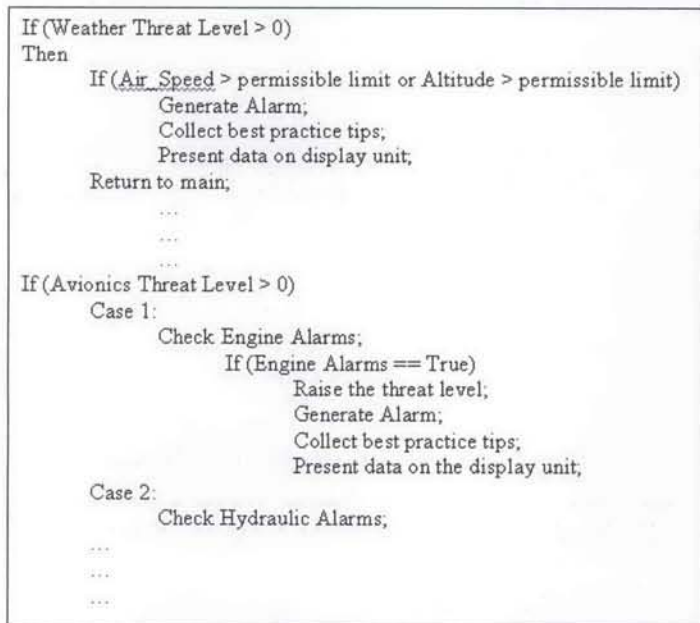
Along with the accuracy of any monitoring system, it is equally important that the person handling this equipment is instrument-qualified and aware of the effects of major flight parameters in detail, and is able to envisage the effects of in-flight observations.

## Weather Monitoring Systems

As a practice, clouds have always been the signposts in the sky. Pre-flight preparations should always include an intricate study of locations of fronts, clouds, possibilities of lightening, thunderstorms, and weather forecasting based on these studies. Concomitance of surface weather charts with illustrated locations of fronts, forecast charts with special analysis are very much needed for flight planning.

Aircraft requires weather radars such as ARINC 708 and lightning during night flights or in instrument meteorological conditions. The following are three recent developments in cockpit weather systems [5].

1. Development of inexpensive lightning detector systems such as Stormscope or Strikefinder;
2. Advanced availability of weather reports, weather observations, and extended radar pictures (such as NEXRAD) through satellite systems; and
3. Integration of data into a single screen.



**Fig. 2. Logical Operation of the Decision Unit**

### Data Logging Systems

OPHIR Corporation came up with Lidar (light detection and ranging) Optical Air Data System (OADS) based on "SenseAir" technology that studies the atmosphere outside an air vehicle and provides information of the environment – including temperature, pressure, and velocity [6]. These parameters are useful for flight control systems, as well as turbulence detection and wind profiling. Avionics Bay Environment Data Logger systems and their sensors record vibrations, temperature, pressure, humidity, and acceleration, which directly impact the design, cost and performance of avionic systems. The data stored on the storage medium should be accessible via any off-the-shelf work station. The data logging system needs to meet applicable environmental conditions laid out in ASSC/210/2/57.

### Collision-Avoidance Systems

Collision-avoidance systems [5] are used to detect the location of other nearby aircraft, and provide instructions for avoiding a midair collision. "Controlled flight into terrain (CFIT) avoidance system" uses systems such as ground-proximity warning systems (GPWS) along with a radar altimeter to alert pilots if their aircraft is in immediate danger of flying into the ground. For this reason, they are sometimes called ground-collision warning system (GCWS). Newer systems such as enhanced systems (EGPWS) use GPS combined with terrain and obstacle databases to provide assistance to light aircrafts.

### Fly-by-Wire

Fly-by-wire is one of the latest innovations in the field of aircraft design [7]. Fly-by-wire helps the flight crew in controlling the aircraft during frequently changing aerodynamics conditions. Fly-by-wire has electronics

displays that present the flight crew with various system parameters. The signal processing is performed by digital computers in a digital fly-by-wire flight control implying that the pilots can "fly-via-computer."

### Intelligent Control Systems

Intelligent flight control systems is an extension to the fly-by-wire system. An intelligent flight control system is built around the theory of automation where the system compensates any damage/failure of components by automatically modifying avionics parameters like engine thrust. This helps in critical conditions where the pilot has exhausted the options to safely fly the aircraft.

### Computer-Assisted Passenger Pre-Screening System (CAPPS)

It is an automated screening system based on passenger profiling which is aimed at separating out the number of risk potential passengers who should be subjected to additional security measures [8, 9]. Profiling is initiated when a passenger makes a reservation. Using passenger profiling and data analysis technology under development by Lockheed Martin Management and Data Systems, the computerized system; i.e., CAPPS II, has developed a risk assessment score for each passenger, and alerting authorities of passengers who may pose an increased security threat to the flight.

### AIRCRAFT HEALTH MANAGEMENT TOOL

Previously, these authors presented methods of collecting flight-critical data when the aircraft is airborne. One of the major aspects that need to be noted here is that while every parameter is collected individually, the flight crew needs to combine these outputs and make inferences manually. While the current system works well in most situations, it may not be very effective in stress situations. In situations involving flight safety, it might be useful if the flight crew were given an analysis of the situation that combines various flight-critical parameters along with best practices in that given situation. This will help the flight crew in making correct decisions and avoid fateful events involving human life.

Herein, these authors attempt to address this scenario and propose a framework that presents flight-critical data in more intelligible manner. This framework also helps the flight administrators in sending flight status data to the ground station in real-time and avails additional help to the flight crew in critical situations.

### Aircraft Health Management Tool (AHMT) Design

The aircraft health management tool will supplement the current system implemented within the aircraft. The basic framework of the Aircraft Health Management tool will have a core unit along with several sub-units, each handling different operating parameters for the aircraft. Figure 1 presents the basic framework for the AHMT.

### Core Unit (Decision Unit)

The Decision Unit is the core of the Aircraft Health Management Tool. It controls the overall operation of the tool along with determining the threat level of the aircraft at any given time.

Figure 2 represents the logical operation of the Decision Unit. The decision unit obtains its inputs from various subunits, from the ground station and from the flight crew. Depending upon the input values, the decision unit determines the threat level for the flight at that time. The present threat level along with threat level for each constituent sub-unit is displayed on the screen for the flight crew. In addition to displaying the threat level, the proposed architecture searches the database located within the flight, as well as the global database (located in the ground station) for remedial actions, and displays options to the flight crew.

### Weather Monitoring Unit

This unit is responsible for monitoring weather parameters including wind speed, air pressure, and dew point and raise alarms when there is an anomaly with respect to weather. Figure 3 represents the design of the weather monitoring unit while Figure 4 explains the logical operation of the weather monitoring unit. The weather unit collects inputs from on-board sensors as well as from the ground station database. Along with that, the weather unit will also have an option for the flight crew to feed information that they collect through CPDLC. The connection to the ground station database will ensure that the aircraft gets up-to-date information along with a prediction for future course. This will help the flight crew make decisions regarding course, speed, and altitude.

### Avionics Control Unit

This unit is responsible for interacting with avionics components including hydraulics, electrical systems, and mechanical systems. The avionics control unit also gathers input from the weather monitoring unit as parameters like speed, altitude, and direction depend upon the current weather. Based on these inputs, the avionics control unit determines the current threat level and updates the decision unit with the same. Figure 5 shows the design of the avionics control unit.

### Aircraft Structure Integrity Monitoring Unit

This module is responsible for alerting the flight crew about structural damage that might incur during the flight. This includes aircraft body, wings, and wheels.

### Network Management Unit

This unit is responsible for monitoring/maintaining network operations within the aircraft. The Network Management Unit consists of an Intrusion Detection System (IDS) that will ensure the security of the network. At the same time, the SNMP engine will collect information from all networking elements pertaining to network health. The decision unit has exclusive rights over the networking elements; during stressful situations, it can force the Network

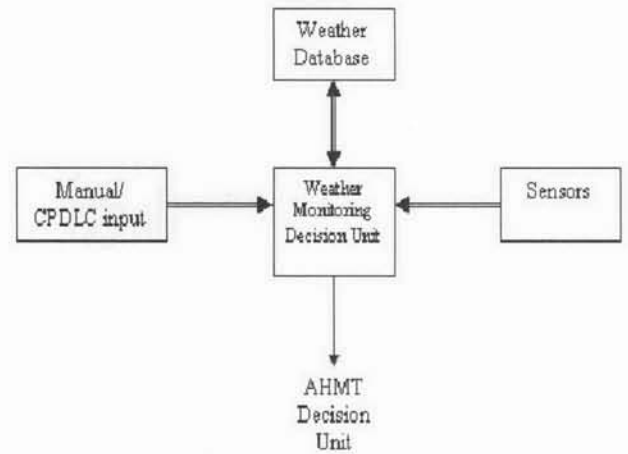


Fig. 3. Weather Monitoring Unit Design

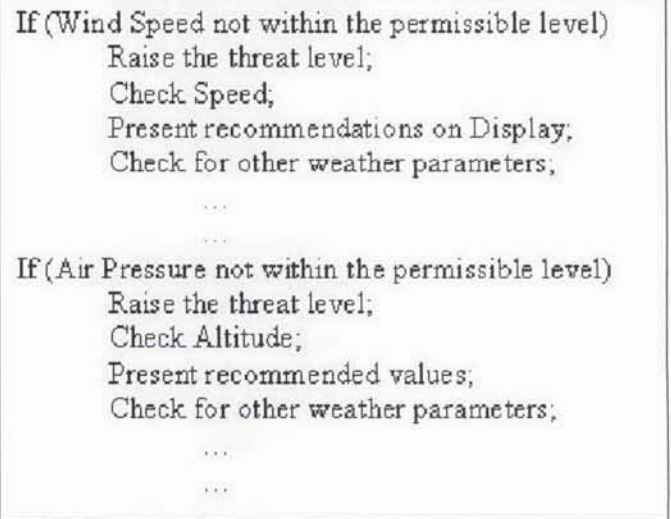


Fig. 4. Logical Operation of the Weather Monitoring Unit

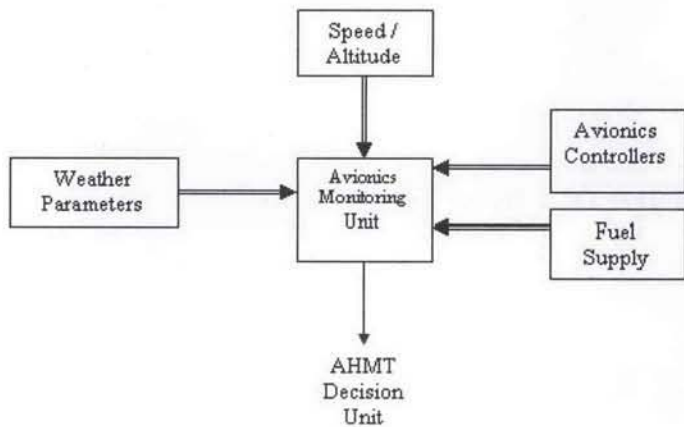
Management Unit to reconfigure networking elements to transfer flight-critical data to the ground station in real-time, blocking user traffic. Figure 6 represents the design of the Network Management Unit.

### Passenger Profiler/Pilot Manual Input

This is an optional unit intended to add an additional layer of security to the aircraft. Including this module ensures that, during flights involving persons of dubious background, enables the on-board surveillance system and transfers the video to the ground station on an on-demand basis. This will help ground crew in assessing the situation within the aircraft during stress situations.

### Database Unit

This is an off-the-shelf module used to store flight-critical information within the aircraft. Along with storing flight-critical information, the database unit will also house information regarding best practices under various weather/avionics conditions. This will help the flight crew in making speedy decisions and avoiding fateful events.



**Fig. 5. Design of Avionics Monitoring Unit**

#### Display Unit

This unit could be either an interactive or off-the-shelf display unit placed within the pilot cabin and presents all data collected by the decision unit and sub-units to the flight crew in a more intelligible manner. This may prove useful during stress situations involving flight/passenger safety.

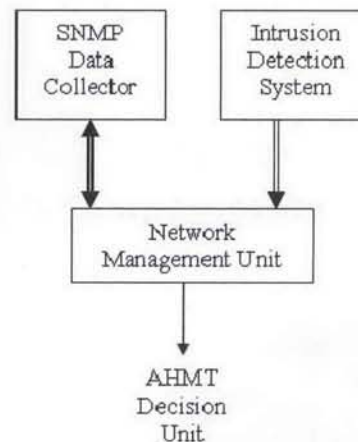
#### AHMT Implementation

A major factor to be considered while implementing any component related to aircraft is the reliability. As mentioned earlier, this proposed system will supplement the current system and help the flight crew in making correct decisions at crucial times. These authors propose implementing most of the system (including decision units, avionics monitoring units, and network management units) in software. The software is being developed on real-time operating system environments as embedded system software. This will ensure that the system is optimized toward the operation for which it is designed. Modules like Weather Monitoring Units and Passenger Profiler/Pilot Manual Inputs need additional hardware to collect information from sensors and cameras. The authors propose using off-the-shelf server units to implement the above-proposed design.

#### CONCLUSIONS AND FUTURE WORK

Herein, the authors presented a framework to improve the aircraft safety when the flight is airborne. The proposed system collects information from various aircraft critical components and determines the threat level based on thresholds. Along with presenting the threat level, the proposed system avails best practice tips to the flight crew in a given situation. This helps the flight crew to make appropriate decisions and improve the safety of the aircraft.

While herein, these authors presented the framework and the theoretical architecture, as a future work these authors



**Fig. 6. Design of Network Management Unit**

If (Passenger has dubious background)  
 Activate Video Surveillance System;  
 Increase Threat Level;  
 Reconfigure Network to allow video traffic to the ground station;

**Fig. 7. Logical Operation of Passenger Profiler Unit**

will work toward implementing and testing the proposed architecture. It will be interesting to evaluate the effectiveness of the proposed system in a real-time environment.

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