ENHANCING CURRENT AIRCRAFT COMMUNICATIONS ADDRESSING AND RECORDING SYSTEM (ACARS)

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DECLARATION

I declare that the work in this Research project has not been previously published or submitted elsewhere for award of a degree. I also declare that this my own original work and contains no material written of published by other people except where due reference is made and author duly acknowledged

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ENHANCING CURRENT AIRCRAFT COMMUNICATIONS ADDRESSING AND RECORDING SYSTEM

ABSTRACT

To many people travelling is a normal routine in life. During every day to day activity the issue of transportation does not linger in our minds as it is a norm. However, this is only realised when a horrific accident happens and we identify the role of secure transits policies. In the aviation industry this phenomenon is no exception. Aircrafts usually move around the world and bare air is their transmission line. To enable safe movement of these aircrafts all airplane communications are conducted through a uniform platform referred to as an Aircraft Communications Addressing and Recording system. This protocol was first introduced in the late 70s and used dedicated telex formats to transmit data. All voice communications carried by this protocol are done over a VHF link. Over the years the VHF has been constrained by the additional data produced. This is because of the increasing number of aviation industry players. To further constrain the same, the current ACARS system consists of communications hardware as well as applications subsystems and these components have changed significantly due to the changing aviation needs. This means that the length of message is constrained in the current communication platform. In effect, pilots receive information that is either incomplete or so limited that they are unable to make effective judgement on plane routing. Messages between the controller tower and the flight crew are usually not encoded. With this in mind it means that such communication is subject to interception and may be used for other malicious purposes. The major objective of this research is to develop an air/ground communication standard to support existing applications while minimizing impact on installed equipment. The problem statement and specific objectives are clearly stated to guide the researcher.The study presents a review of related literature on the subject under study as presented by various researcher scholars' analyst and authors. The researcher also examined the various characteristics of the proposed incorporation of data links to improve the current ACARS and the attributes of the data link. The researcher has examined the methodologies used, evaluated the methodology approaches and described reasons behind the choice of the proposed methodological approach. As a result, if implemented the airline industry will be able to serve the steadily growing consumer needs all over the world since safety concerns of all aircrafts is essential for a competitive and growing world. With the changing business icons and dynamics the aviation industry is finding itself being the most reliable way of goods movement. In the event that the safety of these airlines is not maintained then it would be an economic disaster. At the same time the aviation industry is home to millions of jobs which might be lost in the event of disasters.

Key words:

Gaussian Frequency Shift Keying

National Airspace

Cryptography

Very High Frequency

Aircraft Communications Addressing and Reporting System

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Lastly, my family who gave me their love and support in the most challenging times of my life and made me realize the value of an education.

DEDICATION

This thesis is dedicated to my family who supported me with their love and encouragement through this long and windy academic pursuit by gently encouraging me. Special thanks to my Lord for his providence and divine guidance

LIST OF ABBREVIATIONS

ACARS	Aircraft Communication addressing and Recording System
VHF	Very High Frequency
AIM	Aeronautical Information (handbook)Manual
ATSAT	Aviation Topics Speech Act Taxonomy
FIS	Flight Information Service
TRACON	Terminal Approach Control
ELT	Emergency Locater Transmitters
AM	Amplitude Modulation
NAS	National Airspace Structure
ICAO	International Civil Aviation Agency
ANSPS	Air Navigation Service Provider
ATN	Aeronautical Telecommunication Network
VDL	VHF Data Link
AMSS	Aeronautical Mobile Satellite Service
ATS	Airline Terminal Service
MAC	Media Aces Control
AOC	Airline Operator Communication
ISO	International Standardization of Organization

OSI	Open System Interconnections
IP	Internet Protocol
AEEC	Airline Electronic Engineering Committees
ARINC	Aeronautical Radio Incorporated
ATM	Airline Traffic Management
ADS – B	Automatic Dependent Surveillance – Broadcasts
GNSS	Differential Navigation Satellite Systems
SMGCS	Surface Movement guidance and Control Systems
CPDLC	Controller pilot Data Link Communications

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Aviation security is a study of flight breakdown, and the prevention of such breakdowns in future by provisions of regulatory frameworks that will guide aviation industry stakeholders in development of security solutions in the aviation industry

In the 1920s, laws were passed in the United States of America to standardize aviation and the Air Commerce Act 1926 was of more significance.This required the flight crew to be examined and permitted, for accidents to be appropriately inspected. The development of these rules under the department of Commerce were well received. These incidents haves declined steadily ever since. A large number of crashes occur largely as a result of bad weather conditions and in other aspects of safety is the obvious protection from current attacks commonly known as known as aircraft security. For instance the terrorist airline attacks of 2001 are not recognized as accidents. In this view major safety significance have resulted from engineering and maintenance, improved aircraft design, the evolution of navigation aids, and safety protocols and procedures.

Information exchange among flight crews, traffic management, controllers, and Airline Operation Centers (AOC) / Flight Operation Centers (FOC) is often imbalanced, resulting in inefficient planning, excessive time lapse, and a need for additional communication to compensate for information quality and timeliness. These constraints reduce the scope of planning and narrow the ability of all users to make dynamic, strategic decisions, thus reducing flexible NAS operations. Reliance on voice communications for NAS information can limit flight crew access to shared NAS services and information.

NextGen requires an appropriate air-ground data management and information exchange mechanism to support increased pilot access to relevant NAS information for flight planning. AAtS is the air-ground solution that gives flight crews access to this information available through a shared information source that will promote a common SA between aircraft operators, controllers and air traffic managers. AAtS will use existing NAS and aircraft infrastructure (e.g., SWIM, Federal Aviation Administration [FAA] Telecommunications Infrastructure [FTI], and Portable Electronic Devices [PEDs]), with commercially developed software applications and data communication links necessary for securely accessing the SWIM Service Oriented Architecture (SOA) FTI Network.

The 2006 Advisory Circular titled Introduction to Safety Management Systems for Air Operators came up with the idea a Safety Management Approach to aviation service providers asking for a systems approach to creating a Risk Control process to enable organizations to process safety information, both proactively and reactively. This in turn would help in developing alternative actions that get results in terms of reducing accidents. This approach was specifically built to systematically identify the risks and then decide the way forward in reducing aircraft disasters.

Development of new and advanced methods of flight monitoring is one of the aspects information technology is providing to the aviation industry. In this view then the airlines cannot afford not to develop the best practices in aviation safety management. Over the recent years, many aircrafts have come tumbling down and the results have been catastrophic. The airline management cannot sit back and rely on the old methods of flight management. It is with this view that this study intends to develop an air/ground communication standard to manage communications between controller towers and the flight crew members.

1.2 Definition of Terms

Aviation Very High Frequency Link Control. A protocol used for aeronautical datalink communications.

Communication Management Function. It is a programme that runs in the Communications management unit.

Communication Management Unit. It is a datalink that executes most avionics routing activities among other tasks

The HF data Link : It is a communications platform used to transmit data between the cockpit display unit and the controller tower interface.

Line Replaceable Unit. This is an avionic-black box like device

Multifunction Control Display Unit. This is a device that displays text based information on the flight crew platform

OOOI. This is a short form of Out of the gate, Off the ground, On the ground, and In the gate.

1.3 Problem Statement

ACARS is a path between which data from a cock pit display unit is transmitted. This technology was designed in the late 70's. The technology is found under the famous telex communication protocols to exchange data between stations. Initially it used VHF exclusively to transmit but with the recent changes in the aviation industry it has been upgraded. However, this has not been fully achieved and therefore need for more development.

The Aircraft Communications Addressing Recording System messages transmits three types of signals based upon their content.

Air Traffic Control (ATC)

These types of messages are initiated between the controller tower and the flight crew members. They help the flight crew members to get clearances and en route details of the flight. However the current ACARS has not realised its full potential as far as transmission of these messages are concerned.

Aeronautical Operational Control (AOC) and Airline Administrative Control (AAC)

These messages are used for communications between the plane and its base station and therefore they have a definite shape depending on the ownership of the plane. Information transmitted through them include any technical uploads experienced along the way.

The basic architecture of the ACARS is divided into three major parts. These are:

The Aircraft Equipment

The ACARS apparatus aboard an aircraft is reffered to as the Management Unit and it usually acts as a router . The fligh crew members access information from this equipment via the installed CMU’s on the plane.

The Service Provider

This is a DSP responsible for the transmission of messages via the radio link.

The Ground Processing System

The GPS is the responsibility of a participating An Air Navigation Service Provider (ANSP) or an craft Operator. Most of these operators tend to hire a third party to manage all interactions between these systems. In the event there are automatically-generated ssets of information a similar platform is set to allow the message to be routed to the sole intended recipient.

Despite the major improvements in relaying of messages between ground stations and aircrafts users (pilots, air traffic controllers, and operational management) the world is still experiencing massive loss of human resource, finances, time and long term effects as a result of crashing of aircrafts.

Recently in Kenya, a helicopter carrying top government officials crashed killing all on board. According to the Standard Digital Web Reporter, the preliminary probe pointed at poor weather with locals saying it was misty when the aircraft crashed. The helicopter left the Wilson Airport at about 8.20am and the pilots were informed the next destination was Kericho. Investigators said they were studying the communication between the pilots and the controller to establish what might have caused the crash. Major accidents that have happened including the famous Tenefry tragedy are alleged caused by poor weather conditions or poor communications between controllers and the pilots. In turn pilots tend to make human judgement without adequate information harbouring their ability to navigate through the poor weather conditions. Additionally, frequency interference due to poor weather can result in poor delivery of messages hence uninformed pilots will end making their own decisions which might jeopardize the entire flight plan.

1.4.1 Purpose for research

Accessing information on a timely manner is critical in today's highly competitive environment irrespective of the size of the organization being served. The process of flight data monitoring allows aircraft users to capture raw data and translate it into actionable information which will basically be of importance in assessing aviation accidents. Being in a position to make best decisions out of information is the best thing that could ever happen hence with cost and safety savings more than justifying the cost of setup and maintenance, today's airlines have to establish a program to materially examine their communications. These data recorders can be utilized in both ways i.e reactively (after the accident) and proactively (to monitor precursor events and data needed for an SMS).

Gathering information from flight data recorders is a must aspect of any airline. Other than establishing the major causes of accidents the airlines will be in a position to develop planes fitted with such gadgets to mitigate future aviation risks. It is therefore paramount for any organization to develop such a communication standard.

Due to the increased number of data being produced on a daily basis, it is important for airlines to come up with satisfactory storage platforms to store generated data. The dynamics of business today have changed. If airlines will have to cope up with such dynamics it is important to adopt latest technology to create better communication tools. This research therefore aims at investigating protocols in aircraft communications addressing and reporting system and how to improve them to meet today's aircraft potential causes of distress.

1.4.2 Specific Objectives

The major objective for this study was to develop an air/ground communication standard to support existing applications while minimizing impact on installed equipment.

This research was guided by the following specific objectives.

- To identify appropriate band filters that can filter off interfering signals from neighbouring transmissions.
- Identify encryption protocols to safeguard communications between ground and air communications.
- To design a storage platform that will provide additional data link capacity to satisfy additional system demand.
- Test, validate and gain operational experience with the proposed standard

1.5 Justification of the study

Communication is the key in making tasks happen. Without proper communication then many aspects of management including planning, organization, staffing, decision making will be just but a hunch. In the view of development of terrorist changing attacks, planes are well positioned to be attacked as there is no physical contact of the employees at the controller and the pilots. With this realisation an attack can take at any time and place. The airline industry is steadily growing to serve consumer needs all over the world. Safety concerns of all aircrafts are essential for a competitive and growing world. It is in this perspective that this research proposal intends to improve on the quality of communications carried out between ground and air stations through improving of existing aviation communication protocols and methods.

1.5.1 Significance of the Study

No matter what transport mode, accidents always reduce confidence in the safety of the transport system. Accidents can lead to death or injury and can cause environmental and economic damage. This is why independent investigations of accidents and incidents are important as they help to improve transport safety. Analysis of the circumstances of accidents leads to recommendations being made to prevent these dramatic events from re-occurring in the future.

While some of these air hazards have caused airplanes to crash, these instances have provided researchers and aviation authorities with additional information to prevent them from occurring again. Recognizing these air safety hazards, aircraft crews understand how to reduce risk and address problems effectively. Many travellers may consider the additional time spent on correcting these issues as a hassle, however, it is important for commuters to always remember that these additional steps are taken to maximize the safety of the airplane, its commuters and the crew.

This research aims to use data collected from previous accidents, near accidents, aviation practices, developed and developing policies to improve on safety in the aviation industry hence improve aviation safety in general by education and promulgating the lessons learnt from accident investigations.

1.5.2 Scope and Limitations of the study

The purpose of this study is to develop an air/ground communication standard to support existing applications while minimizing impact on installed equipment. The attainment of the ambitious goals of the research will require a substantial increase in funding and timeframe. If funding and time is made available, the researcher could expand the research in aviation human factors and attain better understanding of the phenomenon under study.

The researcher might get hindrances in accessing various resources and lack support from organizations and participants keeping in mind the area under study is very sensitive and participants might feel at jeopardy while releasing classified data.

However, the proposed standard have been collected in the field, using the Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) simulation software. Since DESIREE provides extensive data collection capabilities The simulation platform is intended for rapid application development commonly known as prototyping and therefore best suites this study. This aspect will give a clear picture of what the research intends to achieve.

This research will establish and implement standard procedures to document and share control information, such as frequency changes, contact with pilots, and the confirmation of the receipt of weather information, at air traffic control facilities that do not currently have such a procedure. These procedures should provide visual communication of at least the control information that would be communicated by the marking and posting of paper flight-progress strips described in Federal Aviation Administration Order 7110.65, “Air Traffic Control.” The research also aims at pointing out the importance of making traffic controllers to use standard phraseology, such as “on guard,” to verbally identify transmissions over emergency frequencies as emergencies.

The research was conducted between September 2012 and March 2013. The base of research was Tropic Air – Nanyuki Station.

1.5.3 Assumptions of the study

Commercial commuter demand is projected to experience has significantly grown over the years due to environmental changes of a business. International commuter activity is expected to continue to grow at a souring pace. Among the most pronounced changes in fleets in recent years has been the replacement of turboprop aircraft with regional jets. The growth in regional jet traffic has primarily been limited by the ability of the manufacturers to produce sufficient new aircraft to meet demand. The continued growth in regional jet use is expected to drive an increase in the average seating configuration of regional airline markets. A number of other general assumptions and factors affecting improved flight safety were also considered in the forecast exercise including, but not limited to, the following:

- Improved commuter confidence in aviation security will return.
- At least during the research period there will be no new commercial service airports will be constructed in the region during the forecast period.
- Industry observers have considered the impacts of communications technology on air travel demand. No reliable empirical evidence has surfaced to date that quantifies the impact of technology on air travel demand. Therefore, it is assumed that air travel demand will not be adversely impacted by teleconferencing during the forecast period

This work describes the elements that make up a Flight data monitoring (FDM) programme and examines what the costs are, to run such a programme by describing the range of benefits available. It is assumed that these benefits are quantified with data taken from the base of study to reflect the state of other airlines that have established FDM programmes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction to Flight Data Monitoring Programmes

The introduction of new technologies into the National Airspace System (NAS) will significantly alter the role of the Air Traffic Control Specialist (ATCS). As the Federal Aviation Administration (FAA) moves forward with NAS modernization and the implementation of Free Flight concepts, the ATCS will move from a controlling role to a collaborating role (Office of Air Traffic System Development, 1997). With increases of up to 60% expected in air traffic over the next decade, automation will play a significant role in supporting the NAS and the ATCS (Office of Air Traffic System Development). The ATCS will be able to approve more user requested routes with the assistance of automated decision support tools (DSTs) (Federal Aviation Administration, 1999). As outlined by Kirk, Heagy, and Yablonski (2000), the anticipated benefits from the use of DSTs will encompass increases in safety, efficiency, and ATCS productivity.

The main objective of Air Traffic Control (ATC) is to improve and maintain safety. Information stored in the computer in the form of bits. The stored bits are usually retrieved from computer memory for manipulation by the microprocessor.Kagawa (2008). The computer system is made up of logic that works only with two states “ON” and “OFF”. For computer to process information, The information computer can store and process. The two states of “ON” and “OFF” are usually represented by the Binary System of numbers. This is a number systems that we are used to, by contrast, uses “0” and “1”. The decimal number system that we are used to, by contrast, uses 10digits (0,1…..9). The decimal number system has been used since time immemorial for counting because it naturally represented the ten fingers of human beings. In the binary system, the “0” is used to represent the “OFF” state and "1" the "ON" state in the computer. For this reason binary numbers – consisting of only "0s" and "1s" are used to represent information in a computer. When applied to computers, each 0 or1 in the binary system, is called bit which stands for binary digit. A single bit alone cannot represent a number, letters and special characters. To represent information, bits are usually combined into groups of eight. A group of eight bits is called a BYTE. Each byte can be used to represent a number, letter (character), and/or special characters (such as ? or $). A combination of bits, that is "0s" and "1s" can be used to represent the complete alphabet, the decimal numbers 0 through 9, special characters.

2.2 Areas of application of Aircraft Communications Addressing and Reporting System

The aviation industry has introduced automation into the working environment with the goal of increasing safety and efficiency in addition to supporting the continued growth of air traffic. In effect the confidence of transversing the entire world using air as a mode of transport has greatly taken shape. With this in mind a conducive tool of communication is important in order to handle the numerous plane flights taking place every second. The aircraft communications addressing and recording system is used for various addressing and reporting purposes which include but not limited to :

Task	**Brief**
Notifications	Notifly is available to the public via their mobile phone and will send a message automatically to that phone when the requested flight is delayed, or indeed early on its scheduled time of arrival.
Passenger Information List	A PIL must be provided to the crew whenever there are deportees or disabled passengers onboard the aircraft. Sections 3 and 4 of the full PIL may be forwarded to the crew for reference, or the information can be sent directly to the flight deck as an ACARS message.
Brakes Off	These are several reports that crews are releasing the parking brake prior to all ground equipment being clear of the aircraft in an effort to

	improve OTP, with the inherent danger from an air bridge still attached to the aircraft. Safety always has priority over OTP, please do not release the brakes until the ground equipment is clear.
Met Chart Validity Times	These charts have a valid time indicated on the chart which is a "snapshot" of what is expected at that validity time. Such charts do not have a "validity period".
QNH and Cold Weather Corrections	Corrections to MSA and **procedural** altitudes are reasonably straight forward. These corrections should be applied as a percentage of the altitude. When under *radar control*, ATC will increase the Minimum Vectoring Altitude (MVA), where required to correct for cold temperature errors
Red Lightning Warnings	The red warning may be lowered despite extremely heavy rainfall, and several inches of standing water still evident on the operational surfaces. Crews are reminded that flight safety is paramount, on time performance takes a very firm second pace in such conditions. It may be prudent to allow some time for standing water to dissipate after such heavy rainfall, and consider use of contaminated runway RTOW data as a precaution against large amounts of standing water on the runway surface, that may not be evident until well into the take-off roll.

2.3 Review of Technologies and Technological Capabilities

Air/ground communication standard

Communication is the key in allowing managers to make decisions at all levels of management. In the aviation industry it is not an exception. Most of the decisions made by pilots and controllers are basically routed via machines which are of course subject to errors. The air-ground communication standard is an appellate feature that allows the craft crew and members on the ground to communicate effectively without any kind of errors. The current standard allows to transmit both text based as well as voice messages over possible VHF. However because of the various technological advancements that have taken place in the recent past, most airline companies are changing the way they do business.

It is quite important for the system to match up to its system integrity as this automatically says much about the scenario in hand.

Existing character-oriented data links in air/ground communication equipment.

According to An ICW research conducted between March 6-8, 2012 in the NIEC at the WJHTC to identify current information flow, flight operations, and information needs based on what is available from ATM systems today. Eight retired Airline Transport Pilots (ATP) participated. These participants first received a briefing on the AAtS concept including its anticipated uses and capabilities, and then they took turns actively flying in two departure scenarios and two arrival scenarios[1] using an Airbus 320 (A320) cockpit simulator integrated with the ATM simulators in the NIEC. Participants also performed over-the-shoulder (OTS) observations of Subject Matter Experts (SME) working as Tower, Air Route Traffic Control Center (ARTCC), and Terminal Radar Approach Control (TRACON) controllers while they controlled simulated traffic in one arrival scenario and one departure scenario both impacted by weather conditions. These OTS observations supported discussion led by the principal investigator that further identified pilot information needs, and the information gaps AAtS could fill, in particular, information from ATM personnel and ATM systems that pilots do not have access to today. Two Human Factors Engineers (HFEs) led the study design and development of the experimental materials such as the experimental tasks and procedures. Pilot and ATC SMEs lead scenario development and validated operational procedures used in the experiment to ensure realism. For each day of the study, the HFEs explained the study and informed consent policy, and provided training on the airspace and research equipment used for this simulation. Additional SMEs were on hand to assist with training. The HFEs managed the experiment and collected data with assistance from Booz Allen Hamilton. System operators started the appropriate systems and prepared the equipment for each run. Support engineers ensured that all hardware and software functioned properly.

VHF communications

According to the Adam (1998), the simulated airspace combine departure sectors 46 and 96 in a south traffic flow operation. All departures use the east side of the airport and departed from runway 17R and the confederate tower controller issued participants progressive taxi instructions to the departure end of 17R (full length at EF, from Gate A using J Y to K or L to EF). The Departure Procedure (DP) use the DARTZ FOUR (RNAV) DP (**Error! Reference source not found.**). Once airborne, the tower controller switches to the flight to departure (TRACON) and from there the departure controller give participants vectors, as participants request, to deviate around convective weather. Once the flight is clear of convective activity, participants are given clearance direct BILEE (a departure fix on the DARTZ FOUR DP) and on course to their destination. This communication is done via VHF. Every microprocessor has a clock that drives its operation. Microprocessors with faster clocks perform operations much faster compared to those with slower clocks. To illustrate how the speed of their operation, suppose that a slow and fast microprocessor are used to ADD 4 to 7. According to the Electronics Journal 2012 vol 12,m icroprocessor speed refers to its clock speed, measured in Megahertz – MHz (million cycles per second). The speed of a microprocessor gives its power – the higher the speed the more powerful the microprocessor. The IBM microcomputer, which has become the industry standard microcomputer uses microprocessors manufactured bu Intel Inc. ADD 4 to 7 is a typical instruction or command that would normally be given to a computer to execute. It requires that the ADD instruction as well as the data 4 and 7 to be added should be fetched. This is then followed by a decoding phase before the instruction is executed. The fetching, decoding and execution of a simple instruction constitutes an “instruction cycle”. An instruction cycle is broken down into several “machine cycles”. In every machine cycle, the microprocessor performs one operation. The operation performed within machine cycles are those that involve the interaction of the microprocessor and its external devices, such as fetching/storing an instruction/data from /to memory. Operations that are processed within the microprocessor such as the actual addition, subtraction , etc. taken negligible time are never bothered with.

Accordingly to Prinzo and Britton (1995). each statement or phrase is coded into one of five categories. One person codes the communications, and works with a pilot SME to develop the categories to suit our simulation and ensure proper placement of communications. After transcribing the recorded communications, each statement or phrase is coded into one of five categories:

1. Address/Addressee,
2. Courtesy,
3. Instruction/Clearance,
4. Advisory/Remark, and
5. Request.

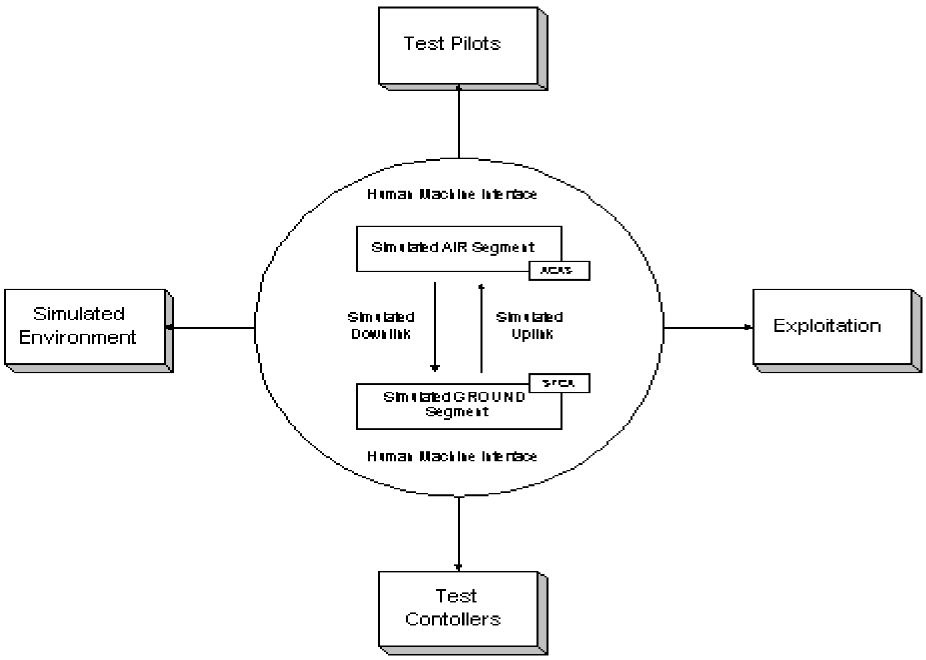

Fig 2.1.Simulation platform schematics

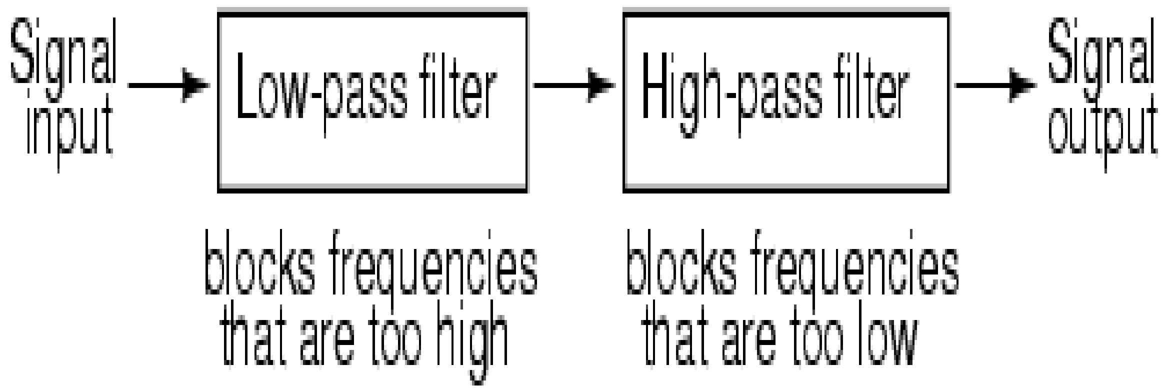

Fig 2.2 System level block diagram of a band-pass filter

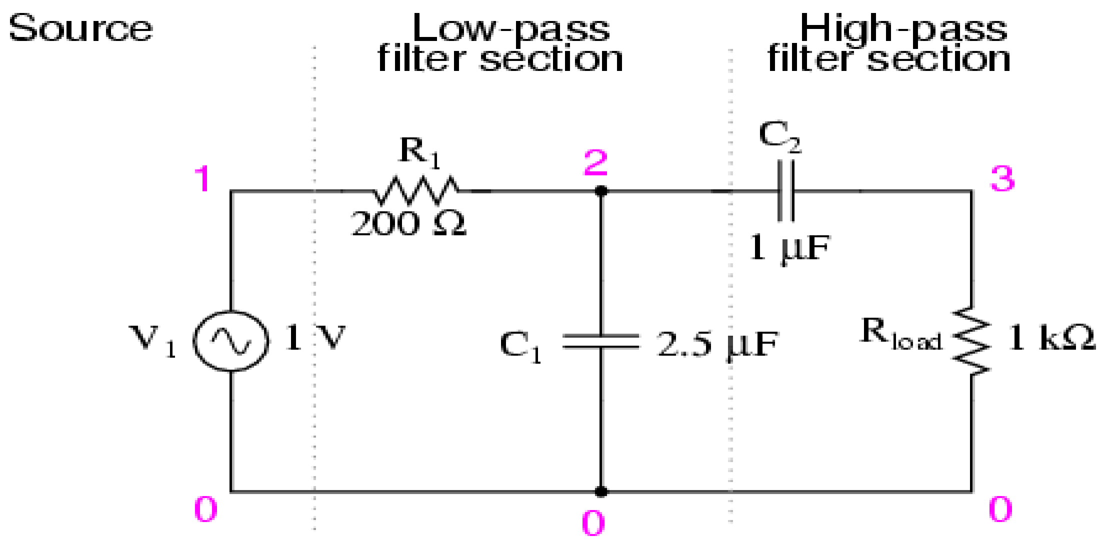

Fig 2.2 Capacitive band-pass filter

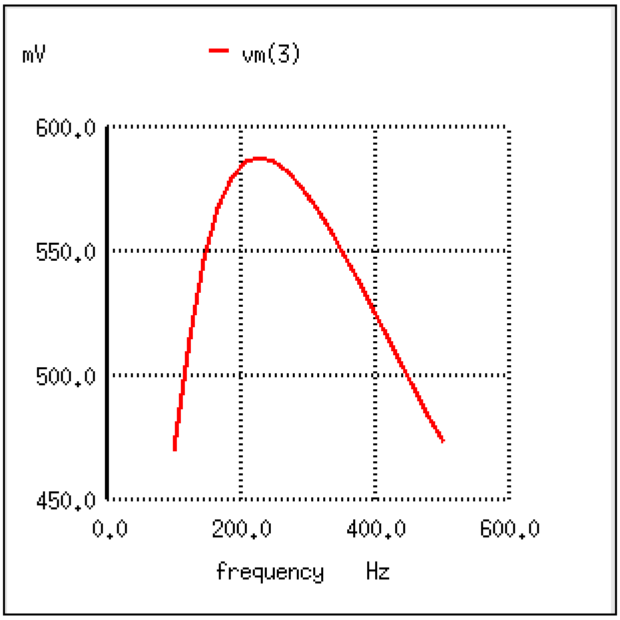

Fig 2.3 The response of a capacitive bandpass filter peaks within a narrow frequency range

Cryptography Protocols

A **security protocol** (**cryptographic protocol** or **encryption protocol**) is an abstract or concrete protocol that performs a security-related function and applies cryptographic methods hence a protocol describes how the algorithms should be used. Majorly an adequately detailed protocol includes details about, at which point it can be used to implement multiple, data structures and representations interoperable versions of a program. These cryptographic protocols are widely used for secure application-level data transport. Wales (2004) Encryption is the process of encoding data so that only a computer with the right decoder will be able to read and use it. One could use encryption to protect files on a host or e-mails sent to other users.

2.4 Critique of Literature

From the literature above, a number of studies have been conducted on the subject of pilot-controller communication errors. The studies have not significantly bought out the mainaspect of dealing with eventualities of aviation disasters or attacks or providing the potential prevention strategies hence did not explicitly state or explain how to solve such issues.

Automation leaves the human with fewer functions but with a more complex system to monitor - a role in which people do not excel (Wickens, 1992). Out-of-the-loop performance problems are a major class of errors associated with automation. Operators who are out-of-the-loop are slower and less accurate at failure detection because they are passive decision-makers (Wickens & Kessel, 1979; Wickens & Kessel, 1980; Young, 1969). Human monitors have problems detecting system errors and performing tasks manually in the event of automation failure (Billings, 1988; Wickens, 1992; Wiener & Curry, 1980). The computers' memory must be designed to accommodate the operating system as well as the application programs. In addition to this, each of the peripheral devices must have memory allocated for its software drivers. The original IBM PC was built around the 8088 processor and the total addressable space was developed based on the Inter 80286 processor with an addressable space of 16MB. The current PCs have an addressable space of up to 64GB. Most researchers in this field have forgotten to address the issue of storage of recorded data by aircraft monitoring programmes yet there have been great strides in addressing memory issues.

Another most important aspect of the ACARS is the user interface. One of the long-established methods by which users can interact with the computer is by the use of commands. Commands enable the user quickly and simply to instruct the computer what to do. However, they require the user to already have the knowledge of what should be typed, so they are more suited to experienced users than to beginners. For these reasons commands tend to be most popular to situations where the end-user is a technical person, such as computer operator or programmer, or where the end-user continually works with the same program and therefore can gain mastery of the commands. One of the most important features normally required in an HCI is that be user friendly**.** As the name suggests, a user-friendly interface is one that the end-user finds helpful, easy to learn and easy to use. It is easy to recognize unfriendly interfaces but not so easy to design one that is certain to be user friendly.

However the current user interface is still limited to multimedia features. This has not been addressed by most researchers and therefore limits the capability of flight crew members in making decisions.

CHAPTER THREE

METHODOLOGY

3.1 Methodologies used

In this chapter the researcher examined the various characteristics of the proposed incorporation of data links to improve the current ACARS and the attributes of the data link. The research also examined the fundamental data communications model i.e the Open Systems Interconnection.

The researcher analysed the appropriate research design, sampling technique, data collection and interpretation of findings instruments to best fit the phenomenon under study.

3.2 Evaluation of Methodology Approaches

3.2.1 Research Design

The research employed an action research approach. According to Mugenda and Mugenda (2005), this research is initiated to provide solution through teamwork and group enhancing mechanisms and by getting insightful information from a group of people known to have expertise in the area under study.

3.2.2 Sampling Technique

The researcher employed purposive sampling method. According to Mugenda, in her book " Research methodologies, "Purposive sampling, is a type of non-probability sampling method which focuses on sampling techniques where the units that are under investigation are based on the judgement of the researcher In this context the researcher purposely targets a group of people believed to be reliable for the study.

3.2.3 Data collection methods and Instruments

The research employed data collection instruments that fit diverse experiences into predetermined response categories. They helped produce results that were easy to summarize, compare, and generalize. The researcher included the following research instruments.

1. Interview Schedules
2. Focus group discussions
3. The Flight simulation software

3.3 Proposed methodological Approach

This study used two subjects to define and compare current ACARS and the proposed standard i.e operating environment (baseline) and the Proposed Standard design. Table 3.1 presents the experimental design matrix used for this study.

Table 3.1 experimental design matrix

Baseline	Proposed Standard

The two independent variables that were used in this experiment are:

- Current Operations (baseline): This condition represented current National Airspace System operations. Information was delivered to the cockpit in the same manner as it is today.

- Proposed standard Operations: This condition represented the proposed standard capabilities (i.e., mode of delivery, or display, of more flight, weather, and aeronautical information to the cockpit).

3.4 Characteristics of Proposed standard

The proposed standard is a communication platform between air/ground stations in aviation communications. Unlike the current ACARS which sends messages in an uncoded way with limited capacity and experiences interferences, the proposed standard will implement the following tools to solve the stated problems. The proposed standard composes the following major areas that will help to improve on the existing communication platform.

Advanced Encryption standard

This is a modern encryption method capable of having symmetric cipher generated key bits in form of 128, 192 and 256. This makes it reliable and more secure for any electronic communications. With AES freely provided by windows and Mac operating systems, then it is locally available and easy to use as one needs to execute the ‘aescrypt’ command with the name of the file accompanied the file to decrypt and encrypt. As a free source code, AESCrypt supports encryption of data even when data is stored on public clouds suiting the operations of this standard.

Gaussian Frequency Shift Keying

This is a frequency smoothening modulation scheme that uses a particular device referred to as a Gaussian to smoothen the frequency spectrum to desired states. When implemented the frequency will be smoothened to minimize interference. GFSK Frequency shift keying is made to encode as a stream of frequency variations in a given carrier the produced noise distortion typically changes the amplitude of a signal. In addition modulation mechanisms that disregard amplitude tend to be relatively immune to noise. Signal processing techniques that prevent widespread leakage of RF energy are a good thing, particularly for secondary users of a frequency band hence this aspect makes GFSK makes more likely to be developed in areas where another user has precedence. Additionally GFSK consumes less power and therefore allows for better utilization of the frequency spectrum allowing for more data capacity. This aspect will allow the proposed standard to increase its space for additional and more growing data demands in the current ACARS

CHAPTER FOUR

CONCEPTUAL DESIGN

4.1 Introduction

In the proposed ACARS standard a Gaussian Frequency shift Keying (GFSK) modulation scheme is used to filter off interfering signals from other transmissions in the vicinity. A family of GFSK modulation scheme known as Chebyshev filters are incorporated in which the transmission frequency curve has an equal-ripple shape, with very small peaks and valleys.

Chebyshev filters are analog or digital filters having a steeper roll-off and more passband ripple (type I) or stopband ripple – type two. The Chebyshev filters have the property that they minimize the error between the idealized and the actual filter characteristic over the range of the filter, but with ripples in the passband. Due to the passband ripple inherent in Chebyshev filters, the ones that have a smoother response in the passband but a more irregular response in the stopband was preferred for this application.

In the same conceptual design an encryption method is introduced with the aim of conveying messages confidentially between aircrafts and ground stations while in transit, change current readable text messages into something that cannot be read and discourage anyone from reading or copying the messages.

Asymmetric cryptography or public-key cryptography was preferred since a pair of keys is used to encrypt and decrypt a message so that it arrives securely unlike in symmetric cryptography where the same key is used for both encryption and decryption. This approach is simpler in dealing with each message, but less secure since the key must be communicated to and known at both sender and receiver locations. Initially, a network user (plane crew/plane administrator) receives a public and private key pair from a certificate authority (ARINC/SITA servers). Any other user who wants to send an encrypted message can get the intended recipient's public key from a public directory. They can use this key to encrypt the message, and then send it to the recipient and when the recipient gets the message, they are able decrypt it with their private key, which no one else should have access to.

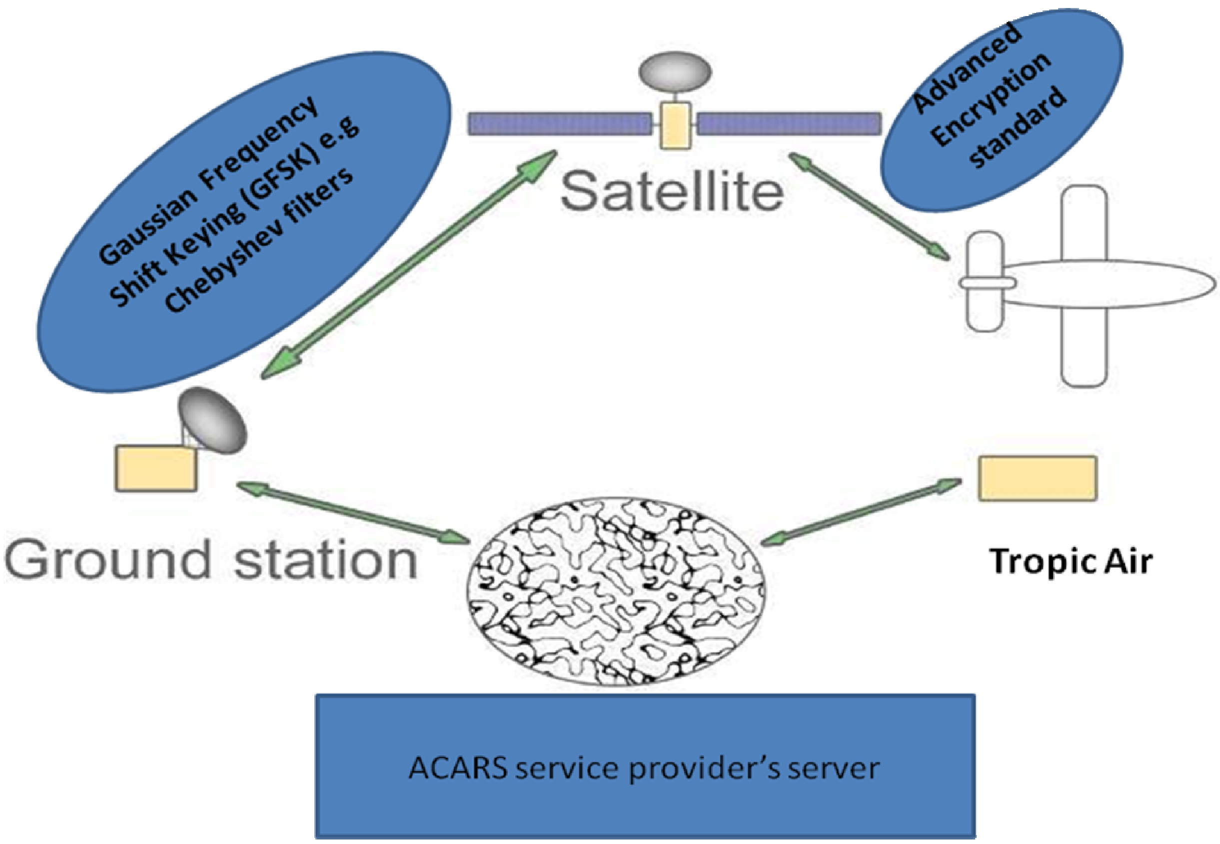

Fig 4.1 Proposed standard conceptual design

4.2 Field Studies

The Aircraft Communications Addressing and Recording System application is severely handicapped by the stop-n-wait protocol which limits character transmission upto 220 data chars. Additionally, sub-network limitations such as security holes, physical channel capacity constraints and a very poor multiple access method are worsened by the current patterns in air transport traffic exchange.

4.2.1 Open Systems Interconnection (OSI) standard

Almost all networks in are based on the open system interconnection platform that allows computerised equipment to form some platform of compatibility anytime they initiate signals. ACARS is not an exception to this. The following is a detail of the seven layers of the OSI model.

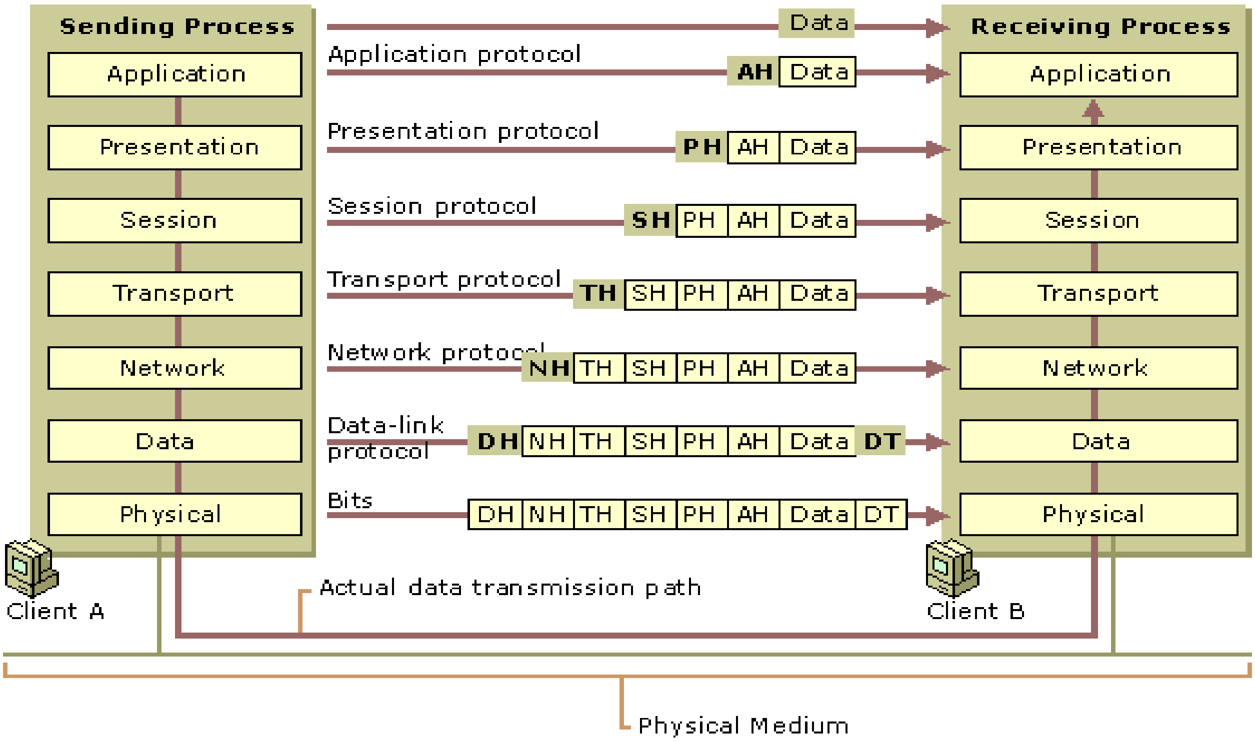

Figure 4.3 OSI Model (Source: AIRCOM Transition From *ACARS* to ATN)

OSI Model

	Data unit	Layer	Function
Host layers		7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
	Data	5. Session	Interhost communication, managing sessions between applications
	Segments	4. Transport	Reliable delivery of packets between points on a network.
Media layers	Packet/Datagram	3. Network	Addressing, routing and (not necessarily reliable) delivery of datagrams between points on a network.
	Bit/Frame	2. Data link	A reliable direct point-to-point data connection.
	Bit	1. Physical	A (not necessarily reliable) direct point-to-point data connection.

Figure 4.3 OSI Model functionalities

4.2.3 ATC Communications

One of the major areas of application of ACARS is to identify any particular changes in the OOOI structure of an aircraft. These changes are determined by the various algorithms put in place to check the said variations hence record the time of occurrence and the changed phase of flight. This information is useful in identifying the location of the flight crew members.

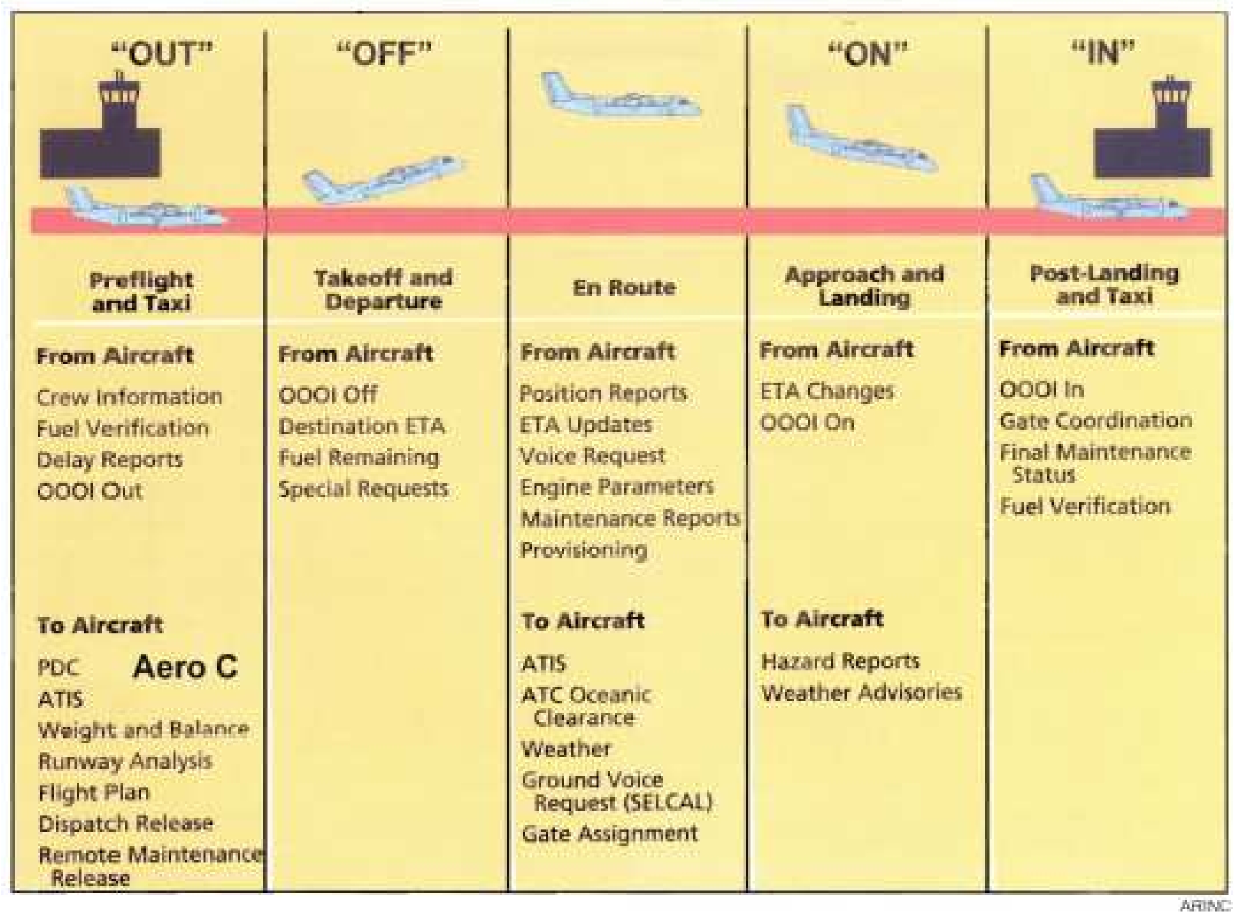

Fig 4.4 OOOI aircraft communications Source: ARINC website

Fig 4.7 Old ACARS Interface

FIG. 8.

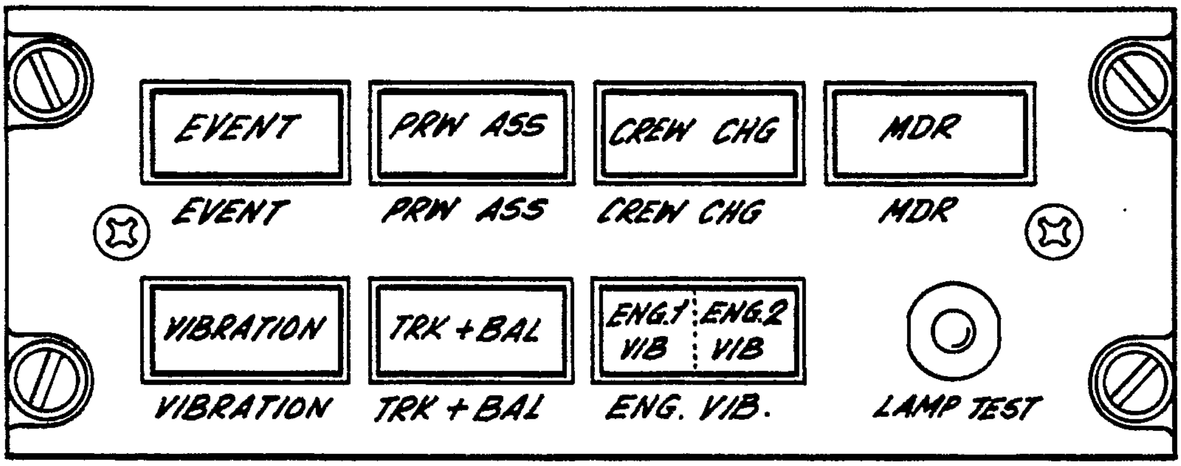

Fig 4.6 Old ACARS control unit schematic Source: ARINC website

4.3 Data Input and Expected Outputs

Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) simulation platform is the most realistic and advanced simulator of en route and terminal air traffic control systems currently available. Elements of DESIREE can be modified in nearly real time to facilitate user-centered design activities. DESIREE is expected to provide extensive data collection capabilities based on the phenomenon under study mainly in the following areas:

- Audio, video, and data recordings
- Communications (e.g., average duration of air-ground communications, communication between controller and pilots)
- Air traffic safety and efficiency parameters (e.g., number of aircraft in the sector)
- Workload ratings (using the Air Traffic Workload Input Technique [ATWIT] via the Workload Assessment Keypad device)

- User-system interaction (e.g., number of data entry errors).
- Performance monitoring

CHAPTER FIVE – IMPLEMENTATION AND RECOMMENDATIONS

5.1 Implementation

5.1.1 GFSK implementation over FSK in the enhanced ACARS

As Kobler explains in the "International Journal of Electronics and Computer Science Engineering (IJECSE) – Volume No.2" **"**A GFSK modulator, is almost similar to a FSK modulator, except that prior to the baseband pulses (−1, +1) go into the FSK modulator, it is passed through a gaussian filter to make the pulse more smoother so to limit its spectral width hence gaussian filtering is one of the standard methods for reducing the spectral width, referred to as pulse shaping. He further states that "if one uses -1 for fc-fd and 1 for fc+fd, once when it jumps from -1 to 1 or 1 to -1, the modulated waveform changes quickly, which introduces large out-of-band scale and if one changes the pulse going from -1 to 1 as -1, -.98, -.93 ..... .96, .97, 1, and use this smoother pulse to modulate the carrier the out-of-band spectrum will be condensed".

From the research findings the following waveform was captured as a true copy of the distinctive differences between the two modulation schemes.

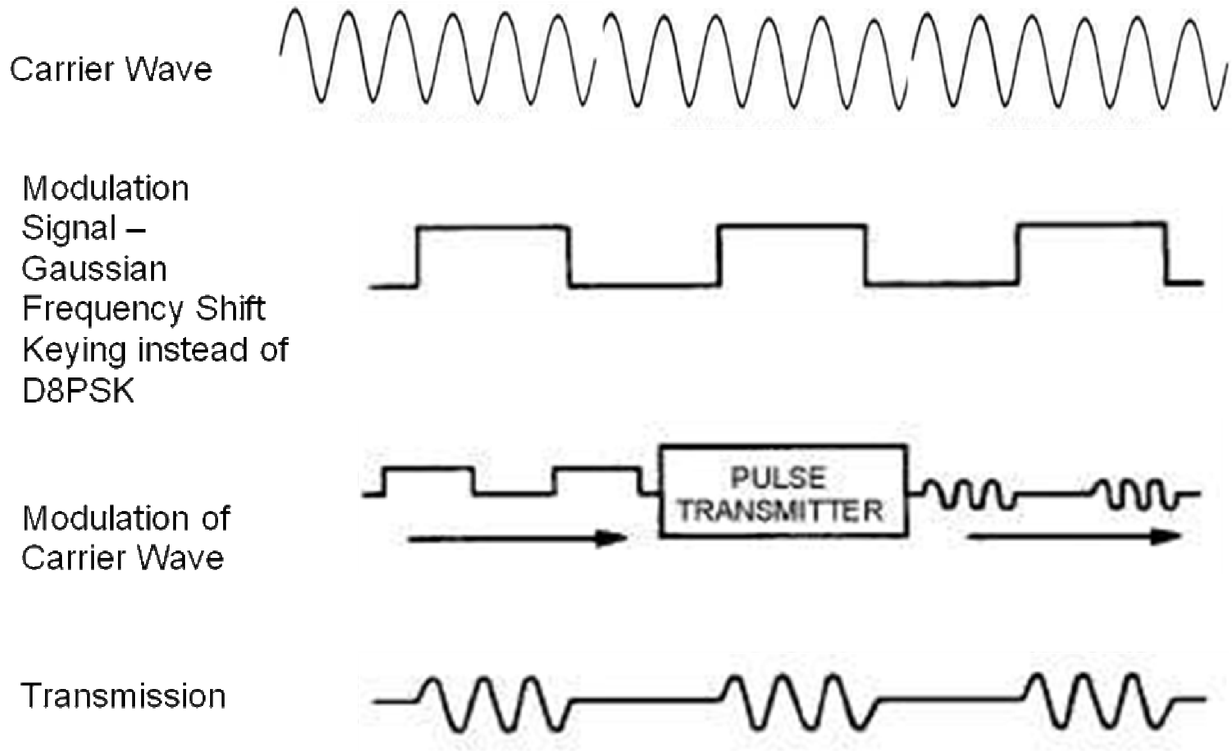

Fig 5.1 Carrier wave Source : Author

5.2 Testing

5.2.1 DESIREE Simulation analysis.

DESIREE precisely provides interfaces that allow users to enter and modify data on the simulation platform on a realtime basis . This makes the researcher to have up to date information about the real visualization of system mode of working.

Fig 5.1 Flight simulator interface Source : Author

It is used most often to describe an iterative processing which a model of a system (typically the user interface) is constructed and adapted in a series of iterative review-change cycles hence the main aim is to quickly come up with a solution to some design problem. In conclusion of a rapid prototyping exercise, one is typically left with a model which forms the basis for an actual product. DESIREE provides realistic Terminal and En-route ATC simulations simultaneously and is now the de facto standard ATC Simulator for the Research Development and Human Factors Laboratory *(*RDHFL*)*. The DESIREE user interface is programmable, a feature which allows the simulator to be used for rapid prototyping and uses a unique internal messaging scheme, which allows nearly any data to be recorded for later analysis and also permits DESIREE to use scripted events. The simulation platform emulates multiple enroute and terminal sectors with automatic handoff and transfer of control features.

In the context of the researchers aim, the following results were obtained during simulation.

1. The researcher was able to add information on the simulator hence navigating the model plane to desired states
2. The simulator was able to display results as expected on the cockpit display unit.
3. Controllers were able to perform basic executions at an operational level.
4. DESIREE had data collection capabilities and stored information of controllers' interaction with it such as controller input entries during an experimental run.

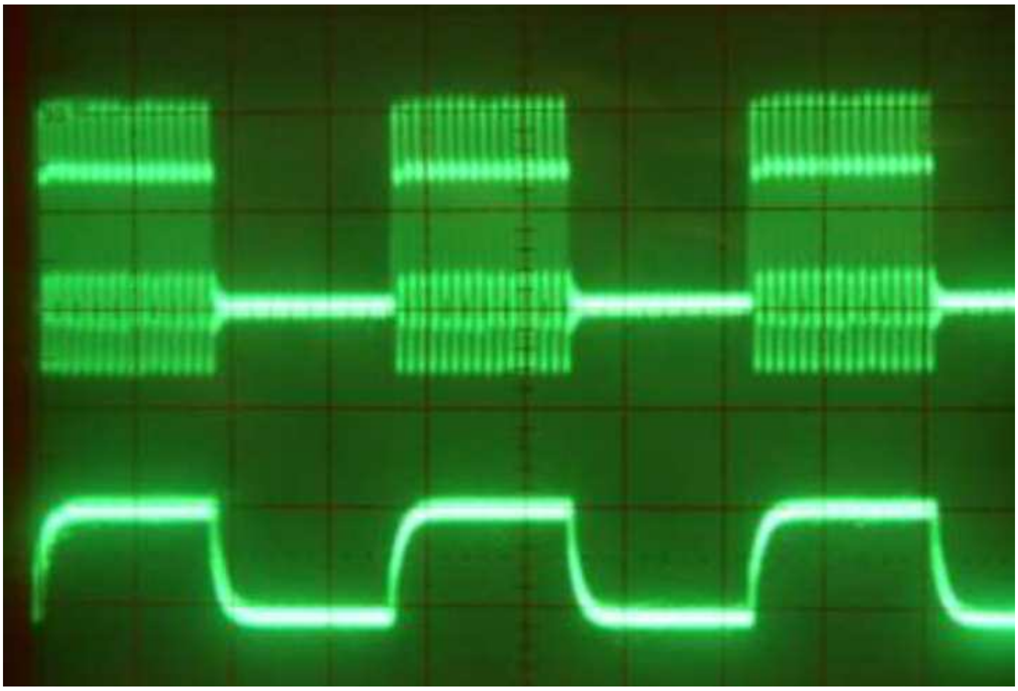

Fig 5.2 Simulated image of a modulated pulse using GFSK

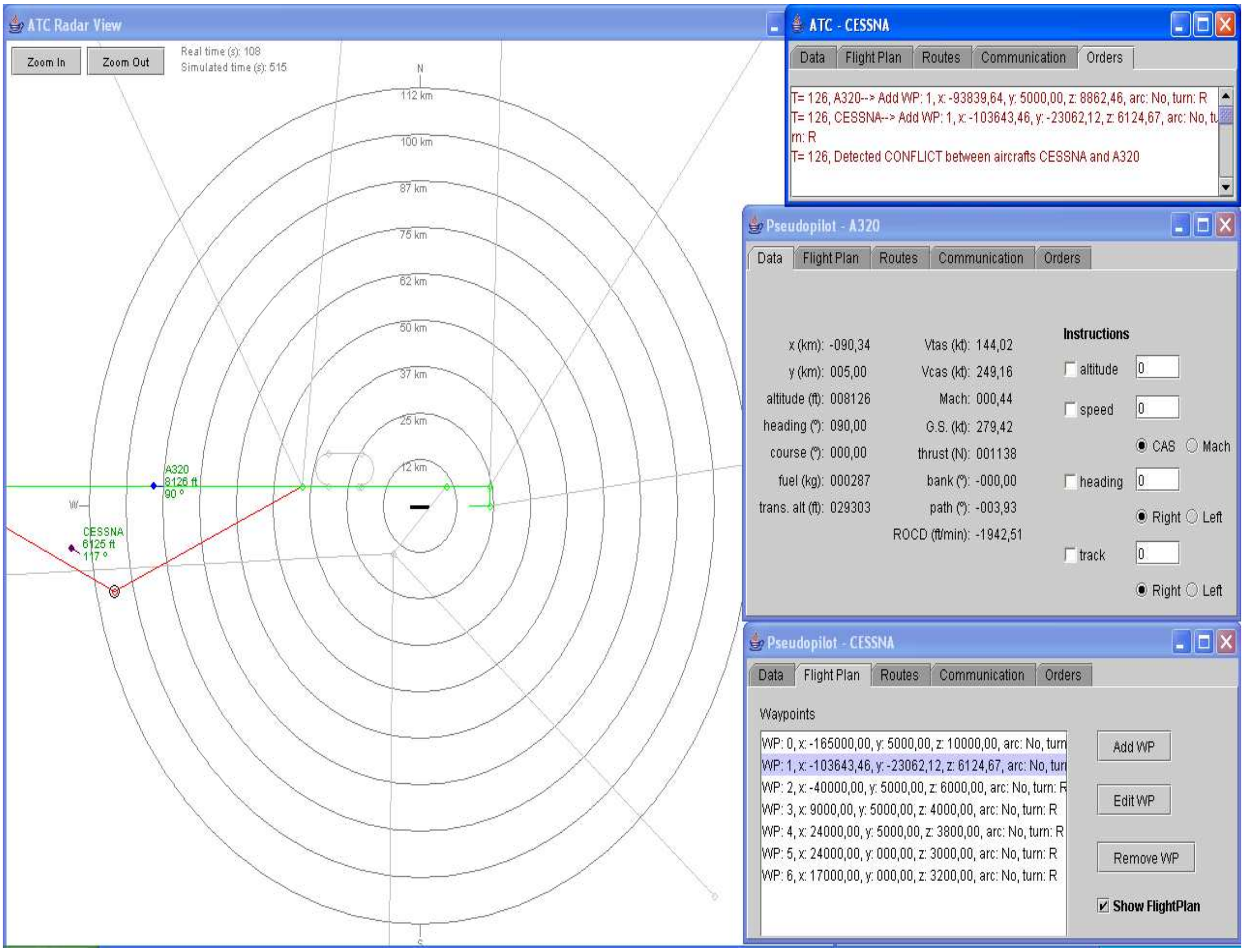

Fig 5.3 Screenshot of DESIREE application

The screen shot above shows a view of communication interface as used during simulation. It is noted that (A320 and Cessna) are deployed and the researcher was able to collect realtime information as provided.

CHAPTER SIX – DISCUSSIONS OF FINDINGS

6.1 Discussions of Findings

Data Communication (Data Comm) is one of the key enablers required for the implementation of the future transport control systems. Next Generation systems addresses increasing air traffic levels and complexity for 2015 and beyond. The currency of information among flight crews, air traffic management, controllers, and Airline Operations Centers / Flight Operations Centers is often imbalanced resulting in inefficient planning, excessive time lapse, and the need for additional communication to compensate for information quality and timeliness. These constraints reduce the scope of planning and narrow the ability of all users to make dynamic, strategic decisions, thus reducing National Airspace System (NAS) operational flexibility. The Next Generation Air Transportation System (NextGen) envisions airborne System Wide Information Management (SWIM)-based flight, weather and aeronautical information exchanges between aircraft and ground-based Federal Aviation Administration (FAA) systems to address these constraints.

NextGen requires an appropriate air-ground data management and information exchange mechanism to support increased pilot access to relevant National Airspace System (NAS) information for flight planning. The proposed standard is the ultimate air-ground solution that gives flight crews access to this information available through a shared information source that will promote a common platform between aircraft operators, controllers and air traffic managers. In realization of the safety concerns in the aviation industry, the enhanced ACARS technology should be immediately implemented to provide effective and reliable communications between pilots and air traffic controllers since from simulation the air-to-ground communications and be able to provide the pilot with integrated services on easy-to-read, real-time displays.

As detailed in the literature most scholars affirm that the primary attribute of Chebyshev filters is their speed, typically more than an order of magnitude faster than the windowed-sinc. After implementation, the filter allowed the designer to specify the desired amount of ripple within a given passband or stop-band. In band pass filter bandwidth is the difference of frequencies between 3 dB points. Over this region, gain reasonably remains constant. Beyond 3dB point, In case of other filters such as Butterworth filters, attenuation is large so there is a chance of losing more information. However, with chebyshev filters, It's at this frequency that the power of the signal is reduced to half its max power/ or the attenuation caused by the system to the signal is such that the magnitude reduces to the max magnitude of the signal. This filter response has the steeper initial rate of attenuation beyond the cutoff frequency than Butterworth. This advantage comes at the penalty of amplitude variation(ripple) in the pass-band. Unlike Butterworth and Bessel response, which have 3dB attenuation at the cutoff frequency, Chebyshev cutoff frequency is defined as the frequency at which the response falls below the ripple band. For even-order filters, all riple is above the dc-normalized passband gain response, so cutoff is at 0dB. For odd-order filters, all riple is below the dc-normalized passband gain response, so cutoff is at -(ripple) dB. For a given number of poles, a steeper cutoff can be achieved by allowing more pass-band ripple. The Chebyshev has more ringing in its pulse response than the Butterworth - especially for high-ripple designs. In conclusion chebyshev have better rate of attenuation beyond the pass-band than Butterworth

As stated in the literature review asymmetric algorithms use pairs of keys. One is used for encryption and the other one for decryption. The decryption key is typically kept secretly, therefore called ``private key'' or ``secret key'', while the encryption key is spread to all who might want to send encrypted messages, therefore called ``public key''. Everybody having the public key is able to send encrypted messages to the owner of the secret key. The secret key can't be reconstructed from the public key. The idea of asymmetric algorithms was first published 1976 by Diffie and Hellmann. As Asymmetric algorithms seem to be ideally suited for real-world use, the researcher implemented it using a hybrid RSA. This involves using RSA to asymmetrically encrypt a symmetric key. The researcher randomly generated a symmetric encryption (say AES) key and encrypted the plaintext message with it. Then, encrypted the symmetric key with RSA. Transmission was done for both the symmetrically encrypted text as well as the asymmetrically encrypted symmetric key. The receiver was able to decrypt the RSA block, which yield the symmetric key, allowing the symmetrically encrypted text to be decrypted. To allow streaming decryption or large messages, one would send shorter messages first and then the much larger.

6.2 Conclusions

In view of the drastic change and massive turnaround going on at the Aviation industry, better service delivery, organizational restructuring, completion of abandoned structures, remodeling of all local and international airports, better welfare packages, state of the art safety and security measures, best airfare prices and new consumer protection policies is of paramount consideration.

The active airline pilots who participated in this simulation evaluated the enhanced ACARS concept favourable, agreeing that it has the potential to provide additional and useful flight information to them in the cockpit during preflight and/or cruise. Participants said they could use this information during flight phases when workload is lower (i.e., preflight and cruise). This would benefit their strategic planning by helping them to be more aware of weather and traffic situations that may affect their flight route, their taxi and departure and/or their arrival and landing.

Participants discussed the proposed standard information they would like to access and the utility of information the researcher simulated as potential proposed standard information.

Their comments regarding the proposed standard information along with their reasoning for why this information would be helpful are summarized and presented in the table below

Table 5.1 Participants comments regarding the proposed standard

Type of Participant	Weather	Flight
Cockpit Pilots	ITWS information, such as microburst information	Airport arrival rates: pilots could pre plan for airborne holdings, plan for diversions and assist in AOC information relay.
Communication Controllers/Pilots	Wind shear information -This is usually obtained through asking a controller A national view of Weather/Traffic (Traffic Flow Management System Traffic Situation Display): this would help keep commuters better informed about arrival airports status, delays, etc.	Traffic Management Advisory (TMA) ASDE information such as sequence in the departure queue: • It could potentially minimize questions pertaining to one's sequence in the departure queue, decreasing pilot-controller communications • It could also decrease fuel costs if pilots know when they need to start engines, and know whether they can perform a single engine taxi or not • Help pilots estimate their actual departure time • Aid pilots in their ability to navigate difficult taxi routes • Would be particularly useful in an unfamiliar airport Route Availability Planning Tool (RAPT)

		Traffic management initiatives (e.g. GS, GDPs etc.) • As long as this information is received in real-time it could eliminate repeated requests from the pilot for current reports of runway visibility from the tower controller • Potentially decrease rate of data interceptions that would see a drastic reduction in aviation accidents especially from a terrorist attack.
Commuters	Traffic Situation Display): this would help keep commuters better informed about arrival airports status, delays, etc.	

The researcher was unable to find out whether the information provided helped their strategy during real scenarios but this could have been due to factors related to training, and approval of the standard shortcomings, scenario complexity, or flight simulator limitations.

In addition to commenting on the information they would find useful, participants also explained that too much information may be an overload; additionally, participants stated that flight route specific information would be beneficial. Participants explained that the additional information expected from the proposed standard would be most useful while on the ground or during cruise. A few of the participants said they liked the low altitude en route charts with weather and traffic overlaid (especially if orientation was the same as actual heading).

6.3 Critical Review and Reflections

During this process the researcher was able to take note of some isues as discussed below:

Flight training in a simulator is much cheaper that flight training in an actual aircraft. The costs of fuel, aircraft maintenance and insurance of a regular aircraft are far greater than the running and maintenance costs of a flight simulator, making flight training in a simulator far more affordable. The environment also benefits from flight training in a simulator, as there is no air and noise pollution created by a flight simulator. The researcher was able to get hands on experience of how to managing dangerous situations in a flight simulator without putting his or instructors' life at risk. Emergency procedures, adverse weather conditions and system failures can easily and quickly be produced or recreated in a flight simulator. Flight training in a simulator therefore gave the researcher necessary preparation and knowledge of how to overcome hazardous situations in future.

The researcher noted that flight simulation saves time. There is no time wasted on booking aircrafts for flight training, scheduling flights or waiting for the aircraft to warm up and travel to the desired destination to undergo specific flight training instruction. When the flight simulator was used for flight training detailed lessons were effectively completed with ample time for the researcher to discuss the flight simulation session thereafter.

The researcher may not have exhausted the simulation process not only because of the complexity of the scenarios, but because of the flight simulator software and hardware limitations in usability and realism. These limitations influenced flight crew coordination and created an unrealistic division of roles and responsibilities and workload. For example, the participant who assumed the role as Flight Officer did not have operable toe brakes. While taxiing, the Captain had to delegate operating the toe brakes to the FO, while in reality the Captain is responsible for maneuvering the aircraft.

As a first timer to use of flight simulation interfaces, the researcher found the touchscreen was difficult to manipulate and this required additional help from the cockpit simulator engineer to input speed, altitude, headings, etc. the researcher had to rely on the cockpit simulator engineer for recording outputs for certain tasks (i.e., for manipulation of heading, course, and altitude), which took time away from other tasks.

6.4 Future Studies

It is now clear that effective communication is the core driver of safety in transportation especially in avionics. It is therefore quite prudent for all airlines to adopt to the proposed system of communication as it has provided an effective communication platform. However, during the study the researcher noted that header information of transmitted frames is not encrypted thus if header information is not encrypted, traffic analysis is possible

Traffic analysis is the analysis of header information in order to derive useful information from the headers. To further improve safety in the aviation industry the researcher recommends the following areas to be critically investigated.

- Identification of Cryptographic methods to be used in encrypting header information with a sense of relaying information to/from the aircraft on a timely basis.
- Use a simulator in which major user interface components are located where they belong to better identify if the proposed standard information will be considered important in contributing to the safety of the aviation industry.
- Analyze verbal pilot requests for information from ATC separately from total number of requests from pilots and controllers. Analysis in this manner may show reduced

verbal requests by pilots for information from ATC. If pilot request for information are reduced, this would be a benefit gained from the proposed standard.

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