Design and Development of a Flight Route Modification, Logging, and Communication Network

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There is an overwhelming desire to create and enhance communication mechanisms between entities that operate within the National Airspace System. Furthermore, airlines are always extremely interested in increasing the efficiency of their flights. An innovative system prototype was developed and tested that improves collaborative decision making without modifying existing infrastructure or operational procedures within the current Air Traffic Management System. This system enables collaboration between flight crew and airline dispatchers to share and assess optimized flight routes through an Internet connection. Using a sophisticated medium-fidelity flight simulation environment, a rapid-prototyping development, and a unified modeling language, the software was designed to ensure reliability and scalability for future growth and applications. Ensuring safety and security were primary design goals, therefore the software does not interact or interfere with major flight control or safety systems. The system prototype demonstrated an unprecedented use of in-flight Internet to facilitate effective communication with Airline Operations Centers, which may contribute to increased flight efficiency for airlines.

Nomenclature

ACARS	=	Aircraft Communication Addressing and Reporting System
ADS-B	=	Aircraft Dependent Surveillance – Broadcast
ANSP	=	Air Navigation Service Provider
AOC	=	Airline Operations Center
ATC	=	Air Traffic Controller
ATM	=	Air Traffic Management
CPDLC	=	Controller Pilot Data Link Communication

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DIP	=	Dispatch Interface Program
DSP	=	Database Server Program
FAA	=	Federal Aviation Administration
FALCN	=	Flight Adjustment Logging and Communication Network
GPS	=	Global Positioning System
GUI	=	Graphical User Interface
IFI	=	In Flight Interface
Mbps	=	Megabits per second
MHz	=	Megahertz
NAS	=	National Airspace System
NASA	=	National Aeronautics and Space Administration
NextGen	=	Next Generation Air Transportation System
SWIM	=	System Wide Information Management
TAP	=	Traffic Aware Planner
TASAR	=	Traffic Aware Strategic Aircrew Requests
TCP	=	Transmission Control Protocol
VHF	=	Very High Frequency

I. Introduction

As in many other industries around the world, the aviation industry is becoming increasingly reliant on advanced networking through modern information sharing technologies. Airlines are highly connected entities that rely on the transfer and sharing of information for day-to-day operations—be it a networked reservation and passenger accommodation service or an aircraft-to-ground network such as Aircraft Communication Addressing and Reporting System (ACARS). Air traffic management (ATM) is becoming increasingly connected through technologies such as Automatic Dependent Surveillance—Broadcast (ADS-B), Controller-Pilot Data Link Communication (CPDLC), and System Wide Information Management (SWIM). The introduction of these technologies into the National Airspace System (NAS) is anticipated to provide many advantages, such as increased operator and system efficiency, enhanced situational awareness for the Air Navigation Service Providers (ANSP), and greater flexibility for airspace users.

The National Aeronautics and Space Administration (NASA) has recognized that this movement in the aviation industry has true game-changing potential. To answer this movement, the Network-Enabled ATM subproject was created within the Aviation Operations and Safety Program. The goal of the Net-Enabled ATM subproject is to investigate methods to apply advanced networking concepts, modern information sharing technologies, and innovative distributed processing technologies to air traffic management in order to improve the safety, efficiency, capacity, and robustness of integrated decision making in air traffic operations.

Researchers at NASA Langley Research Center have defined Network-Enabled ATM as a vision for future airspace operations consisting of three high-level concepts: data sharing, distributed processing, and end-user applications. A key component of this vision is shared situational awareness made possible through modern information sharing technologies. The system described in this paper is a prototype communication system and associated suite of applications that provides a mechanism for shared situational awareness between the flight deck and an airline dispatcher.

This paper is organized as follows: Section II provides justification for this activity and introduces background research on the candidate application that is used in conjunction with the prototype, and aviation communication infrastructures that may be leveraged for this prototype. The prototype system and the design and development approach are discussed in Section III. Section IV provides an in-depth discussion of the subsystems that exist in the prototype, and Section V discusses the high-level concept of operations. Finally, conclusions are presented in Section VI.

II. Background

Since the financial crisis of 2008, the number of annual domestic airline passengers in the United States has been increasing every year.[1] This trend is projected to continue as the total volume of passengers traveling through the NAS is expected to nearly double over the next 20 years.[2] As the number of passengers and flights continue to increase, the already overtaxed airspace will soon exceed its operational capacity.[3] Human workload bottlenecks are the predominant origin behind this anticipated NAS congestion. These human constraints reduce operational efficiency and hinder effective communication to achieve strategic goals set forth by the airlines and the ANSP. The need to facilitate effective communication between multiple separate stakeholders involved in air traffic operations is emerging as a predominant issue.

One proposed solution to increase the capabilities of the NAS is to allow operators in the system, e.g., airlines, to function autonomously by self-governing their flight routes without interference from an outside source. The concept of autonomous flight rules (AFR) has emerged as an application of this idea.[4] AFR would utilize an automation capability located on the flight deck that allows aircraft to modify their own routes during flight. The automation capability takes into account weather, air traffic, and any other airspace constraints (e.g., special use airspace, notices to airmen) in order to offset the human workload experienced by the ANSP. This concept allows users greater flexibility and promotes high efficiency operations in the NAS.[4] Even with modern technological capabilities on aircraft, AFR is still years away from being operationally implemented due to the large paradigm shift that would need to occur in NAS operations (i.e., shifting the focus of control and responsibility for separation from Air Traffic Control). Recognizing this, NASA has developed a related near-term flight deck decision support tool that increases the amount of user flexibility without modifying the current Air Traffic Control (ATC) paradigm.

A. Traffic Aware Strategic Aircrew Requests

Airlines continue to search for solutions that increase flight path efficiency due to their ongoing interest in reducing cost of operations and improving on-time arrival rates. While airline dispatchers utilize the most up-to-date information (including wind patterns, weather systems, and air traffic) to generate the most efficient flight plans, the information used to generate the initial flight plan may be hours old by the time the aircraft is enroute. Additionally, dispatchers are responsible for several aircraft at any given time, therefore they are unable to further optimize flight plans once the aircraft has left the gate. Thus, an opportunity exists for a flight crew to use onboard automation to re-plan their flight path based on the most up-to-date information available.

As a step towards the eventual deployment of distributed ATM (such as AFR) and to respond to the current need for enroute flight path optimization, researchers at NASA Langley Research Center have developed an interim solution known as Traffic Aware Strategic Aircrew Requests (TASAR). TASAR is a concept that allows flight crews to make informed trajectory modification requests to an air traffic controller while enroute.[5] TASAR utilizes the Traffic Aware Planner (TAP), an algorithmic path optimization technology that considers weather, traffic, special use airspace, and wind patterns to generate optimized flight paths that would save time and/or fuel.[6] Distributing decision capabilities to the flight crew when they are in a low-workload portion of the flight could alleviate the workload of dispatchers. Analysis has indicated that aircraft equipped with TAP can reduce travel time by approximately one to four minutes, and reduce the amount of fuel burned by 50 to 550 pounds per operation.[5]

A human-machine interface within TAP provides flight crews the ability to review and select alternative routes before requesting a route modification clearance from Air Traffic Control (ATC) for execution. TAP presents three maneuver options to the flight crew: a vertical flight level change, a lateral path change, and a combination of vertical and lateral change. The combination solution presented to the flight crew is uniquely generated as optimal and is not a simple combination of the suggested vertical and lateral path changes. The lateral components of the flight path modification solution are fixed to known waypoints in the NAS.[5] TASAR's advantage is that the pilot is given flight path options that have a greater chance of success since the options presented have no conflicts with pre-existing flight plans. Since the TASAR concept is designed for a near-term implementation, it relies on the current procedure of requesting a route modification from ATC through voice communications. The pilot will call ATC and request a flight plan change based on the solution that the automation presents.

B. In-Flight Communications

This section describes current air-ground communication methods and introduces the air-ground internet connectivity capabilities that can be employed to enrich communications between airborne and ground-based entities. The two methods examined for current communication are ADS-B and ACARS. The final subsection includes an examination of the opportunities presented by onboard internet connectivity.

1. Examples of Current Air-Ground Communication Methods

Airlines and ATC currently utilize two main air-ground communication networks. This section introduces both the ADS-B and ACARS systems and discusses, at a high level, the advantages and limitations of each system.

A cornerstone piece of the Next Generation Air Transportation System (NextGen) is an aircraft surveillance technology known as ADS-B. ADS-B is a method for transmitting and receiving altitude, ground speed, and location derived from on-board GPS equipment between ground stations and other local traffic. ADS-B has two independent components; ADS-B Out and ADS-B In.[7] The current timeline set forth by the FAA mandates ADS-B Out for all areas where Mode C transponders are required by 2020.[8]

ADS-B Out provides the ability to transmit high-quality traffic state data, via radio broadcast, to ground stations and traffic within reception range. If an aircraft has ADS-B In avionics installed, that aircraft can receive transmitted data from other local aircraft that are within range and are broadcasting ADS-B Out. The FAA recognizes the importance of broad implementation of ADS-B Out; ADS-B Out included in more aircraft would allow ground systems to increase update rates of location information in comparison to radar capabilities. Currently, radar operates at one sweep per 12 seconds, whereas the ADS-B Out refresh rate is once per five seconds.[9] While ADS-B Out will be mandatory for all aircraft operating in or near Class A, B, C, and some E airspace by 2020, ADS-B In does not yet have an installation mandate. However, many Air Traffic Management researchers view ADS-B In as a key enabler for NAS modernization concepts. To incentivize airline operators to equip their fleets with ADS-B In, these ATM research organizations have developed several concepts that might justify the equipage through benefits including operator flexibility, efficiency, and safety. TASAR is such a concept.

Although ADS-B provides many useful capabilities, there are several vulnerabilities to the system. ADS-B relies on a weak GPS signal which can be easily blocked. Additionally, transmission restrictions and frequency congestion result in the operational range being limited to 180 nautical miles for air to ground communications.[10] ADS-B has also faced criticism for being unable to provide adequate security when transmitting information. The current ADS-B system lacks any identity authentication structure and broadcasts messages without encryption. The lack of encryption could present a threat to ATC systems, including the broadcast of inaccurate data or interception of sensitive information.[11]

Another method of air-ground communication is ACARS, which transmits small amounts of text reliably to an enroute aircraft. Before the introduction of ACARS, all enroute communication between flight crews and other entities of the NAS used direct radio communication.[12] Instead, ACARS utilizes a router to connect to a network of radio transceivers controlled by a third party service provider.[13] Typical transmissions include weather information, navigation information, aircraft positioning, and take-off/landing confirmations.

The implementation of ACARS brought forth several problems. One noteworthy safety concern, that has not manifested to date, is the potential for non-airline personnel to easily intercept information from the Airline Operations Center (AOC) communications data link. A simple Very High Frequency (VHF) scanner capable of tuning in to the aircraft band, from 118 to 136 MHz, could receive the same message displayed to ATC. [16] Since the messages appear as plain text, a potential security risk arises from a person gaining unauthorized access to sensitive information or manufacturing misleading information. Additionally, the message size is restricted to a maximum of 220 characters, which is a major constraint on effective data transfer and delivery performance of the system decreases exponentially with message size.[14] Finally, protocols which require buffering a message and waiting for an established data link for each aircraft handicap the data exchange performance of ACARS. Therefore, particularly in overpopulated sectors, the difficulty in locating an idle channel directly reduces the system's effectiveness. Hence, the potential for additional uses of ACARS is limited.

2. Proposed Air-Ground Internet Connectivity

Currently, airlines provide their passengers with Internet connectivity through third party service providers, similar to an Internet service provider on the ground. There are two types of system architectures currently in use: an air-to-ground system that makes use of cellular communications, and a communications satellite system. In recent years, processing and storage capabilities located on the aircraft have augmented traditional in-flight networking avionics. In the near future, these capabilities may be extended for utilizing the existing Internet connectivity for ATM concepts and applications.

Two major in-flight Internet service providers are Gogo and Row 44. Gogo utilizes a cellular-tower based architecture and Row 44 uses satellite based systems. Gogo advertises that their network in North America consists of more than two hundred Air to Ground cellular towers with a peak bandwidth of 3.1 Mbps. Gogo's newly released ATG-4 network has a peak bandwidth of 9.8 Mbps at a frequency of 800 Mhz.[15] Row 44 utilizes the Ku-band and claims a peak throughput of 11Mbps per aircraft.[16]

In comparison to ADS-B, using an Internet based method to transmit data would have essentially no limit for transmission range. Replacing radio transmission with an Internet connection would also result in higher security for both the data messages and the data pipeline. There are various methods to encrypt Internet communications—whether it is by encrypting the connection between two nodes of the network or by encrypting the contents of the package. Several industries, including banking and healthcare, rely on encrypted Internet communications. Encryption capabilities based on cryptographic algorithms would ensure secure data transfer by key generation, encryption, and decryption. As Rivest, et al[19] describes, key generation by the cryptosystem creates asymmetric public and private keys from 1024 to 2048 bits long and relates them mathematically. Encryption methods applied by the public key results in decryption procedures solely by the private key for access.[17]

III. Objective and Approach

Commercial airlines desire that their dispatchers play an integral role in the decision loop within any new NASA concepts enabling flight crews to make route modification clearance requests to ATC. Dispatchers often have a more holistic view and understanding of the airline's overall strategy, and are concerned that independent flight crew decisions may disrupt other same-company flights.

To create this link in the decision loop, it is proposed that the previously discussed in-flight Internet serve as the data link between the flight crew and the dispatcher. This connectivity would provide a means by which dispatchers could be inserted into the decision process, as well as the ability to store aircraft state, intent, and route modification data on the ground. The dispatcher's response can be sent back to the flight crew via the same Internet connection. With dispatch's recommendation, the flight crew can then decide whether to request a route change from ATC or stay on the current trajectory. The implementation of this system has taken form as the Flight Adjustment Logging and Communications Network (FALCN).

A. Approach

The main goal of the FALCN system is to develop an enabling technology that transmits data between the flight deck of an aircraft and the dispatchers on the ground via an Internet connection. The second goal is the development of a database system that will store the aircraft state, intent, and route modification information, as well as allow other systems to access the data. Finally, the third goal is to develop a prototype display interface that can be used to inform dispatchers of any TAP-generated route modifications. In order to complete the outlined goals, the project was separated into two builds.

Build 1 includes developing software tools capable of transmitting, receiving, and storing aircraft state, intent, and requested route modification information via an Internet data link and database system. The aircraft state information is included to inform the dispatchers of the location and condition of the aircraft; the intent data are included to augment the current flight plan. Inclusion of the requested route modifications is very important for insuring that the dispatchers are aware of all changes that deviate from the original flight path. After transmission, all of the data are stored in a database system. The database also provides a method for other automation systems, both airborne and ground-based, to access and retrieve records of interest.

Build 2 of the project encompasses the creation of user interfaces that facilitate communication between the cockpit and the AOC using the FALCN system. The user interface on-board the aircraft, within the In Flight Interface (IFI), allows flight crews to review TASAR route modifications and correspond with dispatch on executing a trajectory change. The dispatchers will be provided with an interface within the Dispatch Interface Program (DIP) which will notify them that a flight crew wants to make a deviation away from the original flight plan. Further research and development is required to obtain human factors statistics for workload and usability of these interfaces. Additionally, the desire for a streamlined procedure for making requests to dispatch may be achieved through the integration of the IFI into the TAP user interface.

B. System Architecture

When creating software interfaces for existing and prospective projects, it is important to consider what technology will manage future development and maintenance. A major design goal of FALCN is the ability to integrate with existing decision support tools, which influenced choices made during the design phase. Code for the FALCN project was developed on a Microsoft Windows 7 operating system in Visual C++ with Microsoft Visual Studio 2010. The code was then tested and demonstrated on a network of machines that included a medium-high fidelity aircraft simulation and the TAP software. Development included measures to provide cross platform utility.

In addition to the standard C++ libraries, FALCN also uses QT third-party code for additional functionality and hardware independence. The QT framework provides support for the FALCN interfaces, as well as the threading for multithreaded processing of data and networking behind the FALCN Graphical User Interfaces (GUIs). The Boost C++ Libraries provide the socket connection structures that allow FALCN to interface with the Internet and TAP. The LIBPQ library function set provides a C-based interface for interacting with the PostgreSQL object-relational database, an open-source database management system which provides the foundation for the FALCN server.

The FALCN system, at the architectural level, controls transmission and storage of flight information. To guarantee the ongoing usability of the FALCN base code, the data management and interfaces are modular component objects. Modularized architecture emphasizes reusability through encapsulation, with data and related functions packaged together. Practicing data abstraction focuses the system on the data itself and allows for easy modification of functions within an abstraction. This ensures a high level of overall system cohesion and a low level of interdependence between subsystem components.

The division of the FALCN subsystem component objects falls into the three main functionality goals of the system. The first object handles data parsing and packaging, and provides the interface between FALCN and TAP. This object also includes functions for handling the identification of data received by the system components over the network. The second object handles the network sockets, enabling communication between the user interfaces and the server. This provides functions for creating and accepting connections, transmitting and receiving data, and directing server data flow. The third object, used only by the server, handles database interactions. This object acts as the interface between FALCN and the database, providing functions for storing, querying, and retrieving data.

One of the main goals of FALCN is to provide a network for facilitating communication between flight crews and AOCs using the Internet. This requires careful consideration of variables associated with wireless networking. These include how traffic behaves during peak bandwidth usage, how latency and packet loss affect execution, and how to keep the transmitted data secure. Transmission Control Protocol (TCP) is one of the primary methods of handling Internet connections. TCP has several advantages over other Internet Protocols, which is why it is the preferred protocol for FALCN. TCP, unlike streaming data protocols, includes priority bandwidth allocation during busy periods, ensuring that passenger network usage will not affect the transmission rate of data from the flight deck. TCP also utilizes a "handshake" when transferring data. This ensures that all messages that are transmitted are received by the respective programs within FALCN.

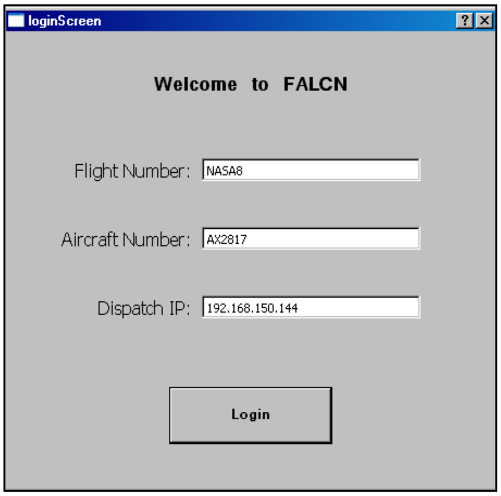

Figure 1: IFI Login Screen.

IV. FALCN Components

This section of the document describes each of the subsystem programs of FALCN. As previously mentioned, each subsystem was designed to be modular and to meet the functional requirements of the system as a whole.

A. In-Flight Interface Program

The In-Flight Interface is a user interface designed to allow the flight crew to easily make a selection of a TAP generated route and sent to dispatch for review. The IFI is designed to be an easy addition to the current flight crew interface during operation. The first screen, Figure 2, begins with the flight crew entering in the flight number, the aircraft number, and the dispatch identification. Once the flight information and the dispatch contact are confirmed, the interface will become functional, as seen in Figure 3. The confirmation is utilized as a form of security for the process. The security measures would prevent unauthorized users from gaining access to the flight system, however the confirmation will be used more frequently to ensure that the flight crew did not enter a value incorrectly. Once the program is unlocked, the IFI and the TAP programs will begin to communicate.

During flight TAP will begin to generate optimized solutions once a minute when improved routes are identified. In most cases, the flight crew has the option to select an optimized lateral, vertical, or combination solution. Once a solution is selected, the table in the IFI will populate with the information corresponding to the selected solution from TAP, as seen in Figure 4. If the solution is not satisfactory, then the flight crew can release the selection in TAP and remove the information from the Incoming Route Request table. If the flight crew is satisfied with their selection, they can proceed to select the

Figure 2: IFI Request Screen.

"Request" button and transmit a request to dispatch. The request button in the IFI will then become inactive but a "Cancel Request" button will appear below the original "Request" button. The "Cancel Request" button provides the flight crew with the option to remove a request from the dispatchers queue. The most common reason to retract a request will most likely be that the dispatchers were too busy to provide a response within a reasonable time and the modified request would no longer be an optimal route.

After dispatch reviews the request, a decision will be returned to the flight crew. The dispatcher has the option to return one of three decisions: a denial, an approval, and a request for contact. The denial will clear the selected response from the Incoming Route Requests table in the dispatch interface. The selection will simultaneously return a message to the flight crew who can then release the selection in TAP to refresh the IFI. If the flight crew is provided with an approved decision, as seen in Figure 5, then they can contact ATC via a radio transmission and request approval. The verdict from ATC will be returned to the flight crew through a similar radio transmission and relayed to the dispatchers within the IFI. The solution would then be released in TAP and if a positive decision was returned, the flight crews can begin executing the revised route.

In addition to an approval or a denial assessment, the dispatchers have been given the option to request contact from the flight crew. Following a request for contact, the flight crew will send a radio transmission to dispatch. Having the flight crew speak directly with dispatch is useful for conveying a large amount of information quickly but requires more of the dispatcher's time. For this reason the dispatchers can vet requests of interest instead of addressing every request. The radio contact allows for minor alterations to the TAP generated route or for the dispatchers to receive additional information from the flight crews.

B. Database Server Program

The Database Server Program (DSP) is the core of the FALCN system. It provides the interface through which the IFI and the DIP communicate with each other and store data. Unlike IFI and DIP, the DSP has no front end user interface, and requires no direct human interaction to operate. Viewing and administering stored data is done through the PostgreSQL database interface, which allows access to the data via authenticated analysis tools.

DSP manages all FALCN system interactions by accepting incoming data transmissions from IFI and DIP. The server establishes a socket and waits for clients to connect, then establishes a direct link to the database. The DSP

Figure 3: IFI Request Screen populated with TAP-generated route modification request.

Figure 4: IFI Dispatch Approval Screen.

handles clients by first identifying whether the connection originates from a flight or a dispatcher, then determines the specifics of the request. This requires parsing the server socket stream and developing a SQL query to appropriately manage database interactions.

When an IFI client connects to DSP, the server checks the incoming data and classifies the type before creating the SQL statement that will insert the information into the database. Transmitted data are stored to the database and any pending responses are retrieved. DSP relays these responses back to the IFI for display to the flight crew. When a DIP client connects to DSP, the server retrieves a list of active requests and returns them to the DIP for display. The server will also notify the DIP of cancelled requests and when there is an ATC decision update available for an accepted request.

C. Dispatch Interface Program

The DIP allows the dispatcher to effectively consult with the flight crew in order to reach an agreeable plan of action. Figure 6 depicts the current prototype for the dispatch user interface. The Incoming Route Request table in the center of the Figure is a queue of all incoming trajectory modification requests from flight crews. Each individual row in the table is representative of one request from a single aircraft. Should the same aircraft make an additional request, the original data in the table will be replaced with the most up-to-date request. The table is sorted by the most recent incoming requests. The dispatcher has the option to re-organize the table based on trajectory modifications that would maximize fuel savings or time savings most effectively. Selecting a request of interest will allow the dispatcher to return an approval, denial, or a request for contact from the flight crew.

If the dispatcher decides to approve a route modification, the row is translated from the Incoming Route Request table to the Approved History table, on the right side of Figure 5. The flight crew will then proceed to request a modification from ATC via radio transmission. As previously mentioned, the approval or denial from ATC will be returned to the flight crew and indicated to the dispatcher within the approved route history table.

The last selection provided to the dispatcher is a request for contact from the flight crew. In the meantime, the solution will remain in the incoming requests table while a requested contact message will be returned to the flight crew through IFI. The flight crew and dispatcher can then discuss the proposed route to reach an agreement on executing a route adjustment. The request contact button is important for situations where the dispatcher wants to gather more information as to why a flight crew plans to execute a certain route modification. Verbal exchanges could provide the dispatcher with more information from the flight crew, such as weather patterns that were previously unknown on the radar. The inclusion of a request contact functionality also provides the capability for the dispatcher and the flight crew to collaborate to make a minor change to the requested route before being approved.

The final aspect of the DIP is the interactive map on the left of the figure. The map is included to improve the usability of the interface and provide information to the dispatcher as efficiently as possible. When a flight is selected in the Incoming Route Requests, the map will zoom to depict the selected aircraft's current route in magenta and the proposed route in cyan. An interactive map will allow the dispatcher to visualize the proposed route quickly, without

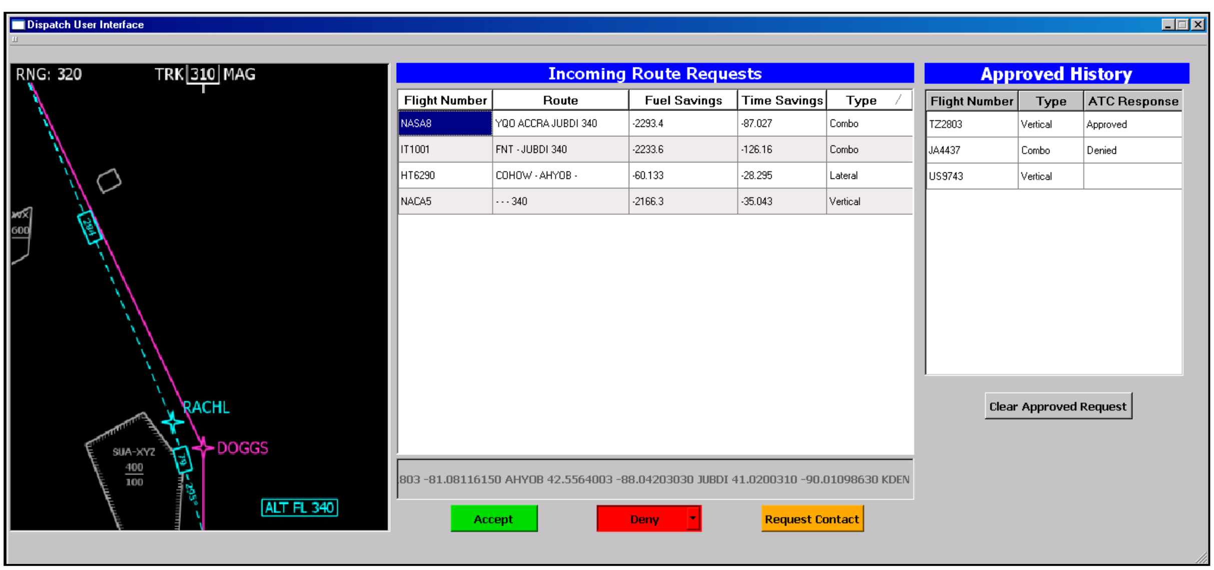

Figure 5: DIP Graphical User Interface

having to examine the entire modified waypoint information line. Reducing the workload on already busy dispatchers is a vital aspect for combining DIP with the dispatcher's current interface.

D. Database Architecture

When choosing a type of database management system to meet the FALCN project requirements, there were many important factors. The database would depend upon the use of multiple tables to catalog records of information. Established tables would then correlate with other data sets housed within separate tables of the database. For this reason, a relational database management system was developed. A relational database maintains storage of data in multiple tables and implements table relationships simultaneously.

The first iteration of the database management system was MySQL. Main project programming was done in C++ with Microsoft Visual Studio version 2010 as an integrated development environment. Issues occurred regarding communication errors between MySQL and Visual Studio. After considerable time was spent troubleshooting technical errors, a decision was made to attempt the use of Visual Studio's pre-installed version of SQL, ultimately yielding the same problematic results. Moving on to GNU Compiler Collection and compiling code via the command line, outside of Visual Studio, still did not correct the communication errors. After consulting a subject matter expert, PostgreSQL was selected and tested successfully.

The FALCN Database was programmed in PostgreSQL version 9.4 on Windows 7. The database, illustrated in Figure 6, was constructed to hold five tables: Aircraft State Information, Aircraft Intent Information, TAP Route Modification Requests, History, and Reasons.

The Aircraft State Information table holds state data information records, i.e., flight number, altitude, and airspeed, which is updated at one hertz during operation. The Aircraft Intent Information table stores limited intent information—the current active flight plan in the Flight Management System (FMS)—as a string of data from an XML file that is generated by TAP during flight for each aircraft. The flight plan is updated only when the active route in the FMS changes, such as when a waypoint in the route is sequenced, or when the flight crew enters a TAP-generated flight route modification. The TAP Route Modification Requests table holds TAP route modification requests, i.e., waypoint name, waypoint latitude and longitude, and fuel/time savings. This table updates any time a request is sent from TAP through FALCN. The History table is a log for air traffic controller and dispatcher decisions with corresponding reasons describing the approval or denial of route modification requests. The storage in the History table will allow the airlines to review previous flights and analyze data trends. This table is updated whenever a decision regarding a flight route modification is made by a dispatcher or a controller. A Reasons table was constructed to correlate a reason with the numeric value stored within the History table.

Every table within the database relates to each other by a flight number key, which links all tables together. The TAP Route Modification Requests table generates a Solution I.D. number that links to the History table and to a specific route modification request.

AIRCRAFT STATE INFORMATION

AC #	FLIGHT #	LATITUDE	LONGITUDE	ALTITUDE	TRUE TRACK	MAG TRACK	AIR SPEED	VERTICAL SPEED	CURRENT WP	WP LATITUDE	WP LONGITUDE	MAX ALTITUDE
DL4424	NASA8	42.48465	-83.0983543	300	272.797	280.239	0.76	0	AHYOB	42.5564	-88.0420303	MAX

AIRCRAFT INTENT INFORMATION

FLIGHT #	FLIGHT PATH DATA	PATH ID
NASA8	JOT* 41.5463448 -88.31840520 JUBDI 41.0200310 -90.01098630 KGEN25 JOT* 41.5463448 -88.31840520 MAX	31

TAP ROUTE MODIFICATION REQUESTS

FLIGHT #	ADVISORY ID	WP 1	WP1 LATITUDE	WP1 LONGITUDE	WP 2	WP2 LATITUDE	WP2 LONGITUDE	WAYPOINT REJOIN	WPR LATITUDE	WPR LONGITUDE	REJOIN ALTITUDE	FUEL	TIME	TYPE	SOLUTION ID	ACTIVE FLAG
NASA8	171	COHOE	42.15664	-80.6941417	N/A	N/A	N/A	AHYOB	42.556403	-88.0420303	340	-2088	67.041	COMBO	13	FALSE

HISTORY

SOLUTION ID	FLIGHT #	DISPATCH DECISION	ATC DECISION	HISTORY ID
13	NASA8	1	1	13

Figure 6: FALCN Database

V. Concept of Operations

FALCN requires TAP to be operational and coupled to the avionics of an aircraft flight deck environment. Data will only be transmitted to the AOC while an established Internet connection exists. When the user selects an optimized route within TAP, the IFI identifies the route modification and transmits the data as a request to the DSP. The DSP receives flight path, state, intent, and route modification data to store in the Database. The DSP simultaneously handles requests from the DIP to retrieve active flight data. The DIP manages the flight data to be displayed in the Dispatch GUI. When a Dispatcher makes a decision for a given request, the selection is made in the Dispatch GUI and transmitted from the DIP through to the DSP. The DSP sends the response to the IFI where it is displayed to the flight crew and stores a history of the requests in the Database.

VI. Conclusion

This paper describes the very first implementation of a prototype system that transmits aircraft flight data from the flight deck through an Internet connection. FALCN facilitates effective communications between flight crew and airline dispatchers. A companion paper[18] discusses the proof-of-concept demonstrations that were performed using this system. The current communication systems are costly with little return value for airlines, whereas FALCN utilizes Internet connectivity that is already certified and installed on aircraft. FALCN does not interact or interfere with flight control or safety systems, which ensures greater safety and reliability while reducing risk and liability.

The capabilities of FALCN are not strictly limited to the applications outlined by this paper. Applying big data analytics concepts to the resulting database would be invaluable to programs that lead towards reduced-crew and autonomous vehicle operations. With simple configuring, data could be sent and stored to an external database system in any location for data mining, researching data trends, content analysis, and remote access. Real-time information from actual flights would be beneficial for aeronautics researchers, scientists, and engineers. FALCN software can also improve efficiency prognostics of air travel through trajectory-based operations supporting NextGen. The scalability of FALCN will help future generations in improving and sustaining the Air Traffic Management System within the NAS.

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