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ATCA would like to thank all candidates who submitted a conference proceeding. This year’s participants covered a wide range of expert ATC and ATM knowledge. If you are interested in participating in 2014, email: Paul.Planzer@atca.org
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Aircraft Access to SWIM: ATM via DTM

Stuart Wilson, Charles Chen
Harris Corporation

Abstract
Information drives the way we interact and behave with the world around us. For pilots, shared information can have major impacts on improving decision making when flying aircraft. Today, pilots have limited access to authoritative aeronautical and meteorological (AI and MET) information in the cockpit. Digital information that is currently available to pilots may not be up-to-date or may not have been received from a reliable source, preventing pilots from safely using certain information for decision making. The Federal Aviation Administration is working through several demonstration tasks to improve and standardize the collection, management, and dissemination of National Airspace System (NAS) information to stakeholders accurately and on time. The System Wide Information Management, also known as SWIM, defines standard protocols, governance, validation, and routing to facilitate the exchange of vital information. SWIM itself does not address the challenges of delivering information to aircraft. Aircraft Access to SWIM, or AAtS, strives to bridge the gap between SWIM and the aircraft, the flight crew, and associated dispatch operations while addressing the challenges associated with AAtS. The implementation of AAtS encompasses several goals: to utilize and promote global standards and data exchange, ensure reliable delivery of information to pilots, improve situational awareness for aircraft crew, dispatch and controllers, support better decision making, and allow for safer and more efficient flight operations.

SWIM promotes global standards adoption and data exchange through the development of standard exchange models and protocols enabling the interoperable exchange of information between aeronautical data systems. In AAtS, these standards define the AAtS messaging infrastructure and data links. Several challenges associated with the implementation of the AAtS messaging infrastructure and data link are addressed by the Open Geospatial Consortium (OGC) in an engineering report titled: “Data Transmission Management.” Data Transmission Management is the concept in which AAtS addresses the challenges of ensuring reliable transmission data to the cockpit. The construct in which Data Transmission Management is employed is the Data Management Service.

This paper introduces the concepts of Data Transmission Management and the standards and capabilities necessary to meet the goals of AAtS. It also describes the impacts and benefits to the airspace, including pilots, airlines ops, dispatch, and Air Traffic Control (ATC). Finally, it addresses the challenges in adopting AAtS, Data Transmission Management, and a Data Management Service as a value-added service to the aviation community.
What is AAtS?
Aircraft Access to SWIM is a set of guidelines that dictate the services and features that must be operational for pilots to access SWIM data while in flight and use the provided information in their decision making process. AAtS implementation guidelines were set forth by the FAA to ensure data being consumed by pilots in flight was delivered while maintaining the reliability, validity, and accuracy of the information transmitted. While airlines and GA pilots are not required to consume their data using AAtS services, they can rest assured that the information being provided via AAtS services are reliable and authoritative.

Beyond SWIM
System Wide Information Management (SWIM) is an FAA NextGen program that provides data exchange services via Service Oriented Architecture (SOA). The primary goal of SWIM is to enable efficient and secure access to aeronautical, flight, and weather information in a net-centric infrastructure to reduce inefficiencies of point-to-point architecture. SWIM ensures the integrity of the information it provides to the service users, also known as consumers. Using SWIM, air traffic controllers, flight dispatchers, pilots and other stakeholders that consume the aeronautical data (charts, NOTAMs, SUA, etc.) flight data (flight plan, boundary coordination, radar track, etc.) flight data (flight plan, boundary coordination, radar track, etc.) and weather data (METAR, TAF, Wx radar, etc.) can depend on SWIM as a reliable source of information when making critical flight decisions.

At this time, SWIM is accessible only through ground-based connections. Using a wireless data link to access the SWIM network directly from an aircraft is not an acceptable SWIM connection. No guarantee of data integrity is made by the FAA for SWIM information accessed outside of the SWIM network. In addition, there is no direct access to SWIM data for pilots in flight. Instead, pilots must rely on indirect access such as contacting a Flight Service Station (FSS) for weather reports or receiving flight plan updates from a dispatcher via VHF data links. AAtS aims to bring a level of integrity to the aircraft by enabling pilots to have direct access to SWIM data.
**Standardized Approach to AAtS.**

In order to overcome the obstacles of exchanging aeronautical and meteorological information, standardization is vitally important. The Open Geospatial Consortium (OGC) has developed a standardized exchange method for implementing data transmission of SWIM via web services. The implementation details are discussed in an engineering report titled, “Data Transmission Management (DTM).” This report was based on a set of engineering demonstrations, including the use of a Data Management Service (DMS). The DMS is a web service implementation that provides aircraft clients with a reliable and efficient connection to SWIM using OGC web-based services. The DMS implements the methods described in the OGC DTM document using the recommended standardized approaches and protocols.

**Data Transmission Management**

The Data Transmission Management (DTM) engineering report addresses the issues in implementing a standards-based Aircraft Access to SWIM service. The report identifies four main goals that must be accomplished to provide a successful AAtS service:

- **Reliability**—Ensure no messages are lost during transmission to an aircraft
- **Efficiency**—Reduce bandwidth required for transmission of messages between ground services and aircraft
- **Provenance**—Provide data quality and data tracking information to aircraft receiving data from ground services
- **Dispatch**—Make dispatchers on the ground aware of the information sent to aircraft
A system or set of systems which can provide a service that meets the above listed goals can be considered eligible for acceptance as an AAtS solution. The OGC DTM engineering report, generated as an output of the OGC Web Services Initiative – Phase 9 (OWS-9), details a specification for a service, known as the Data Management Service (DMS), capable of meeting the four DTM goals using OGC standards.

Data Management Service
The Data Management Service provides value-added services and access to OGC Web Feature Services and OGC Web Coverage Services as an enhanced proxy service that meets the goals of DTM outlined above. As such, the DMS must be aware of the data link when processing messages as data transmission requirements change, depending on the type of data link the aircraft is connected to and the software the pilots are using. When connected to data link, low coverage, restricted bandwidth and signal loss can reduce the reliability of the data transmission. It is the job of the Data Management Service to ensure the pilots receive the data and the dispatchers receive acknowledgment of received data messages.

Data link to aircraft can consist of radio, cellular, satellite, Wi-Fi, or WiMax. As an aircraft disconnects and reconnects to each data link provider, careful management of the data must occur to prevent data loss. In general, most aircraft do not have access to multiple data links and cellular is typically the most common data link for domestic flights.

The valued-added services provided by the DMS to AAtS are encompassed in a series of service features: reliable messaging, data compression, message prioritization, message content filtering, message validation, data provenance tracking, and dispatch services. The reliable messaging feature and message prioritization feature ensure no messages are lost during
transmission. The data compression and data filtering features reduce the bandwidth required for transmission of messages between ground services and aircraft. The message validation and data provenance tracking features provide data quality and provenance information to aircraft receiving data from ground services. The dispatch feature makes dispatchers on the ground aware of the information sent to aircraft. The individual features are designed to address the specific goals outlined by the Data Transmission Management concept.

Component Functionality

The DMS functionality is separated into two categories: Base Features and Modules. This separation enables the DMS to standardize more general functions, such as reliable messaging, while facilitating the customization of more specific functions such as data compression.

Base Features:
- Reliable Messaging
- Dispatch Services

Module Features:
- Data Compression
- Message Validation
- Provenance Tracking
- Message Content Filtering
- Message Prioritization

Figure 4: OGC DTM Architecture
The DMS Base Features create a baseline of capabilities to accomplish the primary goal of Data Transmission Management: to allow aircraft clients to reliably and efficiently communicate with ground services. The DMS Base Features are designed to be implemented as common functionality across all Data Management Services. In conjunction with the Base Features, the Module Features allow for an individual DMS provider to provide implementation specific functionality beyond the Base Features. DMS Module Features can be customized to provide specific functionality required by stakeholders.

**Data Filtering Module**
The Data Filtering Module is a user configurable Module Feature designed to extend the message filtering capabilities of ground services. Message content is filtered using parameters provided by an aircraft client. By allowing clients to provide their own filtering instructions to the DMS, the Filtering Module can be customized to fit the client’s individual needs.

**Data Validation Module**
The Data Validation Module is a client configurable Module Feature designed to track the validity of messages being transmitted to the aircraft client. The module determines the currency of messages received which is provided by metadata included in weather and aeronautical messages. Depending on the configuration, non-current messages are either dropped or flagged and sent to the client marked as “non-current.”

**Data Prioritization Module**
The Prioritization Module is a client configurable Module Feature designed to ensure that messages of high importance are delivered to the aircraft client when transmitted over low-bandwidth data links. This module prioritizes messages based on settings defined by the client. Using these settings, the Prioritization Module assigns priority levels to messages scheduled to be transmitted and sends the highest priority messages ahead of the lower priority messages. A maximum wait time is configured for all messages, ensuring reasonable delivery times for even the lowest priority messages.

**Data Provenance Module**
The Data Provenance Module is a client configurable Module Feature designed to log the performance of the modules. Information such as the changes to message provenance made by the Filtering Module, the number of non-valid messages discovered and the number of non-current messages discovered is stored. This information can be used to identify and troubleshoot issues along the ATxS system. Additionally, this information can be referenced during incident/accident investigation to determine what data was available to the pilot and what errors, if any, occurred.

**Dispatch Module**
The Dispatch Module is a feature that allows a ground-based user (such as an airline dispatcher) to receive copies of the messages sent to an aircraft client. Dispatchers can use the information to track the information that has been received by the client. Additionally, dispatchers may subscribe a pilot to a data source they are currently not receiving. The functionality provided in this module gives airlines greater control over the information being received by their pilots.
Benefits to NAS

Pilots
The benefits to pilots from Aircraft Access to SWIM stem from the reliable availability of aeronautical and weather information that is highly current and easily accessed. Instead of receiving weather updates from an FSS specialist over VHF voice or tuning into ATIS, ASOS, or HIWAS stations, pilots will automatically receive relevant weather updates as they are generated in textual or visual form. Aeronautical information such as changes to Special Use Airspace (SUA) or flight plan updates also will be automatically pushed to the pilot in a textual or graphical form. Pilots can utilize the information received via an AAtS link to enhance their aeronautical decision making process.

Currently pilots are often making critical flight decisions, such as a diversion, at the last possible moment due to the lack of current weather information. Access to more up-to-date information via an AAtS link enables pilots to have better situational awareness during the aeronautical decision making process. The increase in situational awareness provides pilots with the ability to make critical flight decisions sooner, increasing safety and minimizing wasted time.

Commercial Flight Ops
To provide airline operations more control and insight into what weather and aeronautical information their pilots are receiving in flight, the DMS Dispatch Module provides airlines access to a live record of all the aeronautical and weather messages sent to the crew of their aircraft while connected to the DMS. Additionally the Dispatch Module enables dispatchers to subscribe their pilots to additional data feeds. Providing airline dispatchers administrative capabilities to monitor and control what aeronautical and weather information is being received by a pilot enables greater dispatcher-pilot coordination. Dispatchers will use this functionality to augment a pilot’s situational awareness with pertinent information and gain greater insight to the pilot’s decision-making process.

Air Traffic Control
With the adoption of AAtS, Air Traffic Controllers can reduce the amount of coordination required when communicating with aircraft due to increased situational awareness by the flight crew. While the advantage of a single aircraft with AAtS access is minimal, the benefits of AAtS are significantly increased when all aircraft become AAtS capable. Mass AAtS adoption leads to increased situational awareness and a decreased need to coordinate with controllers for decision making, especially for coordination with aeronautical data such as TFRs and weather data such as hazardous weather patterns. Additional benefits include more timely decision making, reduced delays, reduced fuel consumption, and improved passenger experience such as shorter flight times and lessened turbulence.

Challenges
The key challenge in the development of the DMS is creating a solution that can fully communicate with both the North America and European System Wide Information Management (SWIM) environments. Although the overarching system concepts for SWIM are the same in both North American and Europe, the actual SWIM implementations currently employ different technical standards for their communication interfaces. During the development of DMS for OWS-9, the web service technical standard is used as the communication protocol between aircraft, DMS, and grounds services. The use of web service as a communication protocol works well as a connection to European SWIM ground services. Future OGC activity could benefit from a focus on the integration of Message-Oriented Middleware (MOM), which is the communication protocol primarily used by North American SWIM ground services.

**Equipage**
Aircraft Access to SWIM is a system of systems that encompasses data links, messaging services, and displays. All three components must work together to meet the goals of AAtS. Each system contributes its own set of challenges and benefits to the whole of AAtS. Recognizing each challenge and developing an appropriate solution enables AAtS to be successful.

**Displays**
Display technology such as installed certified avionics or Electron Flight Bags (EFB) is possibly the greatest benefit multiplier of the aeronautical and weather information that will be made available by AAtS adoption. A well-designed EFB software application utilizes SWIM data and displays it in a way that improves a pilot’s situational awareness while reducing the time and effort needed to comprehend the information when compared to a textual read-out of the same information. Advances in visual display design have been widely accepted by the aviation community through the adoption of glass panel displays and issuance of EFBs to their crew. Unfortunately, a large portion of the data that is currently available on these displays are from noncertified sources and cannot be used for aeronautical decision making. Implementation of a functional AAtS system enables these inexpensive, yet advanced and proven display technologies to be utilized to their full potential.

**Data Link Quality**
Current data link providers for aircraft access to information are limited to satellite, radio, and cellular spectrums. Coverage across these data links can be unreliable and require constant reconnection and retransmission of data. RTCA SC-206 is tasked with researching and developing an AIS data link standard in order to improve the current infrastructure and better define the data link needs of the NAS in order to support Aircraft Access to SWIM.

**Data Standards**
Data standards are constantly evolving, and OGC web services are updating annually to keep up with the evolution of standard data model versions. During the Air Traffic Information Exchange Conference 2013 hosted in Silver Springs, Maryland, it was explained that AIXM 5.1.1 would be released in Q1 of 2014 and AIXM 5.2 is slated for release in 2015.

FIXM 2.0 was also released just before the conference, and would be incremented with new releases annually. The fast evolving changes to the data model make it difficult for new adopters
to choose a standard and develop accordingly. It may become the role of Data Transmission Management and DMS to mediate version control and provide backward compatibility between versions per requests by aircraft client. Data model mediation would provide a solid construct for adoption of AAtS by ensuring that applications and aircraft client displays can utilize a data model without becoming obsolete within a year.

OGC
OGC Interoperability Program (IP) projects such as the OGC Web Services Testbed Phase 9 (OWS-9) bring together a range of independent participants—from both the public and private sector—to respond to sponsor requirements. This was also true for the design and implementation of the DMS in OWS-9. ATMOSPHERE, TriaGnoSys and Harris collaborated on defining the technical specification of the DMS component, supported by other OWS-9 participants, primarily client developers such as Luciad.

The resulting DMS specification as well as investigation results represent the consensus achieved between the relevant stakeholders within OWS-9. All results of the OWS-9 work on Data Transmission (to Aircraft) Management are documented in the OGC Engineering Report (ER), which is open and publicly available. This allows everyone who is interested to review the results and to provide feedback, thus creating valuable input to improve the specification. This process—the ability to provide continuous feedback and to incorporate it in the specification—will ultimately lead to a DMS specification that is based on broad industry consensus. OWS-9 laid the foundation by creating the first version of the DMS specification. Future work on DMS will lead to further review of the DMS specification as well as new or updated requirements, and thus possibly revisions and extensions.

SWIM
Aircraft Access to SWIM requires a SWIM infrastructure in order to retrieve the SWIM data. In OGC, the SWIM data exists on externally hosted web service databases that, while net-centric, are not centrally hosted by a unified enterprise service bus. In FAA, this infrastructure is the NAS Enterprise Messaging Service (NEMS) and provides a one-stop-shop access to NAS data. As international ANSPs and AOCs begin adopting AAtS, the SWIM component of this must be established and governance policies must be enforced sufficiently at the SOA layer.

Enterprise Services
The goal of deploying DMS as an enterprise service is to provide a cost-effective, net-centric, and service-oriented approach to providing AAtS services without requiring a large initial investment by stakeholders. This means that a centralized service can provide the access needed by registering with the hosting ANSP or vendor with SLA requirements without needing to establish their own infrastructure IT platforms. It may still be desirable for large AOCs to implement the DMS in their own network operations centers, or for large AOCs to implement their own DMS services within their IT infrastructure. By adopting standard data models and open standard protocols, these independently developed DMS services can work interchangeably with developed aircraft clients, leading to global harmonization of services to benefit the NAS.
Data Comm Capabilities Provided by ERAM

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History
Controller Pilot Data Link Communications (CPDLC), or Data Comm as it is used within United States Airspace, has been investigated since the early 1970’s. As its name implies, this application provides a link between the pilots of the aircraft and the ground controllers to exchange information related to the aircraft’s current or future flight. This capability has been used for Oceanic exchanges since the 1990s, where the average aircraft separation distances are 50 nautical miles.

The FAA engaged Lockheed Martin in 2009 to extend ERAM to support Data Comm functionality in continental US airspace. An earlier program tested CPDLC capabilities at Miami HOST center in the early 2000s, but the functions were not incorporated as a permanent change to the system. This latest implementation plan is to roll out the functions to the field in different segments (S) and phases (P).

Why is Data Comm in the US so Different from other CPDLC Systems in use around the World?
Normally, CPDLC services are provided by a single ATSU (Air Traffic Service Unit) for a country. Some countries, such as Canada use a small number of ATSUs. In contrast, the US implementation involves 20 ATSU En Route centers and hundreds of Towers/Terminal Radar Approach Controls (TRACONs). Combining the large number of En Route facilities with a large geographic service area results in the need for a different approach for implementing CPDLC in the domestic US airspace.

When a pilot desires to enter into a CPDLC exchange, the first thing that the pilot must do is to request a logon to that service. This involves the avionics processing the request for the services to be used and sending it to the Communications Service Provider (CSP). The ground station then has the responsibility to forward the received message to the appropriate ATSU for processing. The ATSU has the responsibility for validating the format of the message, the content of the message, the version of the services requested, and also correlating this request to one (and only one) flight plan for the aircraft.

It is the last task, correlating this logon request to one and only one flight plan, where the difficulty of having an airspace maintained by 20 ATSUs presents a problem. How does the system ensure that there aren’t duplicate flight plans being maintained by different centers for that aircraft? If the system finds such a thing, what does it do? To address this problem, Lockheed Martin came up with the concept of having two National Data Centers, which would be responsible for performing this correlation task on behalf of the 20 individual En Route centers. The National Applications (NAP) Realm system is described below.
ERAM’s Role in Data Comm Segment 1 Phase 1 (S1P1)
The first implementation of CPDLC services is provided in the S1P1 portion of the FAA Data Comm contract. This phase of the program allows Future Air Navigation System (FANS) equipped aircraft departing from ATC towers equipped with the Tower Data Link Services (TDLS), to exchange Departure Clearance (DCL) messages with the aircraft. The DCL service differs from the current service (called Pre-Departure Clearance (PDC)), in that amendments to the original clearance will be able to be sent to the aircraft – instead of requiring amendment to be voiced over the radio. Since the FAA will be adding Data Comm function in different segments and phases of the contract in the future, it was very important to incorporate extensibility in the design of the initial system.

As shown in Figure 1, there are several systems involved in providing this service:

1. En Route Automation Modernization (ERAM) Data Comm (DC) National Applications (NAP) Realm components
2. TDLS equipped ATC Tower
3. Data Comm Network Services (DCNS) Communication Towers
4. Federal Telecommunications Infrastructure (FTI) Wide Area Networks (WAN)
5. ERAM system with additional S1P1 software
6. Tower Information Management System (TIMS)
As discussed earlier, a requested Air Traffic Services (ATS) Facilities Notification (AFN) message (also referred to as a logon) from an aircraft must be correlated with a unique flight plan to ensure clearance messages are delivered to the right aircraft. The primary and backup National Data Centers use a WAN connection to each of the 20 ARTCCs (ERAMs) in the US to perform this correlation function at a centralized location using data obtained from the ARTCCs that match certain criteria (all active flights that are controlled by a facility or are not controlled by any ERAM and are proposed flights that have been marked of interest by TDLS). The NAP realm now has a database of the aircraft which have requested CPDLC service or are active in NAS. This data will be used later by TDLS in the creation of a CPDLC session, to exchange DCL messaging.

The NAP realm was added to provide both an external de-militarized zone (DMZ) and an Internal DMZ functionality, which provides security boundaries between National Airspace (NAS) systems and non-NAS systems. The External DMZ elements consist of the Protocol Gateway Front End Processor (PGW-FEP) and associated switches. The functions allocated to the PGW-FEP are:

1. Network Translation (NAT) function so that external network addresses do not know about internal network addresses.
2. Application Layer message inspection (to ensure that all messages meet the requirements specified for that interface)
3. Message routing (to send messages to the TDLS equipped Towers (via the TIMS-BEP) or to NAP processor (NAP)

The internal DMZ elements consist of the Data Comm Ground System (DCGS) Back End Process and associated switches. The function allocated to the DCGS-BEP is message routing to NAS elements.

The final components within the NAP realm are the routers (which provide connectivity to the associated ERAM En Route centers) and the NAP processor (NAPP). The NAPP is the server which contains the logon to flight plan correlation logic and also retains the Blocked List database.

The National facility is also responsible for acknowledging the aircraft’s request for logon and for supporting a new service called the “Blocked List”. The “Blocked List” is an important safety feature provided by ERAM for Data Comm. As its name implies, it is a list of aircraft registration numbers for aircraft that have been blocked from receiving CPDLC services. ERAM automatically adds an aircraft to the Blocked List when it detects multiple credible flight plans having the same tail ID (registration number) that matches an aircraft logon. An aircraft’s registration number is supposed to be unique, but if it is not, the logon could be correlated to the wrong flight plan and clearances sent to the wrong aircraft. ERAM’s Blocked List processing prevents this situation from occurring. ERAM also adds aircraft to the Blocked List when an aircraft repeatedly attempts to log onto the system over a short period of time. This is known as a denial of service threat. ERAM also provides the ability for an Air Traffic Specialist to manually place an aircraft on the Blocked List. An aircraft remains on the Blocked List until it is manually removed by an authorized user.
In addition to adding the NAP realm to the two National facilities, applications were also added to the ERAM suite of software at each ARTCC to support S1P1. These additional applications perform the following tasks:

1. Provide Flight Data to TDLS equipped Towers for use in creating the PDC / DCL clearances to the aircraft
2. Provide interface for Air Traffic Specialists to query the logon/CPDLC state of an aircraft
3. Provide interface for Air Traffic Specialists to add/modify/delete aircraft on the Blocked list
4. Provide Data Comm Aircraft Address information to TDLS Equipped towers
5. Management and Support for these services.

The TDLS equipped towers use the flight data provided to them by ERAM (see Flight Data path in Figure 1 to compose the DCL clearances to the aircraft (and PDC clearances until all systems have transitioned). Once TDLS are ready to send a message to an aircraft, they ask ERAM for the specific CPDLC addressing characteristics needed to establish a CPDLC session with the aircraft (see Logon/session path in Figure 1. This request triggers the correlation logic in the NAP realm to find the one flight plan which matches the characteristics and responds with the specific CPDLC addressing information for that aircraft. TDLS will then establish a CPDLC connection to the aircraft via the TIMS, DC NAP Realm, and DCNS path (see CPDLC Session message/response in Figure 1. TDLS will continue sending ERAM status on the CPDLC session and also the state of the clearance (was it delivered or not) so that this may be updated in the NAP Realm database.

Data Comm Segment 1 Phase 2
FAA planning for the second phase of Data Comm, Segment 1 Phase 2 (S1P2), is underway. The FAA is analyzing various capabilities, finalizing requirements of S1P2 and working towards the S1P2 Final Investment Decision (FID). One capability considered for S1P2 implementation is for ERAM to be able to exchange CPDLC messages with airborne aircraft. This capability requires the ERAM system to allow existing CPDLC equipped systems such as: TDLS equipped ATC towers, En Route systems, Advanced Technologies and Oceanic Procedures (ATOP), and Canadian/Mexican CPDLC systems; to exchange CPDLC data authority with one another.

Another S1P2 capability under consideration is the Data Comm Services (DCSV) application. This application, implemented within ERAM, would be responsible for communicating with the display application, flight application, surveillance application, and the Protocol Gateway Services (PGSV) introduced during S1P1. DCSV would provide the Transfer of Communications (TOC) and Initial Checking (IC) functions which are needed anytime an aircraft travels from one ATSU to another ATSU (for intersegment communications) and also from one Sector of airspace to another (for Intra Segment communication). DCSV will also be responsible for exchange of all CPDLC uplink and downlink messages with the aircraft and management of the eligibility of communication with the aircraft.
Depending upon the types of CPDLC clearances and messages implemented in S1P2, modifications to the ERAM Computer-Human Interaction (CHI) will be required. Controllers at the Radar and Radar Associate positions may need to exchange the following types of CPDLC clearances and messages considered for S1P2 implementation:

1. Transfer of Communications (TOC) and Initial Check-in (IC)
2. Altitude Clearances
3. Altimeters Information
4. Advisories
5. Route Message Clearances
6. Emergency Mode Processing
7. Crossing Clearances
8. Tailored Arrival Clearances
9. Speed Clearances
10. Heading Clearances
11. Beacon Code Clearances
12. Stuck Microphone

Additional icons in and around the aircraft data block on the Radar position Situation Display would be added to present CPDLC status information that can be easily assimilated into the controller’s visual scan of the display. Detailed menus and views would provide additional information and functionality. To provide situational awareness to the Radar Associate Controller, similar status icons, menus and views would be added at that position as well.

Future Phases
Data Comm within the United States will use the infrastructure established in S1P1 and potentially enhanced in S1P2 to extend Data Comm capabilities in the future. They may include augmentations to the existing set of CPDLC messages already exchanged between Towers and En Route centers, along with introducing new equipage to the air-frames and ground systems to be able to process Aeronautical Telecommunication Network (ATN) messages. ATN, a newer communications standard for exchanging CPDLC and other types of messaging, which include:

1. Flight Information Services (FIS)
2. 4-D Trajectory
3. Automated Dependent Surveillance – Contract (ADS-C)

Conclusion
Through the multi-phase Data Comm program, ERAM is an integral part of the FAA’s plan to enhance collaboration between pilots and Air Traffic Controllers, helping to share situation awareness.
Americans often describe being deeply dissatisfied with their commercial air travel experience, even though ticket prices, flight delays, and lost baggage have all declined. This apparent paradox is best explained by research that suggests that customer dissatisfaction is a function of the anxiety associated with the uncertainties of the air travel experience, rather than the technical efficiency of the airlines. This paper describes Fleet™, a system designed to gather, process, and display information in order to alleviate uncertainties in commercial air travel. Fleet™ users access a server-side database of information that integrates distributed data from SIGMETs (Significant Meteorological Advisory), METARs (Meteorological Terminal Aviation Routine Weather Reports), the Flight Information Service, the FAA (Federal Aviation Administration), NOTAMS (Notice to Airmen), and commercial airline data. Fleet™ then augments these data with crowd source data, which is obtained from Fleet™ users. The result is a powerful application that integrates distributed information to provide services to passengers via a single smartphone interface. Fleet™ also provides the FAA with real-time information about congestion at the airport, a communication channel by which airlines can improve customer services, in addition to providing airport businesses with opportunities to increase sales through targeted offers to passengers.

Introduction

Historians describe the decade between 1930 and 1940 as a time of transformation for the commercial air travel industry in the United States (Del Sesto, 1983). The aircraft of the 1920s flew at low attitudes where weather conditions made smooth flight difficult, and aircraft operation manuals such as ‘Safety and Accommodation in European Passenger Planes’ (1928) recommended that airlines stock a good supply of sick bags and disinfectants for “when the results of sickness are on the floor.” By the 1930’s, aircraft enhancements had dramatically improved both flight safety and passenger comfort, but the airlines still needed to relieve customers’ fears about flying (Lyth, 2009). To address the public’s fears, Boeing Air Transport and other companies hired registered nurses to fly with passengers during flight (Corn, 2002, pg 89). These ‘stewardesses’ were even provided with outfits designed to resemble a nursing uniform as a display of air travel safety (Lyth, 2009). By the mid 1940’s, the airline industry was on its way to becoming a major transportation sector because they had found innovative ways to reduce customer anxieties about air travel.

Today, the American commercial airline industry is facing a new set of challenges related to air travel anxiety. Although air travel has now become one of the safest and most cost-effective methods of transportation available, recent surveys by Bowen & Headley (2012), JD Power and Associates (2010), JD Power and Associates, and other market research firms all confirm widespread passenger disappointment with the air travel experience. Bowen et al. (2012) showed that over 53% of frequent fliers in 2011 reported that air travel has “gotten worse” for them over the past year, even though airlines actually improved on-time arrivals and baggage delivery, while reducing complaints and ‘denied boarding’ incidents over that same time period. In addition to improvements in services, air travel has also become less expensive – Perry (2012) shows that fares are now $150-200 cheaper than they were in
the 1980’s. How can it be that air travel has become cheaper, safer, and more reliable, while at the same time alienating its own customer base?

While it is true that some customer dissatisfaction stems from new reductions in airline’s standard services, in other respects, the customer dissatisfaction problems of today echo those of the 1930’s. Researchers have shown that satisfaction may actually depend on how well passengers cope with the anxiety associated with air travel, a trait that is unrelated to the technical efficiency of the airlines (Locke & Feinsod, 1982). Dean & Whitaker (1982) have shown that anxiety during air travel is often caused by mundane events like unanticipated long lines for security, lost baggage, or missed connections (see also IATA, 2012; Stone, 2012). These findings are in keeping with research on anxiety that has linked the uncertainty of events with the creation of anxiety (Hartley & Phelps, 2012). McIntosh et al. (1998) found that reports of air travel anxiety were actually higher for incidents of missed flights than they were for in-flight turbulence, and that air travel anxiety often begins as early as when people leave home to begin their trip. Unfortunately, they also found that almost every major component of air travel, including check in, security, flight boarding, baggage claim, etc., often produced anxiety in at least some of their respondents. These sources of anxiety are likely to have become even more pronounced as additional air travel security measures were implemented following the September 11th attacks on the United States (Lyon, 2006), and as air traffic congestion continues to grow in the coming years (FAA, 2013a; FAA, 2013b).

The FAA ‘Design Challenge’
The Fleet™ system was built from the ground up to provide air-travel customers with targeted information and services designed to reduce anxiety, but the project began as an entry in the Federal Aviation Administration (FAA) Design Challenge for Universities. The FAA Design Competition is an open competition for Universities where undergraduate and graduate students work alongside faculty mentors to develop fully functioning, next-generation technologies for the FAA. Our entry was in response to the design challenge to find innovative applications of FAA Data. The Fleet™ system reported here represents the outcome of six months of work by eight team members from four academic departments at George Mason University: Engineering, Art & Design, Computer Science, and the Human Factors and Applied Cognition program in the Department of Psychology. Our entry took 1st place in the competition, and will now enter an exploratory commercial development phase. More information about the FAA Design Challenge can be found online at: http://faadesigncompetition.odu.edu.

Reducing Air Travel Anxiety with Fleet™
The Fleet™ Mobile Application leverages innovative techniques and technology to enable a new way of engaging users, collecting information, and disseminating information. As shown in Figure 1, Fleet™ provides users with actual and anticipatory real-time information about flight changes, flight delays, flight cancelations, and customer baggage. Fleet™ achieves this at a much higher level of reliability than existing systems by aggregating distributed data from a variety of sources that include SIGMETs (Significant Meteorological Advisory), METARs (Meteorological Terminal Aviation Routine Weather Reports), NOTAMs (Notice to Airmen), data from ARINC (Aeronautical Research Inc.), MOAs (Military Operations Areas), and the flight information service. Our algorithm aggregates these data to predict delays, and improves upon its predictive accuracy as it gets experience with more flight situations.

In addition to information about weather and aircraft conditions, at the core of the Fleet™ Mobile Application is the additional data that Fleet™ collects using ‘crowd-sourcing’ techniques to augment existing knowledge. In broad terms, crowd-sourcing relies on the wisdom of the crowd to obtain timely and reliable
data. In the context of the Fleet™ Mobile Application, this means Fleet™ has the ability to incentivize travelers who use Fleet™ to report on current conditions for the benefit of other Fleet™ users, a departure from more traditional applications that deliver information only from authoritative sources. The crowd-sourcing component of the application provides real-time predictions of wait times at various stages of the travel process including estimates of check-in times, the lengths of security lines, and general airport congestion. Passengers who are provided with this information are more likely to plan accordingly for a more enjoyable travel experience. Ideally, passengers that implement effective planning strategies based on Fleet™ information will also improve the overall efficiency of airports by arriving during optimal windows of time that are neither too early or too late, leading to a reduction in the hindrances associated with poor planning.

A ‘gifting’ feature of the Fleet™ application distributes special offers and services to Fleet™ users, and serves as the primary incentive for customers to provide crowd-source information. The ability for passengers to report information about airport conditions may give some individuals the altruistic sense that they are helping to inform other Fleet™ users, but additionally, Fleet™ users who provide information are also eligible to receive gifts in the form of coupons and offers from local businesses, as a reward for their participation. Gifting also serves a second function in the overall Fleet™ system as another method of reducing passenger anxiety. This is because airline companies will be able to access the gifting system to provide compensation to air travelers who face flight delays or cancelations. In addition, Fleet™ allows friends and families to monitor loved ones’ travel, and in the event of hardships, provide their loved ones gifts via the Fleet™ system. A third advantage of the Fleet™ gifting system is that it is likely to increase airport establishment revenue. Establishments that agree to work with the Fleet™ application are expected to increase their sales revenue because the Fleet™ gifting feature will provide advertising for airport vendors that can increase customer loyalty and sales at participating businesses. Passengers who redeem gifts may also make additional purchases, resulting in sales that would not have occurred without the Fleet™ feature.

**How Fleet™ Works**

Fleet™ consists of three main components: the client, the server, and the analyzer. The client is an iOS application that acts as the front-end of the Fleet™ service. The client communicates to the server, which hosts a persistent database of information about airports and flights that the client can query directly. Finally, an “analyzer” entity queries various data sources and updates the information on the server. For the purposes of this section, these components will be referred to as client, server, and analyzer, respectively. These components interact with various cloud based data sources and with two types of users: travelers and followers.
When a user first opens Fleet™ they are presented with a start-up wizard. The start-up wizard is programmed to open only the first time that the application is used. The wizard provides the user with an overview of how the application works and how Fleet™ can improve the flying experience. They are then prompted to enter their username and password – or login via their Facebook account. This process automatically creates a user account by sending the customer’s information to the Parse server. Once the account is created, the user is exposed to what the application looks like when it is entered after the first use. This view consists of a custom tab bar design with four tabs: home, scanning, gifts, and settings. The home screen is the main view that users interact with. This view is a navigation view controller, where the first step in using the view is to determine the needs of the user (e.g. are they a traveler or a follower). If the user chooses follower, they are asked to enter the username or ticket number of the individual that they want to track. If the follower chooses a username, the traveler has the option to verify whether or
not they want to be tracked by the follower. If the user chooses traveler, they are prompted to enter their flight number, or scan their ticket (see Figure 3). Using the flight number or ticket scan, Fleet™ is able to authenticate the flight using the Parse server, which propagates the most relevant information to the traveler or follower.

Once the flight is verified, the server side infrastructure is used to analyze relevant data from a variety of sources that include SIGMETs (Significant Meteorological Advisory), METARs (Meteorological Terminal Aviation Routine Weather Reports), NOTAMs (Notice to Airmen), data from ARINC (Aeronautical Research Inc.), MOAs (Military Operations Areas), and the flight information service. We plan to augment these data with the flight projections from the airline data, in addition to user provided crowd source data.

We have implemented an exemplary interface of the output of the server. Relevant information is provided to the user using a customized tableview that displays different options in a tile-based format. These tile options include: alerts, Fleet™ questions and deals, weather updates, gifts, relaxation techniques, games, luggage information, and sleep improvement suggestions. All of these tile types can be allocated to each of the three legs of the journey based on the user’s unique needs. Additionally, the Parse server can push alerts to any of the tiles by changing the tile background, thereby making the tile more salient to the user.

Technical Information: The Server
Fleet™ uses a service called Parse (Parse, 2013) for back-end support. Parse provides several core functions for data- and communication-dependent applications, including database functions, push notifications, user authentication and native libraries for many different platforms. Fleet’s server component is implemented as a Parse “App.” Associated with this application are collections of objects (analogous to a database of tables) and cloud functions that provide the client software with ways to trigger custom behavior on the server.

The Fleet™ application exposes two classes of objects to the client: airports and flights. Not surprisingly, each airport object contains data about one of the 306 U.S. airports that have data available through the FAA Web Services API. These data include IATA code, estimated congestion and estimated security delay. Flight objects contain data for all physical flights being tracked by the Fleet™ app, and includes information on the airline operating the flight, departure and arrival airports, as well as estimates of critical times associated with the flight, such as seating time and arrival time. For both types of objects, all estimates have associated with them some measure of confidence.

In addition to exposing airport and flight objects, the server also responds to cloud functions for handling state changes and other kinds of exchanges. Currently, there are two cloud functions; “sendReport,” called by the client to report on errors or the veracity of Fleet’s data, and “registerFlight,” which signals the server to begin tracking a flight.

Technical Information: The Analyzer
The analyzer component continuously monitors user reports from the server and FAA data sources to update the information contained in airport and flight objects. Airport objects are updated on an hourly basis, but flight objects are updated on an adaptive schedule. In simple terms, as the departure time for a flight approaches and as the number of reports associated with that flight increases, the flight object gets updated more frequently. The analyzer is implemented as a collection of python scripts running repeatedly on a virtual private server (VPS) via cron jobs. These scripts make use of a local sqlite database that persists data pulled down from the server component, as well as information necessary to schedule external data source polling.
So far the client, server, and client-server communications have been fully implemented. However, the analyzer and its interface to the server has been specified but not implemented. Because the analyzer's function is critical to the overall operation of the Fleet™ application, a graphical utility has been created to simulate its behavior during parallel development of the other components and user-testing. The analyzer implementation represents a significant research and engineering task, and is beyond the scope of this design competition.

**Technical Information: Ticket Scanning**

A ticket-scanning feature has been implemented using a 3rd party API called the ZXing API (2013), which turns the camera within smart phones into a scanner. In Fleet™, the scanner can be used on QR codes or barcodes that can be found in the airport (see Figure 3). For example, barcodes can be found on your ticket and QR codes can be found on Fleet™ flyers that are scattered throughout the airport for the Fleet™ scavenger hunt. Scanning the ticket is an easy way to populate your electronic ticket and display ticket information in a more efficient way. The Fleet™ scavenger hunt is one way we alleviate anxiety at the airport, by providing the user with fun games that can be performed while waiting for a flight. The games involve finding Fleet™ QR codes that are located throughout the airport, such as in airport museums or other relevant parts of the airport. When these codes are scanned, relevant information about the city or airport is displayed. In addition to dealing with anxiety, this feature of the application can also be used to move people to specified locations throughout the airport and prevent overcrowding.

**Conclusions and Future Directions**

Fleet™ underwent multiple rounds of iterative design to ensure that it addressed the needs of passengers, would alleviate anxiety, and make flying more fun and easy. The result was the development of a novel system that combines available data sources on delays with crowd-sourced data. We believe that Fleet™ has a wide-scale commercial viability, based on its business model of acquiring a small percentage of each transaction that occurs through the Fleet™ platform. In addition to being a viable commercial product Fleet™ can reduce user anxiety, benefit airlines through improved customer satisfaction, and help the FAA by providing them with more accurate data on delays and other issues at the airport.

Fleet™ is still under development, but the principles applied in the creation of this application are relevant to the creation and improvement of many types of mobile applications, particularly those aiming to relay real-time information to a wide user base. Distributed systems combine multiple, redundant sources of information in a way that allows for the reliable relaying of information to users, with each source increasing reliability and accuracy of the other sources (Hutchins, 1995). Gaining crowd-sourced information from users using easy-to-answer queries allows for a much stronger distributed system because the crowd-sourcing fills in gaps in important information unable to be provided by existing sources. Lastly, being able to deliver relevant information to users at key points allows for the application to be the most effective to an individual user, and more utilized on a grand scale.

**References**


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Abstract
To support air transport efficiency, cost reduction and safety, a modernization of the global air transport system's view of weather, natural hazard and related impacts needs to be developed. The modernization will include using information from designated meteorological information service providers, delivered to geographically dispersed air carriers, airport owners and ATM units. That requires that meteorological information be shared seamlessly with air transport stakeholders to enable informed decision making. This effort to share the data will obviously necessitate revised or new data exchange formats, standards and protocols, as well as, an applied service oriented architecture methodology, enhanced methods of communication and governance processes.

Additionally, and equally as important, Air Navigation Service Providers (ANSPs), airlines and General Aviation (GA) airports and meteorological information services providers will have to embrace new ways of sharing/displaying and using meteorological information data and impact assessments. This improvement will allow the ANSPs to collaboratively conclude a system response to anticipated impacting phenomena. Agreement about which specific meteorological information is required to create a Common Operating Picture (COP) for weather impacts needs to be discussed with all stakeholders.

A means to that end has been evolving over the past two decades. Collaborative Decision Making (CDM) has been a cornerstone of the successful operational relationship among stakeholders in the U.S. and Europe since its inception in the early 1990s. There are differences in how the respective CDM communities currently ingest and translate weather to determine a system response. As we modernize the global air transport system, stakeholders need to better recognize the impact of weather, and build realistic response and recovery plans to minimize cost, improve efficiency, and contribute to a safe and managed outcome.
**Introduction**

Global aviation works because of cooperation and agreement between states encapsulated in International Civil Aviation Organization (ICAO) process, procedures and standards. This can be directly refined as “collaboration” which has matured into “Collaborative Decision Making,” as recognition by aviation business elements of emerging interdependencies required to reduce costs and optimize infrastructure.

Aviation is thus no stranger to the notion of collaboration and the advantages, but it was not until congestion, in the air and on the ground, that a need for an elevated collaborative process emerged in the United States.

The focus of this paper is on dealing with the creation of a Common Operating Picture (COP) for weather impacts using the CDM process as practiced in the United States, Europe and Australia, recognizing that there are distinct considerations for CDM to be successfully applied in different regions of the world. Firstly, the types of weather causing the greatest impacts vary by geographic region (e.g., thunderstorms, hurricanes and snow/ice in the U.S.; low ceilings, reduced visibility, wind, snow/ice in Europe; low ceilings, reduced visibility, wind, tropical storms in Australia). Secondly, there are a number of challenges that CDM faces in regions with multiple ANSPs and meteorological information providers.

Examples will be provided of how CDM-related groups are working on tasks which will integrate weather information with aeronautical and flight information to provide weather impacts. These tasks are aligned with NextGen and Single European Sky ATM Research (SESAR) tenets and are in various stages of progress in the U.S., Europe and Australia, and ultimately toward the globally interoperable systems and data envisioned in ICAO’s Aviation System Block Upgrade (ASBU).

**Regional Variations of CDM**

**CDM in the United States**

Within the United States, per the Federal Aviation Administration’s (FAA’s) CDM website, “Collaborative Decision Making (CDM) is a joint government/industry initiative aimed at improving air traffic flow management through increased information exchange among aviation community stakeholders.” CDM is comprised of representatives from government, general aviation, airlines, private industry and academia who work together to create technological and procedural solutions to the Air Traffic Flow Management (ATFM) challenges faced by America’s National Airspace System (NAS). CDM is an operating paradigm where ATFM decisions are based on a shared, common view of the NAS and an awareness of the consequences these decisions may have on the system and its stakeholders. There are two central tenets to CDM: that better information will lead to better decision making, and tools and procedures need to be in place to enable ANSPs and the air carriers to more easily respond to changing conditions.

The Weather Evaluation Team (WET) is a sub-team of the CDM organization and it also consists of representatives from government, general aviation, airlines, private industry and academia, all of whom work together to create solutions focused on meteorological challenges that face CDM stakeholders within the NAS.
The WET has been a sub-team for over a decade, albeit under different names. The WET's first task was to come up with a convective forecast to be used for Air Traffic Management (ATM) decisions for the NAS. The driving force behind this task was the fact that the multiple CDM stakeholders had their own forecasts, which often differed, therefore making it difficult for Traffic Flow Management (TFM) planners to agree on a particular TFM plan for the NAS as the TFM planners perform their daily collaboration. The solution became known as the Collaborative Convective Forecast Product (CCFP). The CCFP is a product facilitated and produced by the National Weather Service with input from CDM stakeholders. The forecast process for the CCFP parallels the CDM Strategic Planning Call in that it is updated every 2 hours and is available to the CDM TFM planners prior to the Planning Call for use in making adjustments to the NAS plan for the day.

In essence, the CCFP provides a Common Operational Picture of convective weather for which everyone in the planning community can use to come to agreement on a particular traffic management initiative. In today's NextGen language, the CCFP was an early version of the Single Authoritative Source (SAS), knowing it is difficult to agree with a plan for the day using different weather forecasts.

The CCFP has changed little over the years, but what has not is the infusion of new science and technology that has provided multiple convective forecasts to include probabilistic forecasts. In addition, unlike years ago where this weather information was limited to within the meteorologist community, this information is now readily available to anyone with access to the internet and perhaps even decision support tools that integrate this information in some manner. One could easily argue that the CDM community is faced with the same challenge seen in the late 1990s when the WET received its first task: how to make sense of multiple, often differing convective forecasts for the development of a TFM plan for the NAS.

Given this challenge, the WET undertook the process of investigating, developing and demonstrating the concept called Operational Bridging in 2010. Operational Bridging (OB) is a set of weather forecasting processes, communication tools and engagement protocols between meteorologists and ATM decision makers, all intended to accelerate the transition of aviation weather constraint forecasts from probabilistic to near-deterministic and enable more timely ATM decisions (flow chart shown below). In many respects, OB processes and protocols are neither new nor revolutionary. Many organizations that successfully manage aviation operations today practice one or more of the concepts that make up OB. What does make this effort unprecedented is the attempt to document and standardize the complete set of concepts for implementation at the national level.

From the perspective of some groups, including the FAA Air Traffic Control System Command Center (ATCSCC), full OB implementation will result in some aviation meteorologists playing a different role than they do today. While the overall concept of OB could appropriately be applied to all weather phenomena affecting the NAS, initial concept development and outreach activities, including the set of “Tabletop” demonstrations that occurred in the first half of 2011, focused on convective weather impacts. This strategy continued in the summers of 2012 and 2013 with a major validation effort focused on the New York Metroplex. These demonstrations were limited due to personnel resource constraints to facilitate the OB process. That stated, results to date
have been positive and the CDM Steering Group (CSG), (which is the CDM senior leadership) has tasked the WET to investigate how OB can be implemented for the entire NAS. WET is currently determining the personnel resources required as well as how the output of the OB will be integrated into the Traffic Flow Management System (TFMS). A proposal back to the CSG is due in late summer 2013.

Because OB is the combination of a national, standardized collaborated weather forecast and communications process, and because there do not currently exist forecast products or communications tools and protocols that would support all aspects of such an effort, the WET investigated a number of potential solutions. At least a portion of that analysis continues today. The National Weather Service (NWS) Storm Prediction Center (SPC) produces an effective national convective forecast product called the Mesoscale Convective Discussion (MD). The MD provides benefits akin to what members of the WET envision from OB: a widely distributed, standardized method of accelerating the transition of probabilistic convective forecasts to near deterministic. Because the MD has a very broad target objective (i.e., the safety of all U.S. citizens), it does not necessarily have the clarity or focus needed by aviation users in industry or government. However, the WET understood the value in its general format, which combines text and graphics, and in its wide and effective communications method.
To fill the OB product void, the WET developed the Aviation Weather Statement (AWS). Modeled after the NWS SPC MD, the AWS is the vehicle through which unscheduled, event-driven updates to forecast weather constraints will be communicated in a standard process on a national basis. It will contain both text and graphics. An example of the AWS is found just above. The AWS will be issued based on specific meteorological triggers or thresholds (e.g., some combination of location, mode and probability of forecast VIP Level 3 thunderstorm activity) identified by traffic managers as being key for their area. Any person identified as an OB collaborator may initiate the process which results in the publication of an AWS. For the purposes of ATM decision-making, AWS information will be considered to supersede any other scheduled forecast product such as the Terminal Aerodrome Forecast (TAF). With respect to communications tools and protocols, the WET determined a modern, web-based chat tool capable of supporting multi-user collaboration and relevant text, graphics and video should be identified and used in support of OB. A final determination of what this tool will be has yet to be decided by the WET.

The WET identified at least two NextGen principles that OB would support:

- The use of a Single Authoritative Source (SAS) of weather to provide a COP on which to base ATM decisions; and
- The use of the Human-Over-The-Loop (HOTL) process with automated forecasts.

As stated earlier, industry and government managers today have multiple convective forecasts available to support their ATM decision processes. In addition to the officially recognized product, CCFP, new fully automated convective weather forecast systems such as the Corridor Integrated Weather System (CIWS) and the Consolidated Storm Prediction for Aviation (CoSPA) continue to be developed and fielded. The accuracy and precision of these products often exceeds that of CCFP, and users generally find them more effective and easier to use. Because they are digital, these products can easily be overlaid on traffic display systems and integrated directly into decision support tools, both actions of which are key steps in the evolution of the concept of ATM-Weather Integration. CIWS and/or CoSPA could potentially replace CCFP as the default SAS for convective weather, except for the lack of collaborated HOTL oversight of the forecast output.
The OB process is clearly capable of being the source of collaborated HOTL oversight of these or any other new forecast products. As such, the WET believes the AWS is a natural evolution of today's CCFP.

In addition to addressing the conceptual aspects of OB, actual operational implementation of the concepts on a national level is the final objective. The following sections will describe progress toward that ultimate goal.

Concept Validation/Outreach Activities—Tabletop Demonstration

To receive broader feedback on the OB concept and gauge its potential utility, the WET organized and executed a series of tabletop demonstrations of the concept in five separate breakout sessions at the 2011 CDM General Meeting in Atlanta in early May 2011. A survey prepared by the WET was provided to members of the CDM community following each breakout session. CDM audience members completed more than 80 surveys. This section contains a description of the tabletop exercises, a review of the survey, an analysis of the results of the survey and a conclusion.

The tabletop demonstrations consisted of scripted scenarios in which the potential utility of the OB process was demonstrated by the WET actors. Each scenario used weather data and graphics associated with recent convective weather forecast situations. The narrator led the audience chronologically through the process leading up to an ATM decision being made in the face of uncertain weather forecasts.

OB products such as the publication of an AWS and an unsolicited briefing call from the OB meteorologist were demonstrated in logical places in the sequence of events. Depending on available time, either two or three scenarios were performed for each breakout group. At the end of each scenario, the narrator paved the way for the survey by asking the audience, comprised primarily of either government or industry ATM decision makers, to think about the value of the OB processes that had been demonstrated, and whether or not they were helpful. Audience members were requested to complete a one-page survey containing six questions relative to the OB concept at the conclusion of each breakout session. The questions, designed to measure the perceived utility of OB, were to be answered from the perspective of either a government or industry ATM decision maker.

Of the 85 survey respondents, 50 stated that they were U.S. ANSP participants, 18 identified themselves as industry participants, and the remaining 17 indicated that they were either contractors or Canadian ANSP representatives. It is unclear whether this ratio of respondents corresponds to the makeup of the entire population which participated in the 2011 CDM Annual Meeting, or whether the U.S. ANSP (FAA) participants were particularly motivated to provide feedback on the OB process. The first question asked the respondents to rate their level of understanding of the described weather situations prior to the use and demonstration of OB processes in the scenarios. Most respondents believed they understood the operational implications of the briefed weather situation fairly well.

Survey Results—Question #1:
Despite the fact that most participants indicated they had a good level of understanding of the underlying weather situation at the beginning of each scenario, a large majority felt their level of understanding improved after viewing the first operational bridging product, namely the AWS. Also important was the fact that no respondents felt their level of understanding was reduced in any way by the AWS. Both of these conclusions are reflected in the responses to the second survey question.

Survey Results—Question #2:
Survey respondents reacted even more favorably to the second demonstrated OB process, the unsolicited briefing call from the OB meteorologist to the ATM decision maker.

Survey Results—Questions #3 and #4:
The next two questions in the survey asked the respondents to assess the benefits of the AWS and the unsolicited OB briefing. Both products were thought to be either very or extremely beneficial by a majority of the participants, and none rated either product as not being beneficial.

Survey Results—Question #5:
The final question asked the respondents to identify one or more outcomes which, based on the tabletop demonstration, could be expected to be attributed to the OB process should it be implemented. Of the six specified outcomes, more respondents thought that OB would result in improved decision making quality, followed very closely and in order by increased situational awareness, improved decision lead times and increased collaboration opportunities. As can be seen, the results of the survey strongly suggest that the members of the CDM community who responded to the survey viewed the OB process as capable of providing significant benefits to ATM decision makers, regardless of whether they represented government or industry aviation concerns. Conversations with several key ATC provider representatives during the remainder of the CDM Annual Meeting not only confirmed the results of the survey, but also added a sense of urgency to the further development and implementation of the OB process.

Live Demonstrations
In the summer months of 2012 and 2013, the WET performed live demonstrations of OB. The intent was to demonstrate the capability and usability of the OB process (including the AWS) within a live, operational setting with a focus on convection. This live operational demonstration was dependent on convective weather impacting the New York Metroplex.

Due to limited resources, only a targeted audience was used for these demonstrations. This targeted audience included the Command Center (ATCSCC), New York, Boston, Cleveland and Washington Air Route Traffic Control Centers (ARTCCs), Aviation Weather Center (AWC) and the airlines.

The objective of the 2012 Operational Bridging demonstration (2012 Demonstration) was to identify operational suitability and usability issues associated with the use of the OB process and the AWS as a forecast input to the strategic TFM decision-making process. The 2012 Demonstration was conducted at select operational FAA field sites and Airline Operations
Centers. Focus points for the 2012 Demonstration included: rating the OB process and the AWS, assessing the process by which strategic TFM decision makers utilize the OB process and AWS, and gathering feedback from TFM decision makers and aviation meteorologists.

The OB process and AWS issuances were demonstrated from July 18 to October 30, 2012, to support the FAA’s severe weather season using a limited geographical area. Due to staffing limitations, demonstration activities occurred on Wednesdays and Thursdays of each week, from 1000Z to 0100Z. AWSs issued only covered convective impacts expected to disrupt, or have a major influence on, air traffic in the New York Metroplex area. Questionnaires, interviews and on-site observations were used to collect suitability data regarding the use of OB and the AWS to support strategic decision-making during convective weather events. Field observations of the OB process and the use of the AWS were conducted during three convective weather events (August 9, September 5 and September 18, 2012) at the FAA Air Traffic Control System Command Center (ATCSCC). Trained observers were on-site during demonstration hours to observe the OB process and the issuance of any AWSs. 2012 Demonstration data collection tools targeted utility, usability and data presentation issues associated with the OB process and the AWS. Operational suitability data was collected at the end of the convective season (early October).

Overall, the OB process and the AWS were rated favorably by demonstration participants and provided sufficient support for strategic planning during convective weather events. The AWS was found to be effective in highlighting small spatial scale events with potentially high impacts and also provided additional trend information to decision makers. Most aspects of the AWS (i.e., accessibility, graphic interpretation, text utility, text discussion) received high ratings, indicating that the AWS provided exceptional support for strategic planning tasks. Two things were rated a step lower, “sufficient” vs. “exceptional,” included the NAS overlays and the text interpretation; however, areas of improvement and consistency between product issuance were suggested by the users. Questionnaire comments indicated that a standard set of NAS overlays were needed to reduce the confusion on which overlays to use.

Results from the 2012 Demonstration indicated that both the OB process and the AWS were considered sufficient for planning in the 0–2 hour and 2–4 hour time horizons. While only a limited number of participants responded to the Traffic Management Initiatives (TMI) decision support questions, those who did indicated OB was sufficient for supporting group situation awareness in CDM and Ground Delay Program (GDP) timing. When OB and the AWS were incorporated into the decision process, it mostly aided situation awareness for en route ATM decisions. Many participants requested improvements that involved the process and platform used to create the AWS. Most of the issues identified during the 2012 Demonstration were addressed and resolved by the end of the 2012 Demonstration.

In 2013, the WET provided another demonstration and the geographic domain remained similar to previous years (NY Metroplex) but the time in which an AWS could be issued expanded to Monday–Friday from 09Z–01Z and Saturday from 09Z–19Z. A dedicated AWS meteorologist was available for the most active convective periods in the afternoon and early evening (after 18Z). The campaign took place from June 1 through August 31. Unlike the demonstration in 2012, on-site evaluations did not take place due to budget reductions. With these things in mind, initial
feedback from the 2013 demonstration has been similar to what was received in 2012 in that the AWS is effective for strategic planning tasks.

The goal of the live demonstrations was to verify and validate the process of accelerating the transition of aviation weather constraint forecasts in sufficient time to enable ATM decision makers to devise and refine better ATM decisions for TMIs in a timelier manner. Although the demonstrations were limited they have provided insight that OB was effective, so much so that the CSG tasked the WET to determine how OB could be implemented NAS-wide. The WET is currently developing this proposal and though not complete, the WET is targeting 2016 for implementation of OB and the AWS for the entire NAS.

CDM in Europe

In Europe, CDM has become a necessary activity because of the number of states represented by European Civil Aviation Conference (ECAC) and many independently managed, Area Control Centers (ACCs) and airports. From the early 90’s this CDM was largely strategic and pre-tactical ensuring strategic developments, demand, concepts and infrastructure were aligned. From 2000 it was evident that the fidelity of collaboration, the partnership base and subjects covered needed expanding to address airfield and en route congestion and consequent delay. In the ECAC region, Eurocontrol expanded the harmonizing activity and inclusiveness of the planning activity to develop and coordinate aviation responses to congestion.

Airport CDM (ACDM)

A practical illustration of this are the Airport CDM (ACDM) systems implemented today at eight ECAC airports. ACDM coordinates all aspects of departure management data from prior to arrival and baggage loading, to push back and departure time. ACDM is the best ECAC illustration of integrating multiple disparate activities to meet a common goal that requires a new level of precision to achieve improved operational performance and manage operational costs. ACDM was the first CDM project to recognize the need for system support because of the level of data interchange required and the precision and timeliness needed to make informed operational decisions.

Eurocontrol, on behalf of ECAC member states, was asked in 2011 to develop a mechanism that provided a transparent centralized network view of severe forecasted weather which may result in capacity disruption at airports and en route. The rationale was to provide weather alerts in sufficient time for ATM partners to make assessments on which to base response strategies. Visibility of the expected weather for customers and decision-making was a key element of the strategy to facilitate CDM. On a daily basis since 2012, Eurocontrol Network Manager (NM) has provided a severe weather assessment with accompanying synoptic weather maps to illustrate the expected condition. The assessment is articulated at the 1600 local pretactical (D-1) telecom and shortly after uploaded onto Eurocontrol’s information portal (NOP Portal) for access by all aviation partners. Prior to 1600 local D-1 NM, pretactical planners use a synopsis of D+1 severe weather risk assessment and convey...
details of it to the principal ANSP planners to ensure awareness. In essence, this process provides a COP for weather for all stakeholders.

On the day of operation, risk assessment is updated at 6-hour intervals from 0600utc to 1800utc and is provided as an alert function to ANSPs and customers. ANSPs are the final arbiters in the assessment governance following trigger prompts from Eurocontrol’s NM. Any required mitigation is reflected in the planning outcome and published on Eurocontrol’s NM NOP Portal Network news. Interesting to note that pilots in Europe operating multiple legs, away from base, now upload the data into iPads to support the situational awareness for the day.

In the first quarter 2014, Eurocontrol NM will launch an automated forecast risk assessment map for en route and airports, visible on Eurocontrol NM’s NOP portal to ANSPs and customers, updated every 6 hours, using color to denote risk. The risk picture will be supported by synoptic weather maps.

This next phase in the ECAC region severe alert sees the introduction of model ensemble forecasting from an authority’s meteorological source. The authenticity of the output is expected to generate greater confidence and thus discussion between NM, ANSP and the customer. Experience to date has shown a marked reluctance by aviation actors to respond to severe weather until it occurs for multiple reasons, but in the winter of 2012/2013, when winter conditions were forecasted, ECAC airports, ATM and customers shared data, expectations and handling strategies resulting in a coordinated managed outcome, where risk and delay were minimized and costs better managed than in previous years. Summer severe weather conditions, particular convective activity, is less accurately determined and decision making is made more difficult because forecasting intensity is more difficult, particularly in the Alpine region. NM is expecting that the authoritative forecasting displayed on the Eurocontrol NM NOP portal will generate more confidence and thus engage the principal decision makers at an earlier stage to carry out local weather and impact assessment. The activity of reviewing weather impact prior to 3 hours will enable earlier interaction with customers, thus avoiding late decision making and reactive uncoordinated responses and the consequence of raising risks and costs.

The ECAC region is made up of fragmented ATM units and the provision of a map that relates severe weather to the ATM infrastructure increases neighboring ATC awareness of potential network and cross-border perturbations because of weather. This common situational information will be the catalyst generating the necessary discussion, assessments, mitigation and decision-making between the principal operational managers in order to reduce risk (the element of surprise) and customer costs. The activity has to start 3 hours in advance to achieve optimum information sharing, collaborative negotiations, coordination and implementation response strategies.
The ECAC region ATM network infrastructure is complex and thus decision-making is made locally. In such conditions, CDM and the sharing of data to support decision-making is an essential tool to optimize ATM operations in periods of uncertainty and garner the support of multiple decision makers. To start to elicit the right responses, CDM has to be supported by the provision of objective unbiased datasets, preferably provided electronically, to enable objective engagement when negotiating in a network where performance regimes and objectives can be very different. The paradigm “Act Local, Think Global” is very relevant to the ECAC region.

CDM in ECAC.

As outlined at the start of this section, ECAC region collaboration has been essential to develop a common network. This is now being enhanced by tactical CDM whose success going forward will be predicated on developing common collaborative triggers and associated detailed procedures and processes encompassing each aviation discipline. NextGen/SESAR has identified that CDM needs to be supported by enhanced data and information exchange, both locally and intercontinental. In Europe, 5 years of increasingly severe weather have illustrated that data exchange between ANSPs, Eurocontrol NM and customers is still not sufficiently robust or granular to support very difficult decision making, or to bind the actors in a fully supportive and collaborative process required to manage risk and costs, in a performance monitored environment.
CDM can be based on very little information, so it is easy to attribute it to many ATM interactions. Today, however, CDM is more a management tool to manage risks, costs and performance. CDM has therefore become a vital collective aviation partnership tool to address these issues. Critical to the process is anticipation/triggers, data sharing and processing, decision making regimes and lastly the time and accountability to carry out the associated tasks. It is no longer a nice-to-have process, but a critical tool in the management of today’s air traffic; however, there is still some work to be done to document the processes to achieve the consistency and regularity of the activity. However, CDM should not become a routine, as its value will be diminished. Inevitably events/perturbations happen without notice, and the success of handling such occasions is having well-defined processes, and not leaving it to chance or experience to deliver a complete process.

European CDM is slowly gathering momentum; seeded ideas on data exchange, exchange medium, presentation and tools are being matured. ECAC is keen that CDM only be employed when needed, within the confines of the resources currently available, and importantly when the resources have or can make time to fulfill the partnership role. Data exchange and presentation are to be triggered by defined criteria and decision-making data presented in the optimum manner to the end user, supported by the underlying data sets. It is a fatal flaw if CDM partners are blasted with too much data relating to the issue.

It is of course not always practical to avoid this but decisions will be distorted or not made if partners are overwhelmed by data. CDM can only be effective if it is largely an orchestrated activity. CDM on-the-fly may address a local difficulty in the short term, but is likely to distort network operations in one way or another.

In the ECAC region, the Eurocontrol NM provides the leadership to develop inclusive Network partnership CDM on behalf of ECAC ANSPs, airport owners and customers, while local and cross-border CDM is developed and managed by the local partners. The differing levels of CDM works well currently. The question arises, however, as to whether a single process rather than a system could be employed worldwide, for electronic or digital CDM where data and communications are carried out, and where voice communication becomes the exception, saving resource time and effort, and costs. In addition, such an approach would support improved consistency and track decision making.
**TCDM (Transcontinental CDM)**
The FAA and the Eurocontrol NM, with partner ANSPs and customers, run a joint FAA/Eurocontrol daily D-1 briefing session. This briefing provides an overview of the weather situation at the east coast U.S. airports and the available ATM and airport facilities, similar briefing is given for the European ECAC region. But weather is of specific interest to both parties because the consequences of receiving demand well in excess of what can be landed or managed in the air is a consequence of transcontinental operations. Once in the air, the armada of 600 aircraft flying eastbound across the North Atlantic cannot be stopped. If 30 percent of this demand is about to land in a defined land mass experiencing the same weather condition, planners need to agree about strategies before departing to mitigate the potential impact, knowing the phenomena impact will surely change over a period of 5 hours. For ECAC, snow-delayed early morning arrivals from the U.S. place the flights into the key congested hours of domestic operations leading to significant delays if mitigation is not initiated. In reverse, westbound departures to the U.S. may choose to remain on the ground in the ECAC region to avoid the worst of the severe weather in the U.S. Winter weather also brings the displacement of flights to other airports on both continents, resulting in a major shift in the demand pattern. In such examples, CDM becomes critical for managing the Network and airport impacts, and the sharing of intent becomes ever more critical in delivering an efficient ATM operation, under these conditions. But equally important for ATM is for the customer to see that he is not individually disadvantaged in a mass transport environment that must try and satisfy competing and often very different business continuity demands.

**CDM in Australia**
Background
The Australian National Aviation Policy (Green Paper) released in 2009 made the statement that “More than perhaps any other country, Australia’s economic prosperity is closely tied to the health and competitiveness of the country’s aviation sector. This is largely due to the vast distances within Australia, and between this continent and the rest of the world”. It is also correct to say that over the next decade, the greatest challenge will be how to manage the current and predicted growth in traffic demand in an already constrained runway capacity environment.

The amount of traffic continues to increase and currently most Australian major airports are runway capacity-constrained during peak periods of the operating day. These constraints become worse when airports or terminal areas are impacted by weather, with capacity further reduced. This sensitivity to weather is not easy to manage and valuable landing slots are being either lost or airborne holding increased.

New runways are being planned at Brisbane and Melbourne to relieve this situation, but these will not be in place until the end of this decade. This runway capacity constraint and the subsequent inability of ATM to deliver the maximum runway capacity impacts the airlines’ ability to operate to the published schedule and maintain an efficient, cost-effective operation.

As the AirServices Australia (AsA) website page on Airport Capacity Enhancement (ACE) states, “Collaboration: Every movement matters and every second counts. Over many movements, the
seconds add up to create additional capacity that in turn can reduce delays. The benefits are shared by all and can be achieved collaboratively.”

AsA, with cooperation from airlines, introduced an interactive commercial integrated and collaborative ATFM Tool to provide the capability to better balance the traffic capacity with demand. Located in Canberra, the National Operations Center (NOC) is responsible for traffic flow and capacity management within Australian airspace utilizing the slot allocation program. This is currently operating for three major airports but the impact of weather still remains as the movement rates are not being dynamically altered in line with the weather. Moreover, the movement rates set by AsA apply agreed guidelines using the Terminal Aero-drome Forecast (TAF).

Improvement is needed to ensure every opportunity is taken to use available capacity but achieving the required improvement with current processes is not possible and airlines are rarely in a position to instantly react to an increase or decrease in capacity, at least in an efficient manner. This reduced capacity at a major airport becomes further compounded as a “gate hold” or “gate stop” is introduced at airports to reduce airborne delays but the available airport gates at unaffected airports are quickly occupied creating a logjam of traffic at these airports.

To make the aviation system far more predictable enabling the available capacity to be consistently utilized, major position changes are required from both ATM and the airlines. Clearly, there had to be a collaboration effort between AirServices Australia, QANTAS, Virgin Australia and the Bureau of Meteorology (BoM).

*MET-CDM in ATM*  
ATFM in itself does not deliver additional capacity, but when the current capacity is not being fully utilized efficiently the aim has to be to ensure every opportunity is taken to occupy a landing slot. This is where CDM, if used properly, can significantly assist to achieve this aim.

For CDM to be effective requires the active participation of all players: ATM, BoM and the airlines. However, this must first be broken into parts because although the BoM-produced TAF may offer all players the same forecast, it does not provide a COP.

In Australia, the BoM has Regional Forecasting Centers where aviation forecasters provide not only the TAF but they also have embedded aviation forecasters at:

- Sydney Airport MET Unit (SAMU) situated within the AsA Terminal Control Unit (TCU) at Sydney;
- The AsA National Operations Center. AsA provides additional services that are supported by a national network of communications, surveillance and navigation facilities and infrastructure. This includes managing the GDP as a consequence of reduced capacity.

Additionally, meteorologists are also employed by the two major Australian airlines, QAN-TAS and Virgin Australia and embedded within their respective operations centers.
It was obvious that this level of MET resource had to be harnessed, allowing the expert evaluation of all the meteorological resources to be used and their evaluation injected into the CDM process.

The outcome agreed to by all stakeholders was to develop a CDM process to set the optimized movement rates with the commercial system. To achieve this aim, all stakeholders needed to share the COP to provide consistency. Once the COP is achieved, the CDM process can continue with the Airlines and Air Traffic Flow Managers establishing the agreed movement rates for each airport.

Having this COP sanctions airlines to actively participate and accept higher or lower movement rates based on the agreed probability of passing critical weather thresholds along with the likely impact of reduced movement rates. This is the opposite of current practice where deterministic TAF conditions are assessed and the movement rates based on historically agreed guidelines. This new way of working allows airlines to participate actively in the setting of rates and importantly, the associated risks. With airlines sharing this risk they have enhanced operational predictability and can proactively as well as reactively respond to anticipated changing conditions. This is an improvement in efficiency.
The initial trial of this collaborative decision analysis process took place during the summer of 2012-2013 for Sydney only. The outcomes were clearly encouraging but changes were required to support the subsequent CDM process which would actually set the movement rates to be used by the commercial system.

Following a desktop exercise it was decided to conduct an expanded operational trial commencing October 2013. This trial will test the veracity of the MET process to provide the COP for multiple airports and be effectively incorporated into the CDM process.

The original concept was for collaboration of meteorologists to occur prior to issuance of the TAF(s), however this was problematic and it was decided for the next trial that it was best if the BoM aviation forecaster developed the TAF, but prior to issuance explain his/her forecast strategy and where uncertainty existed to the other meteorologists. These forecasters can ask questions, but with multiple airports involved it is considered better they remain silent.

The team of Meteorologists from the NOC and the airlines would then assess the background forecast information and overlay probability of severity as well as refined timing around conditions which could cause reduced capacity. This will be entered into a MET Forecast Probability Matrix against which the movement rates will be agreed collaboratively. This matrix will contain significantly more information than the TAF and will be subjected to verification. These movement rates will then be inserted into the commercial system.

It is not intended that the actual TAF will be changed due to this process, so although a level of operational business risk will be accepted by the airlines, this will not translate into a risk to safety.
This CDM process will most certainly have many challenges still to come, one being to eventually achieve dynamic updating of the COP as the operational refresh time improves over time especially for earlier onset or later cessation or even unforeseen conditions. This will be the next stage of the development.

Currently, the focus is on:

- Developing guidance for the BoM aviation forecasters to provide the background to their forecasts;
- Developing the ATM rules at each airport affecting capacity so the forecast and the matrix probability can relate to agreed thresholds;
- Developing the next trial, which will demonstrate CDM being applied across multiple airports.

Importantly, through CDM, Australia is attempting to balance the sometimes conflicting goals of efficiency, capacity and cost by recognizing that in our capacity-constrained environment the cost benefit of effectively using all available arrival slots outweighs the cost of incurring additional targeted airborne delays or a diversion on those occasions when the collaborative MET-CDM proves to be less accurate than the aerodrome forecast. Another goal will be the application of the MET in CDM to influence the operating procedures for long-range ATFM where long haul aircraft will likely be introduced into the commercial system and the airlines will be expected to be compliant within the agreed parameters.

Foremost, in Australia, MET in CDM has commenced lifting the collaboration of all players to a new level of understanding and with it a plan to improve operational efficiency. Moreover, this could not come about without the active willingness and belief of AirServices Australia, the Bureau of Meteorology and the major airlines.

**Summary**

This paper described how CDM has enabled the concept of a Common Operating Picture for weather impacts which is leading to a global operational picture of weather impacts. While progress varies in world regions, the paper confirms that much headway has been made. Further, it should be apparent that there are differences in the CDM approach used in these regions based on things such as the number of ANSPs, airlines, meteorological service providers, as well as the different types of weather impacts in each geographic location.

Many challenges lie ahead before a seamless global air transportation system can become a reality, including one which is based on a Common Operating Picture for weather impacts. For example many world regions have yet to embrace the CDM process in any form, airlines closely guard their operational data and the different providers of meteorological information, both government and commercial sectors, have a monetary stake in the outcome.

However, based on the information provided by the three regions for this paper, there is hope for a future that will possess a more efficient global aviation system.
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Abstract
Telecommunication service providers worldwide have transport networks that were originally designed to deliver voice services over time-division-multiplexed (TDM) infrastructure. As one of the largest users of telecommunications in the federal government, the FAA National Airspace System (NAS) depends upon this infrastructure for air traffic control (ATC) operations. Current FAA systems rely on TDM services and technology to provide full coverage of NAS airspace and ensure the safety of the flying public. Due to the exponential growth in data services experienced over the past few years, carriers are facing scalability and cost challenges using this legacy infrastructure. Telecommunications service providers cannot deliver the bandwidth required by the consumer cost effectively using the existing TDM infrastructure. In response to these demands, commercial carriers have begun a steady migration away from their TDM core infrastructures and are replacing them with packet technologies, typically referred to as Metro or Carrier Ethernet.

As the FAA’s network provider, Harris Corporation has addressed this challenge with both near-term and long-term strategies. In the near-term (now through 2017), Harris will migrate existing commercial carrier Private Line TDM services onto the FAA Telecommunications Infrastructure (FTI) private optical backbone. In the longer term (post-2022), Harris is working with the FAA and various commercial carriers to evaluate Carrier Ethernet performance in the NAS and develop application and migration requirements and strategies to ensure the integrity of current NAS systems as well as preparing for deployment of the coming NextGen air traffic control systems.

This paper analyzes the dependency of the NAS applications and services on TDM infrastructure, provides an overview of Carrier Ethernet technology and products, identifies several challenges to migrating NAS services onto a Carrier Ethernet infrastructure, and summarizes the near-term and long-term activities and strategies Harris is employing to preserve the integrity and affordability of the FTI network.

Introduction
FTI is the primary means through which the FAA acquires the telecommunications services required for the NAS. The NAS, consisting of thousands of people, procedures, facilities, and pieces of equipment, enables safe and expeditious air travel in the United States and over large portions of the world’s oceans.
Harris Corporation is the prime contractor for the FTI program and functions as a network integrator leading a team of telecommunications companies, consisting of Sprint, AT&T, CenturyLink, and Verizon Communications. FTI interconnects over 4,400 FAA sites and over 20,000 services through a dedicated, secure Wide Area Network (WAN). FTI also interoperates with hundreds of non-FAA facilities including the Department of Defense (DoD) and the National Weather Service. Harris manages 16,800 distributed network devices containing over 104,000 manageable components. Through FTI, Harris also provides network engineering services and order fulfillment for evolving FAA communications needs. Since the network is a key contributing system to the Next Generation Air Transportation System (NextGen), Harris is continuously identifying initiatives and implementing upgrades to FTI providing increased capacity, greater flexibility, and improved system performance. One recent example is the implementation of a dedicated optical backbone network and private Metropolitan Area SONET rings throughout the continental United States.

To ensure the reliable and efficient operation of the NAS, FTI is highly reliant on the commercial telecommunications offerings provided by the Local Exchange Carriers (LECs) and IntereXchange Carriers (IXCs) in the contiguous United States, Alaska, Hawaii, Southern Caribbean, Canada, and Mexico. To implement the FTI services required by the FAA, Harris contracts with over 200 carrier organizations to establish Last Mile, Intra LATA and Inter LATA connections using the commercially available telecommunications service offerings. These connections are established at over 3,300 Serving Wire Centers (SWCs) and are represented by tens of thousands of individual circuit and product orders. The great majority of the services FTI receives from these providers are traditional TDM, circuit switched, private line services.

Recently, the industry has signaled their planned transformation of the Public Switched Telecommunications Network (PSTN) from TDM technology to IP (Internet Protocol). Where the TDM network provided single-purpose voice connection to the consumer, the emerging IP network will transport consumer connections over a multipurpose broadband connection. This “shared-use” feature of IP transport provides the telecommunications carriers the mechanism required to address the ever-increasing bandwidth requirements of their customer base. As the telecommunications industry discontinues the existing TDM infrastructure, future service orders will be fulfilled using IP transport technology, and as discussed in this paper, this has significant implications to the continued operational efficiency and security of the NAS. NAS applications have evolved to be highly dependent on the synchronous nature of TDM telecommunications infrastructure. The FAA’s NAS operations are highly reliant on the ability to create channels or tributaries allowing transmission of multiple subscribers’ data along the same transmission medium without the risk of contention for resources or intrusions from other users—critical for implementing the required traffic security. This inherent Constant Bit Rate (CBR) capability of TDM services also enables NAS applications to establish clock synchronization as well as deterministic latency and jitter performance. TDM’s circuit mode communication paradigm is based on a fixed number of channels and constant bandwidth per channel, ensuring the underlying NAS applications do not suffer from the Variable Bit Rate (VBR), “best effort” nature of Packet Switched networks. While FTI currently provides many IP services for these programs, over 92 percent of FTI services continue to be TDM-based.
As described in this paper, Harris is implementing near-term changes in its network provisioning model to replace the commercial carrier transport segments with dedicated FTI backbone segments that not only maintain the essential TDM service bas, but do so in a manner which is less costly, more reliable and offers improved provisioning timelines.

**Carrier Ethernet**
Following the lead established by the Metro Ethernet Forum (MEF), the PSTN transformation to IP-based technology will leverage Carrier Ethernet services carried over physical Ethernet networks and other legacy transport technologies. At its core, Carrier Ethernet can be defined as:

- A ubiquitous, standardized, carrier-class Service and Network defined by five attributes that distinguish it from familiar LAN based Ethernet, namely (i) Standardized services,
- (ii) Scalability, (iii) Reliability, (iv) Service management and (v) Quality of service; and
- A set of certified network elements that connect to transport Carrier Ethernet services for all users, locally and worldwide
- Carrier Ethernet service offerings can be categorized in the following three primary categories:
  - E-Line: a service connecting two customer Ethernet ports over a WAN;
  - E-LAN: a multipoint service connecting a set of customer endpoints, giving the appearance to the customer of a bridged Ethernet network connecting the sites;
  - E-Tree: a multipoint service connecting one or more roots and a set of leaves, but preventing inter-leaf communication.

At its core, Carrier Ethernet extends the familiar Customer Ethernet LAN into the WAN/Transport environments. This protocol convergence addresses the ever-increasing need for bandwidth delivery in a highly cost-effective manner. The Carrier Ethernet community will advertise the following advantages to this technology:

- **Lower cost**—On average, Carrier Ethernet bandwidth is 50 percent of the price of traditional TDM bandwidth.
- **Scalability**—Base connection offerings of increased bandwidth with entry level offerings of typically 10 Mbps with some carriers offering 1 and 2 Mbps User Network Interfaces (UNIs). These fixed rate connections can be easily increased for special needs with the consumer paying only for the bandwidth as it is needed, giving the customer a “bandwidth on demand” experience.
- **Familiarity**—Carrier Ethernet is fundamentally a Layer 2 Ethernet technology, offering simple Ethernet handoffs that interface with existing equipment.
- **Reliability**—Protected E-Line services are available in protected configurations with Service Level Agreements (SLAs) for 99.999 percent uptime.

There are, however significant challenges with replacing the TDM-based PSTN system with Carrier Ethernet technology within the NAS, namely:

- Supporting legacy NAS applications built on a core TDM infrastructure;
- Meeting security requirements in what is essentially a shared networking environment;
- Providing operational visibility to diagnose and triage network events;
- Ensuring ubiquity of service offerings at all 4,400 FTI customer locations.
Inherent Carrier Ethernet Challenges Within the NAS

As described above, Carrier Ethernet-based networks promise lower cost per bit of delivered bandwidth, scalability for ever-increasing bandwidth needs, a familiar universal protocol and Carrier-class availability. However, these advantages must be balanced against the realities of communications needs within the NAS as discussed below.

Support for Legacy NAS Applications

As the primary provider for NAS telecommunications services, the FTI network provides many IP services for these programs, but over 92 percent of FTI services continue to be TDM-based. The reason for this is twofold: (i) a significant majority of the more than 4,000 FTI customer locations require access bandwidth of relatively small bandwidth typically delivered as an analog Voice Grade circuit and (ii) the NAS systems resident at these customer locations were designed assuming an underlying TDM infrastructure. This latter reality is typified by the need for NAS systems to receive a network-based timing source, allowing the system to synchronize messaging between local and remote locations. While there are ongoing FAA initiatives to upgrade these legacy systems and benefit from the coming IP infrastructure migration (e.g., NVS, SIM), the FAA’s planned migration does not support the aggressive migration schedule being implemented by the telecommunications carriers.

The FAA’s NAS applications, which operate natively using synchronous protocols, require a highly reliable synchronization source with exceptional stability. Without the inherent synchronous capability of TDM, applications will experience out-of-sync clocks, resulting in buffer overflows, lost frames and variable latency; such a result will have a detrimental impact on the operation of these critical NAS applications. The very nature of packet-based switching networks relies on dynamic routing and application retries which result in variable and nondeterministic latency. Until NAS applications can be modernized, the discontinuation of TDM services would at a minimum degrade FAA air traffic control operations and, at worst, put them at significant risk.

As a packet-based system, Carrier Ethernet requires emulation of a Constant Bit Rate (CBR) service on a Variable Bit Rate (VBR) network. Because Ethernet deals with congestion and oversubscription by discarding packets with subsequent retransmissions, the customer application must be tolerant of the variable nature of a Carrier Ethernet protocol by establishing a messaging queue to hold and reassemble network traffic. Legacy NAS applications such as air-to-ground voice communications and digital TDM applications are very intolerant of dropped and retransmitted packets. The single discard of a packet transporting 20 milliseconds of audio would result in an air-to-ground radio being unavailable to air traffic controllers for 2 to 4 seconds as the link is re-established.

Consideration for Network Security

Current FTI security policies rely heavily on the separation and control of traffic provided by the inherent Layer 1 separation of subscribers offered by TDM. The Layer 2 Carrier Ethernet architecture raises issues of fundamental network security given its shared nature. Fortunately, the MEF has addressed these concerns through the creation of port-based solutions ensuring a
single service instance per UNI (dedicated network resource). Table 1 summarizes the MEF defined Ethernet service types, identifying the port-based options for each major variant.

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Port-Based (All-to-One Bundling)</th>
<th>VLAN-Based (Service Multiplexed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Line (Point-to-Point EVC)</td>
<td>Ethernet Private Line (EPL)</td>
<td>Ethernet Virtual Private Line (EVPL)</td>
</tr>
<tr>
<td>E-Tree (rooted multipoint EVC)</td>
<td>Ethernet Private Tree (EP-Tree)</td>
<td>Ethernet Virtual Private Tree (EVP-Tree)</td>
</tr>
</tbody>
</table>

Table 1: MEF 6.1 Ethernet Services Definitions

Figure 1 illustrates the inherent trade-off faced when selecting a Carrier Ethernet solution. Within the Carrier Ethernet environment, the recognized best security practice continues to be Ethernet Private Line over Synchronous Transport. While the port-based Ethernet Private Line (EPL) offers network security assurance comparable to TDM architectures, it provides the least service flexibility, essentially obviating the two primary advantages advertised—lower costs and increased scalability. One must also consider the long-term viability of an underlying synchronous transport infrastructure as MPLS continues to gain market share.

The IEEE has recently introduced the 802.1AE MACSec protocol, which addresses hop by hop security. This protocol does not guarantee end-to-end security across public networks and there are active discussions within IEEE for definition of acceptable end-to-end Layer 2 security protocols.

Operations Visibility
Within any network, the ability to have direct and immediate visibility into network elements is essential to meet customer SLAs. This is especially true of the FTI network, where worst-case service restoration times are 3 hours or less and where the FAA typically demands detailed service outage explanations and corrective action plans to eliminate observed failure modes from reoccurring. In the shared environment of Carrier Ethernet, access permissions to view network elements may not be granted by the Carrier. Even more problematic, if access privileges can be negotiated, the highly dynamic nature of the Layer 2 switched environment means that
the network configuration being triaged may likely not be the same configuration that existed at the point of anomalous service behavior. New rules and protocols between the Carrier Ethernet providers and their customers must be established to address these challenges.

**Ubiquity of Service**

Carrier Ethernet is an evolving market with various Carriers’ initial service offerings located in large metropolitan areas. In these markets, entry-level offerings are typically 10 Mbps with some carriers offering 1 and 2 Mbps services. Recognizing that roughly half of the 4,400 FTI customer locations are not in large metropolitan areas, it may be many years before Carrier Ethernet services are offered at these locations, if ever. Even if Carrier Ethernet services are delivered, the typical bandwidth needs at these FTI customer locations are 64 to 512 kbps—far below the offered Carrier Ethernet port speeds, negating the perceived cost advantage.

Compounding the outlined challenges of Carrier Ethernet, some carriers have indicated their intent to provide last mile access via a wireless LTE solution. Citing cost as a major obstacle, carriers would elect to abandon any existing physical infrastructure connecting these locations in favor of leveraging their tower-based wireless coverage. Carriers currently offer no SLA for wireless products. Reliability and availability of this service by its nature are of concern due to susceptibility to environmental and topographical conditions. In addition, a whole new layer of concerns from a security perspective arises.

The evolving nature of the Carrier Ethernet market is currently represented by competing and sometimes proprietary offerings, making the design of a common suite of FTI Customer Premise Equipment challenging.

**Near-Term FTI Activities**

As noted above, the telecommunications industry has started a shift away from a TDM-based PSTN to a packet-switched architecture. As part of that shift, Harris has received notice from several partner InterExchange Carrier (IXC) transport providers that, starting in 2017, they no longer plan to offer a subset of TDM-based product offerings, which are used by FTI today to provide Intra- and Inter-LATA transport. The products that will be discontinued account for approximately 12,000 individual circuits within the FTI network.

In order to continue to provide NAS services without interruption or degradation, Harris has implemented connection strategies in the FTI network architecture to address TDM products being discontinued by carriers. Traditionally NAS services have been delivered between FAA locations with a Local Exchange Carrier (LEC) connection to an IXC provider with the IXC providing transport across the LATA boundaries. Harris has begun proactively redesigning the FTI network to remove IXC-based connections. In order to do this, Harris is taking advantage of its private, dedicated optical backbone network. To achieve this, Harris has replaced existing LEC/IXC access from FAA locations with new LEC/Competitive Local Exchange Carrier (CLEC) access circuits aggregated at one or more of the 42 points of presence (POP) nationwide connecting to the FTI backbone. Harris has equipped each of its POPs with the ability to provide switching at the service level, allowing traffic to be redirected as needed. This allows for better bandwidth management and resiliency across the FTI backbone.
Along with mitigating the impact of carrier's sunsetting of IXC-based TDM products, the drive to move FAA traffic to the FTI backbone provides additional advantages as well:

- **Lower Cost**
  - Introduction of CLECs allows for purchase of nontariff products at often great savings over LEC offerings. Additional IXC transport costs are completely eliminated.

- **Reliability**
  - Traffic provisioned across the FTI backbone is provided as a path-protected circuit regardless of FAA requirements. Additionally, FTI traffic can be redirected across the FTI on a real-time basis in the event of a disaster without the intervention of a third party.

- **Faster Provisioning**
  - As the number of FAA locations connected to the FTI backbone increases, it allows for faster turn-up of services by reducing the number of orders and vendors Harris must work with to provision the circuit.

**Long-Term Strategies**
Concurrently with near-term strategies, Harris is preparing for the inevitable decline of TDM-based product offerings from the telecommunications industry. Harris has established a Carrier Ethernet working group that is approaching this challenge from two directions:

- Working with partner telecom vendors to understand their Carrier Ethernet product offerings as well as convey the FAA's service requirements; and
- Identifying equipment-based solutions to keep network changes transparent to the FAA while NextGen systems are developed that can tolerate a packet switched network.
As of July 2013 Harris began meeting with its telecommunication partners concerning their forward looking plans for TDM product offerings as well as their current and planned Carrier Ethernet product lines to define which are equivalents to currently used TDM products. Additionally, Harris is using this forum to convey the needs and requirements that are vital to maintaining a reliable and secure network for the FAA.

To date, Harris has met with three of its major providers and has received similar response concerning the planned trajectories of their product offerings. Concerning the phase-out of TDM-based services, only one vendor has defined an explicit goal to discontinue all TDM products by 2020. The remaining providers, while continuing to expand their packet-switched networks, have no timelines or immediate plans to discontinue their TDM networks.

The second front involves establishing a test and demonstration Carrier Ethernet network. Harris will be working both its equipment and telecommunications partners to establish a small network with the following goals:

- Understand behaviors and characteristics of Carrier Ethernet;
- Evaluate existing bookend equipment solutions that provide pseudowire TDM circuits over a packet-switched network; and
- Determine which FAA applications requirements can accommodate the solutions currently available.

After completing internal proof-of-concept testing, Harris intends to work in conjunction with the FAA to test and evaluate the equipment and network to thoroughly determine what applications do and do not work. This will involve working with the FAA’s national test center and connecting FAA systems and services into the test network. Through these pursuits the goal of Harris is to be prepared for the eventual technology shift that is coming in the telecommunications industry. Harris intends to have ready a solution that will provide a transparent migration for the FAA with no interruption to NAS critical services.

**Conclusion**

The telecommunications industry is currently undergoing a transformation of the PSTN from TDM- to IP-based transport mechanisms. This change not only has immediate impact to long-haul network transport segments, but will likely impact the local access portions in the coming years. This paper has identified several significant challenges faced by the NAS as a result of the replacement of the TDM-based PSTN system, namely:

- Support for legacy NAS applications;
- Network Security;
- Operations visibility; and
- Ubiquity of service offering.

In the near term, Harris is implementing changes in its network provisioning model to replace the commercial carrier transport segments with dedicated FTI backbone segments that not only maintains the essential TDM service base but does so in a manner which is less costly, more
reliable and offers improved provisioning timelines. While this protects the NAS for the immediate future, Harris is working with several commercial carriers to quantify performance impacts of a Carrier Ethernet based network and develop strategies to address them.

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Safety Initiatives in Flight Services

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Abstract
Lockheed Martin is approaching the mid-point of a multi-year effort to introduce new technology and capabilities into the Flight Services operational environment that improve safety and efficiency for the General Aviation (GA) community. This paper provides an overview of five initiatives for which the primary objective is safety. They include Adverse Condition Alerting, Surveillance-Enhanced Search and Rescue, Next Generation Briefings, Flight Services Data Link, and Automated Flight Risk Assessment.

Introduction
Lockheed Martin (LM) has operated Flight Services on behalf of the FAA since 2005 for the continental U.S. (CONUS), Hawaii and Caribbean service areas. There are a wide variety of functions performed by Flight Services; Figure 2 provides an overview of the most common.

In the preflight phase, pilots plan their flights, obtain briefings on relevant weather and aeronautical conditions, and file their flight plans. This can be done with the assistance of a Flight Service Specialist or using the Lockheed Martin Pilot Web Portal, as well as by using one of several commercial websites/apps, or one of the FAA-sponsored Direct User Access Terminal System (DUATS) websites.
In the in-flight phase, pilots activate their Visual Flight Rules (VFR) flight plans and fly the route. During flight, a pilot can contact flight services by radio for routine briefing updates, to report weather, or to request emergency assistance for situations such as equipment failure, lost pilot orientation, or locating urgent medical care facilities. Flight Services operates a network of over 2000 radios to support in-flight communication. In-flight support can be provided to IFR flights, including in some cases commercial passenger airlines, but generally they are handled by air traffic control.

Post-flight, pilots contact Flight Services to close their VFR flight plans. When this occurs within 30 minutes of the estimated arrival time it represents the nominal case for termination of services. If a pilot doesn’t close a flight plan within 30 minutes of the estimated arrival time, Flight Services personnel begin an escalating Search and Rescue (SAR) process. This process starts with attempts to locate the pilot at the filed destination airport and, when necessary, culminates with a Rescue Coordination Center (RCC) initiation of an actual Search and Rescue operation involving aircraft and ground personnel as appropriate.

The five safety initiatives discussed in the following sections of this paper address opportunities for improvement in these major functions performed by Flight Services. They are key elements of a much broader set of enhancements LM is making to improve the overall Flight Services environment for General Aviation (GA). Two of the initiatives are already implemented and deployed. Particular emphasis is given to the Next Generation Briefing capability as the initial subset of that capability is being deployed in the same timeframe as the publication of this paper. The remaining two are planned for early and late 2014 respectively, providing the reader some insight into longer term plans and directions.

All of the capabilities are or will be free to pilots and are being developed and deployed at no additional cost to the FAA. In addition, the capabilities are also being made available for use by commercial providers of flight planning apps and websites via a set of web services. LM believes ongoing, proactive collaboration between an FAA-provided Flight Services automation core and the commercial aviation applications and hardware marketplace provides a powerful path forward for maintaining and improving safety, fostering ongoing innovation that continually improves capabilities available to pilots, and reducing costs.

**Adverse Condition Alerting Service**
The Adverse Condition Alerting Service (ACAS) was the first LM safety initiative implemented and deployed. It has been operational since October 2012.

The ACAS addresses pilot awareness gaps that occur due to limitations in the way briefing information was previously provided to pilots. Prior to the ACAS, information delivery was based on a pull model, meaning pilots only receive briefing information when they ask for it. By regulation, pilots are required to be aware of all meteorological or aeronautical information pertinent to their flights. Pilots typically obtain a briefing over the phone or via the internet some time before a flight; e.g., the night before, the morning of, or an hour two prior to departure. Pilots may also obtain an updated briefing when they call to activate. However, as soon as a specialist briefing is completed or a web briefing is generated, new or modified safety critical conditions can arise, such as a severe weather forecast or observation, an airport closure,
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or a temporary flight restriction. Unless pilots call Flight Services again or regenerate the briefing via the web, they may remain unaware of the new or changed information. In the preflight time frame this is primarily an issue of convenience; in the in-flight time frame, it becomes a matter of safety.

The ACAS addresses this deficiency by monitoring flight plans continuously from the time they are filed until the time they are closed. Any new or modified adverse condition information is proactively sent to the pilot. Email and text messages are used to deliver the alerts during the preflight phase; satellite communications devices are used during the in-flight phase, providing alert delivery directly to the cockpit. The SpiderTracksTM Iridium-based tracking and communications products were the first supported devices. Support for devices from additional vendors is being deployed in the fall of 2013 and will continue as more vendors elect to participate.

Adverse conditions for which the ACAS generates alerts includes Temporary Flight Restrictions (TFRs), airport/runway closed/unsafe NOTAMs, urgent PIREPs, SIGMETs, Convective SIGMETs, AIRMETs, Center Weather Advisories (CWAs), and Severe Weather Watches/Warnings.

All alerts are made available to Flight Services specialists so that if a pilot calls back in, the specialist has immediate access to new, safety-critical information about which the pilot may be unaware. Alerts are only sent to pilots via text, email, or satellite communications device if the pilot has registered for the service. Registration is free, straightforward and is done on the LM Pilot Web Portal (www.lmfsweb.afss.com).

While the volume of alerts varies depending on weather conditions and traffic, nearly a year into operation, LM is observing on the order of 2,000-2,500 alerts across all filed flight plans per day on average. In some cases pilots do learn about the new or modified adverse conditions through other means such as calling Flight Services for a briefing update or checking conditions on a website. However, in a survey of early users of the service, approximately 43% indicated they had received an ACAS alert and it was the sole reason they became aware of the adverse condition. This is a compelling confirmation of the safety benefit of the ACAS.

Early work making ACAS available through web services illustrates the creative synergy that occurs in collaboration with the commercial flight planning app/website marketplace. At the request of multiple vendors, LM has made a preflight ACAS web service available that provides a quick means to identify adverse conditions that affect a route as it is being constructed rather than waiting for review of the actual briefing. This capability shortens the flight planning period by reducing or eliminating iteration on the flight plan route.

A more detailed description of the ACAS is provided in [1].

**Surveillance-Enhanced Search & Rescue**
The second safety initiative already implemented and deployed is Surveillance-Enhanced Search and Rescue (SE-SAR). SE-SAR became operational in April 2013.
The most significant hindrance to a more responsive Search and Rescue environment is the absence of surveillance information for VFR aircraft. Because VFR aircraft cannot be monitored throughout the flight independent of SE-SAR, the standard procedure is that the Search and Rescue process is initiated when a flight is 30 minutes overdue at the destination. This creates a built-in delay to the process that is magnified the earlier an accident occurs during a flight. Further, pilot-provided position reports are rare; consequently, the search area when an aircraft is not found at the destination airport is frequently the full route of flight. In aggregate, these factors contribute to an increased time to reach accident survivors.

SE-SAR improves the Search and Rescue environment by adding surveillance data and automation that monitors the surveillance data for indicators of an accident.

SE-SAR was designed to work with ADS-B-out data; however, equipage is relatively low at this point. Consequently, the initial focus has been on satellite-based position reporting devices. This provided a relatively low-cost means for pilot participation and also addressed the likelihood that a satellite-based solution will be required even when ADS-B equipage becomes ubiquitous because some remote areas (e.g., parts of Alaska) will not have complete ground-based transceiver (GBT) ADS-B coverage. (Many satellite-based position reporting devices have the additional advantage of supporting an addressable message uplink capability which is an enabler for our Flight Services Data Link plans.) Support for ADS-B position report ingest for SE-SAR will be enabled in the near future.

With SE-SAR, position reports are ingested and logged by the Flight Services automation system on an ongoing basis. This means that if an actual search has to be initiated, the search area can be reduced significantly.

In addition, the SE-SAR function analyzes the position reports continuously to detect loss of movement for fixed-wing aircraft, loss of position reports, or receipt of an emergency signal. Each of these can be an indicator of an accident or pending accident. Triggering the SAR process on these alerts rather than waiting for an aircraft to be 30 minutes overdue can improve the time to reach survivors by hours.

As with the ACAS, SpiderTracks™ was the first supported product family. Support for devices from additional vendors is being released in the fall of 2013.

A more detailed description of SE-SAR is provided in [2].

Next Generation Briefings

Briefings are a set of meteorological and aeronautical data that let a pilot know what conditions exist or will exist along an intended route of fight. Per FAA Order JO-7110.10, which specifies the procedures by which Flight Services operates, briefings include adverse conditions (e.g., severe weather, temporary flight restrictions, closed or unsafe airports or runways), an overall synopsis of weather conditions, details of current weather conditions, forecast weather conditions, a wide variety of Notices to Airmen (NOTAMs) and a few miscellaneous categories of information.
In the abstract, the content of a 7110.10-compliant briefing is well-conceived in that it addresses the types of information a pilot needs for safe flight. In practice, however, there is significant opportunity for improvement in the way briefings are presented to pilots in the self-service environment where the focus for too long has been primarily 7110.10-compliance and not efficiency and efficacy from the pilot’s perspective.

There are three major concerns with self-service briefings frequently voiced by pilots. The first is that briefings can be exceedingly voluminous. It is not uncommon for a briefing printout for a modest flight (on the order of 150-200 nautical miles) to be 50 pages or longer. The length alone is a deterrent to fully understanding the content and how it affects a particular flight, particularly for pilots that have always depended on a specialist to explain the information. Further, not all information in the briefing needs to be understood in detail. For example, NOTAMs are provided for all airports along a route of flight. Particularly for a longer route, this can result in a tremendous amount of data that a pilot could not possibly assimilate and retain mentally. It amounts to reference information that only becomes of interest if the pilot needs to land early.

The second major concern is that briefing information, particularly for less experienced pilots, can be difficult to read and understand. Most of the briefing content is textual and provided in highly abbreviated, “encoded” formats. Plain text translation is a common capability which helps to an extent, though it further exacerbates the volume of information issue. In addition, the key piece of information in a particular weather product (for example, an area of thunderstorms) can be surrounded by a significant amount of other text, including textual descriptions of the geographic location. Finding the key information can be a challenge.

The third major concern is the absence of a graphical orientation to the presentation, or when there are graphics, the lack of graphics that focus on the area of interest in sufficient detail. These concerns are addressed in a specialist-provided briefing environment because specialists have extensive training that allows them to understand the encoded text quickly; a rich display application that presents information graphically; and they have the ability to summarize the content of a briefing in a relatively short period of time.

Automation cannot fully mimic all facets of the cognitive process a specialist provides; however, automation can move significantly in that direction for those pilots who choose to use a self-service briefing capability.

In essence, the following are the high-level goals of Next Generation Briefings (NGB): to address the major concerns with the volume of data, understandability of data, and lack of effective graphics, and to mimic to the extent possible the techniques employed by specialists to summarize and help the pilot understand the briefing information quickly.

These NGB notions are best understood through examples. The following subsections provide examples of how three specific sections of a briefing are handled in NGB: METARs, TAFs, and Area Forecasts. Each example includes a sample of traditional briefing data, a discussion of what the challenges are for that particular type of data and how specialists address the data, and how it is being presented in the NGB framework.
METARs are recent weather observations at fixed locations. Most commonly they are associated with airports, but the reporting location can be elsewhere such as a mountain pass or an oil rig. Observations are typically reported at least once an hour and in many cases three times per hour. METARs are categorized based on well-defined criteria involving visibility and ceiling as indicating VFR, marginal VFR (MVFR), IFR or low IFR (LIFR) conditions. METAR-indicated conditions are a primary factor in the decision to fly or what route to fly.

Depending on the length of flight and region of the country, there can be a few to dozens of METARs included in a briefing. When a large number of METARs are included in a briefing, it can be challenging to traverse them all and find the most important data.

Specialists take the presentation of METAR information a step further by summarizing conditions along the route into groups with similar conditions, providing geographic references along the way. The description of the groups typically includes a lowest common denominator characterization – e.g., some IFR with ceilings as low as 800 feet. The automatic identification of these groupings and the generation of the summary characterization are the key additional features of NGB relative to METARs. An example of the NGB presentation is provided in Figure 4.

The example NGB presentation shows a grouping of METARs along a flight plan route from Philadelphia to Lancaster, OH. The text summary for the group is provided in the upper left. The corresponding METARs that comprise the group are highlighted both on the graphic and in the full METAR text.
section beneath the summary area. (Users can also view a three hour history of METARs in the full text area for trend analysis.) The graphic is fit to the route plus a buffer around the route. The controls above the summary area allow the pilot to step through each page of the groupings.

In this particular example, there are four groups plus the first page shows all METARs beyond the briefing corridor. This view allows the pilot to see weather in the broader area that may be approaching the route of flight. Beginning with page two, the pilot is presented with a specialist-like summarization using only the METARs that fall within the briefing corridor. This summarization includes a full METAR for the origination, detected groupings along the route of flight (two in this case) and then the full METAR for the destination. If alternate airports are filed, they are shown after the destination.

Significant input from the Flight Services specialist community was used to define the logic for identifying groups. The first half of this flight is clearly VFR. The second half of the route encounters areas of IFR and LIFR, so a new group is created. The balance of the route is mixed, ranging from VFR to IFR, but not in sufficient concentrations to warrant additional groupings. The summary, always presented in plain English, emphasizes the worst of the conditions in the group.

For this particular route there are 24 METARs. Given the conditions at the time, NGB automatically reduced the 24 METARs down to four summary statements. The benefit increases for longer flights.

**TAFs**

Because weather can change significantly in short periods of time, pilots must supplement current observations with forecast information. Aerodrome Forecasts (TAFs) provide forecast information in the vicinity of airports, typically covering a 24-hour period of time. The forecast information is further subdivided into forecast periods. The information provided for each forecast period is similar to METAR information, including expected winds, ceiling, visibility and other weather conditions. Sample TAF messages are provided in Figure 5. Each of the forecast periods is on a separate line and typically begin with FM (from) or BECMG (becoming).

The primary challenge in using TAF information is determining the forecast period that will apply to a particular route of flight when the aircraft passes the associated location. Both pilots and specialists have to perform the analysis manually. Secondarily, once the applicable forecast period is determined, the pilot still needs to interpret the information.

The NGB implementation for TAFs, shown in Figure 6, addresses both of these issues. The forecast period is automatically determined based on

![Figure 5 – Sample TAFs](image)
extrapolating the aircraft location using the departure time, filed speed, and forecast winds. This is denoted in the text by displaying a box around the applicable forecast period. The text is also characterized as VFR/MVFR/IFR/LIFR using the same conventions and color-coding as is applied to METARs.

The graphical portion of the NGB TAF presentation is even more powerful in terms of giving the pilot an extremely quick overview of forecast conditions along the route. The TAF symbols are color-coded using the METAR conventions, for the time the aircraft will pass the location. The route is also annotated with time references (departure, arrival, and top of the hour points along the route) to support further analysis. In essence, this single graphic is the overall summary pilots must construct through manual analysis today.

Another important facet of the NGB TAF implementation is recognizing situations where the projected time of passing is close to the boundary between two forecast periods that could have significantly different forecast conditions. These situations are identified both in the text and on the graphic. In the text, annotations are added to the adjacent forecast period if the time of passing is within a configurable number of minutes (e.g., 60). This allows the pilot to know that departing earlier or later could result in avoiding undesirable conditions. On the graphic, the left or right edge of the TAF icon is color-coded according to the conditions for the adjacent forecast period if the time of passing is within the same configurable number of minutes to the adjacent forecast period. Color-coding on the left edge indicates the point of passing is close to the

Figure 6 – NGB TAFs
previous forecast period; color-coding on the right edge indicates the point of passing is close to the following forecast period. In Figure 6, KSFO and KOAK provide examples of this situation.

**Area Forecasts**

Area Forecasts contain forecast information related to large regional areas, typically comprised of multiple states and sometimes including regions of coastal waters or the Great Lakes. The message text of an Area Forecast can be quite long, frequently providing summarized forecast information at a finer granularity than the state level (e.g., Northern and Southern Maine).

Figure 7 shows a typical Area Forecast message for the Northeast (Boston) region. The blue labels identify the different parts of the message including the states or groupings of states and areas associated with water. The section for New York and Lake Ontario provides a good example of how a state can be further divided into smaller areas each with its own forecast. One point to note is that an Area Forecast contains information that is already summarized. For example, it is not appropriate to attempt to derive a higher level summary of the forecast information for New York. The granularity provided is what the National Weather Service (NWS) has determined is necessary.

The primary issue in dealing with Area Forecasts in a briefing is that if the route of flight intersects any portion of the Area Forecast region, typically the entire Area Forecast is included even though the vast majority of it may not be applicable to the flight. Specialists filter the inapplicable portions of the Area Forecast when providing a briefing to a pilot; pilots must do this filtering manually in a self-briefing environment. For some pilots, the encoded forecast text is also difficult to understand.

NGB handles the filtering automatically. The Area Forecasts are decomposed to the state or body of water level and then only those that intersect the briefing corridor are presented in the briefing. This is illustrated in Figure 8.
This example again uses a flight from Philadelphia to Lancaster, OH. Previously the pilot would have received the full Area Forecast message shown in Figure 7, including Maine, New Hampshire and several other states nowhere near the route of flight. In this case it is reduced to four areas – New Jersey, Pennsylvania, Ohio, and a combined forecast for West Virginia, Maryland, Washington D.C. and Delaware.

The Previous and Next buttons allow the pilot to step through each of the states/groups of states that are applicable, in route order. The corresponding forecast text is indicated by the dashed box in the text area. Pilots also have the option of displaying the forecast information in plain text.

For this particular example, the filtering of inapplicable data results in approximately a 50% reduction in the information with which the pilot is confronted. For shorter flights, which tend to be the norm for GA VFR flights, the reduction can be significantly larger.

Readers may wonder why this concept is not taken a step further and applied to regions within a state. For example, why should a flight contained in East Tennessee receive forecast information for West Tennessee? This would be preferable, but the regions within a state do not have consistent, precise geographic descriptions used by the NWS. If that changes in the future, then the increased granularity can be used in NGB.

**Next Steps**

The examples given above provide insight into the types of techniques that are being applied and the types of results that are being achieved with NGB. Each section of the briefing requires specific analysis to determine how best to convey the information. The precise methods for presenting and summarizing each section necessarily vary according to the characteristics of the
data. Nevertheless, there are prominent recurring themes: graphic orientation, extraction of key information, summarization, selective plain language translation, and filtering – all of which contribute to a more rapid and accurate understanding of the briefing by the pilot.

Support for the data types described above plus several other polygon-oriented adverse conditions is being deployed in the fall of 2013. Remaining sections of the briefing will be addressed during the first half of 2014.

In addition, while the initial deployment of NGB is only available on the LM Pilot Web Portal, NGB support will be added through web services in 2014 so that vendors who wish to do so can provide them through their apps and websites.

**Flight Services Data Link**

As described in the introduction, pilots can contact Flight Services via radio during flight for both routine and emergency communications. However, unlike the ATC environment where pilots are required to maintain radio contact with the appropriate controller and generally can always be reached, VFR pilots typically do not maintain radio contact with Flight Services. Typically they are monitoring ATC frequencies, even if not under ATC flight following. This means that if Flight Services detects a situation that is of importance to a VFR pilot, there is no reliable method to deliver the information. Conversely, if a VFR pilot does have ATC Flight Following, they must notify the controller if they leave the ATC frequency to contact Flight Services. This is a contributing factor to the low number of PIREPs received from VFR pilots.

An electronic data link independent of the Flight Services radio infrastructure addresses this problem and provides the basis for a range of safety and convenience-oriented capabilities.

The ACAS in-flight alerts already in operation represent an example of a single-purpose data link application. The concept of a Flight Services Data Link is to expand the set of services and capabilities to address all routine interactions as well as introduce new applications specifically enabled by the data link. Radio communications remain available for non-equipped aircraft and for emergency support.

Two examples of safety-enhancing data link applications are targeted PIREP solicitation and Search and Rescue Alerts.

PIREPs are particularly valuable in understanding actual weather conditions in the context of broad forecast areas. AIRMETs, for example, can cover large areas where there is a potential for adverse weather conditions, but the conditions frequently do not occur across the entire area. PIREPs provide a more detailed picture of what is actually happening. However, in practice, PIREPs are relatively infrequent and it is common that there is insufficient PIREP coverage of a forecast area to make informed decisions.

The concept of targeted PIREP solicitation starts with identifying aircraft currently operating in an area for which inadequate PIREP coverage exists. This is accomplished through a combination of SE-SAR style aircraft position monitoring and flight plan extrapolation. Once the aircraft are identified, the data link can be used to send a PIREP request to appropriately
equipped aircraft. Pilots will not be obligated to respond, but it is anticipated that many will because of the safety benefit to other pilots.

The user interface presented to the pilot can be optimized to enable very quick composition of a response. All of the data required in the PIREP except for the actual conditions can be automatically supplied; for example, the aircraft ID, type, time, altitude, latitude and longitude. The particular condition identified in the AIRMET (e.g., icing, turbulence) can be presented with as little as 2-4 screen touches required to compose a negative or affirmative response. Once the PIREP is sent and received by Flight Services, it immediately becomes available for inclusion in all subsequent briefings; urgent PIREPs are also immediately made available to the ACAS so that other pilots that will traverse the area can be alerted.

Even without targeted solicitation, electronic PIREP submission from aircraft is very valuable. This will be the first additional data link application implemented beyond ACAS alerts early in 2014.

SAR alerts would be used when an aircraft is known or suspected to be down in an area and Flight Services automation detects that other equipped aircraft are in the same vicinity (again using the ingest of position reports and flight plan extrapolation to make the determination). Via the data link, a pilot would receive an alert explaining the situation, the last known location, and asking if they can help in trying to locate the aircraft. Pilots who are able can then contact Flight Services for further information / coordination.

The combination of a Flight Services Data Link with a position reporting capability enables automatic uplinks based on geo-fencing. For example, when an aircraft is within a certain distance of the destination airport, the latest METAR, including the altimeter setting, can be automatically uplinked without any action required by the pilot or a specialist. Surveillance information also raises the possibility of tactical alerting for terrain avoidance, one of the most common causes of GA accidents. [3]

Flight plan activation and closure, briefing updates, extending an ETA, and notifying Flight Services of a route change are examples of other routine operations that can be supported via a Flight Services Data Link.

LM is pursuing Flight Services Data Link initially using satellite communications devices operating on Iridium or Globalstar, and in collaboration with cockpit applications providers. As with SE-SAR, this strategy is being pursued because of the availability of low-cost devices, the likely long-term need to support remote areas using satellite communications, and because it allows the concept to be implemented, evaluated and refined relatively quickly. Longer term LM Flight Services envisions integrating into the FAA Surveillance and Broadcast Services infrastructure which provides the equipment necessary to support ADS-B, TIS-B, and FIS-B. An initial set of data link applications is expected to be implemented in 2014.
Automated Flight Risk Assessment

When a pilot receives a briefing from a Flight Services specialist, the specialist assesses the conditions and may choose to state VFR Not Recommended (commonly referred to as a VNR). Per FAA Order JO-7110.10, this recommendation is made when “current or forecast conditions, surface or aloft, would make flight under visual flight rules doubtful.” This is a form of risk assessment a specialist can make based on the training and expertise they have.

In the self-service briefing environment, which has expanded dramatically over the past 20 years, no VNR assessment is made and added to the electronically provided briefing. Pilots must make this determination on their own.

The idea behind an automated flight risk assessment is to provide automation capabilities that better support pilots in making the determination that a flight can or should not be taken.

Important considerations that are factored into the concept for an automated flight risk assessment capability include: integration with flight planning software so that pilots do not have to reenter flight plan information; the ability for pilots to specify personal minimums which may be more conservative than standard VFR, marginal VFR, or IFR conditions and to have those minimums be factored into the assessment; access to automatically maintained pilot certifications and experience; access to current weather, aeronautical and terrain information; post-flight risk assessment; and others.

LM Flight Services is still in the process of refining the final concept for Automated Flight Risk Assessment in collaboration with the GA community. The initial deployed capability is planned for the fall of 2014.

Conclusion

The ACAS is operational today and is alerting pilots to adverse conditions about which they otherwise would have remained unaware. SE-SAR is operational today and provides the means to significantly reduce the time between an accident and the arrival of first responders. The Next Generation Briefing capability dramatically improves the presentation of briefing information using graphics, automated summarization, information filtering and other techniques so that a pilot can more quickly and thoroughly understand the meteorological and aeronautical conditions pertinent to a flight. The first set of Next Generation Briefing capabilities are being deployed during the fall of 2013 and will be completed in 2014. A Flight Services Data Link provides electronic communications from the cockpit and enables both routine and safety-oriented interactions. The first Flight Services Data Link applications beyond in-flight delivery of ACAS alerts, including electronic PIREP submission from the cockpit, will be deployed early in 2014. Automated flight risk assessment will provide pilots summary information that allows them to make better decisions about whether or not to fly.

This is a period of dynamic and rapid change in the Flight Services environment. Fiscal realities are driving efficiency and changing the ways in which services are provided; however, safety remains the FAA’s and Lockheed Martin’s primary objective. The capabilities described in this paper demonstrate that safety can be improved while reducing the overall cost of providing Flight Services.
References


Voice Communications Solution for UAS Integration in the NAS

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Abstract
Today there are several operators of Unmanned Aircraft Systems (UAS) within the National Airspace System (NAS) that are only accommodated and not integrated. Due to the possibility of loss of communication between the UAS pilot and the Air Traffic Controller (ATC), these UAS operations require special operating restrictions. UAS that operate beyond line-of-sight rely on satellites to relay pilot voice to ATC. When the UAS pilot loses radio connectivity with the Unmanned Aircraft (UA) they also lose voice communications with ATC, significantly impacting UAS and ATC operations. The reduced quality and timeliness of satellite-relayed voice communications also increases radio step-on and clearance readbacks. To eliminate the lost link impact along with the quality and timeless issues of satellite relay, a ground-based communication network capable of providing voice communications between UAS pilots, Air Traffic Control, and other air traffic should be implemented.

The purpose of this paper is to discuss a potential UAS voice communications solution that will allow seamless integration into the NAS. The proposed solution involves the use of all available resources, including terrestrial networks, Command Non-Payload Communications (CNPC), and ground-based radio relays. The solution leverages possibilities that arise from having the pilot located on the ground; such as direct network access to the FAA NAS Voice System (NVS).

The issues and corresponding solutions discussed in this paper were identified through the development of a prototype UAS Voice Communications System utilized during Federal Aviation Administration (FAA) UAS Demos 3 and 4. True UAS integration into the NAS will require a high availability system that meets or exceeds the current manned aircraft pilot-controller voice communications capabilities. The proposed solution is a human-centered design that minimizes the impact that UAS integration into the NAS will impose on current ATC and pilot procedures.

Introduction
Integration of UAS into the NAS is fast approaching. There is a strong push from both civil and public sectors for the FAA to support routine UAS operations through simple file-and-fly procedures. UAS being physically and geographically disconnected from the pilot creates several issues that need to be resolved prior to supporting safe and efficient operation in the NAS. The FAA's primary focus on safety requires that risks be understood and mitigated prior to seamlessly supporting UAS. One such risk that still has to be resolved is providing uninterrupted, clear, and timely voice communications with Air Traffic Control (ATC). The current methods that UAS uses to provide voice communications to ATC are not sufficient
for supporting safe and efficient UAS operations in the NAS. This paper discusses the current methods of voice communications for UAS, issues with these methods, and a possible voice communications solution that would allow for safe and efficient operations.

The UAS Voice Communication Issue
UAS are very similar to manned aircraft. Both manned aircraft and UAS consist of a flight crew, an aircraft, and a communication medium between the two. The exception with a UAS is the flight crew and the aircraft are physically separated from each other. To accommodate this separation, the communication medium required to support UAS operations now must include a wireless segment in addition to the physical linkages or wires that provide control of the aircraft. The wireless communications system supporting operation of the UAS has been defined by RTCA 203 as the Command Non-Payload Communications (CNPC) link. The CNPC link provides the transport of telemetry, control, voice, and video required for command and control of the Unmanned Aircraft (UA).

UAS CNPC Operating Categories
For this paper UAS operations are grouped into two categories that address the type of CNPC link required to provide operation of the UA: Line-of-Sight (LOS) and Beyond Line-of-Sight (BLOS). UAS are considered operating LOS when the UA is within direct line-of-sight of the Ground Control Station (GCS) where the CNPC radio is collocated. When the UAS are not operating in LOS, they are considered operating BLOS. Operating BLOS requires some method of transport to complete the connection between the GCS and the CNPC radio that is not within line-of-sight of the UA. Today the BLOS connection is primarily provided through a satellite relay. To support UAS integration into the NAS, a ground-based network of CNPC radios providing a more reliable and timely communications with the UA will be required in addition to the satellite communication system. Any time a UA will need to be operated with low latency and high reliability, such as at low altitudes or in congested airspace, a ground-based CNPC network will need to be utilized. When operating in an environment where latency and high reliability are not necessarily required,
such as high altitude remote areas, satellite communication systems may suffice. Figure 1 depicts these two operating categories along with the two types of BLOS UAS operations: terrestrial and satellite communications.

The CNPC Voice Communications Issue
Reliance on the CNPC link to relay voice communication between the GCS and UA is the root cause of all current voice communication issues for UAS. The primary issue that results from using the CNPC link to transport voice communications is the loss of voice communication capability if CPNC link loss occurs. Loss of Voice Communications during CNPC link loss is one of the primary concerns that the FAA has for integrating UAS into the NAS. Harris’ role within the FAA UAS Demos 3 and 4 was to demonstrate a backup voice communications solution for when a UA went lost-link. During research and development of a prototype voice communications backup solution, it was quickly realized that there are more issues with using the CNPC link for voice communications than lost-link, especially when operating a satellite-based BLOS UAS. Primary issue with satellite-based BLOS UAS operations is the high latency that occurs between the GCS and the UA. High latency requires the UAS pilot to perform an additional step when conducting their voice communications task. When the UAS pilot wants to transmit a voice communication they must press Push to Talk (PTT) and then monitor an indicator light that will notify them of when the UA has received the PTT signal. The indicator light informs the pilot that they are connected and transmitting through the UA. This additional step can add seconds to the pilot’s communication task and restricts them from performing other duties. Latency also causes up to seconds of delayed audio reception from other aircraft and ATC resulting in increased step-ons of other aircraft and ATC transmissions. These step-ons are due to the UAS pilot constantly using seconds’ old voice receptions, creating a perception that a channel is clear when in actuality ATC or another aircraft could already be transmitting and the UAS pilot just “stepped on” them. The increased step-ons also result in multiple retransmits and requires ATC to regulate who speaks and when. This will be especially problematic in highly congested airspace where it may not be possible to support one UAS, let alone multiple ones. To allow for integration of UAS into the NAS, these issues must be resolved.

Harris Support of FAA UAS Demonstrations
Harris Corporation was a prime partner in the FAA’s UAS Demos 3 and 4. Harris’ role within these demos was to demonstrate the ability to provide continuous pilot-to-controller voice communications along an entire route of flight, primarily for use as a backup during lost-link events. Harris was able to provide and successfully demonstrate a ground-based voice communications solution that would allow for safe and efficient operation required for UAS integration into the NAS. The Virtual Radio Network (VRN) was the solution Harris developed to provide this capability. Harris’ VRN system provided multiple UAS pilots with the ability to communicate to ATC through a network of radios deployed throughout southern Florida. Figure 2 illustrates the VRN deployed to support the FAA UAS Demo 4. UAS pilots were able to communicate on frequencies from the ground hundreds of miles away. The entire system was designed to provide UAS pilots the ability to communicate with ATC while maintaining party-line ability to
hear other air traffic communications, supporting situational awareness without altering how pilots and ATC communicate. Harris’ VRN system provides the UAS pilot with an interface that looks and functions identical to an aircraft radio. This allows any pilot of manned or unmanned aircraft to use the radio with minimal training.

UAS Voice Communications Solutions for NAS Integration
According to the FAA’s UAS Concept of Operations (CONOPS) for integrating UAS into the NAS, UAS will be required to file and operate under Instrument Flight Rules (IFR); as well as operate with constant human monitoring and control. The UAS pilot will also be responsible for maintaining voice communications with ATC and complying with their instructions. Specifically, the UAS CONOPS states “instructions from ATC to the PIC result in the same pilot acknowledgement response time as those typical for manned aircraft.” The FAA UAS CONOPS assumes that the CNPC link will provide the primary means of voice communication through relaying pilot-controller voice through the aircraft. With the issues discussed in this paper regarding lost-link situations and the latency associated with using the CNPC link for transport of voice communications, the primary means of voice communications should not be through the CNPC link but rather through a communication medium that is agnostic of the UA. The CNPC link should be used as an alternate means of providing voice communications in case the ground-based communications system fails, which is less likely than the CNPC link failing.

The proposed ground-based solution for UAS NAS Integration consists of three integrated systems: an NVS UAS Gateway, a Virtual Radio Network, and the CNPC link.

NVS USA Gateway
The NVS UAS Gateway provides the UAS pilot with access to any facility-frequency supported by NVS. A UAS Pilot Radio Client application would connect to the NVS UAS Gateway over an IP network and allow the UAS pilot to select a frequency and communicate identical to how they would with a manned aircraft radio. Once connected, the UAS pilot would be able to receive voice transmissions from ATC, other air traffic receptions received through the ATC air-to-ground radio, and other UAS pilots on the same frequency. The UAS Gateway would also provide the UAS pilot with the ability to communicate directly to ATC through the IP network and broadcast their transmission for manned aircraft to receive. This system provides the same voice communications capability as a manned aircraft. In addition, the NVS UAS Gateway will also be able to provide PTT arbitration preventing step-ons or the ability to disconnect a UAS pilot if they have a stuck microphone. The NVS UAS Gateway should be considered the primary solution for a ground-based UAS voice communications system.

Figure 3 depicts the NVS UAS Gateway concept. UAS pilots would access the UAS-GW over a commercially provided IP network. Once authenticated and connected, the UAS pilot would then have access to all frequencies NVS is supporting in the NAS. Using VoIP and ED137 type protocol, this solution provides additional capabilities that currently are not available with VHF-based voice communications. These capabilities include: consistent clear voice transmissions regardless of UA location, PTT arbitration to control step-on of
transmissions, and the ability for ATC to disconnect a UAS pilot if they have a stuck microphone.

Virtual Radio Network
Where NVS is not supported or not yet deployed, a Virtual Radio Network (VRN) could support UAS voice communications needs for integration into the NAS. A VRN is a network of IP-based software defined aeronautical band radios that provide the same connection and functionality to the UAS pilot as the NVS UAS Gateway but provided as a commercial service. The radios would be deployed in close proximity to ATC air-to-ground radios. In this scenario, a radio would relay the UAS pilot’s voice transmission to the ATC air-to-ground radio, as well as to all air traffic on the selected frequency. (See Figure 4.) The VRN also contains a gateway allowing multiple UAS pilots to share the same frequency radio providing seamless communications.
End Solution
In addition to the UAS NVS Gateway and the VRN, the CNPC link may still be needed to support backup voice communications or in areas where NVS is not deployed or VRN service is not available. Such situations may be at uncontrolled airports or for accessing airport services such as ATIS, AWOS, or UNICOM. With a full deployment of NVS to all air traffic facilities, the NVS UAS gateway would be able to provide all UAS pilots with a ground-based voice communications system capable of supporting the voice communications required for UAS integration in the NAS.

Pilot Interface
The voice communications interface for UAS integration in the NAS will need to be a single application that performs management of the different systems supporting UAS voice communications. Since there may be a combination of systems such the NVS UAS Gateway, VRN, or relay over the CNPC link supporting UAS pilot voice communications, the interface should be able to provide the same functionality regardless of the supporting system. This is imperative to ensure the UAS pilot does not have to manage three separate system interfaces to perform their voice communications tasks. In addition, the UAS Pilot Radio will also need to provide the UAS pilot with a method to select the right frequency and the correct facility. Due to frequency reuse it is not possible to simply enter a frequency; the associated facility will also need to be identified. To solve this, the UAS pilot voice radio will need to provide a list of facilities that are associated with the frequency for selection. This allows for the UAS pilot to operate the radio nearly identical to how a manned aircraft radio operates. The UAS pilot would enter the frequency, a list of the facilities supporting that frequency would populate, and then the pilot would select the correct facility according to the operating location of the UAS. Once selected the UAS Pilot Radio application would connect the UAS pilot to the associated resource either through the NVS UAS Gateway, the VRN, or directly to the UA through the CNPC link. Figure 5 provides a concept of how the UAS Pilot Radio interface may look.
Conclusion
To ensure safety and airspace efficiency, UAS Integration in the NAS will require seamless voice communications between UAS pilots and ATC. In addition to voice communications between UAS and ATC, party-line communications between UAS and manned aircraft will be necessary to support pilot situational awareness. Having reliable voice communications is crucial for the safety case, especially in NAS airspace used regularly by commercial aviation traffic. Current technology supporting voice communications between UAS pilots and ATC is not sufficient to support the needs for integration into the NAS. A ground-based voice communications system consisting of an NVS UAS Gateway and a VRN would need to be implemented to support the integration of UAS in the NAS. In addition, the CNPC link should be used as a backup to the ground-based communications system. The CNPC link will also need to provide the voice communication required to access airport facilities such as ATIS, AWOS, and UNICOM.

References

White Paper
Lockheed Martin Full-Lifecycle
Cloud Broker Offering

Scott Anderson, James Wei
Lockheed Martin IS&GS

Introduction
The concept of a broker is nothing new to humankind. Goods created by one party being resold by a third party have been around for thousands of years. Think of a cloud broker as A&P of the early 20th century, at which point in time grocers didn’t have significant combined buying power nor the ability to offer specialty foods. Out of that scenario the first grocer came into being. A&P in the early 1930’s represented a new way of selling food to people around the country. The modern day cloud broker, much like A&P, offer common items at the lowest current market pricing while also offering specialist services (Business Process as a Service or Data as a Service) in a controlled environment.

In the Cloud Computing context, the broker concept expands on the role of reselling goods and services to include additional core critical components, adding value to the services being delivered beyond the original services. This marketplace offers a number of core solutions, inherently allowing different requirements to be baked into the offerings; rather than hoping for solutions that would meet potential customers’ requirements. This whitepaper will discuss the concept of a Full-Lifecycle Cloud Broker and the value the cloud broker model offers, and that compared to the traditional broker model, also referred to as a Technical Cloud Broker. Cloud Broker Ecosystem.

The Cloud Broker Ecosystem provide benefits and enables compliances such as:

- **Reducing the complexity of an increasingly complex supply base** – Request system (computing resources) for new functionality from CSPs based on the agency’s overall business requirements. CSPs are managed by the CSB.
- **Reducing the complexity of an increasingly complex demand base** – Cloud Service Management (SM) helps vet applications, allowing for increasingly complex solutions to be built and deployed into the cloud.
- **Reducing the long lead times for cloud procurement** – Rapid support for agencies requesting new CSP functionalities and ever-expanding CSP ecosystem maintained by the broker.
- **Supporting OMB directives** – The broker model helps agencies adopt federal mandates such as the Federal Data Center Consolidation Initiative (FDCCI), shared services and cloud first/future first policies; for agencies that are ready to move now as well as agencies that need additional support to prepare for meeting these goals.
- **Reducing duplication of cloud acquisition across agencies security requirements (e.g., FedRAMP)** – As more solutions are instantiated in the broker model they are becoming more readily available to be consumed by all agencies. As agency requirements drive the expansion of the CSPs base, they will become available for other agencies once instantiated.

- **Reducing cloud acquisition sprawl** – The FCB allows the agency, should the agency choose, to interact with only one entity as they move to the cloud. The agency can maintain existing and new relationships including all vendor management. This reduces the number of vendors, allowing the agency to focus on their mission.

- **Unified Vendor Acquisition Solution (VAS):** CSPs offer a number of solutions and levels within the solutions they offer. The VAS solution will allow Lockheed Martin to present the agency with a structured CSP/TCB acquisition process. VAS includes:
  - Vendor financial stability review (credit worthy)
  - Vendor solution and functionality review (what does the solution do and how is it done? Is the solution a pure cloud or a hybrid – cloud and on-prem?)
  - Vendor solution mapping (comparison with other vendors in the same space, based on cost, performance, operations)

- **Supporting shrinking budgets** – Reducing the cost of acquiring and moving to new solutions as well as allowing smaller software vendors to interact with the US Federal Government without risk to the Agency’s Mission.

Illustrated in the figure below is Lockheed Marin’s Full Lifecycle Cloud Broker ecosystem.

![Figure 1: The Lockheed Martin Full-Lifecycle Cloud Broker Ecosystem](image-url)
Cloud Service Provider vs. Cloud Service Broker

There are a number of organizations that will offer dedicated cloud services but not cloud broker services. These organizations are considered Cloud Service Providers and may or may not offer connections to Cloud Service Brokers to support the delivery of their solutions. The Cloud Service Broker space itself encompasses two types of brokers, the FCB and the TCB. Both enables the adopting organizations to focus on short term economic savings and apply those, over time, to reduce the net cost of their on-premise IT systems, including application migration to the cloud – the end state solution as considered by many organizations. The services cloud brokers provide include:

- **Integration with hardware providers** – Our catalog supports hardware purchasing including the purchasing of mobile devices creating a one stop managed portal (a further introduction to the catalog can be found here)

- **Cloud Suitability Matrix** – To guide customers in making sound IT strategy choices, Lockheed Martin has developed a Cloud Suitability Matrix (CSM) that can be applied to specific applications in the customer’s mission focused portfolio, to ensure the brokering to Cloud Service Providers (CSPs) meet the customer’s requirements. This workflow process maps requirements with the best possible solution, i.e., CSPs, based on a number of attribute requirements, including location, security, etc.

Cloud Service Providers

The initial tier of cloud service providers is the CSP market. This market may offer many new rapid innovations that benefit organizations. The CSP market is growing rapidly, from low cost alternatives to FOSS solutions that offer new and existing organizational benefits. CSPs range from large IaaS providers (such as Amazon or Rackspace) to core business process as a service offerings (BpaaS). Within this space there’s additional differentiation, between providers of specialized cloud services and commoditized cloud services. In general CSPs provide:

- **Integrated Service Catalog** (and associated Broker/Orchestration Engine): Baked into the catalog are the business models by which the broker offers and resells the services of the CSPs and TCBs it partners with. It is via catalog (the front end) and the broker/orchestration (the back end) that the broker will offer distinct and unique services that differentiate the broker from other broker solutions. Once the business logic has been determined, the provisioning engine will execute to the decisions and provide linkages to the CSPs and/or TCBs. The service catalog and broker/orchestration engine factors in Questionnaires, Requirements, Proposals, and RuleSets, in order to determine the optimal results.

- **Security Based on Needs**: Lockheed Martin’s adopts the industry’s best standards in implementing cloud security and data protection. Operate using best practices and top government and industry standards to ensure appropriate protections and segregation of customer data and applications including:
- Cloud Security Alliance best practices for securing cloud computing and the security controls framework for cloud providers.
- Defense-in-depth approach delivering confidentiality, integrity and availability.

### Device/Service Monitoring
Lockheed Martin’s FCB provides enterprise-level NOC/SOC monitoring (setup and execution). The visibility through the stack is governed by the business model, some CSPs may allow for near complete control of the cloud aspects that can be controlled and monitored (networking, VM health, security components, SLA management, etc), whereas some others may allow customer visibility in their respective environment, albeit with less control over the components. The incorporation of these monitoring tools and security components have been carefully vetted, selected and designed to minimize performance impact to cloud customers.

### Integrated Governance
Lockheed Martin’s Integrated Governance & Security Office supports ITIL, ISO and COBIT management solutions ensuring that business, service and quality requirements of the broker solution are met.

### Support for Mobile Device Management (MDM)
Lockheed Martin has a solution that supports two factors of MDM: the creation and management of a secure container on the device and the ability to remotely wipe the container if the device is lost or stolen
- Device Diversity,
- Reduced device acquisition cost
- Ability to provide a common device and in-office desktop,
- Standards based MDM approach,

### Cloud Readiness Assessment (CRA)
A service offering from Lockheed Martin that focuses on determining your organization’s IT maturity, from a business, technical, and cultural perspective, to help you realize where you are and help you move to where you want to be.

### Flexible service offerings
Matching your mission requirements (e.g., data center security, MAC, etc.) with the capabilities of the CSPs as shown in Figure 6.

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Technical Cloud Brokers vs Full Lifecycle Cloud Brokers

Technical Cloud Brokers offer a focused solution set in the market, who have a core set of specific skills – or broader, a core set of specific partners – to offer market focused solutions. The old adage “you want management from the vendor that made the product” applies. In a TCB environment you have a vendor that offers cloud services based on a solution they build and develop, at specific points in time. This robust ecosystem thrives because the system is built around a unifying solution.

Full Lifecycle Cloud Brokers would engage both CSP and TCB solutions, depending upon the missions, needs and goals. The FCB solution would provide access to the TCB and CSP solutions at the appropriate level the customer requires. Customer would own the relationship but FCBs would provide the services. Customer will have a direct contractual relationship with the FCB, TCB and CSP, but can also rely on the FCB to manage all the relationships. A Full Lifecycle Cloud Broker, specifically Lockheed Martin’s FCB offers a number of additional services components. Those service components are detailed below:
• CSP solutions mapped to your business needs: We can quickly add new providers based on our easily expanded catalog model.
• Software rentals: For software vendors that support the concept of software rental, the Lockheed Martin’s FCB catalog offers this feature through the use of the portal.
• Integration with our billing system: Lockheed Martin has integration with several customers allowing us to build and connect to billing systems.
• Multiple forms of contract vehicles: A number of different contract vehicles are offered within the FCB model, this includes Federal Energy Management Program (FEMP), hardware modernization, and the different broker business models mentioned in this document.
• Tiered Membership Model: Buy what you need when you need it based on what and how you will use it. At the highest membership levels (Gold and Platinum), agencies would be invited to sit on the Broker Solution Council, or attend council meetings where offerings, solutions, TCB and CSP solutions would be considered and evaluated.

From Lockheed Martin’s neutrality in the cloud marketplace to its innovative storefront catalog solution, the FCB from Lockheed Martin will help customers achieve their mission and goals effectively. Later this document will focus on the “storefront” concept of our cloud catalog offering. A comparison of the services offered by different roles is listed in the table below:

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<tr>
<th>Service</th>
<th>Tier 1 CSP (Commodity)</th>
<th>Tier 2 CSP (Specialized)</th>
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Figure 2: Services Offered by Different Actors of the Cloud Broker Ecosystem

The Value of Cloud Broker
Cloud computing is a business strategy that leverages technology to improve the effectiveness and efficiency of sustaining organizations’ missions. The Cloud Brokerage model reduces overall
organizational risk. The depth of this organizational risk has been prevalent throughout the U.S. Federal Government and commercial sectors for many years. Moving to the Cloud Brokerage model allows organizations to remove many of the stumbling blocks to successful solution management.

Cloud computing is more than deployed hardware and software services. It is also about the operations and management of the solutions going forward. The Cloud Brokerage model reduces the overall organizational risk by assuming a myriad of responsibilities, managing contractual relationships with multiple vendors, managing and operating multiple deployed solutions, upgrading solutions as vendors release new capabilities, and multiple internal and external Service Level Agreements (SLAs). This allows customers to simplify the operations and management of their missions by dealing with a single interface. These contractual agreements span across financial, legal, and technical perspectives; from Service Level Agreements to new product integration agreements. Where some vendors may see cloud brokerage as an additional layer of complexity to the overall cloud computing implementation, it is Lockheed Martin’s experience that over time, the broker model will reduce complexity for both industry and the government, resulting in affordable access to the best solutions.

1. Cloud Service Providers can quickly respond to market requirements but don’t focus on security and operations, nor the suitability of solutions.

2. The overall market can be slow moving which can be very dangerous for organizations that don’t watch ahead.

3. FCB ensures that the cloud consumers can enjoy the benefits of cloud computing but is also shielded from all the pitfalls.

![Figure 3: Cloud Broker Beneath the Surface](image-url)
The Value of LM Full Lifecycle Cloud Broker
Industries often ask why customers wouldn’t go directly to a CSP and skip the broker in the middle. The answer is the neutrality of the solutions they can provide, which is the most important value and differentiator between an FCB and a CSP or TCB. An FCB would in fact have a greater ability to remain neutral, and thus truly place the customers’ needs as the priority.

The second value builds on the first. Most TCBs do not have relationships with each other, and a number of large Email as a Service providers are a prime example of that. In this sense an FCB would, through its neutrality, be able to offer broader solution options to address customers’ needs. Whereas a TCB would offer the full service within their specific sphere it would still be limited to their specific solution and expertise.

The next value is the end-to-end integration, a critical feature from which a number of lower layer cloud services could be easily added to the FCB solution space. It would provide to its customers a one-stop-shop for services including:

- Secure online data storage
- Content Delivery network services
- WAN Traffic reduction
- Crisis service expansion
- HA and DR additions
- Multiple selection of solutions

The LM solution takes a slightly altered approach in that it enables the provisioning of resources from a wide array of highly integrated resource pools that meet the customer requirements. These resources would be used to compliment the overall enterprise strategy and vision, and any constraints would not be a limitation of a technical nature. LM is a proven systems integrator with deployed Private Clouds, Community Clouds, and Virtual Private Clouds services to more than a dozen agencies. We differentiate our clouds by equipping them with industry-leading security measures, tools, processes, and talent. We also invested in research and development centers around the world for customer and partner collaboration, to solve technology challenges leveraging partner relationships with the top IT manufacturers including EMC, Oracle, IBM, Cisco, Juniper, Hewlett-Packard, Dell, and NetApp, to name a few, to create rapid prototypes and solutions. Our Operations Team is leveraging cloud management best practices as part of our IT Service Management (ITSM) for Cloud Computing standard operating procedures. Lockheed Martin’s intent is to apply these operating principles to every cloud solution we deliver.
“Will interpersonal and group conflict create more delays in NextGen programs?"

Phil Mullis, MADR, CCM

Introduction
The theme for this year’s conference, The Future of Air Traffic Control is well chosen. Our Air Traffic/Aviation System is feeling stress from production and implementation delays, along with cost overruns never before seen in transitions to new technologies. I feel certain that the majority of conference time will be spent on how to incorporate new technologies so system participants will receive the best return on investment (ROI).

This approach makes sense because of the vast sums of money and number of personnel involved. However, the usual philosophy of saying: “By creating new technologies we will better deal with the challenges we face in moving NextGen forward to a successful conclusion”, may not be the only challenge to our success. Are we overlooking the human component in this philosophy? And will the lack of the inclusion of this human component add to our already stretched resources of time, money and human capital? Of all the components that make up aviation’s technological system, the human component is by far the most complex, culturally diverse, and challenging to understand.

Why do I introduce the concern of conflict in general and interpersonal conflict in particular? Does it really matter if people or groups are in disagreement or conflict? Will it actually slow or sabotage a project, and in the process, end up adding unnecessary delay and increase cost of the project? With the reality of additional budget cuts and reduced funding in our future; it is important that we consider the possibilities. To answer these important questions, first let us start by looking at conflict. According to Professor Wilmot and Hocker’s book, Interpersonal Conflict [1], “Conflict is ever present. Where you have people you have opposite views and objectives...thus conflict. It is always present and humans are forever coping with its complexities, even when not mindful of doing so.”

Another-view on the subject is Dr. John Gottman [2], founder of The Gottman Institute's and a 35 year researcher at the University of Washington on interpersonal communication says, “Conflict can go in two different directions. One direction can lead to happiness on the job, good relationships at home, and self-fulfillment. The other direction can lead to strife, anger, and a loss of focus on the task at hand, resulting in a loss of productivity. The distractions caused by poor relationships and anger can interfere with the vigilance needed to see a danger or perceive a coming threat.” Can we turn our costly conflicts into positive situations that lead to beneficial results?

According to the United States House of Representatives Committee on Transportation and Infrastructure, the committee has “serious concerns regarding the FAA’s ability to effectively and efficiently implement NextGen. I’ve heard that some transformational NextGen programs
aren’t truly transformational, that the FAA will never make the tough decisions required to advance NextGen, and that nobody can really agree what NextGen means today or what it should be in 2025.”

These concerns should not be downplayed, ignored, or outright dismissed. Whether you agree with them is irrelevant. We – taxpayers and airspace users – have invested billions of dollars in NextGen and it’s clear that billions more still need to be invested. Every concern should be acknowledged, reviewed, and properly addressed.

It appears we have a conflict of the highest level facing the NextGen program. If we can turn this conflict and others into a positive, using Dr. Gottman’s example, that will aid our cause. However, if we allow our interpersonal communications to turn negative, that will be counterproductive for the objectives of reducing cost and increasing productivity.

The Air Traffic System has introduced a large amount of change over the past twenty years with the addition of new aircraft, new flight-route technologies like RNAV, RNP, GPS, and new air traffic control technologies like ADS-B and Flow Control procedures. The amount and pace of change happening in our lives today is well documented. Just visit any bookstand at the airport to find numerous books dealing with change in the workplace and magazine articles discussing ways to relieve stress. Like it or not, aviation is in the middle of one of the largest patterns of change in its history. The Air Traffic System is filled with people who have different wants, needs, and expectations. So, of course, conflicts will occur.

Okay you say! So we have new technologies, new ways of doing business, and everyday change to deal with. This causes conflict. I get it. Where does the increase cost in money, time, and poor quality come in? What can we do about these pressures? How can we turn conflict into a plus for the system from a negative drain? First we will look at the drivers that increase cost and then, in my solution section, we will look at ways to turn conflict into an asset.

Here are a few ways guaranteed to increase cost for the aviation system. Some of these relate to how we interact with others or new ideas, or change (new technologies) whether we are Congressional personnel, Air Traffic Controllers, Pilots, Program Directors or Procedure Developers.

- Stress, frustration, and anxiety
- Work or intellectual sabotage
- Strained relationships
- Grievances
- Employee turnover
- Loss of productivity
- Increase in customer complaints

The impact of conflict in the workplace can be devastating to the parties involved and to the business system. These symptoms of unresolved conflict are a significant cost factor in any
organization. How much is conflict costing our aviation system? Bill Carey of Ainalerts [3], reported, on July 18, 2013, 1:40 PM that the FAA budget for FY 2014 may be cut to below the levels of FY 2000. Granted not all the cuts are because of conflict pressures. But they conflict does play its part in cost escalation.

Conclusion
The economic issues our Air Traffic/Aviation System is facing are no longer strictly local or even national; they are truly global. What the United States aviation community does to address these financial and implementation delays will have a ripple effect throughout the global aviation system. Today, all aviation interests compete for scarce resources on a worldwide scale. The competing groups are feeling the forces of rapid change in funding and customer demand. We must adapt or become irrelevant.

It is important that we acknowledge our stress and anxiety for us to begin the path to overcoming these challenges with new and thoughtful methods. By acknowledging that change is constant and never-ending, we begin to realize that conflict is the natural result of interpersonal interactions, changes in life and work, and the fear of that change. Conflict by itself is neither good nor bad; it just is. The Chinese have two symbols for the word conflict; one symbol means crisis and the other means opportunity. They believe good can come from conflict if one is willing to search for it and then respond appropriately.

As we begin to understand the true cost of unresolved conflict in our Air Traffic/Aviation System, we realize the need to seek a different path. Destructive conflict is one of the hidden costs in the workplace, draining the energy and creativity of employees. This happens at a time when we need the attributes of energy and creativity the most. We have refused to deal competently with it long enough. Our present approach to dealing with conflict in our NextGen organizations, technical/development groups, Congressional oversight groups, and controller and pilot implementation teams will continue to lead to a loss of productivity within a vital portion of our nation’s economic engine.

We are living in a new economic/budget environment that is foreign to most of us. We feel insecure about our jobs, the competitiveness of our companies or programs, and the frustration of failure. Here is one small example, from boston.com [4], of the cost of doing business in our current mode. “The United States of America may have pioneered commercial aviation, but today the crossroads of global air commerce are places like Dubai, Frankfurt, Istanbul, Seoul, and Bangkok. These are the places -- not New York or Chicago or Los Angeles -- that are setting the standards. They have the best airports and the fastest-growing airlines, and they offer the most convenience for travelers.”

Solution
Now we will look at ways of turning conflict into an asset so that the system will be able to use these opportunities to add value by improving the atmosphere for creativity and collaboration.
Under the auspices of the Professional Women Air Traffic Controller Organization [5]; I have successfully implemented Conflict Resolution training seminars on the topic of *Interpersonal Communications and Conflict Management* for FAA Air Traffic Controllers in Phoenix, AZ, Sacramento, CA and San Diego, CA. Since universities have complete PhD and Masters program’s that dealt with Conflict Resolution issues and I cannot give it its full worth in one paper. But, I hope that I have elevated your interest in the possibilities for cutting the cost of producing NextGen procedures and for increasing productivity in the development, implementation and use of NextGen flight procedures.

For a return to real progress and positive growth in our Air Traffic/Aviation System we require willingness, on part of all interested parties, to address and resolve the roadblocks in our Air Traffic facilities and NextGen programs. These roadblocks are usually emotional and positional stances taken by individuals or groups as a result of conflict. We can resolve these by teaching new skills that can be taught to anyone. We can turn our destructive conflicts into opportunities through training, open dialogue, collaboration and negotiation.

My experience in Air Traffic, Airline Operations, FAA employee training, and Civil Court Mediation give me a unique position to provide the training I have outlined above. Listed below are five areas that my training will provide. This training will be a positive step in returning financial stability to the NextGen procedure development and implementation system. I look forward to working with ATCA members to help move the Air Traffic/Aviation System forward to a more robust, cost effective system.

1. **Understanding the communication issues**
   - Create shared purpose
   - Build more synergy and cohesion among teams
   - Foster new ideas, alternatives, and solutions

2. **Realization of conflict**
   - Conflict is with us
   - Openly and honestly communicate with other people
   - Commit to working it out

3. **Why work it out...commitment**
   - Stimulate involvement in the discussion
   - Arouse creativity and imagination
   - Watch out for emotional triggers

4. **Get involved...accountability**
   - Recognize and flag the problem
   - Increase movement toward goals

5. **Focus on results**
   - Learn from it
• Ask questions
• Deal with conflict now and focus on results

References
Wireless Aircraft Data Analytics

James Ziarno
Harris Corporation

Abstract
Commercial Air Transport aircraft are equipped with a wide array of sensors which generate operational and performance data during flight. Several U.S. airlines are now participating in the FAA’s Flight Operational Quality Assurance (FOQA) program (FAA Advisory Circular 120-82) to acquire, archive and perform post-flight data analysis in the interest of improving the safety of flight. Additionally, other sensors are capable of monitoring the health, status, performance and efficiency of aircraft systems.

Introduction
Today, airline operators are using a wide variety of approaches to obtain operational and performance data from aircraft systems.

Ex: Older generation analog aircraft are limited to sensors mandated by the FAA and captured by the Digital Flight Data Recorder System (FAA Advisory Circular 20-141B). The FAA mandatory data from these aircraft is only analyzed following an accident or major incident.

Current generation aircraft such as the Boeing 787 Dreamliner contain hundreds of sensors that store data in the aircraft’s Central Maintenance Computers which can be wirelessly accessed for post-flight analysis. Airline operators generally refer to this type of monitoring as Maintenance Operational Quality Assurance (MOQA). FOQA programs monitor how the aircraft was flown or commanded, whereas MOQA programs monitor how the aircraft systems responded to pilot commands.

Harris is in the process of applying Advanced Data Analytics techniques for the benefit of commercial aviation. The high sampling frequency of modern aviation sensors enables detailed signature analysis and the ability to characterize subtle and developing failures. This paper describes several high value applications utilizing an integrated Wireless Aircraft Data Analytics system for providing operators the ability to automatically and remotely monitor all aircraft systems, from “Tip-to-Tail.” The application of data analytics is expected to provide significant benefits to airline operations in each of the following areas: Flight Operations; Engineering & Maintenance; and Passenger Services.
The commercial aviation industry is seeking prognostic technologies to convert unscheduled maintenance events to scheduled events. Today’s aircraft provide significantly more data enabling the application of advanced predictive maintenance techniques.

Most all NowGen aircraft employ aircraft data acquisition equipment, such as a digital flight data acquisition units (DFDAU), which monitor signals supplied from a wide variety of sensors distributed throughout the aircraft. These sensors provide analog, discrete and digital data representations of the aircraft’s flight performance. Critical flight performance data is obtained by the aircraft acquisition equipment and subsequently stored in the “crash survivable” Digital Flight Data Recorder (DFDR) also commonly referred to as the aircraft’s “black box.” The DFDR can be removed following a significant flight event to enable investigators insight into both how the aircraft was flown and how aircraft systems responded.

In a further effort to improve flight safety the Federal Aviation Administration (FAA AFS-230) issued an Advisory Circular AC-120-82 entitled, “Flight Operational Quality Assurance Pro- gram” (FOQA), which recommends airlines review flight information provided by the aircraft data acquisition equipment at regular intervals.

One suggested response to this recommendation is to equip aircraft with a redundant flight data recording unit having a removable data storage medium, such as a floppy disc or PCMCIA card (Personal Computer Memory Card International Association). Such an auxiliary digital data recorder allows airline personnel the opportunity to access the stored flight performance data by physically removing the auxiliary unit’s storage media. The contents of the storage media can then be manually downloaded into the airline’s ground-based FOQA/ MOQA performance analysis system.

The acquisition and installation costs associated with retrofitting older generation aircraft with such a redundant flight data recording can be substantial. These units which are generally referred to as a Quick Access Recorders (QAR) require the costly exercise of scheduling airline personnel to manually retrieve and forward the storage media to the Flight Safety or Maintenance departments. This costly manual process results in several days’ delay between media removal and data analysis. This delay may prevent analysts from identifying precursors to failures or analyzing a problem before it becomes a hard failure resulting in a mechanical flight delay or cancellation.

Wireless Ground Data Link
The Harris Wireless Ground Data Link provides an automated solution to exchanging data between aircraft systems and the airline’s enterprise network. Configurable flight and engine performance data files are wirelessly downloaded at hub airports to improve both operational safety and flight efficiency.
A benefit of GDL’s spread spectrum modulation is its inherently low energy density waveform properties, which is required for its acceptance for unlicensed product certification.

Spread spectrum also provides the additional benefits of resistance to jamming and immunity to multipath interference. The spread spectrum signal can be either direct sequence or frequency hopping.

![Figure 1: Harris GDL System](image1)

A representative system architecture of a wireless ground link-based aircraft data communication system is illustrated in Figure 1. The architecture has three interlinked subsystems:

- Aircraft installed GDL subsystem
- Airport-resident ground subsystem, and
- Airline Operations Control Center (OCC)

The aircraft-installed Ground Data Link (GDL) subsystem includes a plurality of GDL airborne segments, installed in the controlled environment of the avionics compartment. Each GDL airborne segment is operative to communicate with a wireless router segment of the airport based ground subsystem through a wireless communications link.
Aircraft System
The GDL system provides a Wireless mechanism for transferring data files to and from commercial aircraft (Part 121) while they are on the ground at GDL equipped airports. The GDL is designed to support multiple airline applications, such as flight safety, engineering and maintenance, and passenger services.

In one basic application of the system, a ground data link unit obtains flight performance data representative of aircraft flight performance. This type of data is conventionally forwarded to the “black box” or DFDR. A multitude of sensors generate data, which is multiplexed within the GDL unit.

An archival data store is operative to accumulate and store flight performance data during flight of the aircraft. A wideband spread spectrum transceiver is coupled to the archival data store and includes a transmitter that only operates after the aircraft completes its flight and lands at an hub airport.

![Diagram of Aircraft System](image)

**Figure 2: Aircraft System**

Hub Airport-Based System
An airport-based transceiver includes a wideband spread spectrum receiver that receives the
communication signal from the aircraft and demodulates the signal to obtain the flight performance data.

Additionally, an adaptive power control unit varies the emitted power level of the wideband spread spectrum communication signal based upon the geographic location of the airport. The system includes an airport based spread spectrum transceiver with a probe beacon on each sub-band frequency channel approved for use by the local regulatory body.

The fixed ground-based spread spectrum transceiver selects the desired sub-band frequency channels and dynamically assigns channels based on signal quality for the geographic location of the airport.

An airport-based archival data store is coupled to the airport-based wideband spread spectrum transceiver that receives and stores the flight performance data. An airport based processor can be coupled to the archival data store for retrieving flight performance data from the airport based archival data store for further processing. A remote flight operations control center can also be operatively coupled to the base station to download flight performance data.

Air-to-Ground Operation
The ground data link transceiver can also be used in an air-to-ground application, where the range is about 20 miles.

Figure 3: Air-Ground Operation
Air-to-Air Repeater Operation
Aircraft using the GDL network can act as wireless repeaters. Aircraft can be spaced five or ten miles apart and the wireless communication system can be extended, depending on the range of various aircraft.

When aircraft leave every 45 seconds, an air-to-air repeater network can extend the communication range of the ground-based network. This can also enhance scheduling and airline maintenance.

The on-ground application uses data rates up to 11 Mbps for downloading aircraft files such as electronic maintenance log books, cabin maintenance logs, and weight & balance reports. During flight the data rate can be varied to accommodate the quantity and priority of data, based on the required distance.

Additionally, engine events are sensed and stored not only in the archival storage during flight of an aircraft, but also downloaded during the first 30 seconds of takeoff and/or during initial climb. Thus, it is possible for the flight operations control center or maintenance personnel to obtain critical engine performance data during the initial takeoff and climb phases of flight. This data can be used to determine whether engine maintenance is required at the destination station.

It is also possible to download 000I (Out, Off, On, In) times of a flight. Additionally, data such as the weight of the remaining fuel can be downloaded and used for refueling and
fuel management programs. Last minute changes in gate assignments can be uploaded. En route wind and temperature data can be downloaded and used to enhance the flight planning of subsequent flights within the same area.

**Engine Data**

A great amount of mechanical stress is placed on jet engines and their associated components during the takeoff phase of flight. Some jet engine components and processes are controlled through the FADEC (Full Authority Digital Engine Controller), which may include the sensing and control of core compartment bleeding, sump pressurization, sump venting, active clearance control, draining, and pressure differentials. In other jet engines sensors directly monitor associated components without the aid of a FADEC.

During the take-off phase of flight, the pilot is provided visibility into a limited set of engine performance parameters. It is very difficult for pilots to observe transient conditions such as short-term excursions of EGT ( Exhaust Gas Temperatures) which are precursors to engine failures. Figure 5 illustrates the importance of monitoring EGT excursions versus time. The close monitoring of this critical engine parameter ensures both the safety and efficiency of flight.

![Figure 5: Engine EGT-vs-Time](image)
An engine maintenance action can be automatically generated when the aircraft lands at a ground data link airport.

**Additional Applications**

Full flight performance data is acquired, stored and transmitted post flight to an airport based spread spectrum receiver coupled to an airport based server. The GDL system supports a variety of data exchanges between the aircraft and the airline enterprise as shown in Figure 6.

<table>
<thead>
<tr>
<th>Application</th>
<th>File Type</th>
<th>File Size (k Bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOQA/Engine Maintenance</td>
<td>ARINC 717 Binary Data</td>
<td>3,390</td>
</tr>
<tr>
<td>Electronic Maintenance Logbook</td>
<td>ASCII Text</td>
<td>870</td>
</tr>
<tr>
<td>Cabin Maintenance Log</td>
<td>ASCII Text</td>
<td>20</td>
</tr>
<tr>
<td>OOOI “On” and “In” Times</td>
<td>ASCII Text</td>
<td>1</td>
</tr>
<tr>
<td>Flight Plan/Release</td>
<td>ASCII Text</td>
<td>10</td>
</tr>
<tr>
<td>Weight &amp; Balance Report</td>
<td>ASCII Text</td>
<td>10</td>
</tr>
<tr>
<td>Graphical Weather</td>
<td>GIF File</td>
<td>130</td>
</tr>
<tr>
<td>FMC Nav Data Base Updates</td>
<td>Binary File</td>
<td>1,000</td>
</tr>
<tr>
<td>Onboard Performance Computer</td>
<td>Executable File</td>
<td>10,000</td>
</tr>
<tr>
<td>Online Electronic Publications</td>
<td>HTML or Adobe</td>
<td>100</td>
</tr>
</tbody>
</table>

**Figure 6: Additional Applications**

**Wireless Engine Monitoring**

The Federal Aviation Administration requires commercial airlines to monitor the health and status of aircraft engines. The health and status information is used to determine the current performance for an aircraft engine and determine if maintenance is required.

WEMS is aviation certified and environmentally ruggedized small module that can be installed directly on an aircraft engine FADEC. The WEMs module acquires, stores, encrypts and transmits “Full Flight” engine data. It has the capability of recording hundreds of engine parameters at a rate of eight samples per second. The miniaturized WEMs
module is equipped with dual conformal antenna diversity and communicates via IEEE 802.11/802.16 or variety of cellular approaches.

The Harris Wireless Engine Monitoring System (WEMS) monitors the health and status of aircraft engines. WEMS automatically downloads full flight engine data and routes the data to the ground-based operations center for post-flight analysis.
Presented at the 58th Air Traffic Control Association (ATCA) Annual Conference & Exposition. 
Gaylord National Resort and Convention Center, Maryland, October 20 – 23, 2013

Today, airlines take a simple “snapshot” of few basic engine parameters (e.g., N1, N2, EGT and Wf) which greatly limits the capability of understanding exactly how the “engine was commanded” and how the “engine responded” to pilot inputs (Figure 10).

**Engine Data Snapshots**

Current techniques are limited because of data latency and the limited quantity of collected data restricted analysis.

**Data Analytics**

Managing and optimizing aircraft maintenance processes has become increasingly complex due to advances in technology, changes in business processes, safety and security concerns. Maximizing the availability, reliability and performance of aviation assets such as the engine drives airline’s bottom line.

The WEMs technology described in this paper integrates existing engine sensor and model data from various diagnostic, prognostic and usage sources with information fusion algorithms to assess engine condition. A complete maintenance recommendation can then be made based upon all available information rather than several independent and potentially conflicting sources.

### Value proposition:
- Turning previously unscheduled maintenance events into scheduled events
- Decreased maintenance costs from improved reliability and availability
- Reduced maintenance caused delays and cancelations
- Reduced cost through more accurate and actionable alerts
- Scalable for all types of aircraft, including NowGen and NextGen platforms

The ability to monitor full flight aircraft and engine data provides analysts with the opportunity to predict failures prior to their occurrence.

Figure 12 illustrates an actual engine data file which was obtained from a B777 aircraft. Analysts applied advanced engine data analytics techniques to prevent a serious engine failure by identifying a subtle precursor to an engine failure two weeks prior to the failure actually occurring. This type of analysis conducted automatically will reduce airline maintenance costs by reducing the number of unscheduled maintenance events and the number of maintenance-caused delays and cancellations.
Conclusion

Commercial airlines experienced increased maintenance costs due to inadequate diagnostics tools and time-scheduled maintenance practices. The lack of a reliable and accurate diagnostic/prognostic system increases turnaround time and leads to an increase of D&Cs (Delays and Cancellations).

The lack of near-real-time diagnostic capability to identify and isolate the root cause of problems also results in multiple component removals.

Commercial airlines are seeking methodologies to improve safety and reduce maintenance and logistics burdens associated with complex aircraft systems. Commercial airlines have the opportunity to employ Wireless Aircraft Data Analytics and associated aircraft technologies such as the Harris GDL or WEMs to automatically monitor and control operational, performance and maintenance costs.