AIR TRAFFIC CONTROL COMMUNICATIONS TEST FACILITY
AND AVIONICS SYSTEM TEST (ACTFAST): GEARING UP FOR
NEXT GENERATION AVIONICS SYSTEMS TESTING

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ABSTRACT

Growth in civil aviation is overwhelming worldwide airspace and air traffic services. The International Civil Aviation Organization (ICAO), Federal Aviation Administration (FAA) and Department of Defense (DoD) are proposing or implementing numerous changes to address this growth. The changes are broadly contained in what the civil aviation community calls Communication, Navigation, and Surveillance/Air Traffic Management (CNS/ATM) and the DoD calls Global Air Traffic Management (GATM). A major component of both civil and DoD proposed changes are data link systems digitally transmitting information between aircraft, air traffic control centers, and aircraft operations centers. The real-time interactive nature of these data-link systems and the integration of the aircraft avionics into a worldwide network are forcing aircraft test agencies to acquire access to this capability. Aircraft flight-testing must address both the specific aircraft avionics test requirements and the system-of-systems aspects of data-link applications.

This paper describes the factors driving changes in the worldwide CNS/ATM system and identifies specific proposed or implemented changes. Various flight-test requirements, both civil and military, of the proposed changes are enumerated. Particular attention is paid to the DoDs GATM certification requirements. Finally, we present the Air Traffic Control Communications Test Facility and Avionics System Test (ACTFAST) program and explain its capabilities. Rationale for ACTFAST component parts is included along with a brief outline of how the capabilities represented by each component part are used during flight test to acquire the necessary information to meet civil and DoD aircraft certification requirements.
INTRODUCTION

Changes in the air traffic management (ATM) system is needed as civil aviation air traffic increases and the existing ATM system ages. ATM changes are devised and implemented throughout various regions of the world in a slightly ad hoc manner. Some changes happen quickly while others are years in the making [1]. All the changes have varying impacts on the DoD, as a minimum requiring some investment to accommodate the changes. Other changes require certification by Civil Aviation Authorities (CAAs) of specific equipment or performance levels to operate in preferred airspace. Aircraft without the certified equipment or performance are denied access to the airspace. For the DoD, denial of access to preferred air routes could add flight time, increase fuel costs, and reduce tonnage delivery rates. All of these translate directly into reduced mission effectiveness.

The terminology used when discussing these changes can be confusing. CAAs discuss the changes as Communication, Navigation, and Surveillance/Air Traffic Management (CNS/ATM). Within the DoD and the USAF in particular, the changes are discussed as part of Global Air Traffic Management (GATM) and covered in an Air Mobility Command (AMC) Capstone Requirements Document (CRD) [2]. Additionally, because the changes span both time (10 years in the future) and distance (worldwide coverage), care should be taken to specify which changes are being discussed. Confusion abounds when statements are made concerning implementing GATM changes on an aircraft without specifying which changes.

This paper describes some GATM changes affecting test and evaluation (T&E) agencies and aircraft certification associated with those changes. Each is discussed at high level allowing the reader to understand the issues involved without becoming lost in the details. Following the discussion of GATM changes and aircraft certification, we present the Air Traffic Control (ATC) Communications Test Facility and Avionics System Test (ACTFAST) program. The ACTFAST program is presented in terms of equipment being acquired, test capability the equipment provides, and additional test capability development activities.

GATM CHANGES

The issues faced by the GATM or CNS/ATM community center around safely addressing the increases in civil aviation. In essence, how to safely pack more aircraft into the limited amount of airspace. One approach CAAs are pursuing is increasing the accuracy requirements of aircraft navigation and altitude reference systems. The increased accuracy allows a safe reduction of in-flight aircraft spacing and corresponding increase in air traffic volume. The reduced spacing concepts, illustrated in Figure 1, are termed Reduced Vertical Separation Minimum (RVSM) and Required Navigational Performance (RNP). The RVSM concept is responsible for changing oceanic air route vertical separation minimum from 2,000 ft to 1,000 ft while RNP is allowing changes to the horizontal separation minimum from 60 nm to 30 nm. Test issues of GATMs ‘dense packing’ aircraft are the measurement of the aircraft’s 3-D positional accuracy. Obviously, avionics positional accuracy requirements are at least twice as tight as before.
Simply putting more aircraft into the same airspace causes other problems within the ATM system. Namely, how does an already overloaded civil air traffic controller handle a four-fold increase in the number of aircraft controlled? How does the controller communicate with this four-fold increase in aircraft traffic using today's overloaded VHF voice channels? One solution changes VHF voice channel spacing, increasing the number of available channels. The approach is generally referred to as 8.33Khz VHF radios. By splitting the current VHF 25Khz channel spacing into three parts (25KHz divided by 3 = 8.33KHz), three times as many communication channels are available. A second solution is digital data links. Using digital data links some current voice communication is accomplished with digital data, reducing frequency congestion and enhancing controller-pilot communications.

Data links also help spread the communication load to other parts of the frequency spectrum. Civil aviation voice and data link radios are being designed to communicate through HF, VHF, and SATCOM. In military avionics, ARC-190 and ARC-210 radios upgrades are adding this capability. Additionally, a communications management unit (CMU) added to the avionics suite picks between the best media at any time. Note that defining 'best' can be done using a variety of methods (cost of link, signal strength, connection speed, etc.). The data link however, is just the data transport mechanism for an application. Which raises the next issue, what applications are being developed to use the data links?

GATM data link applications can be viewed as servicing a user ‘triad’ shown in Figure 2. The triad players are the aircraft, the ATC facility, and what civil aviation terms the Airline Operations Center (AOC). In the DoD, the AOC function is most closely associated with AMCs Tanker Airlift Control
Center (TACC) [3]. Within the DoD, however, GATM data link upgrades are focused on the aircraft-to-ATC portion of the triad. Specific applications added to USAF aircraft include Controller-Pilot Data Link Communications (CPDLC) and Automatic Dependent Surveillance (ADS); both implemented using Future Air Navigation System (FANS) Aircraft Communications and Reporting System (ACARS) based architectures.

The aircraft-to-ATC applications improve the efficiency of communications between the ATC and aircraft by replacing normal or routine voice communications with digital data. CPDLC replaces most current enroute controller-pilot voice communications with text messages. Automatic Dependent Surveillance-Addressable (ADS-A) supports oceanic position reporting requirements. The ADS-A system can be configured to provide event-based or periodic digital position reports. The aircrew simply establishes an initial data link connection with the ATC facility and the system to gives the controller the position reports required when they are required [4].

**AIRCRAFT GATM CERTIFICATION**

Aircraft certification is the process by which aircraft manufacturers, parts manufacturers, modification centers, T&E agencies and operators ensure compliance with applicable standards. The standards are derived from public safety laws and concerns. Certification is done in a building block fashion,
involving component, design, system integration, installed system, flight, and operational certification [5]. In the United States, the Federal Aviation Administration (FAA) is the federal agency tasked with administrating all phases of the civil aviation certification process. In the USAF, aircraft certification responsibility is distributed among a number of different organizations.

USAF aircraft flight worthiness and equipment certification responsibility rests with the aircraft program office while operational certification responsibility rests with the major command owning the aircraft. Complicating certification for USAF aircraft is the distribution of policy authority among other agencies including the Air Force Flight Standards Agency (AFFSA) and Electronic Systems Center's Global Air Traffic Operations/Mobility Command and Control (GATO/MC2) program office. Test and evaluation (T&E) agencies act as certification data providers, supporting the aircraft program office, the GATO/MC2 program office, AFFSA, or the operational command.

Further complicating the USAF aircraft certification processes are those aircraft the USAF has decided will maintain a civil certification (like the KC-10 and C-9). For these aircraft, although the civil certification is not required to operate the aircraft, the USAF has chosen to maintain some level of civil certification. For these aircraft, a joint USAF and FAA certification effort is required. The USAF decides what civil certification is desired and the FAA works with the USAF to provide the desired civil certification. The USAF then certifies the military aspects of the aircraft not covered under the civil certification. A KC-10 is a good example; most aspects of the aircraft's flight worthiness and equipment safety are covered under an FAA Type Certification. The FAA, however, doesn't certify airborne refuelers and thus the USAF certifies airborne refueling aspects of flight worthiness and equipment safety.

The GATO/MC2 program office is the de facto lead organization assisting USAF aircraft program offices certifying their aircraft meet GATM requirement [6]. Acting as a common avionics source, the GATO/MC2 program office actively participates in numerous civil and military aviation forums, consolidating the sometimes conflicting certification requirements into GATM Certification Matrices [7]. Additionally, the GATO/MC2 program office was delegated the administrative responsibility of ensuring USAF aircraft meet GATM certification requirements. The GATO/MC2 program office certifies that an aircraft's proposed GATM design or architecture is capable of meeting performance requirements and that actual performance meets requirements. T&E agencies provide the performance data needed to support certification decisions.

**GATM DATA LINK FLIGHT TESTING T&E NEEDS**

GATM data link systems operate within the Aeronautical Telecommunications Network (ATN). The ATN is an evolving set of standards, created by the International Civil Aviation Committee (ICAO), covering all aspects of aeronautical communications. The major players in the ATN system are shown in Figure 3. Elements of the data link applications user triad (the aircraft, CAA ATC facilities, and AOCs) can be seen in the figure. The service provider's cloud represents the network infrastructure that ties the elements of the user triad together. Service providers own and operate worldwide networks of HF, VHF, and SATCOM facilities and the connections to the ATC facilities and AOCs. The ACTFAST block illustrates its logical position within the ATN structure, simulating both ATC and AOC facilities.
Data link systems generally require certification of the data link itself and the applications, which use the data link [8] [9] [10]. Data link communications certification addresses the systems providing communication link and general cover the CMUs and transceivers for HF, VHF, and SATCOM systems. Data link application certification includes the implementation of CPDLC, ADS, and AOC systems making use of the data link communications services. Application certification also addresses integration of the data link applications into the rest of the aircraft’s avionics suite. For example CPDLC applications, in addition to a data communications link, require various pilot controls and display interfaces, crew qualifications, and procedural implementations [11]. The GATO/MC2 developed certification matrices recognize the distinction and specifically address certification the data link and the application.

T&E of these next generation avionics data links and applications present some unique challenges for T&E agencies. First and foremost is simply establishing the data link with the aircraft. T&E organizations either need access to or must replicate the ground infrastructure. As a minimum, the media used by the data link under test (HF, VHF, or SATCOM) must be available. Without the data links, testing the aircraft avionics is like testing a phone without a phone line and someone at the other end. Additionally, the ground systems side of the applications used by the aircraft’s data link systems are needed to test the interactive nature of ADS-A and CPDLC applications [12] [13].

Figure 3: Aeronautical Telecommunications Network.
Total system performance issues must also be addressed. T&E agencies must ensure that the ATM functions implemented by these data link systems meet safety needs. Because of the reduced aircraft spacing, end-to-end system performance timelines are important. Measuring the end-to-end performance requires T&E organizations also have access to the service providers’ networks. End-to-end system performance measures must account for the service provider’s reception, routing, and transmission performance. Finally, T&E agencies must ensure compatibility with and safe hand-off between various CAAs as the aircraft transitions through different CAAs’ airspace during its flight.

ACTFAST SYSTEM DESIGN AND DEVELOPMENT

The ACTFAST program is focused on supporting flight testing of civil aviation data links and applications. Its first goal is to simply provide the other end of the data link. As it stands today, an aircraft equipped with civil aviation data links cannot be tested at Edwards AFB; we do not possess the capability to communicate over the data link. The second goal is to support testing of the data link. Testing means not just using the data link, but also evaluating performance (the data link and the application). Performance evaluation boils down to providing data to meet certification requirements. Certification requires error conditions are correctly detected, message priorities are enforced, aircrew alerting functions work, and aircrew procedures are correct.

The first goal, providing the other end of the data link communication, is achieved with an ARINC commercial-off-the-shelf (COTS) CNS/ATM Gateway. The gateway is an IBM RS/6000 workstation with two large color monitors. The workstation hosts the gateway and routing software, the CPDLC, ADS, and ACARS applications, ARINC’s Operation Center software, Voice Transcription System, and Geographic Map Display System.

The Gateway, Geographic Map Display, CPDLC, ADS, and Voice Transcription system allow ACTFAST to ‘act’ as an Air Traffic Control facility for testing purposes. From the aircraft’s perspective, the CNS/ATM Gateway system appears to be an ATC facility. A ‘controller’ sitting at the workstation can establish connections, send and receive CPDLC messages, and create ADS reporting contracts with aircraft under test. Data linked position reports can be displayed on the Geographical Map System. Additionally, the Operation Center software allows ACTFAST to appear to the aircraft as an AOC.

The first goal is further enhanced with the installation of three VHF Integrated ARINC Ground Stations (IAGS). One ground station, referred to as the ‘live’ IAGS, is owned by ARINC and is part of ARINC’s Global Link network. The other two IAGS are referred to as Test IAGS and will be equipped with ARINC’s standard ACARS character-based systems and the next generation data link communications, VHF Data Link (VDL) mode 2. VDL Mode 2 uses a faster; non-character based data link protocol developed by the International Civil Aviation Committee (ICAO). One Test IAGS will be installed to support open-air testing and one will be installed in the Benefield Anechoic Facility (BAF). The open-air Test IAGS supports testing of data link systems and applications without interfering with ‘live’ systems, while the BAF Test IAGS supports electro-magnetic compatibility (EMC) and electromagnetic interference (EMI) testing in an electro-magnetically controlled environment. The BAF system also supports evaluations of DoD operations on civil data links. The entire ACTFAST demonstration system installation is shown in Figure 4.
Coupled with the R-2508 restricted airspace and a frame-relay connection to ARINC's Global Link network, ACTFAST can fully support flight test of GATM data link communications systems and applications. Test flight profiles exercising CPDLC message functions, reception and transmission, ADS periodic and event-based reporting and other functions as required can be created and flown. The connection to ARINC's Global Link network allows messages to be routed via HF, VHF, or SATCOM and allows true end-to-end performance evaluation. Additionally, aircrew procedures and initial test cadre aircrew training can be accomplished.

ACTFAST's second goal, developing test tools and methodologies will be accomplished with the demonstration system. We are already looking at ways to modify the CNS/ATM Gateway to perform more as a test station than a COTS ATC workstation. For example, the COTS workstation is designed to prevent error conditions, yet in testing, repeatable error conditions are desirable. With ARINC's assistance, ACTFAST has begun looking at methods of error injection. Finally, ACTFAST is looking at methods to provide certification performance data through message stream analysis tools. In particular, we are looking at message format compliance, response time measures, sequence compliance, and media selection algorithm (the CMUs algorithm to pick between HF, VHF, or SATCOM) evaluation.

Figure 4: ACTFAST Components at Edwards AFB
CONCLUSIONS

Worldwide CAAs are embracing digital data links as means to improve ATM system efficiencies. The DoD, as a user of civil air traffic services and airspace, is installing digital data links and associated applications. Aircraft test and evaluation agencies must expand their test capabilities to include these data links and associated applications. The ACTFAST program is providing these test capability needs for the Air Force Flight Test Center (AFFTC) at Edwards AFB.

The ACTFAST program is procuring an ARINC commercial-off-the-shelf (COTS) CNS/ATM Gateway and ACARS/VDL Mode 2 compatible ground stations. The gateway includes ACARS Op Center, CPDLC, and ADS-A application software. These COTS products are being integrated into a demonstration test capability. The demonstration capability allows conducting flight test of GATM data link avionics systems, currently a capability not available at the AFFTC. The demonstration system can send and receive digital messages and determine correct response to normal data link system operation.

Additionally, ACTFAST is developing test tools and methodologies to adapt and expand the COTS CNS/ATM Gateway into a system capable of supporting more robust developmental testing and certification needs. Specific adaptations include error injection, multiple simultaneous ATC ground stations, CAA hand-off testing, and data link end-to-end performance evaluation tools and displays. Finally, ACTFAST is providing the USAF and the DoD with a capability to evaluate data link issues within the electro-magnetically-controlled environment of the BAF. Integrating the BAF into the ACTFAST system architecture allows test programs to test and evaluate the impacts of civil aviation data links on DoD aircraft and to evaluate the impact of military operations on civil aviation data links.

REFERENCES

NOTE: Where possible, a WorldWide Web address has been provided to allow readers to obtain electronic copies of referenced documents.


