ADS-B TO LINK-16 GATEWAY DEMONSTRATION: AN INVESTIGATION OF A LOW-COST ADS-B OPTION FOR MILITARY AIRCRAFT

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Summary

A new system was demonstrated as a prototype that provides the advantages of Automatic Dependent Surveillance-Broadcast (ADS-B) for the military, yet totally avoids military aircraft modifications. The system was demonstrated on operational United States Air Force (USAF) aircraft using ADS-B equipped general aviation aircraft as the source. The demonstration was conducted in 2003. The result of the demonstration was highly positive commentary from engineers and the pilots. Although significant work remains prior to full fielding and operations, a decision was made to incorporate the prototype into a future datalinks concept.

Introduction

In certain regions of the world, military aircraft actively and heavily share airspace with general aviation (GA) aircraft and need deconfliction for improved safety. The ADS-B system demonstrated provides increased situational awareness of GA aircraft to military aircraft and to ground air traffic monitors.

Today, that deconfliction is handled primarily by scheduling, public communications, limits and delays to flights, and controlled flight rules. These rules sometimes severely limit where, when, and how both general aviators and military aircraft can fly. However, in spite of the rules, neither the military nor general aviation cockpits have the situational awareness of each other that is needed in busy, shared airspace, thus limiting potential increased levels of safety.

Improvements in air safety would be a major benefit if both aircraft had the situational awareness that ADS-B information provides. There have been, and continue to be, incidents where civilian aircraft and fighter aircraft were unaware of each other's presence, resulting in either a close-call midair incident or tragedy. Although the occurrence of these incidents is statistically low, the impact is large on both life and cost. Operationally, there are rather lengthy delays in moving DoD aircraft to and from locations of operation and practice ranges. Full deployment of ADS-B could mitigate all of these issues and provide most of the benefits mentioned above.

While the Federal Aviation Administration (FAA) is steadily moving towards equipping general aviation with relatively inexpensive ADS-B systems, experience indicates that it will be expensive to equip all military aircraft with ADS-B compatible systems. Specialized purpose, design complexities, limited space, weight versus performance trades, highly integrated avionics architectures, high volume of aircraft (thousands), and other well-known military requirements, priorities, and restrictions drive prohibitive integration costs on military aircraft. For this reason, a search began for alternatives to the retrofit installation of an ADS-B in existing military aircraft. The result of that search is an inexpensive, ground-based gateway between ADS-B and existing military communications systems. Such a gateway, which has recently been designed, developed, and proven, will provide ADS-B to DoD military aircraft connectivity without any retrofit to LINK-16 equipped military aircraft.

This concept leverages the following existing planned and funded programs:

- FAA ADS-B CAPSTONE
- Joint Tactical Information Distribution System (JTIDS) LINK-16 airborne systems; and
- JTIDS LINK-16 ground transceivers program.

Similar concepts of a ground-based gateway could be applied to other locations, countries, and systems.

The proposed concept is to provide the position information of the GA traffic, now contained in ADS-B and collected on the ground in Traffic Information Services-Broadcast (TIS-B), to military aircraft, by translating and uplinking it to the LINK-16 network. LINK-16 will then be able to display the civilian traffic as identified tracks. The CAPSTONE Air Route Traffic Control Center (ARTCC) is the only ground location where the data of all the ADS-B air traffic is fused with conventional FAA RADAR track to form TIS-B. Therefore, the ARTCC is the natural source of the information in the future. Ultimately, a gateway could be set up where the data from ARTCC goes to both a ground LINK-16 terminal for relay to aircraft, as well as to an operational center, such as military command and control. The idea of using LINK-16 for Air Traffic Control (ATC) related information is not new, however, using emerging information technology standards as a solution is novel.

In this paper, the reader is introduced to the purpose of this demonstration, objectives, the experience during three days of flight testing, and conclusions. Finally, the paper provides a recommendation to develop a Concept of Operations (CONOPS) in order to proceed with system deployment.

Discussion

The FAA Alaska Region has deployed a new air safety system called ADS-B, which provides increased safety for all participating equipped aircraft. If the situational awareness can be increased, a number of applications could immediately be enhanced: air traffic safety, homeland defense, and AF range safety and monitoring.

In other areas of the United States and other countries, the Federal Aviation Administration and Civil Aviation Authorities (FAA/CAA) may one day rely primarily upon the ADS-B derived tracks for surveillance and situational awareness. This system will supplement visual flight rules and in some cases replace and/or supplement positive radar control. The ARTCC fuses this data with other primary and secondary radar information into the TIS-B system.

Gateway Description

The overall Gateway concept is illustrated in Figure 1. The GA aircraft send positional information omni-directionally. It is received by Line of Sight (LOS) antennas on the ground. That data is forwarded to the FAA ARTCC. This Gateway translates the data to JTIDS tracks. The JTIDS tracks are placed in the IMTDS host processor and then radiated as LINK-16 formatted data to the USAF aircraft. The translation from an ADS-B report to the LINK-16 military datalink format (J3.2) message is relatively simple and straightforward because the two messages contain similar fields of information. As can be seen in Figure 2, civilian air tracks, ADS-B reports, can be obtained from individual Ground Based Transceiver (GBTs) or the Capstone Communications and Control System (CCCS) and forwarded to a military controlled gateway for further routing, processing and display. Likewise, military air tracks, J2.2 Air Precise Participant Location and Identification (PPLI) messages, can be obtained from ground-based

LINK-16 terminals and forwarded to an FAA controlled gateway for further routing, processing and display.

The J2.2 Air PPLI message provides LINK-16 users with situational awareness of LINK-16 equipped aircraft. The PPLI capability of LINK-16 is analogous to the ADS-B system because all LINK-16 equipped assets (ground, maritime, subsurface and airborne) have a graphical depiction and textual data on all aircraft within the operating range of the system.

The Gateway design is based upon a common transport mechanism and a common data schema to exchange information between tactical datalinks which was developed by MITRE. The messages that are exploited from each system contain basic positional information such as time of the track message, latitude, longitude, altitude, speed, course, and unique track number.

The air tracks depicted on the military cockpit multi-function display that originate from ADS-B or TIS-B are created from the information in the J3.2 Air Track message. The J3.2 is the primary message used to report initial and updated positional information on aircraft that are airborne. The ADS-B report contains enough information to meet the minimum requirements for populating and transmitting a civilian aircraft's position using the J3.2 Air Track message.

For giving military LINK-16 derived tracks to the FAA, the key data that is valuable for potential forwarding to the FAA is the aircraft's 3-D position, speed, heading, time stamp, and aircraft address. The information to be exchanged from the military to the FAA would be obtained from the J2.2 Air Precise Participant Location and Identification (PPLI) message. PPLI messages are automatically transmitted by the LINK-16 terminal and require no operator intervention. The PPLI message or J2.2 is composed of an initial or base word, an extension word and up to five continuation words.

More information on the MITRE Gateway design can be obtained by contacting the author.

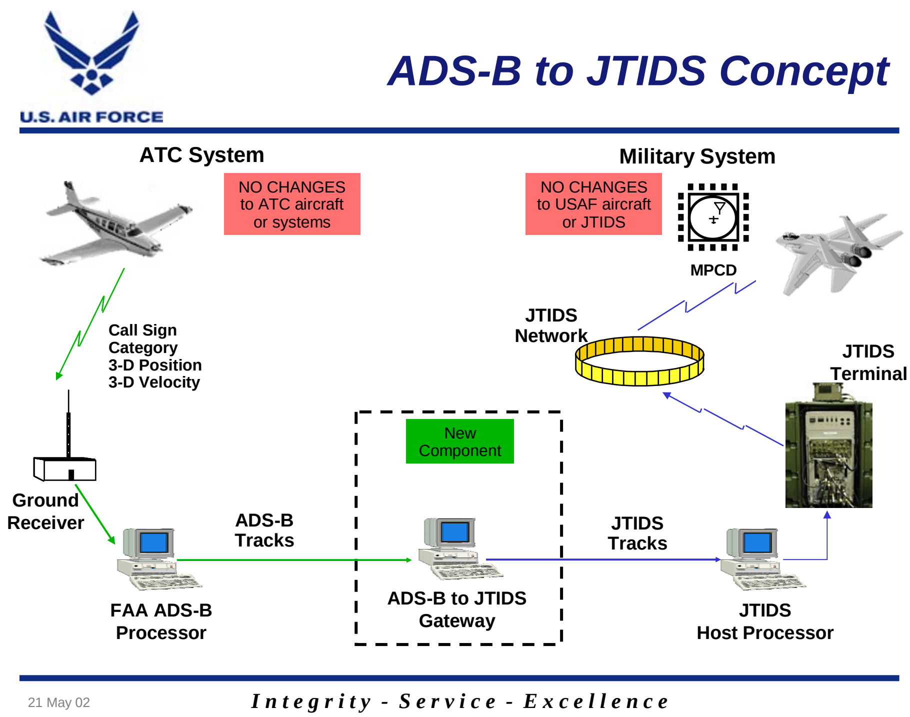


Figure 1. Overview Diagram of the Gateway Concept.

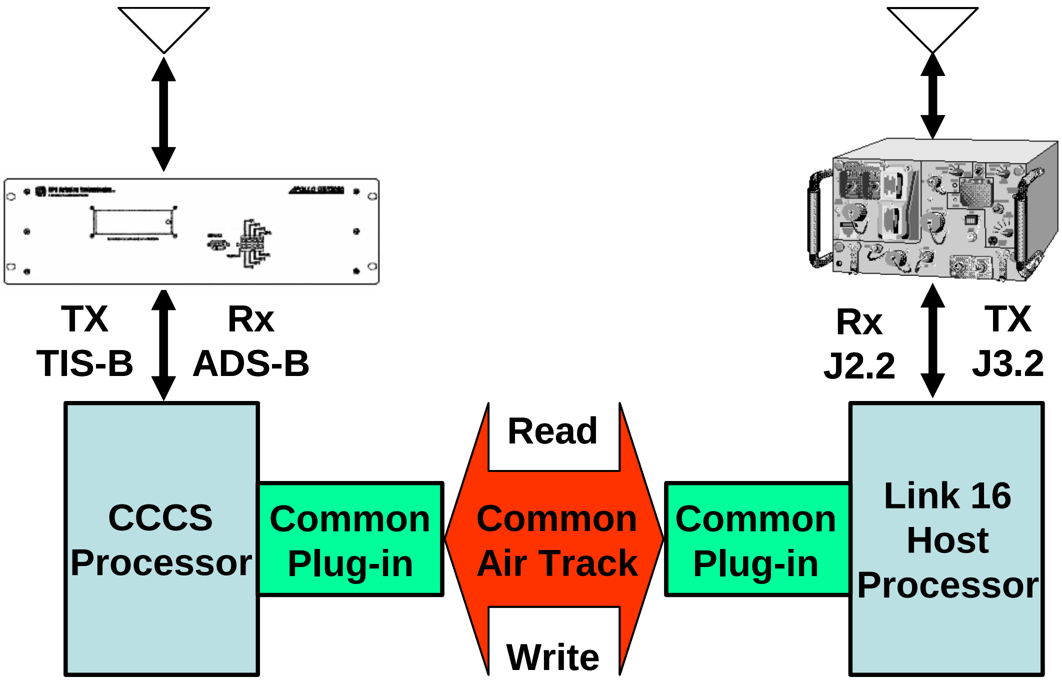


Figure 2. Common Schema.

Ultimate Configuration

The ultimate configuration would require a tap into the CAPSTONE server system at the ARTCC to provide real-time ADS-B data on CAPSTONE equipped aircraft. This would require a circuit connection between the ARTCC and the JTIDS ground-based system. Given time and budget constraints, this link was not established for this demonstration. Instead, a stand-alone ADS-B receiver and a stand-alone LINK-16 transceiver, both capable of LOS connectivity, were set up. However research did reveal an existing communications data bus between the two facilities that should be connected when engineering work continues.

The Demonstration

Electronic Systems Center (ESC), Hanscom Air Force Base, Global Air Traffic Operations/Mobility C2 Systems Program Office (ESC/GA), and The MITRE Corporation led a project to demonstrate the ability to put ADS-B targets on LINK-16 aircraft. ESC's Tactical Data Link (TDL) Systems Program Office (ESC/NI) provided the ground-based LINK-16 and sent two contractor technicians from Eglin Air Force Base to support the radios. ESC/GA coordinated with the FAA CAPSTONE program office the loan of an ADS-B (FAA self-tracking and broadcast system) Ground Based Transceiver (GBT) and antenna. The FAA also provided an ADS-B CAPSTONE equipped aircraft.

The demonstration was intended to be the first ever using LINK-16 to display ADS-B targets in the cockpit. The demonstration was designed to show that a gateway on the ground was the only new equipment necessary, and it was a first attempt at evaluating the usefulness of ADS-B data in cockpits. The demonstration stirred interest in both the DoD and FAA for further study and possible ultimate deployment.

Day One: Orientation, Equipment Gathering & Setup, and In-briefings.

The team met with the FAA ADS-B CAPSTONE office to coordinate the demonstrations and future plans, as well as to get the loaner ADS-B GBT and antenna. The CAPSTONE program office also provided an ADS-B aircraft target that flew a pattern and sent out positional information every second. MITRE Center for Advanced Aviation System Development (CAASD) personnel were also on the aircraft and provided pre-flight and post-flight coordination. In addition to the above support, the demonstration was supported by ESC/GA and the ESC/NI LINK-16 technical support team. Overall, the support of the FAA CAPSTONE program office, with MITRE CAASD and other contractors, was pivotal to the success of the demonstration. Vital in this gateway demonstration was the support of the Air Force and their numerous aircraft and flights that were briefed-in and cooperatively received the ADS-B tracks that were provided. They also provided real-time and post-flight feedback, including interviews and recordings.

Day Two: Completion of Technical Set-Up and Debug.

The ADS-B ground and LINK-16 antennas were 100 feet apart on the same hanger roof and simultaneously transmitting and receiving. Although precise measurements were not taken, there was no evidence of interference. The GBT was in receiving mode only. The LINK-16 was in full operations: transmit and receive. Setup included a radio chassis in a closet, and the GBT in the main operations room, the gateway, and finally the Improved Multi-TDL Translating and Display System **(**IMTDS**)** as the host processor for the LINK-16 driving the radios.

Figures 3 and 4. GBT, Gateway and IMTDS systems, set up. The LINK-16 radio rack.

Day Three: Static and Flight Demos.

After LINK-16 radio setup, the team achieved success. All the LINK-16 formations and wingmen reporting on the net were visible from the perspective of our IMTDS console.

Our control ADS-B aircraft appeared on the ground gateway monitor and the system forwarded its tracks to LINK-16 as ADS-B track (Unique ADS-B ID). Another FAA ADS-B equipped target-of-opportunity aircraft was flying the whole time and was identified.

Figures 5 and 6. Close up of the IMTDS display. Shows Air Force aircraft and an ADS-B track; these were forwarded to the cockpit.

At approximately 2:15 PM, the team received a call on radio from an airborne Air Force aircraft, indicating that a civilian track on his LINK-16 cockpit display was received. He saw both an ADS-B target-of-opportunity and the UAK ADS-B equipped control aircraft.

The team then went out to the flight line where a static demonstration of an Air Force aircraft on ground power was held.

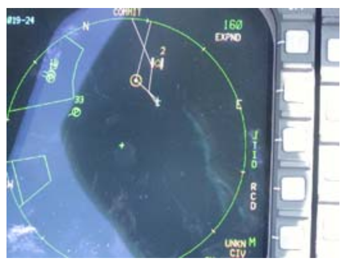


Figure 7. Cockpit shot of the LINK-16 display, ADS-B track in upper right hand corner, ID in lower right hand corner. ADS-B track highlighted and details in lower right corner "unknown civilian."

The two officers in the cockpit of the Air Force aircraft were also both quite excited. When they came down from the aircraft, one stated, "This is great, there are so many civilian aircraft flying around here, it is a real plus to see them (so readily) when we are so mixed in with them."

One Aircraft pilot called on radio and said, "Gateway OPS, I have two civilian tracks. I painted them with my radar and they are 'right on.'"

The team sent up simulated tracks, after getting permission to do so. They were sent up for just under an hour. The simulation had four computer-generated tracks.

Day Four: Flight Demos.

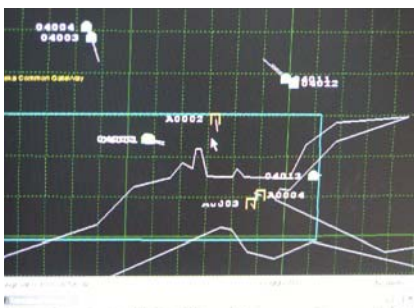
Generally, a few ADS-B targets appeared as the day started and as aircraft departed the test area for distant destinations, and then very few showed up during the rest of the morning.

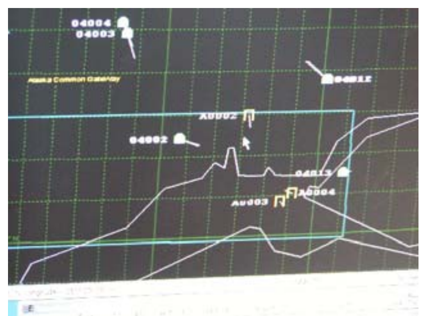
The team got the LINK-16 on the net. Air Force aircraft were up early as well. A number of ADS-B tracks appeared early, but later in the morning there were no civilian tracks for a couple hours.

We had another ADS-B track which took off locally, and the system displayed its location in the air for about twenty minutes. During his time in visibility, there were a number of Air Force aircraft in the air.

Figure 8. Hangar located IMTDS LINK-16 display, showing one ADS-B and several aircraft.

Five minutes later, three total ADS-B tracks were displayed.





Figures 9 and 10. Displays of the three ADS-B tracks while seven Air Force aircraft are airborne.

The control aircraft took off for the second day. His track appeared and while he was up another ADS-B track-of-opportunity appeared. The JTIDS network aircraft were airborne.

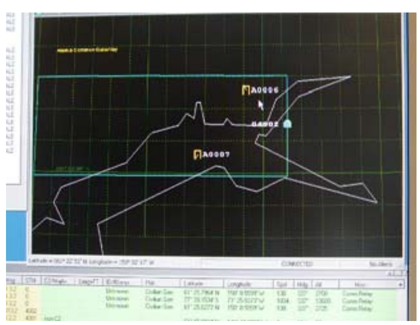


Figure 11. LINK-16 ground host IMTDS display of tracks, included our control ADS-B aircraft.

We had a number of Air Force aircraft and ADS-B tracks displayed. At one point, it appeared a group of four aircraft were going to intercept.

Figure 12. A group of LINK 16 aircraft on "intercept" with our ADS-B control aircraft in flight.

Summary of Pilot Surveys.

- "It's great!" and "highly valuable" checked off.
- "Excellent Situational Awareness on Civilian ADS-B Tracks," and "highly valuable" checked off.
- "Great Provider of SA; particularly if ATC is busy or doesn't 'see' the traffic," and "highly valuable" checked off.
- "Good... but only outside the AIS," and "valuable" checked off.
- "Yes, it is useful, assuming the information is accurate," and "highly valuable" checked off.
- "Good SA," and "valuable" checked off.
- "Good," and "valuable" checked off.

Conclusion and Recommendations

A capability has been proven which can provide ADS-B to DoD military aircraft without a prohibitively expensive retrofit to DoD aircraft, nor changes to civilian aircraft other than their standard ADS-B. This concept leverages existing planned and funded programs: 1) FAA ADS-B CAPSTONE; 2) LINK-16 airborne systems; and 3) LINK-16 ground transceivers, and needs only a gateway. The ground gateway was demonstrated at the test location. To move the concept towards implementation requires coordination and joint funding by the FAA and the DoD. The next step recommended is to develop operational concept cost estimates; pursuit of funds through the government's POM process; a trials period; a detailed architecture development; and systems testing. Other countries should seriously consider applications of this concept to meet their needs.

Remaining Hurdles

Classification.

To initially keep the project achievable, only a one-way information pipe from ADS-B/ATC to JTIDS USAF was demonstrated. In the ultimate configuration, a guard would be required to isolate and protect military datalinks from intrusion and from leaking out sensitive position information while in certain combat modes of operations. The challenge will be to extract from the classified network only aircraft position information that adds to safety but does not reveal any closely-held operational techniques.

Regional Architecture and Integration.

Each regional implementation requires study. The study must address LOS connectivity and beyond-LOS considerations, availability of equipped aircraft, and ground infrastructure. For example, if beyond LOS is necessary because of a lack of ground infrastructure (antenna coverage), then options such as satellite, relays, or other approaches must be considered for areas of operational needs. CONOPS must be developed and may be somewhat unique for each site.