The Role of Automated Sensing, Information Fusion, Situation Assessment, and Decision Aiding Methods in Assisting Civil Defense Activities

Todd Stock, Doyle Peed, and Stephen V. McBrien, Ph.D.
The MITRE Corporation
7515 Colshire Drive, MS N659
McLean, VA 22102-7508 USA
Email: tstock@mitre.org, peed@mitre.org, mcbrien@mitre.org

Abstract

Great strides have been made in helping ensure the safety of commercial aircraft operating in controlled airspace across most parts of the globe. Recent investigations into existing avionics systems available to General Aviation aircraft suggests that there are cost effective solutions to the issues of providing comparable levels of security to the wide range of aircraft operating in very different flight regimes. This paper identifies some of the potential solutions to aircraft operating in unauthorized regions.

1.0 Introduction

Air attacks by a variety of non-military sources pose a tremendous threat to civil society, as demonstrated by the September 11 attacks on New York, NY, Washington, DC, and western Pennsylvania. Existing technologies, developed for the U.S. FAA, and being deployed in both Europe and the United States, may offer methods that will allow homeland defense organizations to identify and track potentially threatening aircraft operating in domestic and international airspace. Such anomaly-detection technology may also be useful in detecting UAVs and some classes of cruise missiles.

This paper argues that the greatest part of the threat from commercial aircraft has been substantially overcome in the time since the attacks on September 11, due to the use of procedures, advanced technology, and increased physical guards against attack. Further, it will argue that the ongoing threat from general aviation aircraft, while quite real, can be substantially reduced or eliminated by use of currently available technology. The number of "incidents" from this sector in the United States suggests that any reduction of inadvertent intrusions into controlled airspace by the general aviation sector will help civil aviation authorities identify true threat aircraft and act accordingly.

2.0 Status of Protection Efforts in the Commercial Sector

Both the U.S. and Europe have made great strides in the past four years in detecting and defeating attempts to hijack commercial aircraft operating in controlled airspace throughout most of NATO airspace. These efforts have included both physical restraints as well as employment of advanced technology and procedures.

While there is ongoing debate in the aviation community about the effectiveness of airport screening of passengers, it is generally agreed that this screening program has at a minimum made it more difficult to bring counter band on board a commercial aircraft. Passenger screening also offers some, albeit limited, ability for both government and airline officials to identify potential threats to aircraft, despite several well-publicized instances of high-level political figures being identified as threats. While identification programs are still in their infancy, and subject to human and machine failure, these programs offer at least a rudimentary improvement in identifying persons who could pose a threat to the safety of flight. The presence of hardened cockpit doors and the ability of pilots to carry arms also make it more difficult for a potential hijacker to gain access to the flight deck of a commercial aircraft. These doors, while not impenetrable, are certainly a massive step forward in securing the flight deck from unwanted intrusion, and would offer flight crews substantial time to sound an alert to air traffic control authorities in the event of an attack on the restraining door. Finally, general awareness of the flying public serves as a deterrent to hijacking – suspicious behavior (e.g., attempting to light matches in the cabin, presumably to ignite explosive devices) is likely to be quickly identified to flight attendants. In addition to these physical impediments, there are a number of advanced technology and information technology capabilities that help government officials, especially air traffic control officials to identify and track potentially suspect aircraft.

Existing technologies can be used to identify potential threat aircraft based on their ability to track the vast majority of aircraft against pre-determined flight paths and / or plausible behaviors. For most of the airspace in the United States, and even greater portions of airspace in Europe, airspace used by commercial aircraft is tightly controlled. (Even general aviation aircraft operate in controlled airspace much of the time, especially in Europe.) Also, in “Free Flight” control schemes where aircraft no long use standard fly-ways, certain types of threatening or aberrant behaviors can be automatically detected and reported by civil systems.

The User Request Evaluation Tool (URET) being deployed in U.S. Air Route Traffic Control Centers (ARTCCs) and comparable systems deployed elsewhere combine real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four-dimensional flight profiles, or trajectories, for pre-departure and active flights. For active flights, it also adapts itself to the observed behavior of the aircraft, dynamically adjusting predicted speeds, climb rates, and descent rates based on the performance of each individual flight as it is tracked through en route airspace.

This technology, which reflects the position and other reports from commercial aircraft, has been enhanced by the fact that transponders in these aircraft are no longer readily controlled from within the cockpit, and are in an “on” position at all times during aircraft operation. This is true for comparably equipped general aviation aircraft, as illustrated by the ability of the air traffic control system to track the tragic fate of the high end private jet aircraft carrying golfer Payne Stewart to his death several years ago.

URET uses its predicted trajectories to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification, both of potential conflicts among planes in an air traffic control sector and substantive deviations from filed flight plans. The system enables expeditious coordination of legitimate changes to flight plans and amendments among sectors and facilities with its auto-coordination function, as well as coordination of activities related to deviations from expected flight plans. The controller interface to these detection and resolution capabilities supports flight data management and task prioritization using both text and graphic displays. The text-based Aircraft List and Plans Display help manage current flight plan information, trial plan information, and conflict data. The Graphic Plan Display provides for a graphic view of aircraft routes and altitudes, predicted conflicts, and results of trial plan resolutions. The point-and-click interface enables quick access to system functions and entry of flight plan amendments.

As part of the URET Conflict Probe deployment, a computer complex of processors is networked to the air traffic Host Computer system and to the DS D-Controller consoles. The network includes interfaces to the Weather and Radar Processor (WARP) for weather data and to Monitor and Control (M&C) positions for system support. The URET conflict probe computer complex is also connected to an external network for communications with systems at neighboring ARTCCs (See Figure 1)**.**

Figure 1. URET System Interfaces

In short, the use of automated systems such as URET, coupled with processes that have made it extremely difficult to disengage transponder equipment, allows the air traffic control community to track commercial aircraft with high certainty.

Unfortunately, there is no such comprehensive system for tracking and resolving issues with many general aviation (GA) aircraft operating in or near flight restricted zones (FRZ). These planes do not have the benefit of the physical restraints now commonly found in commercial aircraft, and operate in an environment that is substantially more open than is typically the case for commercial aircraft.

As a result, it is entirely possible to envision a situation where a legitimate GA aircraft intrudes, inadvertently, into a FRZ, and is mistaken for a true threat aircraft. Such an incident very nearly occurred, with potentially disastrous consequences, on a flight carrying a U.S. Congressman to the funeral ceremony of the late President Ronald Reagan in Washington, D.C. While the cause of this incident has been linked to human error in the coordination chain between the air traffic control and national defense authorities, such errors can be largely eliminated with the use of currently available technology. The remainder of this paper suggests alternate ways to inform GA aircraft that they are within a FRZ, and ways to use both technology and procedures to identify mistaken entry to those zones and true threat aircraft. Given the potentially large number of GA aircraft, such a distinction is needed to allow national and civil defense authorities to concentrate their efforts on aircraft that pose a legitimate threat.

The remainder of this paper explores methods using existing technology to assist civil aviation authorities in identifying and managing GA aircraft, especially in difficult to manage FRZs, so as to allow those authorities to better interact with civil defense officials to protect both critical sites and population centers from attack from these classes of aircraft.

3.0 Unique Issues for General Aviation

The security fixes that work for air transport aircraft -- armored cockpit doors, extensive passenger and baggage screening, and policies to restrict access to ramp and baggage handling areas - are often times not applicable to the diverse world of General Aviation (GA).

Table 1 illustrates just a few of the salient differences in fleet size, operational characteristics, and the degree of control exercised by ATC over aircraft movements. Many of these restrictions work well within the scheduled air carrier environment, but may not be applicable to the diverse operations associated with US general aviation.

Table 1: General Aviation versus Air Carrier Operations

Criteria	General Aviation	Air Transport
Size of Fleet	~215,000	~7000 (including regional/commuter aircraft)
Fleet Makeup	Diverse, multi-tiered fleet with wide differences in performance and capabilities	Relatively homogeneous; largely composed of aircraft with similar operating characteristics and capabilities
Route Structure	From nearly anywhere to anywhere; over 18,000 local	- 70% of air carrier flights utilize just 30 hub airports.

	community airports, of which over 5,000 are public use facilities. Innumerable off-airport sites suitable for light aircraft or helicopter operations	- Scheduled air carriers serve fewer than 350 airports
Use of Air Traffic Services	Optional; aircraft may be operated IFR or may be operated VFR (with or without flight plan on file in most areas)	Mandatory; all flights operate under Instrument Flight Rules
Surveillance Environment	Often operated outside areas served by enroute and terminal radar	Seldom operated outside areas serviced by either en-route or terminal area radar services
Predictability	GA is essentially ‘on-demand’ or unscheduled in nature; predicting where any GA aircraft is difficult	Highly predicatable activity

To be effective, GA security solutions must combine appropriate cockpit technologies with cost-effective security measures on the ground. Organizations such as the Aircraft Owners and Pilots Association have promulgated effective airport operations procedures to minimize the opportunities for unauthorized use; however, application of avionics technologies to give pilots better situational awareness have not reached many GA pilots.

It is reasonable to assume that terrorists examining the use of GA aircraft as a means of attack wish to determine and exploit any vulnerabilities detected in our defenses. Thus, a scenario which assumes use of a GA aircraft for an attack implies that the terrorists will attempt to identify and capitalize on any weaknesses detected. This further implies that terrorists will probe target areas to determine the available resource level and response of the defenders, and that the results of these probes and feints will be used to improve the effectiveness of the actual attacks.

The possibility of probing actions, feints, or diversions by terrorists suggest that defenders must accurately class each violation an intentional violation with the purpose of conducting an attack, an intentional violation as a prelude to possible attack (e.g., reconnaissance, feint, or diversion), or an unintentional violation. Security asset managers have likened the task of identifying intentional violations to that of finding the proverbial needle in the haystack -- that is to say inadvertent violations masking the intentional violations from detection). In the view of these same security asset managers, making the haystack smaller (i.e., reducing inadvertent violations from hundreds per year to a mere handful) would greatly simplify the task of identifying intentional violations, as well as allow post-incident investigators to spend significantly more time and resources on examining each event in detail.

With this in mind, MITRE has been examining the application of existing technologies to accomplish the following:

- Enhance situational awareness for pilots operating in the vicinity of restricted airspace, particularly where those restrictions result in a large volume of restricted flight operations or where the restriction is of a very temporary nature.

- Enhance tracking and identification capability of low altitude aircraft in and around restricted airspace.

4.0 Situational Awareness Enhancements for General Aviation

One of the most basic of technology enhancements for GA is automation of the navigation function through use of GPS-based moving map displays. These systems, implemented either as installed avionics or as hand-held systems, depict aircraft position in relationship to the destination, as well as display relative position of airspace boundaries, navigational aids, and on some systems, hazardous terrain. While moving map systems may partially automate the navigational tasks relative to operations in and around restricted airspace, lack of current status of airspace (e.g., outdated database) or simple misuse on the part of the pilot may still result in poor situational awareness. Indeed, a frequent topic in flight training periodicals is discussion of the pros and cons of an observed increase in dependence of many pilots on moving maps for basic navigational tasks.

Further value can be derived from moving map presentations when TFR and ADIZ boundaries are depicted. Several companies have begun offering updates of TFR information via weather data link; however, moving map software must be modified to provide display of these 'on-the-fly' database updates, limiting their application. Flight Information Service –Broadcast (FIS-B) may also be used to provide updated TFR information, and possibly automating the plotting task for pilots.

While moving maps may provide a visual presentation of airspace boundaries, and in some cases provide proximity warnings, discussions with various GA users in mid-2002 led MITRE to begin researching technologies which might provide explicit alerting and avoidance cueing, leading to development and testing of the Airspace Alerting and Avoidance System (A3S). This system was developed to provide the following baseline capabilities without any required ground infrastructure in or around TFR or ADIZ airspace:

- ❖ Ability to generate timely restricted airspace proximity alerts
- ❖ Ability to display avoidance cueing in both horizontal and vertical planes, and to provide exit cueing for aircraft already within a volume of restricted airspace
- ❖ Ability to provide time and distance to violation/loss of separation with the restricted airspace boundary
- ❖ Ability to provide ‘TFR close by’ or ‘TFR below’ notification when operating close to an active TFR
- ❖ Utilizes a comprehensive on-board database of restricted airspace areas to generate warnings
- ❖ Utilizes Internet or available data links for preflight and airborne updating of on-board database
- ❖ No requirements for additional infrastructure beyond current and anticipated near-term systems available to the GA user

The results of the team’s initial assessments indicated that two development paths were available for the prototype device; a simple, single purpose, device with symbolic display based on integration of very low cost electronic components (e.g., the $200 kitchen timer or hockey puck using LED and LCD display elements), and a slightly more expensive ($350-$500) software-driven implementation with graphical moving map display using existing personal digital assistant (PDA) and a separate GPS antenna/receiver.

With the project’s goals of low cost development, rapid technology transfer and commercialization of the technology, and use of COTS hardware and software to the maximum extent possible, the team elected to develop the initial A3S system using a personal Data Assistant (PDA) platform as core hardware, reducing development time and overall cost.

The team's final system configuration for the functional prototype (Figure1) included the use of the following components/technologies:

- ❖ PDA (Microsoft ®PocketPC®-based system with color display) for emulation of symbolic interfaces as well as more complex moving map presentation
- ❖ Low-cost wireless GPS to eliminate aircraft interfaces (e.g., BLUETOOTH GPS devices)
- ❖ Secure Digital data storage and transfer cards to permit preflight updating of the application database
- ❖ Satellite phone-based data link for demonstration of airborne database updating

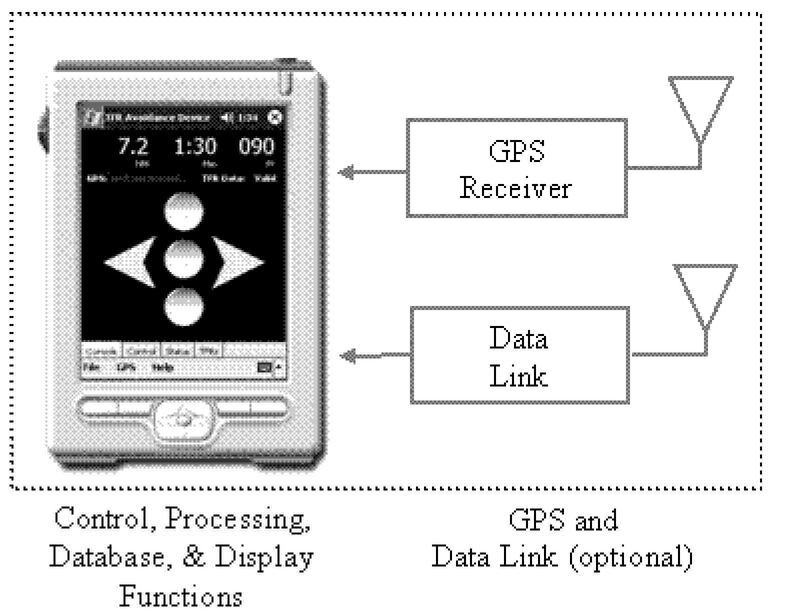

Figure 1. A3S Functional Prototype System Configuration

As seen by the authors, the A3S is both an existing low cost alerting and avoidance system and a set of algorithms and concepts capable of being implemented in a variety of systems with various user interfaces.

5.0 Enhanced Tracking and Identification of Low Altitude Aircraft

There are several issues associated with radar tracking and identification of low altitude aircraft in and around TFR, ADIZ, and Flight Restricted Zone (FRZ) airspace areas, to include minimum altitudes where radar is usable and what information is available within the surveillance system to positively identify aircraft operating in and around sensitive areas.

The current implementation of secondary radar technology in the NAS results in much of the information received from a Mode S transponder reply being dropped at the radar site. This results in 24 bit ICAO address characteristic of the Mode S reply being unavailable to the controller for use in identification of a secondary radar target, and requiring controller action to initially associate a Mode A code with any given target.

Additional Secondary Surveillance Radars (SSRs), as well as fusing tracks from these installations will improve minimum altitude performance, but does nothing to address either the lack of unique aircraft identification or the 80% of aircraft in the NAS without Mode S transponders. Further, simply adding radar sites to address coverage issues ignores the relatively high cost associated with these facilities – typically in the millions of dollars – even without operating costs included.

With limitations on affordability and issues with just what unique aircraft-related information is available for positive identification of aircraft, both U.S. domestic and international groups are examining the role of Automated Dependent Surveillance – Broadcast in security roles. While by nature dependent surveillance (as is secondary surveillance radar), site costs and the wealth of unique information in the message format suggests that ADS-B may be an effective and affordable supplement to radar to expand the volume of airspace under surveillance in the vicinity of sensitive areas.

In terms of cost, ADS-B sites are from one to two orders of magnitude less expensive than radar, at approximately $150K-$200K per site. In areas where cooperative surveillance is to be extended to near ground level (e.g., Washington, DC or other region with significant levels of low-altitude traffic and a large number of attractive targets), ADS-B may represent one of the few options available to achieve that goal in a cost-effective manner.

In terms of providing what has been termed ‘aircraft DNA’ – positive identification of an aircraft from taxi to shutdown, the capability exists for ADS-B systems to broadcast a unique flight identification, the ICAO 24-bit address associated with aircraft registration number, and a 4096 peudo-Mode A code. While flight identification and ICAO address may be determined from aircraft registration records, the combination of 4096 code with this other information may provide an effective method to positively identify aircraft operating within an ADIZ, FRZ, or TFR with a high degree of confidence.

A basic ADS-B surveillance system consists of one or more ground sites with related infrastructure, airborne ADS-B transmitters or transceivers, and the automation necessary to present the received information in a useful format to ground-based controllers or other activities. Figure 2 below illustrates these key elements combined to provide both air-to-air connectivity and air-to-ground surveillance information. Not shown in the illustration is the potential for uplink of radar-based traffic information (Traffic Information Service – Broadcast (TIS-B) already operating in Alaska and other ADS-B pocket implementations.

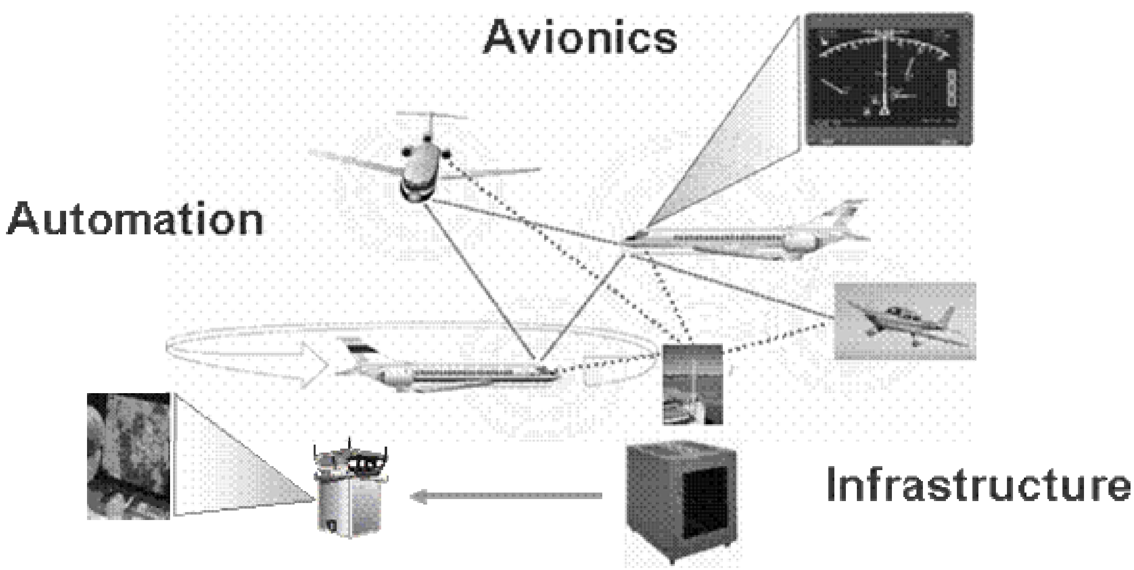

Figure 2. Basic Elements of an ADS-B Based Surveillance System (Graphic Source: FAA)

6.0 Conclusion

ADS-B and A3S technologies represent just two more elements in a layered scheme of defense.. While not a security panacea, they are a low-cost, effective adjunct to radar based surveillance for extending surveillance down to near ground level in sensitive areas and for providing situational awareness. They can help address the issues associated with the wide variety of GA aircraft, while providing a cost-effective solution to many of the security issues facing that element of the overall aviation security picture.