Aerospace Aircraft Display System

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ABSTRACT

The John D. Odegard School Of Aerospace Sciences at the University of North Dakota operates flight training centers at a variety of locations, including at the Grand Forks International Airport | Mark Andrews Field. The Grand Forks operation includes a fleet of 116 Aircraft and conducts approximately 120,000 flight hours per year. With student tasked to certain training exercises in certain regions of the airspace, this level of activity makes it desirable to have some way of tracking aircraft while in-flight. While a commercial system is available, it is prohibitively expensive. Therefore, a system originally designed to support unmanned aircraft systems (UASs) operation was modified. This system integrates aircraft position data from Automatic Dependent Surveillance-Broadcast (ADS-B) along with Doppler weather Radar and overlays this georeferenced information on an aviation sectional chart. In addition, the “Aerospace Aircraft Display System (AADS)” uses NATO/APA icons for the different aircraft types.

1. Introduction

The John D. Odegard School of Aerospace Sciences (JDOSAS) at the University of North Dakota (UND) is a world-renowned center for aerospace learning, nationally acclaimed for achievements in collegiate aviation education, atmospheric research, space studies, and computer science applications. JDOSAS has over 500 faculty and staff members, over 1,500 students and over 300 contract students and a myriad of programs and projects.

The JDOSAS operates flight training centers at the Spokane Falls Community College in Spokane, Washington, the Chandler-Gilbert Community College in Phoenix, Arizona, the University of Minnesota, Crookston at Crookston, Minnesota, and the University of North Dakota in Grand Forks, North Dakota. The JDOSAS flight operations at the Grand Forks International Airport | Mark Andrews Field (GFK) is the largest with approximately 120,000 flight hours per year. The JDOSAS fleet at Grand Forks includes 116 Aircraft (fixed wing single engine and multiengine and rotary wing), 19 flight training devices, 9 UAS's, and 6 UAS flight Training Devices. Figure 1 shows a section of the flight operations area and aircraft at GFK.

Figure 1: JDOSAS GFK fleet.

As JDOSAS / GFK is located in northeastern North Dakota, on the North Dakota Minnesota border, the JDOSAS has established practice areas in northeastern North Dakota and northwestern Minnesota. Practice areas are assigned to teach training flight with the exception of IFR, cross country, and traffic pattern flights. The purpose is to help spread out our fleet over a wider area, increasing safety and reducing risk to the flight crews. The SOF (Supervisor of Flight) monitors and assigns the practice areas based upon a maximum number in each. Once an area is full, it's no longer available until one of the aircraft assigned to that area returns. Some practice areas are used more than others, specifically the ones that have other airports within them or are closer to GFK (to reduce transit flight times).

2. Background

The Aerospace Aircraft Display System (AADS) is an offshoot of a project originally funded by the United States Air Force (contract number FA4861-06-C-C006) whose goal was to explore ways of integrating Unmanned Aircraft Systems (UASs) into the National Airspace System (NAS). Given the regulatory difficulties of operating UASs in the NAS, UND was tasked by the United States Air Force with identifying airspace within the state of North Dakota where organizations interested in developing UASs can test/operate their systems without the need for an on-board sense and avoid system. The core of the risk mitigation system was three Ganged Phase Array Radars (GPAR) connected to a set of Information Display Systems (IDSs). This system is referred to as the GPAR-RMS [1, 2].

The GPAR-RMS is meant to be an extension of the ground-based observer. The system integrates aircraft position (latitude, longitude, and altitude) data from sources such as Automatic Dependent Surveillance-Broadcast (ADS-B), ground based radar, and telemetry data from Global Positioning System (GPS) equipped aircraft. Sensor data is fused and forwarded to the Range Control Center (RCC). Data from a weather station located at the UAS operations center and Doppler weather radar would also be forwarded to the RCC. As the data are fused they are multicast (for scalability) to the IDSs, including a high-resolution wide-screen Range Control Center Information Display System (RCC IDS) and one, or more, high-resolution wide-screen Ground Observer Information Display Systems (GO IDS). The RCC IDS, which is modeled after existing Air Traffic Control display systems and existing Traffic Information Service-Broadcast display systems**,** displays the georeferenced GPS positions of all aircraft operating in the area, the georeferenced positions of ground-based hazards/targets, weather information, system health data, and an operational risk parameter. The GO IDS, which is modeled after existing Flight Information Service-Broadcast moving map display systems, portrays the positions of all aircraft operating in the area in relation to a specific UAS of interest, weather information, system health data, and the operational risk parameter.

While Unmanned Aircraft Systems (UASs) offer a unique range of features and can be used in dangerous situations or for very routine and mundane operations; flying UASs in NAS of the United States (US) can be problematic as it has not yet been determined if Federal Aviation Regulations even apply to unmanned aircraft [3]. Of major concern are the requirements of Visual Flight Rules (VFR) and their basic underlying concept, generally referred to as see and be seen. The pilot’s duty of vigilance to see and avoid other aircraft, poses possibly the greatest technical challenge to the UAS community and the Federal Aviation Administration (FAA). Therefore UAS operations are strictly limited. However, military and public entities may apply for a Certificate of Authorization or Waiver (COA) to conduct operations outside of special use airspace, yet strict limitations on their operations are still in place. Additionally, civil operators of UASs must obtain a special airworthiness certificate for their UAS (essentially an experimental certificate) which does not allow the aircraft to be utilized for commercial purposes [4].

While regulatory restrictions still limit UAS operations in North Dakota, the GPARS-RMS system developed proved useful when modified for manned flight operations.

3. AADS Architecture

The UND SOF expects to have a large number of aircraft operating at any given time. Yet the system theoretically only requires one AADS located at the SOF desk. However, the desire did exist for a system that was scalable and that could support the simultaneous operation of multiple AADSs located at various sites around the airport and campus. Thus, for our system, a thread-based data manager subsystem [5] was developed to accumulate the relative data and multicast it to any number of AADSs. However, due to network congestion concerns, the system was modified to resemble a more tradition client-server system where clients request data from the server. Whether a particular AADS functions as a client or server is determined by a command-line argument.

Figure 2 shows the AADS architecture. When operating in server mode, a multithreaded data manager subsystem communicates with the various data producing systems/sensors using BSD-style sockets and serial ports; using similar operations on different ports. Once a connection to a data producing source is established, the socket remains connected to the data source and continuously polls the socket for data. When data are received they are parsed into their required form and stored in a local data structure for further processing/display. To date, interfaces to a Davis weather station, a Garmin GDL-90 ADS-B transceiver, an Insitu ScanEagle Ground Control Station (GCS), and a MicroPilot GCS have been developed. However, for the AADS only the Garmin GDL-90 ADS-B transceiver interface (via a serial port) is employed. When operating in server mode, the system also sends aircraft data to any AADS clients who are connected to the server.

When operating in client mode, a multithreaded data manager subsystem now communicates with the server using BSD-style sockets. Once a connection to a server is established, the socket remains connected to the data source and continuously polls the socket for data. When data are received they are parsed into their required form and stored in a local data structure for further processing/display. However, before a client can receive data it must request a pool of credits from the server. Once a pool of credits is established the server will automatically send aircraft data to that client without further interaction, until the pool of credits has been consumed. If a client consumes all of its credits, it can request another pool of credits at which point it can again receive aircraft data. The purpose of this credit-based scheme is to prevent the server from sending data to clients that are no longer on-line or active.

In addition to interfaces to data producing sensors, the system also acquires data from various sources on the Internet. Current atmospheric pressure readings from the National Oceanic and Atmospheric Administration (NOAA) weather database is required as aircraft ADS-B units broadcast their aircraft altitude based on standard barometric pressure (29.92 in Hg) and this altitude data must be converted to actual altitude using the current barometric pressure at, in our case, GFK. We also acquire the national composite Dopper weather radar image from the NOAA Internet site and overlay a section of this data on the display (server and client mode).

Finally, we have embarked on a complete rewrite of the system; however, the basic architecture will remain the same.

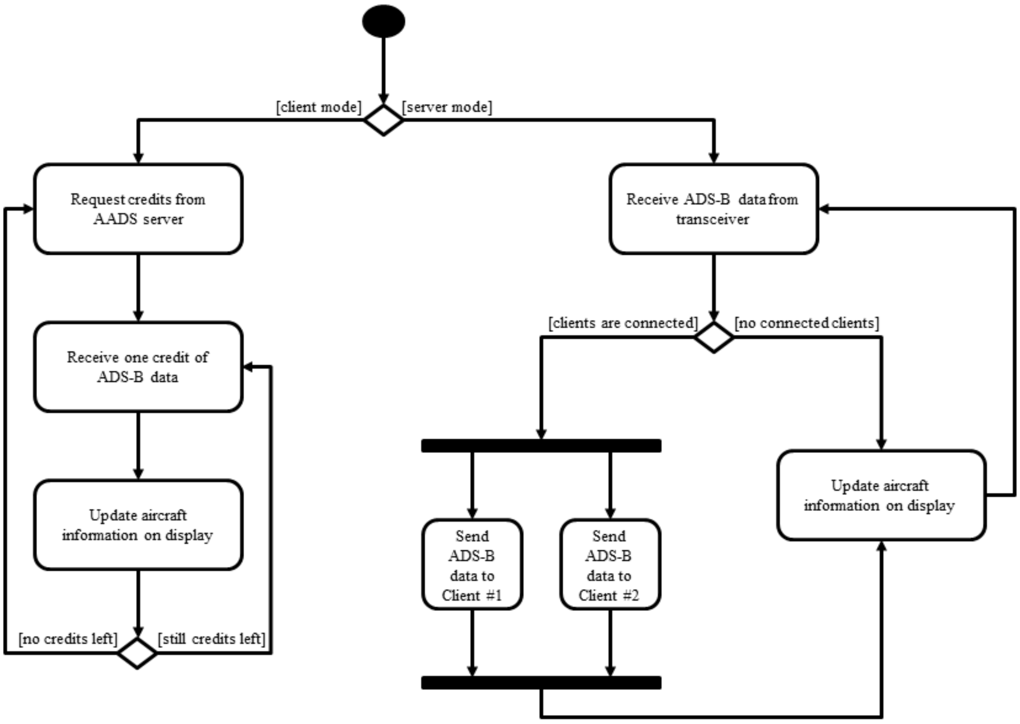

Figure 2: AADS architecture.

The original GPAR-RMS was considered a safety critical system, where DO-178B [6] and system reliability were of concern. Hence, a redundant system was developed that used languages (C/C++), operating system (Linux) and a graphics library (OpenGL) that could be DO-178B certified. However, even in an ideal situation, where two complete copies of the system are constructed and the failure of any portion of either system is statistically independent, the probability of both systems failing would be equal to the square of the probability of either system failing:

$$P(A \text{ and } B) = P(A)*P(B)$$

Common mode implies A=B, thus:

$$P(A \text{ and } B) = P(A)*P(A)=P(A)^2$$

This estimation is optimistic due to Common Mode Failure (CMF) where a single cause leads both copies of the system to fail [7]. Fortunately, the AADS is not being used in a manner that would make it be considered a safety critical system. So, no further efforts have been made regarding DO-178B compliance or CMF.

4. AADS Display

An ongoing task is the continued refinement of the design of the AADS graphical user interface (GUI). However, the design of an IDS is not as obvious as one might think as there is no one model to follow. As a DOT/FAA technical report sites [8], there are several different types of IDSs in use throughout the FAA's facilities. The variety of IDSs may be expected given the variety of tasks each FAA facility is expected to perform; however, what is not expected is that supposedly identical IDSs have different interfaces depending on who the contractor was. Yet, one can argue that this is to be expected given the work of Nielsen [9] who concluded that "No design standard can ever specify a complete user interface" and the work of Ahlstrom and Kudrick [10] who point out that the same (interface) standard may be implemented in a variety of ways. Given the lack of a uniform IDS model and the unique requirements of UND's IDSs, it seemed prudent to design an IDS from first principles using a spiral model (such as Boehm's) where the IDS designers can work directly with those developing the rest of the system and with those who will use the resulting IDSs.

Using the 2004 DOT/FAA technical report as a guideline, one sees that an IDS should be well organized and that organization of the information and controls greatly affects the operator's ability to effectively use the system. The IDS must be navigable and consistent. The IDS should clearly indicate when pertinent information was last updated. Information displayed should be complete and relevant. Use of color and color combinations should be consistent. Buttons should be represented in shades of gray and use a consistent font size and font type. Hardware selection is also an important issue as the use of a keyboard for required data entry should only be provided to operators who have the authority to enter data. The use of a mouse or trackball versus a touch screen display has advantages and disadvantages. Both facilitate interaction with the IDS. However, use of a mouse/trackball requires the operator to coordinate the position of the physical device with the icon on the screen and when used with multiple displays the operator can momentarily lose track of the icon during the screen-to-screen transition. Use of a touch screen can be problematic if the screen has a low touch resolution, a touch screen requires some form of adjustable mounting as the operator's arm will fatigue, and a touch screen requires frequent cleaning to remove fingerprints which obscure information. The report indicates that touch screen users often preferred to use a trackball over their finger/stylus or a mouse. Finally, screen size and resolution must be sufficient to clearly display the relevant information.

Xing's [11] report cites the non-standard use of color schemes by the different manufacturers of ATC displays and proposes guidelines for use of color in IDSs such as:

- To capture attention. However, the effectiveness of color in this manner is highly dependent on the luminance and chromaticity differences of the colors used and on the consistent use of specific colors to represent specific situations across all components in the IDS.
- To identify certain types of information to improve the operator's effectiveness in retrieving relevant information in complex/cluttered displays.
- To segment complex display scenes to organize/cluster related information. However, in some cases segmentation is better achieved through a reorganization of the display.

It should be noted that many of these concerns/requirements are echoed in the US Department of Defense's Design Criteria Standard: Human Engineering (MIL-STD-1472F, 1999).

Taking into account the previous work done in this area, the AADS was developed incorporating the ability to:

- Import near real-time data (1 second intervals) from the ADS-B transceiver.

- Display cooperative aircraft types using NATO/APA icons.
- Import from a file and display boundaries of regions such as aircraft practice areas and allow the user to toggle this overlay on or off.
- Import and display the regions' NOAA Doppler radar data, allow the user to toggle this overlay on or off, and allow the user to set the transparency of the overlay.
- Import and display the regions Aviation Sectional Chart, allow the user to toggle this overlay on or off, and allow the user to set the transparency of the overlay.
- Allow the user to zoom, pan and/or scroll the display.
- Provide the time and date of the last ADS-B, Doppler radar, and weather sensor (barometric pressure) updates.
- Allow the user to select an aircraft via the mouse to obtain flight data (position, heading, etc) on that aircraft.
- Allow the user to search for aircraft via the tail number.

The current AADS display is shown in figure 3.

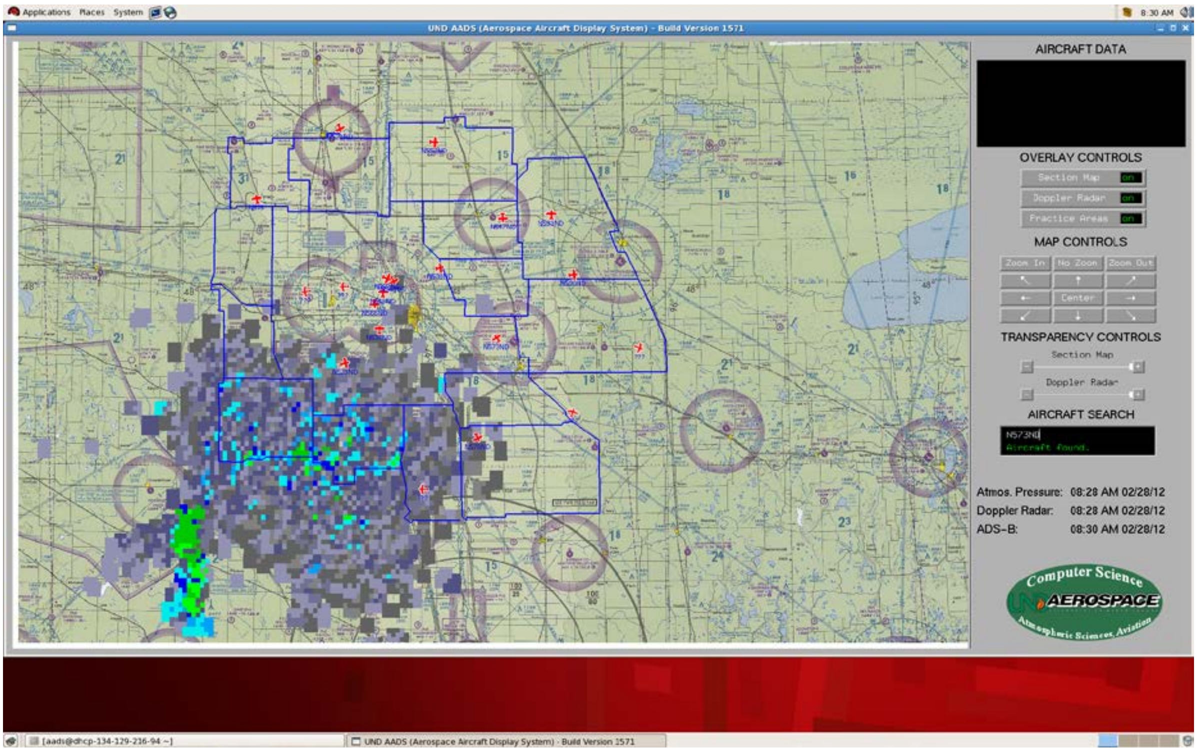

Figure 3: AADS display (revision 1).

Other features that were added include compile-time flags. One flag removes aircraft that are parked on the ramp at GFK as these aircraft are not of interest to the SOF and clutter the screen. Another flag removes all ground vehicles. Finally, a highly desired feature that we added was the ability to search by aircraft tail number. The user can simply enter the tail number of an aircraft they are looking for (into a window in the display) and press enter. If the aircraft is not found, the text "Aircraft not found." is displayed with red characters below where the tail number is entered. If the aircraft is found, the text "Aircraft found." is displayed with green characters below where the tail number is entered and the screen is panned/scrolled such that the aircraft of interest is now centered in the display. To return to the nominal pan/scroll mode the user clicks on the “center” button.

6. Version 2

As noted above, we are developing a second version of the system. The reason is simple; the first version was adapted from an earlier system (GPAR-RMS). As a result the design was less than ideal (sluggish GUI, memory leaks, difficult to maintain, etc). While the basic architecture will remain the same, the implementation is substantially different: the code base is much smaller and the GUI has been modified using the lessons learned and feedback from the SOF.

For example, we rearranged the location of the menu options and display sub-windows on the left side of the screen to better reflect how the SOF used the information. We also did a better job of grouping together controls, buttons, sliders that had similar functionality (from a user’s point of view). Several options previously set by compile-time flags are now specified by a configuration file. We also included functionality to save the current display settings (zoom, pan, scroll, etc) and included functionality to make these settings automatically load on start-up. We are also experimenting with a different color set for the aircraft icons; aircraft icons are by default blue. If an aircraft stops transponding for a specific amount of time, the icon will turn a bright red. This frequently occurs when a student lands at one of the smaller local airports and parks the aircraft, something the SOF can readily determine by looking at the AADS. Of course an aircraft would also stop transponding should an emergency occur. Once an aircraft icon turns red it will disappear from the display after another set amount of time unless it begins transponding turning the icon blue again.

We also modified how a user selected aircraft is denoted making it easier for the SOF to keep track of the selected aircraft on a cluttered screen. We modified how an aircraft is denoted that was searched for by tail number as the old approach of centering the screen on the aircraft would “confuse” inexperienced SOF personnel. We now leave the screen settings alone and instead draw a think dotted line from GFK to the aircraft (if it was found) and display its flight data (position, heading, etc). In either case, user selected or searched for aircraft, the display will automatically return to its nominal settings after a set amount of time.

A significant change to the system is how we ingest ADS-B data. We will now decode and display (user selectable) Traffic Information Services-Broadcast (TIS-B) messages as well. TIS-B allows non-ADS-B transponder equipped aircraft that are tracked by radar to have their location and track information broadcast to ADS-B equipped aircraft. While all UND aircraft are ADS-B equipped, many of the other aircraft operating in the region are not.

The revised AADS display (with simulated aircraft) is shown in figure 4.

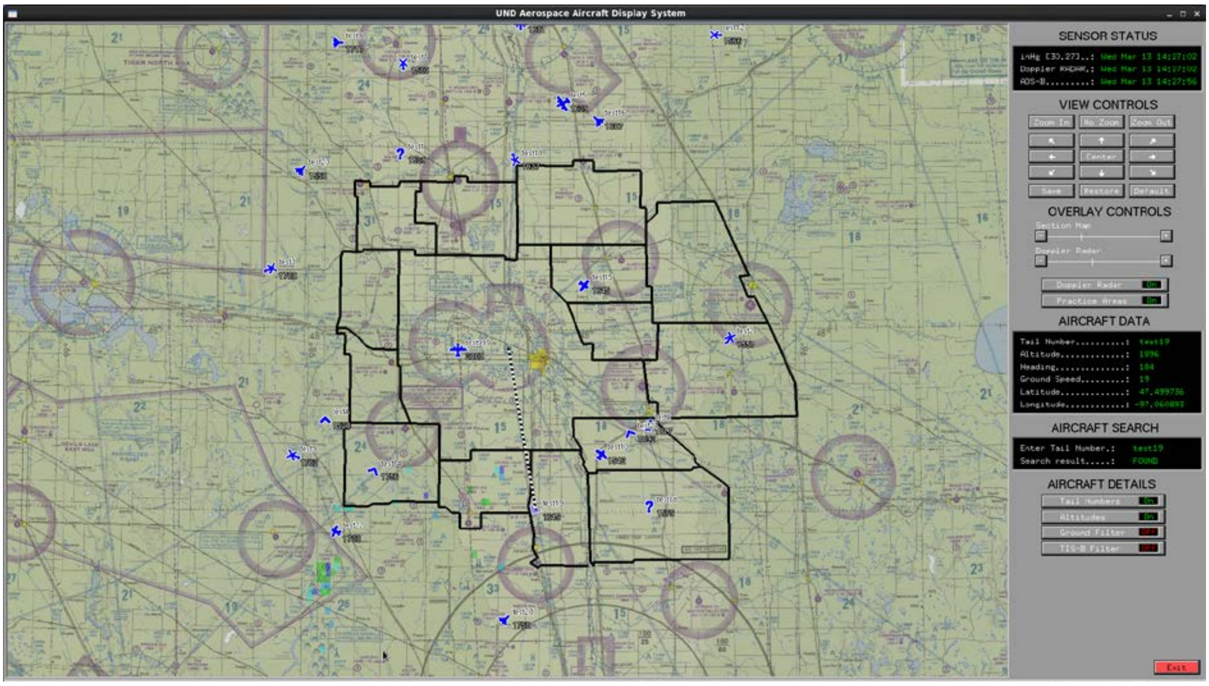

Figure 4: AADS display (revision 2).

Finally, given all of the aerospace related activities that are ongoing at UND, we hope to expand the capability of the AADS such that it can be used for all of these activities. For example, we are working with the Limited Development - Cooperative Airspace Project (LD-CAP) to include features required to support that project. And we have plans to include features to support the High Altitude Balloon (HAB) projects as well.

7. Conclusions

We were originally tasked by the USAF to develop a novel IDS for use with civil UA operations in the NAS; an IDS that is intuitive enough such that UA operators will not require significant training before usage. This development provided the code base and expertise to develop a variation that is now known as the AADS.

Our AADSs are primarily used by the SOF to UND student flights. Each aircraft is due back at set times, depending on how many 'launches' they have scheduled for that flight. If we have any overdue aircraft, AADS is the first place the SOF looks to locate the aircraft. We have had outstanding success in this area. With AADS, we no longer have to call ATC, Flight Service, or individual airport managers to try and locate aircraft. Of course, if the aircraft is not in range of the AADS or if they are not showing up on the display, we fall back to making phone calls. We've also used it along with the Doppler radar overlay to help gauge when incoming weather will affect our practice areas and dispatched aircraft. We currently have five displays set up at various hangers at GFK with another scheduled to be installed in a public area in the JDOSAS.

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