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Development of a Mobile Information Display System for UAS Operations in North Dakota

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***Abstract*: The University of North Dakota is developing airspace within the state of North Dakota where unmanned aircraft systems (UASs) can be flown without an on-board sense and avoid system or temporary flight restrictions. The John D. Odegard School of Aerospace Sciences, with funding from the United States Air Force, is developing a mobile ground-based radar system to detect low observable aircraft and to display the information to the UAS operator using a novel visualization system. The only stated desirable feature was that the visualization system use NATO/APA icons as applicable. The system integrates aircraft position data from Automatic Dependent Surveillance-Broadcast (ADS-B), ground based radar, telemetry data from Global Positioning System (GPS) equipped UASs, and sources for weather information relevant to the monitored airspace. As the data is accumulated it is fused and multicast to the Information Display Systems (IDSs) where it is displayed on two types of high-resolution wide-screen IDSs. The two types of IDSs include a Range Control Center Information Display System (RCC IDS) and a Ground Observer Information Display System (GO IDS). This paper focuses on the developed IDSs and on the simulation system used to test the IDSs.**

***Keywords*: Unmanned Aircraft, Simulation, Information display systems, Computer graphics.**

I. Introduction

Unmanned Aircraft Systems (UASs) offer a unique range of features. With no pilot on board, UASs can be used in dangerous situations or for very routine and mundane operations. With no pilot to account for in their design, UASs can be designed to carry more fuel/payload thus optimizing operational capabilities. With their smaller size and weight, they also benefit from lower manufacturing and operating costs.

However, flying UASs in National Airspace System (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 [1]. 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).

This duty is described by the requirements of Visual Flight Rules (VFR) and their basic underlying concept, generally referred to as "see and be seen" (Title 14 USC Part 91.111 and 91.113(b)). The history of this concept is delineated in a paper presented to the American Institute of Aeronautics and Astronautics (AIAA) in 2009 [2]. According to the authors, in 1968, the FAA, having established the new Part 91 from the earlier Part 60 of the Civil Aviation Regulations, published an amendment in the Federal Register to specifically reconfirm that it is the pilot's responsibility to ". . . maintain vigilance so as to see and avoid other aircraft when weather conditions permit." [Air Commerce Act of 1926. Pub. L. No. 69-254, 44 Stat. 568 (1926)] The amended §91.67(a) [now §91.113(b)], clearly required that each person operating an aircraft under VFR or IFR (Instrument Flight Rules), weather permitting, had a duty to be vigilant to see and avoid, and give way to other aircraft in accordance with the right of way rules of this section [3]. This regulation does not excuse pilots who are operating under positive control or IFR from the duty to be vigilant. Even if operations are under IFR, if operating in visual metrological conditions; pilots must see and avoid other aircraft.

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].

In 2005, the FAA issued a memorandum, AFS-400 UAS Policy 05-01, entitled, “Unmanned Aircraft Systems Operations in the U. S. National Airspace System - Interim Operational Approval Guidance,” dated September 16, 2005. This policy guidance was to be used by the FAA to determine if a UAS may be allowed to operate in the NAS. It also acknowledges the problem UAS operations have complying with the duty to “see and avoid” other aircraft. The FAA’s latest guidance, Interim Operational Approval Guidance 08-01, was published in 2008. In it, the use of alternative measures for compliance, specifically “special types of radar or other sensors must demonstrate that both cooperative and non-cooperative aircraft, including targets with low radar reflectivity, such as gliders and balloons, can be consistently identified at all operational altitudes and ranges, and the proposed system can effectively deconflict a potential collision.” Regardless of these problems, it is clear the FAA is committed to this concept and operations in the NAS that fall short of this mandate will not be authorized, including UAS operations.

There is also the issue of safety that UAS operators must contend with. A prior analysis of ground and midair collision risk found that most UAS operations would not meet FAA target levels of safety without the incorporation of a mitigation strategy. Mitigation techniques being considered include operating restrictions, mission scheduling, fault detection and accommodation, path planning, and execution elements with a focus on emergency scenarios; including, and not limited to, collision avoidance and forced landings [5].

Given the regulatory difficulties of operating UASs in the NAS, the University of North Dakota (UND) is 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 (RMS) is three Ganged Phase Array Radars (GPAR) tied to a set of Information Display Systems (IDSs).

The GPAR-RMS is meant to be an extension of the ground-based observer. The system will integrate 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 UASs. As the sensor 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 and weather information. The weather information displayed at the RCC IDS and GO IDS is that obtained from a weather station located at the UAS operations center. Finally, Doppler weather radar data would also be obtained via the Internet and forwarded to the RCC IDS. The remainder of this paper describes the graphical IDSs, but starts with a brief description of the simulation architecture.

II. GPAR-RMS Simulation Architecture

One of the challenges faced from the beginning is that the ground-based radar(s) are not yet fully functional. Thus, a system to simulate the expected environment such that development of the related systems can proceed was developed. Thus, several software simulations have been developed, including an Unmanned Aircraft (UA) simulation, a radar/airspace simulation, a radar fusion simulation, a risk mitigation simulation, and the IDSs.

The current GPAR-RMS simulation architecture, shown in figure 1, must acquire and present the applicable data in real-time; thus, multi-threaded software systems were designed and multi-core computer systems to execute that software were selected.

Our initial task was to develop a simulation of the airspace that included a human-controlled UA, several manned aircraft (varying from private aircraft to commercial), and a range control center. Our current task is to refine the architecture such that it is suitable for field operations. However, due to space limitations all of required changes cannot be described here.

A. UAS simulation

Since the airspace and UA simulations must model the flight characteristics of the UA and manned air traffic, the cost of developing such a simulation package must also be considered. Several UAV/UAS simulation packages were investigated for potential applicability and Microsoft’s Flight Simulator X (FSX) or FlightGear (FG) were found to be the most cost-effective solutions for the UAS simulation for our application.

FSX was initially deployed to model the airspace. However, FSX was not intended for use in an application such as this and we were forced to developed several custom solutions using the SimConnect API to bypass limitations inherent in FSX. Using FSX in multiplayer mode allowed the creation of a good rendition of the airspace and a UAS. However, the ability to send FSX airspace information to a Linux based IDS eluded us forcing a port of our FSX capabilities to FG, an open-source, multi-platform, flight simulator; which is still being used to simulate the UAS. Approximately once per second, FG sends updated UA information to the UAS polling thread (figure 1) [6].

B. Airspace simulation

While FG works very well for simulating the UAS, it was decided that neither FSX nor FG would provide the required flexibility for the airspace simulation. Thus our own was implemented. Upon startup, the airspace simulator reads the intended locations of the three ground-based radars from a file, calculates the location of the centroid for the radars, gets the locations of airports within 50 miles of the centroid location from another file, and reads flight characteristics from a third file for the aircraft to be created. Each of the created aircraft is assigned a unique set of flight characteristics and a random starting location. Approximately one third of the aircraft start at a cruising altitude at a distance of 50 miles from the centroid location. The remaining aircraft start on the ground at random airports and take off. Aircraft that start in the air will fly straight through the airspace, while aircraft that start on the ground will take off, climb to cruising altitude, and eventually land. Approximately once per second, the airspace simulator sends updated information about each aircraft to the radar polling thread (figure 1) [6].

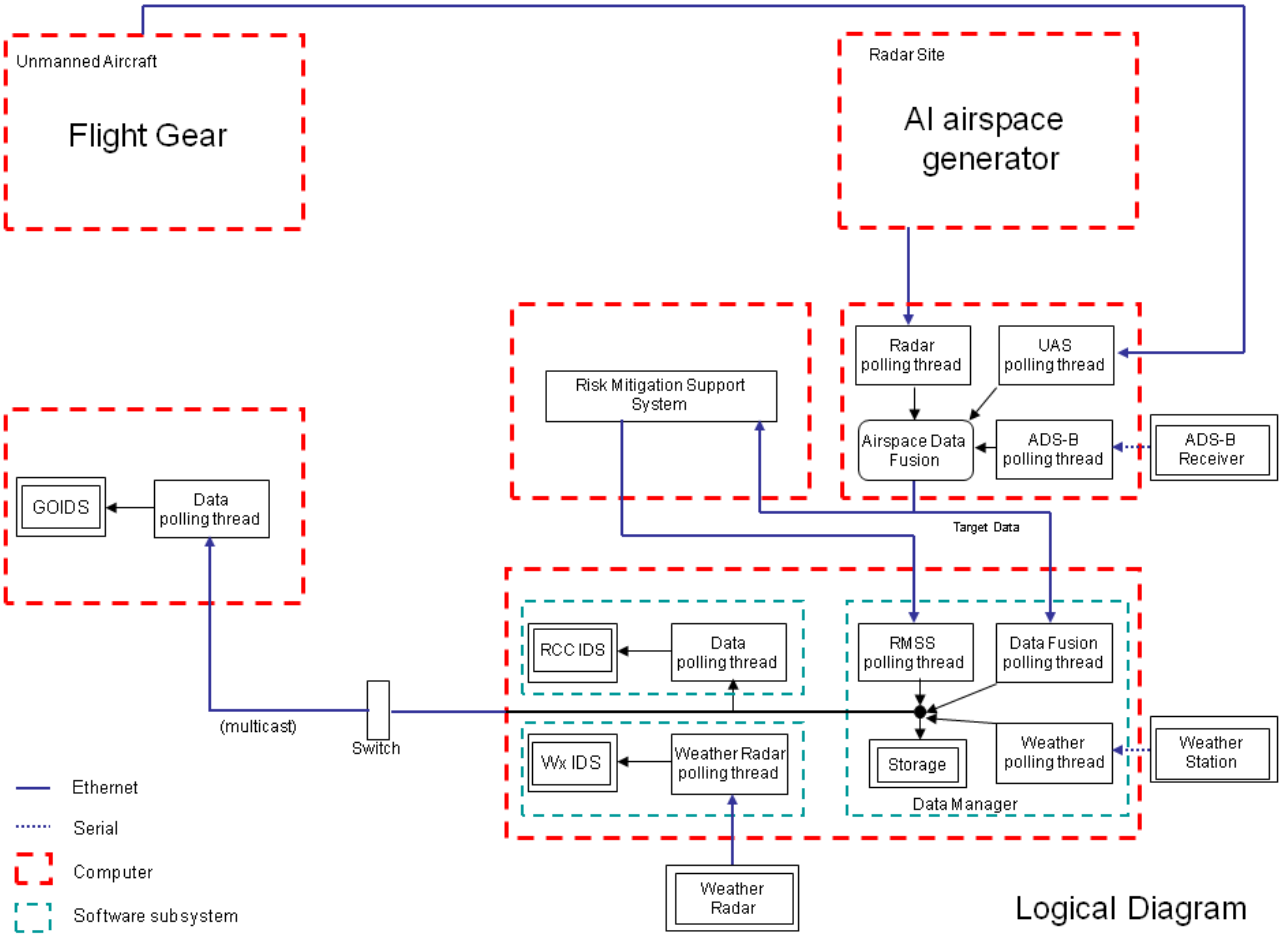


Figure 1. GPAR-RMS simulation architecture

A related body of work is the University and National Guard Air Truth Study (UNGATS). The University of North Dakota has been involved with two collaborative multi-purpose mission with the North Dakota Army National Guard (NDNG) 188th Air Defense Artillery Battalion. These missions utilized three MPQ-64 Sentinel radars that were deployed at specified locations in northeastern North Dakota. These locations were chosen as they provided security for operations of these systems, resembled the GPAR-RMS configuration, and allowed for overlapping coverage of the scanned airspace above and around the Grand Forks Air Force Base. The main goals of these collaborative efforts were to provide the soldiers of the 188th Air Defense Artillery Battalion with training on their assets and provide UND with the opportunity to record airspace data. The data is used to create airspace climatology and can be used in testing components of the GPAR-RMS, including the sensor data fusion system and injecting the real-time data into the airspace simulation.

The first mission was held from 4-12 October 2008. The data was securely sent to proper authorities to be sanitized as the information recorded by these systems was classified in nature. Figure 2 provides a 2-D display of the daily air traffic over the operations area on October 7, 2008 (note that the original data is 3-D) as recorded by the three Sentinel radars. During this effort, the region experienced several days with rain and thunderstorms reducing the number of detected aircraft. Also, a large migration of geese occurred possibly skewing the radar dataset at times with biological scatters. A second effort was organized to address these and other problems experienced throughout the first effort and to also increase the length of the dataset to make it more statistically significant.

This second effort was successfully accomplished from 16 August 2010 through 24 September 2010 providing over five weeks of continuous airspace data. Other datasets requested during these efforts include those from ADS-B, Airport Surveillance Radar (ASR-11) at Hector International Airport in Fargo, ND, and the Air Route Surveillance Radar

(ARSR-4) near Finely, ND. The combination of data from these different sensors will aid in the testing and development of the data fusion system within the GPAR-RMS.

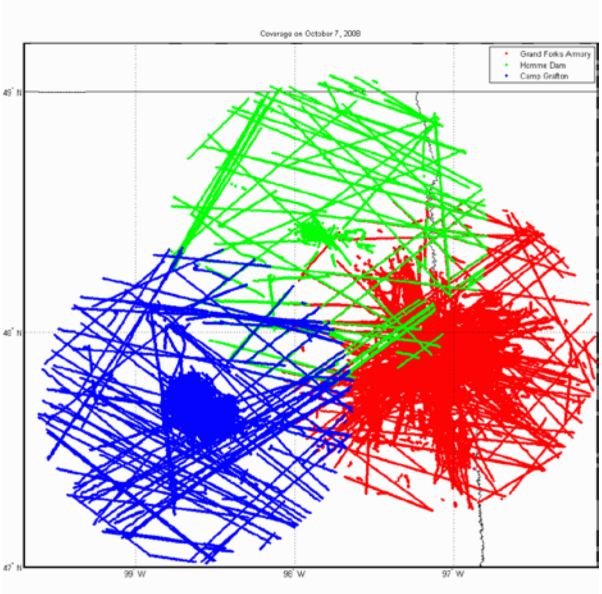


Figure 2. 2-D plot of un-fused UNGATS radar tracks

C. *Risk mitigation simulation*

An ongoing task is the development of the risk mitigation system (RMS) which will provide the UA operators with a quantitative measure of risk associated with the current state of the airspace. Figure 3 shows the current aircraft position uncertainty volume. The volume of any overlap of any aircraft's uncertainty volume with a UA's uncertainty volume determines the current risk. The risk mitigation parameter is continuously calculated and passed in real-time to the RCC IDS and GO IDS.

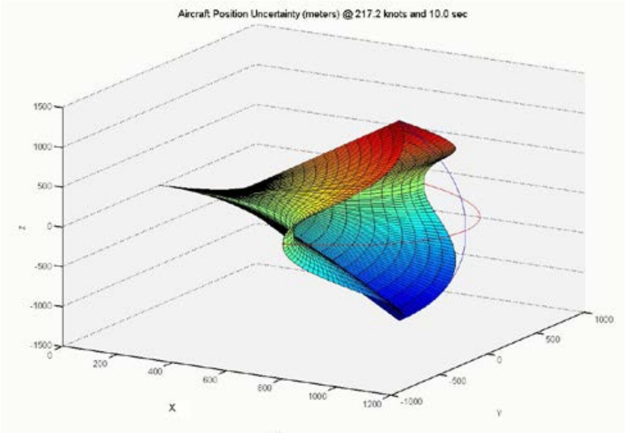


Figure 3. Aircraft position uncertainty volume

However, obtaining a quantitative measure of the risk associated with the current state of the airspace is algorithmically complex. In order to obtain a quantitative measure of risk, one must first calculate the risk for every possible collision that could occur between the UA and every other aircraft in the airspace. Furthermore, the RMS must obtain this risk mitigation parameter in near real time. To calculate the risk of collision between a UA and another aircraft, the RMS needs to be provided with the probabilities of a pilot performing various maneuvers with the aircraft during the next minute. Obviously, the pilot controlling the UAS from the ground control station will know the maneuvers the UA will perform during the next minute. Thus, only probabilistic models for manned aircraft are needed.

Although the set of basic maneuvers (e.g. straight ascents, straight descents, and level turns) that a pilot can perform in an aircraft is known, the flight path a pilot chooses for an aircraft can be composed of any combination of these basic maneuvers. Also, many variations on each basic maneuver are possible. The pilot of an aircraft may, for instance, perform a level turn at different rates, such as two degrees/second or three degrees/second. Furthermore, according to FAA regulations [7], pilots flying aircraft under VFRs in Class E airspace (i.e. at altitudes of at least 14,500 feet MSL but below 18,000 feet MSL) are not required to file flight plans. Hence the probability of the pilot of an aircraft performing any of these basic maneuvers in Class E airspace is not currently known.

One approach being considered is data mining ADS-B data sets for probabilistic models of pilot behavior in Class E airspace [8]. An ADS-B data set contains very accurate data about the flight paths of ADS-B-equipped aircraft over a specific period of time. The positions reported by ADS-B-equipped aircraft are georeferenced GPS positions that are accurate to within a few meters. With this level of accuracy it's feasible that automatic analysis of ADS-B data sets using data mining could aid in finding probabilistic models of pilot behavior. If these probabilities can be accurately estimated, the probabilities could be used by the RMS to obtain a quantitative measure of the risk associated with the current airspace configuration.

III. GPAR-RMS Information Display Systems

As stated above there are two IDSs, the RCC IDS and GO IDS. The intent of the RCC IDS is to provide a Range Safety Officer (RSO) with an overall view of the airspace providing another level of safety and redundancy. For example:

1. The RSO is not required to fly a UA, so it is possible for the RSO to monitor many UAs acting as a redundant ground observer.
2. The RCC IDS provides a certain level of redundancy should the GO IDS fail; the RSO can then help with separation or can call a halt to activities.
3. The RCC IDS also provides a recording mechanism for the archives.

The intent of the GO IDS is to use sensor technology to greatly expand the field of view of the ground observer. The GO IDS also provides a top-down orthogonal view of the airspace around the UA providing an unambiguous check of the UA's position compared to that of surrounding aircraft. Should the GPS position of the UA become unavailable to the UA pilot, the GO IDS (using data provided by the radars) could be used to help guide the UA back to the launch point.

An ongoing task is the continued refinement of the design of the IDSs. 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 [9], 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 [10] who concluded that "No design standard can ever specify a complete user interface" and the work of Ahlstrom and Kudrick [11] 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 [12] 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 criteria are echoed in the US Department of Defense's Design Criteria Standard: Human Engineering (MIL-STD-1472F, 1999).

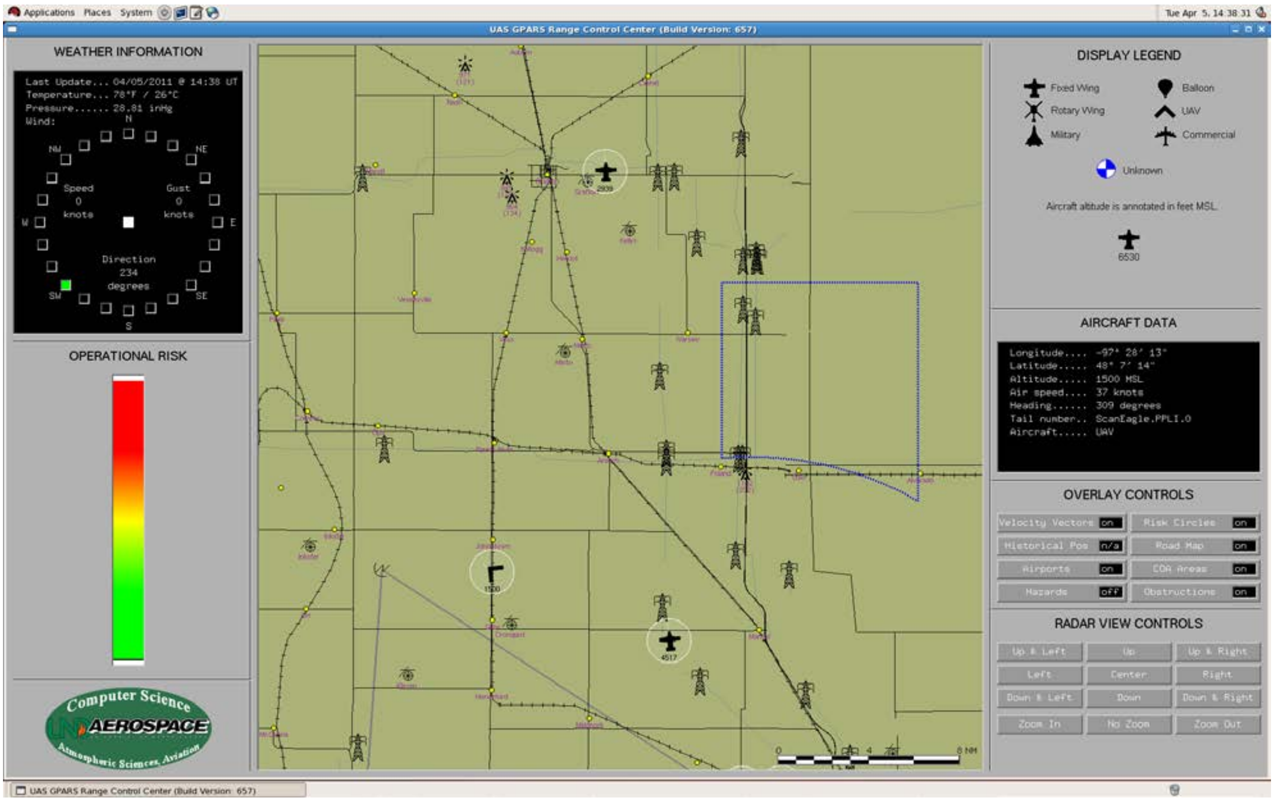
Taking into account all of the previous work done in this area, the current IDSs were developed using OpenGL on Linux, render the applicable airspace in 3-dimension, and have the ability to:

- Acquire from the local weather station and display weather information on 1 minute intervals and include a displayed timestamp for that data.
- Display the regions' National Oceanic and Atmospheric Administration Doppler radar website.
- Import and display Graphical Information System (GIS) shape files. Data currently exists for political boundaries, roads, railroads, towns, high tension utility lines, schools, airports, and towers (TV/radio transmission and wind turbines).
- Import and display areas such as UA operational areas / Certificate of Authorization or Waiver (COA) areas.
- Track-ball driven. The user interfaces for both IDSs is via a trackball.
- Import near real-time data (1 second intervals) from the ADS-B transceiver, radar and GPS system.
- Display cooperative aircraft types using NATO/APA icons.
- Display non-cooperative aircraft types using an icon that readily distinguishes it from any other aircraft.

The RCC IDS and GO IDS [13] share several common components, thus they have a similar appearance. In both IDSs, the upper left displays weather information obtained (temperature, barometric pressure, and wind parameters). In both IDSs, the upper right provides an icon legend, the center right provides information on any aircraft that the user has "moused over," and the lower right provides simulated buttons allowing the user to adjust the display (zoom, pan, scroll, etc) and to toggle the display of the available GIS information.

In the center of both displays is the airspace information. The RCC IDS provides a wide angle all-encompassing, north always up view of the airspace. Items currently displayed include georeferenced locations of aircraft operating in the monitored airspace, georeferenced locations of expected ground hazards, towns, airports, a road map, and any COAs. The lower left has a colored vertical linear meter indicating the risk mitigation parameter (green – low risk to red – high risk). The aircraft icons are rotated to indicate the current aircraft heading. The aircraft displayed optionally include (user discretion) a velocity vector (indicating heading and velocity) and a one minute range ring (corresponding to the current risk mitigation algorithm). The RCC IDS is shown in figure 4.

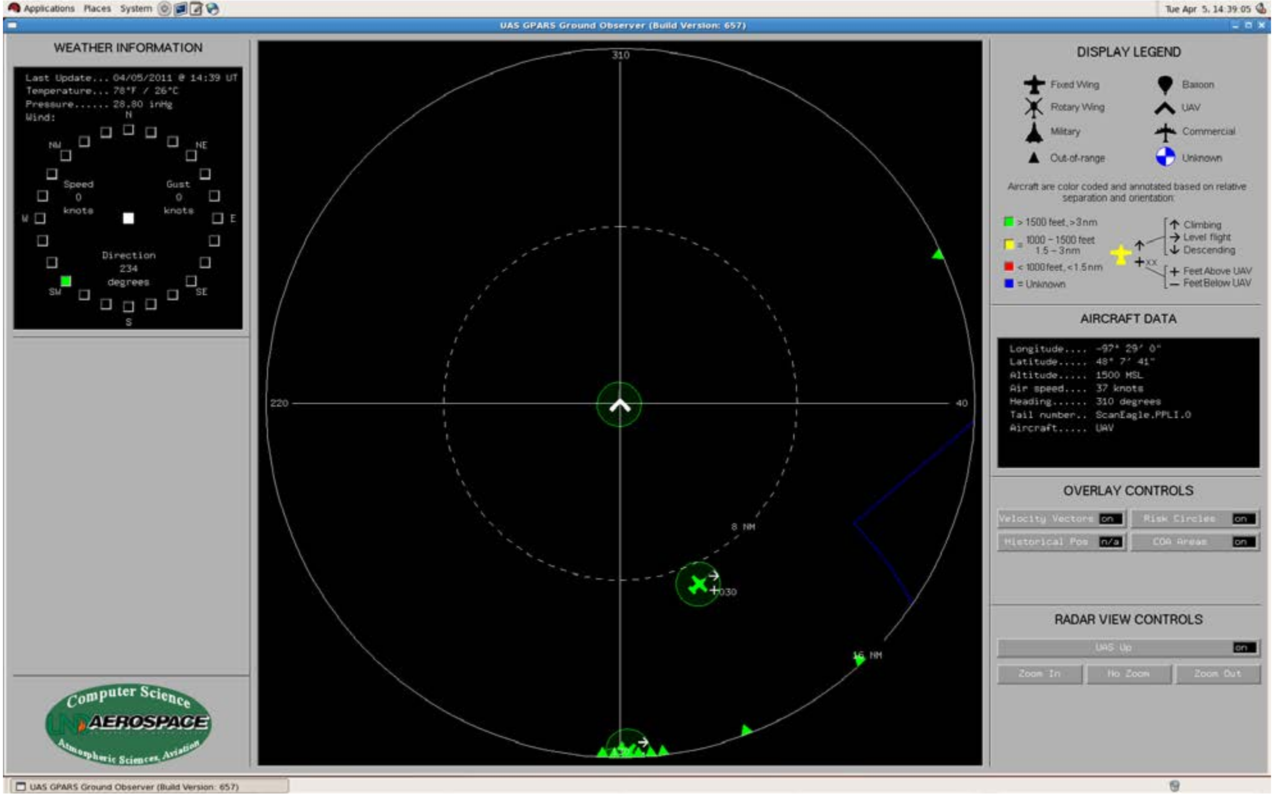
While the RCC IDS provides an all-encompassing view of the airspace, the GO IDS provides a UA centric view of the airspace. The GO IDS user can select either a north up or a UA heading up view. Centered in the display is the UA of interest (if multiple UASs are in operation, multiple GO IDSs can be employed, each centered on a specific UA as determined by UA tail number). Aircraft within the user selectable display range are georeferenced and displayed with icons appropriate to their type and rotated to correspond to the current aircraft heading (with respect to the UA). Next to each icon is information regarding the aircraft's relative altitude to the UA and orientation (ascending/descending/level flight). Aircraft outside the user selectable display range are displayed as triangles along the outer ring of the display. All aircraft icons are colored (red, yellow, green, and blue) based on their separation distance from the centered UA. Red is used to indicate aircraft that have less than 1.5 nautical miles horizontal separation and less than 1000 feet vertical separation. Green is used to indicate aircraft that have more than 3 nautical miles horizontal separation and/or more than 1500 feet vertical separation. Yellow is used to indicate aircraft that are between these two ranges. Blue indicates an aircraft that is non-cooperative (altitude and type unknown). The UA icon is white with a one minute range ring around it. The color of the UA range ring corresponds to the color of the nearest aircraft (white if there are no other aircraft). The GO IDS also includes the georeferenced (with respect to the UA) location of any COAs. The GO IDS is shown in figure 5. Note that both figures 4 and 5 were acquired at the same time for the same airspace.



Last Update... 04/05/2011 @ 14:38 UT
Temperature... 78°F / 26°C
Pressure...... 28.81 inHg
Wind:
Speed 0 knots
Gust 0 knots
Direction 234 degrees

Longitude.... -97° 28′ 13″
Latitude..... 48° 7′ 14″
Altitude..... 1500 MSL
Air speed.... 37 knots
Heading...... 309 degrees
Tail number.. ScanEagle.PPLI.0
Aircraft..... UAV

Figure 4. RCC IDS



Last Update... 04/05/2011 @ 14:39 UT
Temperature... 78°F / 26°C
Pressure...... 28.80 inHg
Wind:
Speed 0 knots
Gust 0 knots
Direction 234 degrees

Longitude.... -97° 29′ 0″
Latitude..... 48° 7′ 41″
Altitude..... 1500 MSL
Air speed.... 37 knots
Heading...... 310 degrees
Tail number.. ScanEagle.PPLI.0
Aircraft..... UAV

Figure 5. GO IDS

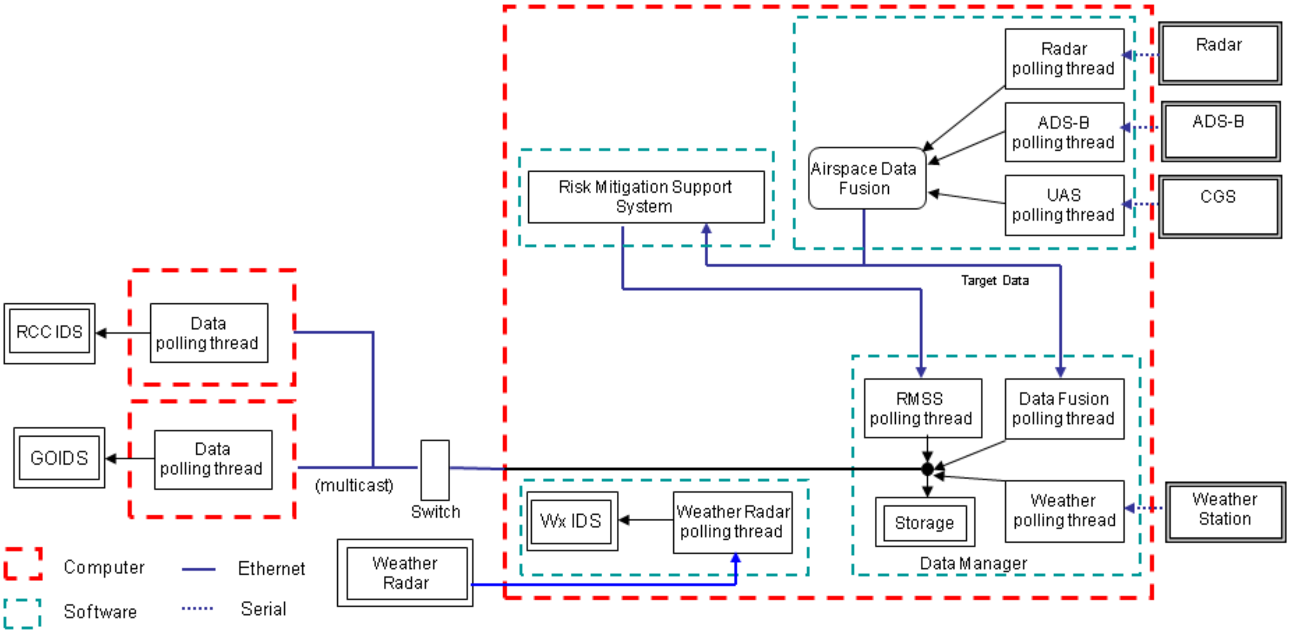


Figure 6. GPAR-RMS architecture

IV. GPAR-RMS Architecture

The intent of the GPAR-RMS is to allow UAS research and development outside restricted airspace while maintaining deconfliction. The system must also be portable. However, the system shown in figure 1 was not designed to be portable nor does it have any level of redundancy. Thus, the next stage of development was to enhance the system reliability through partial system redundancy. Constructing a complete copy of the system and properly outfitting two portable systems would be prohibitively expensive. Given this limitation, the decision was made that the best course of action was to isolate those components most critical to the system's purpose and replicate them. Figure 6 (above) shows the architecture of the modified risk mitigation system, while figure 7 shows the trailer that houses the GPAR-RMS system.

Figure 7. GPAR-RMS trailer

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. This estimation is optimistic due to Common Mode Failure (CMF) where a single cause leads both copies of the system to fail [14]. Given the number of shared resources in our system, CMF is a large concern and special efforts must be made to minimize its influence. The probability of CMF can be reduced by use of different hardware configurations and venders for each copy of the system; however, this technique does not address problems that result from faults in the software design [14]. Our approach to minimizing the impact of these design issues centers around formal methods of design and verification. Other techniques, such as design diversity, help to reduce the likelihood of CMF but require large investments of resources due to the need to design and construct the system at least twice [14]. We do not expect the probability of failure in the system in figure 6 to reach the optimistic estimate described above, but improvements in overall system availability are anticipated.

A. *Sensor Management*

The UND airspace is not expected to have a large number of UAs operating at any given time. Thus, the system theoretically only requires one RCC IDS and one GO IDS. However, the desire does exist for a system that is scalable, that can support the simultaneous operation of multiple UAs. Therefore, the system should be able to support multiple GO IDSs (only one RCC IDS would ever be required for a specific airspace). Thus, for our system, a thread-based data manager subsystem [15] was developed to accumulate the relative data and multicast it to any number of IDSs. There is a significant benefit to using a multicast approach for the delivery of information to the IDSs: Multicasting allows the system to be expandable to any number of GO IDSs which, in turn, allows for multiple UAs to operate simultaneously in the airspace.

The multithreaded data manager subsystem communicates with the various data producing systems/sensors using BSD-style sockets; using similar operations on different ports. Once a connection to a client 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. 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.

B. Sensor Fusion

The sensor fusion subsystem (a thread in the data manager subsystem) correlates the sensed incoming targets to a known set of targets. Each sensor supplies detected target information to the correlating algorithm. If the detected target has an attached flight or aircraft identification number, this number is used to match the detected target to the data of all known targets stored in the base map. If there is no match to the identification number, the detected target is passed through a positional correlation algorithm that compares the detected target's position and positional uncertainty with the advected positions of all known targets. If there is still no match, the detected target is then added to the base map as a new target. Current efforts are underway to try to incorporate a Kalman filter advection routine and comparison of projected non-aerobatic maneuvering volumes to enhance the target correlation algorithms, but these efforts have not yet been fully integrated.

C. System Monitor

The System Monitor (a thread in the data manager subsystem) provides the RCC operator with information regarding system status. It uses data collected from the various subsystems to evaluate the health of each copy of the system. The system monitor provides the RCC operator with a simple display indicating if a switch to a different redundant copy of the system is necessary.

V. Conclusions

We were 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. In addition, the desired IDS would provide for timely response to airspace activities that impact pilot situational awareness, as a study conducted by Arik-Quang, et al [16] implies that response time may be a more sensitive index of situational awareness than the accuracy of responses. And, while the developed IDSs appear to meet the needs of our constituents and feedback from them has been very positive, there are still concerns to be addressed.

The first is the consideration of non-cooperative aircraft. We are aware that our system may have to deal with aircraft tracked by 2-D radar and/or aircraft tracked by 3-D radar. In both cases, the current icon for non-cooperative aircraft is acceptable. However, it is expected that the risk mitigation system will have to be adapted in accordance with whatever radars get purchased. A second consideration is a formal human factors –based evaluation of the IDSs. A paper by Bi and Balakrishnan [17] suggests that there are two common strategies for arranging windows and this finding has not gone unnoticed by the developers. The RSO workstation is configured such that the application requiring interaction activities (RCC IDS) is displayed on the monitor in the center of the workstation; while applications only passively displaying information, such as the Doppler weather radar display and system health monitor are provided on a second monitor on the right side. As cited by Bi and Balakrishnan, this strategy aims to facilitate the interaction with the applications within the focal region.

A second concern is the prevention of “radar-assisted collision”. However, a study by Parasuraman, et al [18] found that an operator can experience diminished situational awareness when it is delegated to either automation or to other human operators and a study by Dwye1 and Landry [19] claimed that the two most likely options for separation assurance and collision avoidance are automation monitoring and supervisory control (airspace management), with the assumption that some responsibility for separation assurance and collision avoidance would remain with the pilot and a controller (RSO in our case). Therefore, we do not plan to implement any automatic collision assistance system at this time.

A third consideration is compliance with DO-178B/C. A fourth consideration is the broadcasting of an ADS-B signal for the UA via the GPAR-RMS system (effectively making the UA a “cooperative” aircraft). These concerns will be addressed as the project progresses.

Finally, early efforts in simulation of unavailable sensors have not only aided in development of dependant systems, but provided a controlled environment for system testing and potentially training operators on an offline system.

Acknowledgment

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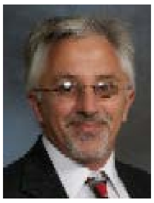
Author Biographies



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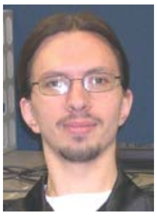

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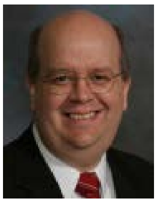

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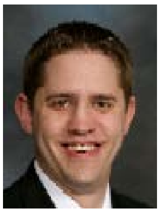

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