An important real case considered is the case of Malta FIR [11]. This case is analyzed as a reference for the integration of RPA into non-segregated airspace. Also, the drills performed in the airspace of Barranquilla FIR, in Colombia are presented, where the operation and integration of two MQ9B aircraft into a non-segregated airspace were done. The coordination of the operation mentioned was executed by one of the paper writers.

Consequently, a proposal of actions to integrate RPAS to the air traffic of manned aircraft is presented. The proposal aforesaid is composed of three points that are described, including examples of the actions needed to be carried out. The three points are: First, the reclassification of current airspaces, which could keep current names, but must change their navigation requirements for manned aircraft and RPAS. Second, the need to classify the RPA systems under the PBN concept, and the third of them is associated with the definition and standardization of the contingency and emergency procedures for those systems.

As a conclusion, the impact of those actions on air navigation safety is analyzed. Another finding is that air traffic controllers have been pushed into the background in the process of integration to RPA Systems into non-segregated airspaces, as they are the main actors of this operational scenery of manned and remotely piloted aircraft.

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[8] Colombian Civil Aviation Authority, General requirements for airworthiness and operations for RPAS, 2015.

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[10] G. Forte, on line: http://www.infodefensa.com/mundo/2016/05/20/noticia-sagem-comienza-fabricar-patroller-ejercito-frances.html

[11] R. Sant, RPA Operations in the Malta FIR 2015.

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Leonardo Gomez, was born in Soata (Colombia). He is Electronical Engineer, Engineering Projects Manager and he has a Master degree on Telecommunications Engineering at the National University of Colombia. Currently he is the leader of the Research Group "GINA", of Colombian Civil Aviation Authority. Also he is professor at the Aeronautical Engineering Faculty of the San Buenaventura University in Bogota (Colombia). John Romero, co-author, is Air traffic controller at the Air traffic control center in Barranquilla city. He has participated in the execution of RPAS integration succesfull procedures into non-segregated airspaces in Barranquilla FIR (Colombia), wich were the base to writing this paper.

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**Abstract**

**166**

**Experimental prototype for remote tower systems design**

**Student**

**Yes, Full-time graduate**

*Jaime Lopez-Araquistain, Universidad Politecnica de Madrid*

**Topic Area(s)**

Airport & Airspace Optimization/Operations, CNS Integration, Consolidation and Miniaturization, Surveillance & Situational Awareness

Concern about efficiency, comfortability and security in air transports, and especially in airports, has boosted in last decades caused by the increase of passenger traffic and the number of operations. Accordingly, priority in control services and air traffic management is to facilitate efficient and safe transits of aircraft, with improvements in navigation and in procedures on ground. These processes are carried out in control towers, essential elements in the functionality of the current airports.

But control towers are expensive, so small and medium airports face an economic dilemma. To overcome that problem, remote towers, allowing to operate these airports by air traffic controllers from a bigger airport or controlling several small airports form a central facility [1][2][3], are appearing. This solution consists of transmitting images in real time from cameras placed in the airport to a tower located far away. Ornskoldsvik Airport in Sweden was the world's first remote control tower.

This paper describes a model built in Universidad Politecnica de Madrid for the research in remote control tower technologies and operations for advanced monitoring in airports. The idea is to use this model to test concepts of surveillance and air traffic monitoring, and see how could be extended to airports of low or medium size. The model is composed of a hybrid system encompassing a physical model of the aircraft implemented using drones, and a simulation of other operations, synchronized with real time operations, using high fidelity trajectory simulation and augmented reality techniques. This hybrid simulation-physical prototype has been created in order to help design and validate the key elements of the system: sensor systems, surveillance data-fusion chain, traffic management systems (separation, conflict detection and resolution, etc.).

This prototype can be divided into five main different functionalities. The most basic of these processes is a high-fidelity trajectory prediction engine, whose objective is to predict/calculate trajectories both for simulation and for ATM procedures.

Some of the outputs of the engine are used to design actual physical drone operations. Drone operations are then translated to a suitable flight plan and communicated to the drone through MAVLink protocol. So, another key functionality of the prototype is the communication and piloting of the drones fleet to perform theseoperations.

The third functionality is the development of a surveillance/vision system capable of emulating remote tower visualization, and of performing the tracking of unmanned aerial vehicles. This is performed with several cameras and other sensors, working synchronously and in real time. For this, images, captured in real time, are processed by a color detection and tracking algorithm and stereoscopic vision so position of the drone in 3D is obtained. Results are shown in a video wall. Also, the GPS coordinates received from the drone are integrated in the data fusion process.

The fourth functionality is the emulation of virtual aircraft/drones using virtual/augmented reality models. In this case we can emulate synthetically video flows that define different scenarios with simulated targets, where the background can be synthetic or real. The simulated aircraft trajectories follow realistic paths calculated using our high-fidelity trajectory prediction engine. We built tools to integrate the real-time surveillance/vision system with this emulation, so that hybrid real/simulated scenarios may be defined. Using this process, we can check the performance of the whole system in different scenarios changing the targets, the background, the weather, etc., enabling the analysis of risky situations, and also aiding to controller training.

The final functionality or set of functionalities are those related to the implementation of ATM/ATC decision support tools, which are the subject of experimentation of the prototype. For instance, different separation, or conflict detection and resolution processes may be assessed in the system.

The resulting prototype can be used as a design/training tool to gain expertise in the creation of remote towers, helping the developed solutions allow guaranteeing an efficient service (hopefully reducing reaction times, increasing safety, reducing the stress and workload of the controller, etc.).

The paper will describe the prototype in detail, the implementation constraints and the complete HW/SW deployment to model a remote tower scenario.

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[2] Papenfuss, A.; Friedrich, M., "Head up only – A design concept to enable multiple remote tower operations," Digital Avionics Systems Conference (DASC)

[3] Eier, D; Gringinger, E; Klopf, M., "Semantic information management in a SWIM enabled remote

tower environment," ICNS 2016

Jaime Lopez-Araquistain got a telecommunications engineer from the Universidad Politecnica de Madrid in 2013. He is currently pursuing his Ph.D at the same university. He is working in SESAR projects related to airport surface surveillance and Time Based Separation. His research interests are signal processing and data fusion.

| Abstract | Sharing the Skies (Safely): Near Term Perspective on sUAS Integration in the NAS | Student |
|---|---|---|
| 167 | | No |

*Allison Ferguson, PrecisionHawk*

**Topic Area(s)**

UAS Integration in the NAS

Commercial UAS operating in the US airspace will grow substantially over the next 5 years, creating a need for smart, scalable integration into the NAS. To fully enable the pending influx of commercial UAS operations requires a blend of operational and technological improvements while preserving the current level of service to other operators within the system; specifically to make UAS operation in the NAS as routine and as structured as possible throughout all aspects of the flight. Accommodating these unique needs in all phases of flight is critical, beginning with flight planning through in-flight monitoring including separation assurance, where needed, ensures sUAS mission accomplishment within the fabric of the most complex airspace system in the world.

To satisfy the need for scalability in the future, this workflow will have to function without significant changes across multiple existing airspace classes, supporting an assortment of equipage types and performance characteristics, while enabling different mission deliverables (i.e. not necessarily only point-to-point travel). This means that that early stage decisions must be made carefully to avoid creating additional constraints that would require major changes as the system expands into new scenarios. Since sUAS creates a level of dynamic operations never before experienced within structured airspace, restrictions against operations that may be allowable in the future should be in place only until sufficient data has been collected such that risk-based decisions can be made and implemented. Constructing this solution poses a number of questions that need careful consideration to augment the system as it is currently designed.

First, when considering any approach to integration, especially near-term ones, it is crucial that any additional workload on ATC be minimized, and the workforce have total confidence in the operational aspects. The primary responsibility of ATC is for the safe, orderly, and expeditious flow of air traffic, which requires equipment interface for many functions. However, any requirement for additional tasks must be incorporated with workload and functionality considered as key factors. A successful integration strategy will capture the requirements of ATC by applying a scalable solution which captures the needs of the local and national mission specifics of the affected ATC operation. For instance, the needs of an ATC Tower with local operational responsibility below 3000 feet, are substantially different than those of an approach control. Most importantly, requirements must dovetail with existing ATC processes, providing intent, predictability, and recall capability.

Secondly, information sharing strategies are foundational elements of any integration scheme. In a traffic management approach, it is crucial that all parties be able to access the common data (i.e. ground obstacle data, sUAS position and trajectory) to make decisions both at the planning stage and during operations. Ideally, a long-term approach will involve a data lake of information with access to different components within the repository governed by the needs of the end-user, from hobbyist to government. This tactic will allow for securing of sensitive information while still permitting the sUAS traffic management system to resolve user issues without needlessly burdening ATC.

For sUAS in particular, the proposed commercial operations often occur in Class G airspace, and incursions into controlled airspace would often be limited to Class D or Class C. These operations will have

their own traffic management needs which will evolve over time (via NASA's proposed UTM system, for example), but interaction with ATC in these scenarios could be limited to a reasonable notification and authorization protocol. Therefore, to accommodate at least those operations that meet the above description, a near-term approach is paramount. As a foundational element of such an approach, PrecisionHawk has developed the LATAS platform, a combined set of geospatial, software, and hardware tools to facilitate safe UAS operation. Operating over the world-wide cellular networks and satellites, the LATAS platform integrates technologies enabling scalable airspace management to provide necessary services such as geofencing and aircraft tracking, into a flexible and accessible service package. Engineered with privacy and security protections, LATAS promotes compliance with privacy and data security requirements.

As previously described, defining and meeting the diverse needs of ATC will be a critical step in designing a successful system. Tetra Tech AMT has significant experience incorporating new technologies, processes, data sharing techniques, and IT solutions into critical FAA Programs such as Navigation Services and Performance Based Navigation. As a diverse team with common operational interests, PrecisionHawk and Tetra Tech AMT will give their perspective on potential solutions to sUAS integration based on current research and past experience.

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Abstract is a joint effort and submission from two companies:

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**Abstract**

**168**

# Simulation and Analysis of Standard Operating Procedures (SOPs)

**Student**

**Yes, Full-time graduate**

*Houda Kerkoub, Center for Air Transportation Systems Research at George Mason University*

**Topic Area(s)**

UAS Integration in the NAS, Safe & Secure Air Transportation Systems, Air Traffic Management

Safety-critical, time-sensitive operational environments, such as the flight-deck of an airliner, mission control for space flight, satellite control, and air traffic flow management rely on Standard Operating Procedures (SOPs) to conduct normal, non-normal and emergency operations.

SOPs, and the associated training, provide the means for operators to reliably perform complex tasks in a reliable manner in time compressed/safety-critical situations. In particular SOP must be robust to variance in the Allowable Operational Time Window (AOTW) (due to aircraft performance, environmental conditions, air traffic, etc. ) as well as variances in the the Time on Procedure (due to workload, fatigue, interruptions etc.) resulting in a failure to complete the procedure.

In addition to safety, the SOPs also ensure standardized performance and allow pairing of crew members without the need for crew specific familiarization training. In this way, SOPs are the "glue" that holds the system operation together.

Airline industry SOPs are developed according to industry standards such as ICAO & FAA (see Barshi, et. al, 2016). Both the design and review processes rely on subject-matter-experts for defining the operator actions that constitute the building blocks of the procedure, and vetting the procedures. SOPs are tested in the simulator for a handful of likely scenarios. In some cases, the SOP is tested in a fixed-base or motion-base simulator using a small sample of line-pilots. Due to limits in time and resources the SOP vetting in the simulator cannot be exhaustive and cover all combinations of procedure scenarios including variances in aircraft performance

(e.g. acceleration during takeoff under different weight, wind, etc. conditions) and in the presence of interruptions (e.g. ATC communications).

Advancements in technology have enables the application of Computer-Aided Design (CAD) and Model-based System Engineering (MBSE) to most engineering disciplines. CAD tools now ensure the mating of physical components, functioning of data interfaces, and appropriate system behavior and performance.

Despite the importance of SOPs for safe and efficient operation, there is no industry accepted CAD-like tool that provides a formal, structured method for modeling the procedure's interaction between operator and the machine.

This paper describes a CAD-like tool for Simulation and Analysis of Standard Operating Procedures (SASOP). The tool can be used by airline, military, and space flight-crews operating in time-sensitive environments, to perform computer-aided design and evaluation of Standard Operating Procedures (SOPs).

The SASOP tool has 4 functions. (1) The SOP is captured in a GUI that allows the designer to assign distributions to each SOP action according to the action type. (Kourdali, Sherry, In Review; Sherry & Kourdali, 2016). (2) The distributions for each action type are generated from flight data (FDM/FOQA) and stored in a Time Distribution Data-base. (3) The SOP actions are stored in the SOP data-base. (4) The SOP performance is generated by Monte Carlo simulation. The results of the vulnerability analysis and simulation of the SOP are displayed on the SASOP GUI. The percentage of times the Buffer Time distribution is below zero indicates the probability of the procedure not being completed with the Allowable Operational Time Window (AOTW). When this probability is less than agreed upon threshold (e.g. 0.015), the SOP is considered validated.

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Houda Kerkoub Kourdali is a Certified Flight Instructor with a License from the Royal Jordanian Air Academy. She holds an Airline Transport Pilot License from Oxford Aviation Academy, Great Britain AND British Aerospace (BAe) Europe, Spain. She has a total of 1100 hours of aeronautical experience. Mrs. Kourdali has Bachelor of Science in Systems Engineering with a concentration in Air Transportation Systems from George Mason University. Mrs Kourdali is working on her Masters of Science in Systems Engineering, George Mason University.

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**Abstract 169**

## Airspace Sectorization Optimization Using Fast-Time Simulation of Air Traffic Controller's Workload

**Student No**

*Premysl Volf, Czech Technical University in Prague*

**Topic Area(s)**

Airport & Airspace Optimization/Operations, Air Traffic Management

The air-traffic management (ATM) is a very complex system. Increasing air traffic and demands on efficiency of the systems requires improvement of the system. One of possible improvements is to optimize sectorization of the airspace to improve selected metrics. Each proposed sectorization has to be evaluated to determine impact of changes to current system. Evaluation usually consists of several approaches to cover all aspects of the change – e.g. expert groups, statistical data, real-time simulations, fast-time simulations, etc.

The paper presents fast-time simulation system AgentFly used to evaluate proposed variants of sectorization. The simulation is able to compute and evaluate metrics important for a sectorization selection. Metrics could be related to aircraft, whole sector, and air traffic controller, e.g. horizontal and vertical profile of an aircraft, number of aircraft in each sector, number of entries in selected time intervals, occupied flight levels, number of hand-offs, arrivals, departures, and workload of the air traffic controller. The fast-time simulation is able to run a lot of different scenarios and configurations, compute evaluation metrics. Based on results, selected scenarios and configurations can be used for real-time simulations to measure additional data.

The AgentFly system is a high-fidelity multi-agent-based simulator for a simulation of runway-to-runway air traffic management. It includes precise simulation of aircraft based on Base of Aircraft Data (BADA) Performance model, trajectory planning respecting horizontal and vertical flight profile and rules and restriction

related to flight plan, and detailed model of a human operator, specifically air traffic controller (ATC) and pilot. The model of air traffic controller is based on Multiple Resource Theory (MRT) using VCAP (visual, cognitive, auditory, and psychomotor) resources. It models activities (e.g. hand-off, collision detection and resolution, clearance) triggered by actual traffic in simulated sector. Each activity has assigned duration and level of used resourced. Workload of the ATC is computed as composition of these activities. This approach allows to model artificial situations and configurations where cannot be used estimates based on statistical data.

The paper presents case study of an application of described approach for a sectorization of the airspace of the Czech Republic. Selected proposed sectorizations was initially created by Czech ANSP. Scenarios were simulated using current and predicted future air traffic. The AgentFly gathers data related to aircraft and ATC to compute requested metrics. Simulation outputs was directly used for evaluation and comparison of proposed sectorizations.

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Premysl Volf is a senior researcher in the Agent Technology Center at the Department of Computer Science, Czech Technical University in Prague.

His research is focused on distributed large-scale high-fidelity simulation in the air traffic domain, simulation and modeling of behavior of human air traffic controllers and distributed cooperative algorithms used for collision avoidance in the air traffic control. Premysl is the leader of the AgentFly project and participated in many related projects.

Premysl holds master degree in Software Systems from Faculty of Mathematics and Physics at Charles University in Prague and PhD degree in Artificial Intelligence and Biocybernetics from Czech Technical University in Prague.

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**Abstract** 170

**Balancing Security and Performance within EMS Profiles**

**Student** No

*Peter Huang, Concepts Beyond*

**Topic Area(s)**

Cyber Security, Future Communications

The emergence of Enterprise Messaging Systems (EMS) as a powerful message-oriented middleware has facilitated aviation data sharing at an agency level. Projects such as Mini Global(MG) and International Interoperability Harmonization & Validation (IIH&V) strive to take the next step to investigate aviation data exchange at a global level through established exchange models and ICAO provisions. One area that has not been focused on by these models and provisions is security, specifically application layer security. Within the FAA, this issue was recently addressed with security profiles that were developed for use by NAS systems and services. This paper provides an analysis of security and performance tests performed utilizing the implementation of these security profiles. In addition, the paper will provide recommendations for EMS security at a global level based on results from the performance tests. These recommendations may service as guidance for the future development of Global Enterprise Messaging Service (GEMS) or as additional provisions for ICAO Flight and Flow Information for a Collaborative Environment (FF-ICE).

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Peter Huang is a software / systems engineer with a background in computer security. His current work at Concepts Beyond spans across many future-seeking subject within FAA NextGen.

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**Abstract**

**The Bridge to Space: CNS Technology for High Altitude Operations**

**Student**

**171** **No**

*Ruth Stilwell, Aerospace Policy Solutions, LLC*

**Topic Area(s)**

Special Topic/Other, UAS Integration in the NAS, Operations Above FL600

The US Class E airspace from 60,000 to 100,000 feet is currently designed for military operations, however, new commercial operations, including unmanned free balloons, high endurance UAS and commercial space operations (including manned free balloons) are beginning to occupy that airspace, and will require air traffic services. Technological developments in CNS will not only enable IFR services in this airspace, but could provide a CNS roadmap for the complete integration of commercial space operations in the National Airspace System.

Current technologies are being validated to support aircraft surveillance to 100,000 MSL. Communication with these vehicles is currently achieved with a variety of ground-based and satellite-based systems. Transitioning from barometric to GPS altimetry in this stratum may provide opportunities for vertical separation standards that maximize airspace efficiency and access and provides concepts that may prove valuable for services above this airspace.

High endurance, high altitude, unmanned operations are sufficiently different from current aviation operational concepts and have significantly diverse mission needs to warrant an examination of new operational concepts for ultra high airspace. This paper will consider new concepts for separation and planning that may be necessary to provide IFR services in this airspace. The development of CNS standards and airspace planning are not divorced partners. The mission needs of unmanned operators, coupled with new capabilities offered by technical innovation should be exploited to maximize the opportunities presented by new entrants seeing to occupy currently uncongested airspace. This is a unique opportunity in aviation history.

In taking the clean slate approach to the airspace management above FL600, the recognition of commercial space operations as airspace users allows for integrated design concepts, to include CNS standards appropriate for all user types.

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Dr. Ruth Stilwell is the Executive Director of Aerospace Policy Solutions LLC,

A 25-year air traffic controller, experienced labor leader and policy expert, Dr. Stilwell is also an accomplished researcher and lecturer. Her numerous publications and presentations cover a wide range of space and aviation, public safety, human factors, administration, financing, and industry reform topics. Dr. Stilwell's specific areas of expertise include: integrating commercial space operations in civil airspace; projecting air traffic controller retirement and staffing requirements; and FAA funding and financing structures.

Dr. Stilwell served from 2010-2015 as the industry expert representing air traffic controllers on the International Civil Aviation Organization (ICAO) Air Navigation Commission in Montreal. Her air traffic control experience includes 25 years at the Miami Air Route Traffic Control Center, two years as liaison to the FAA Requirements Service, and six years as Executive Vice President of the National Air Traffic Controllers Association.

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**Abstract** **Economic Impact of Level-Altitude Flight Segments** **Student**

**172** **No**

*Benjamin Levy, MCR, LLC*

**Topic Area(s)**

Air Traffic Management, Airport & Airspace Optimization/Operations

Current air traffic procedures use data from real-time ground-based surveillance systems. Air traffic controllers manage aircraft with these surveillance data, and rely upon assigned level-altitudes in separating and sequencing of aircraft. The use of crossing restrictions causes sub-optimal, level-altitude flight segments for extended distances, which results in excess fuel burn, excess flight duration, and higher airline operating costs. Design and use of uninterrupted climb and descent profiles will recover the lost operating costs.

We estimated the impact of level-altitude flight on aircraft operating at airports in the New York City (NYC) area (e.g., EWR, JFK, LGA Airports) for FY2015. Results indicate that, in FY2015, approximately 204,000 minutes and 10 million kg fuel were lost due to use of level-altitude procedures for aircraft operations at the NYC-area airports. The study also provides preliminary estimates of the burden of level-altitude flight sections for aircraft that operated in FY2015 at other major terminal radar control (TRACON) facilities in the US: Atlanta (A80), Charlotte (CLT), Chicago (C90), Dallas-Ft Worth (D10), and Northern California (NCT). In total, for the TRACONS studied in this work, the estimated annual penalty of level-altitude operations is 775,000 minutes and 53 million kg fuel.

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Dr. Benjamin Levy works for MCR, LLC as a senior operations research analyst. His work supports the US FAA in their Acquisition Management System process. Prior to joining MCR, he ran his own company, was the manager of the Operations Research group in the Advanced Development Division of Sensis Corporation, worked at MITRE/CAASD, and earned his Ph.D. at the University of Maryland/College Park. He is the author of more than 20 papers and presentations relating to air traffic management, and has been past General and Technical Chair for the DASC and ICNS conferences.

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**Abstract 174**

## Algorithms Using a LOST Protocol in Complex UAS Operations

**Student No**

*Dieter Eier, Frequentis*

**Topic Area(s)**

UAS Integration in the NAS, Future Communications

Soon our National Airspace will be flooded with flying unmanned aerial systems (UAS) from fixed wing drones with aircraft-similar flight characteristics to multi-rotor UAS the flight pattern of which allow 3-dimensional flight with ultra-small turn radius. Further down the road, single drones will make way for fleets of drones generating so-called drone swarms.

Responsible integration into the national airspace (NAS) is paramount. This contribution discusses the use of a location-to-service translation (LOST) concept to provide seamless operation of drones in the NAS. Multiple communication links between drones and the ground control station (GRS) are used to establish positive control of the UAS. For drones operating in controlled airspace, additional communications links are required to provide data and voice communications to the air traffic control system. This intercommunication may include links into en-route centers, TRACONs or ATC towers. Additional interconnectivities to other drone operators should be available to allow coordination of operation and self-separation.

NASA's Unmanned Aircraft System (UAS) Traffic Management (UTM) concept envisions a system where drone operators would file drone flight plans defining their volumes and duration of operation, which in turn are coordinated by the NASA UTM back end service. This coordination aims at providing safety net functions to drone operators and the possibility to send messages directly to drone operators as well as policing directives.

The LOST service concept supports not only the NASA UTM concept by drone platforms it also provides a seamless service platform to host data as well as voice services. This paper further discusses the concept of location based services (LBS) in support of the LOST concept which allows the mapping between the user location, the service boundary, and associated system service. Besides the mapping within the sector boundaries, the LOST concept for UAS operations also addresses the transition between sectors and possible

implementations.

The paper ends with the discussion of the enrichment of the UTM concept from a location/surveillance management system to a fully-fledged extension of our National Airspace ATM system.

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Dieter Eier is the Vice President, Business Development for FREQUENTIS USA. Mr. Eier has over two decades of experience in high availability communications systems for mission critical applications. He is a renown expert in voice-over-IP solutions for air traffic control applications. Most recently Mr. Eier led the Frequentis contribution to NASA's UTM drone flight tests in Reno, Nevada.

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| Abstract | Investigation of Tropospheric Attenuations for UAS Beyond-Line-of-Sight Communications, and the ITU-R Tropospheric Attenuation Model | Student |
|---|---|---|
| 175 | | No |

*David Matolak, University of South Carolina*

**Topic Area(s)**

UAS Integration in the NAS, Future Communications, Commercial, Military, and Consumer UAS

The growth in use of unmanned aircraft systems (UAS) will require highly reliable control and non-payload communication (CNPC) links to ensure safety. In cases where UAS are beyond the range of a communication ground station (GS), an alternative communication path must be employed. The primary candidate for such beyond-line-of-sight (BLOS) links is an air-satellite (AS) link. Wireless communication between a satellite and GS or satellite and aircraft can suffer severe fading due to tropospheric effects, and hence these effects must be quantified as accurately as possible for reliable CNPC link design. Although such tropospheric attenuation modeling is relatively mature, these attenuations have not been accurately modeled as a function of aircraft altitude, nor has attenuation variability been thoroughly studied. In this paper, tropospheric attenuation modeling for AS links is described and analyzed. After providing a brief discussion on background and related literature, we include a short description of the characteristics of tropospheric attenuation and its causes: hydrometeors and gases, and tropospheric inhomogeneities that cause scintillation. We discuss each attenuation component individually, and describe the most popular time series attenuation model from the ITU-R Recommendation P.1853. This model is based upon both atmospheric physics and several decades of experimental data from locations worldwide. We also describe a simulation implementation of this model, and provide example attenuation results and statistics for two temperate climate locations: Columbia, SC, and Cleveland, OH. We employ frequencies that are being considered for UAS BLOS links in the Ku band (12 GHz) and the Ka band (30 GHz). The impact of tropospheric attenuation on BLOS UAS communication performance is described, including a discussion of attenuation variability and link margins. Future work and implications for BLOS link design and network operation are also described.

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David W. Matolak received the B.S. degree from Penn. State, M.S. degree from Univ. of Massachusetts, and Ph.D. degree from the Univ. of Virginia, all in electrical engineering. He has over 20 years of experience in communication system research, development, design, and deployment, with private companies, government institutions, and academia, including AT&T Bell Labs, L3 Communication Systems, MITRE, and Lockheed Martin. He has published over 180 papers, has eight patents, and expertise in wireless channel characterization, spread spectrum, networking, and their application in civil and military terrestrial, aeronautical, and satellite communication systems. He was with Ohio University from 1999-2012, and is now with the University of South Carolina. Prof. Matolak is a member of Eta Kappa Nu, Sigma Xi, the AIAA, AAAS, URSI, and a senior member of IEEE.

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| Abstract | Cooperative Surveillance for Drones | Student |
|---|---|---|

*Olivier Rea, Thales*

**Topic Area(s)**

UAS Integration in the NAS, Air Traffic Management, Commercial, Military, and Consumer UAS

The fast growing RPAS/UAS market and the foreseen density of drones flying in the NAS will very shortly require infrastructure, equipment's and systems to support their operations (particularly for professional drones) while supporting safety and security constraints; cooperative surveillance being a pillar to fill these requirements.

Considering that the cost for non-cooperative surveillance will, at the beginning, cover only limited size areas that have particular risks and that the malicious drones will represent a limited number of infringements compared to human error and technical issues, the cooperative surveillance of drones will enable the provision of advanced services to drone operators which will increase their mission efficiency and will support authorities to manage the airspace in a safe and secure way. This is particularly true for very demanding missions (BVLOS and BRLOS) but also for reinforcing geo-fencing, protecting the area from non-intentionally intrusion and detecting a drone switching from cooperative behavior to non-cooperative behavior (conformance).

Unlike manned aviation, the model of drones (size, payload, etc.) and their operations (from agronomy to parcel deliveries) can already be counted in thousands and this number will increase in the coming years. As a consequence, considering only one or two technologies like in aviation (SSR and ADS-B for example) might not be suitable, indeed a drone with a 10kg payload flying in urban areas will not require and be equipped with the same system than a drone with a 250gr payload flying in the countryside.

We also foresee that at mid-term airspace will be divided into areas (similar to class principle), a said type of area having specific equipment requirements to access to it (related to the safety and security risks).

Even if a lot of solutions are still in R&D phase, we have already seen various potential and very promising offers on the market::

- ADS-B
- 3G/4G/5G network (with numerous commonalities with connected cars R&D)
- GNSS
- FLARM
- IoT network
- Etc.

From this initial list we can note the following trends:

- Re-use of what has been done for manned aviation and to adapt it to drones (miniaturization, etc.)
- R&D is shared with other domains (telecom, connected cars, etc.)
- Most of these technologies try to cover both secondary surveillance and detect & avoid requirements

It is interesting to notice that the current technologies do not require deploying new ground infrastructure as they rely either on manned aviation technologies or on shared infrastructure with other markets. It will help to speed up the technology insertion by limiting the infrastructure investments.

Coming back to the requirements for using cooperative surveillance efficiently, the tracker system is an important piece of the puzzle. A tracker is obviously not dedicated to handle a single technology, today in aviation we are used to gathering, correlating and fusing surveillance data coming from different type of sensors and sources.

However, this has been done only because the in-use cooperative surveillance sensors data are standardized in term of format and the range of performance are well known. The range of performance is

certified in aviation, in order to allow the tracker to manage separation and help to enhance airspace capacity.

This point out two critical needs:

- The standardization of the data format for cooperative surveillance
- A certain level of certification (not necessarily up to aviation certification in order to keep reasonable costs)

As soon as a technology has a standardized data format and a certified range of performance, a cooperative surveillance tracker can accommodate its outputs.

Allowing the cohabitation of different technologies will enable innovation and propose to end users a various range of solutions with a different level of price and performance. It will also allow the regulator to set up different requirements according to risks (from light requirements for no risk areas to aviation certified equipment for high risks areas). Again, with the right level of standardization and a sufficient level of certification, the tracker can be agnostic from the sensors and enable the use of any sensor compliant to norms.

In a nutshell:

- Cooperative surveillance for drones is needed to support the rapid growth of the market as it will actively contribute to mission efficiency, safety and security of the airspace
- Technologies will come from various markets (aviation but not only)
- Trackers will help to manage this heterogeneity and as such will play a critical role in enabling innovation

To achieve this objective, it requires standardization and to set up appropriate norm and certification

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Oliver Rea is Unmanned Traffic Management Solution Manager for Thales, Air Traffic Management. His responsibilities include co-leading a sub-group of the French Civil Drone Council, working on identification and localization technologies. Rea also leads Eurocae Working Group 105 – Unmanned Aircraft Systems which includes standardization activities on identification and geo-fencing for drones. Further, Rea is a member of the Programme Committee of the EUROCONTROL Agency Research Team.

Prior to his current role, Rea worked in the Thales Programme Management Office of SESAR and managed ATM Products and R&D Investments. Previous to this, he worked for the Air Command & Control Systems division of Thales.

Rea received a BA in Embedded Systems from ESIEE, France, and an MSc in Business from Kedge Business School, France.

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| **Abstract** | **Integrating Space Operations Surveillance Data into an Air Traffic Management Simulation Environment** | **Student** |
|---|---|---|
| **177** | | **No** |

*Thomas St. Clair, The MITRE Corporation*

**Topic Area(s)**

Surveillance & Situational Awareness, CNS Integration, Consolidation and Miniaturization, Airport & Airspace Optimization/Operations, Integration of Space Launch and Reentry Operations into the National Airspace System

The Federal Aviation Administration (FAA) is faced with the challenge of safely and efficiently integrating the growing number of space launch and reentry operations into the National Airspace System (NAS) while minimizing impacts on NAS users. Due, in part, to the lack of real-time surveillance of space operations, the FAA must segregate large amounts of airspace (called aircraft hazard areas [AHAs]) to maintain safety. Impacted NAS users must plan and reroute around AHAs, which can cost those users additional time and fuel. Minimizing these impacts and making space operations more efficient requires more flexible and

agile Air Traffic Control operations, which require real-time surveillance of space launch and reentry operations.

The FAA is currently examining options for acquiring real-time space launch and reentry operations surveillance data, but it also needs a simulation environment that integrates surveillance data from space operations (either real or simulated) with traditional air traffic data (real or simulated) in a flexible and adaptable lab environment. Such a capability would allow the FAA to rapidly prototype, explore, test, validate, and perform Human-in-the-Loop (HITL) simulations of more efficient and integrated space launch and reentry operations in the NAS.

The MITRE Corporation's Center for Advanced Aviation System Development (MITRE CAASD) is working to integrate space launch and reentry surveillance data into a variety of MITRE's simulation and airspace design tools and capabilities with an initial focus on MITRE's Integration Demonstration and Experimentation for Aeronautics (IDEA) Lab and the MITRE Enterprise for Space Analysis (MESA) Lab. Integrating space operations surveillance data into these tools would provide an environment for all parties to share the experience of a proposed concept, discuss their perspectives on workload, communication, safety, efficiency, roles and responsibilities, as well as other topics. Visualization, iterative changes, and evaluations allow the parties to come to an agreement quickly and lead to faster implementation of beneficial enhancements. This paper discusses MITRE's current efforts to bring together a broad set of integrated capabilities for Human-in-the-Loop (HITL) simulations, demonstrations, and visualizations incorporating the use of space operations surveillance data.

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Thomas St. Clair is a Lead Aviation Systems Engineer for The MITRE Corporation. He has 28 years of experience working for the FAA in En Route Air Traffic Control, Traffic Flow Management (TFM), and En Route and TFM automation systems requirements, development, testing, and implementation. He spent 15 years working in TFM operations at the FAA Air Traffic Control System Command Center. His work at MITRE includes integration of space launch and reentry operations into the National Airspace System and TFM concepts and system development. He is a commercial instrument pilot with a Bachelor of Science degree in Aeronautical Industrial Technology from Arizona State University.

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UAS classification, UAS Mission Classification, and demand forecasts. It is clear that similar work is being carried out in several other forums such as FAA, RTCA, EUROCAE, ICAO, and ITU. Our goal is to consider what has already been done by these standards and regulatory organizations, provide an independent assessment and fill in the gaps where necessary. In particular, our emphasis is on features of the UAS and missions that affect the requirements and architecture.

We consider the UAS classifications by DoD, ASTM, EUROCAE, and RTCA and propose a modified version that allows both designers and regulators to easily identify a UAS class. It includes both the physical characteristics such as weight and usage, such as visual line of sight (VLOS) and above-ground level (AGL). EUROCAE, ITU, and RTCA have also classified UAS missions. The UAS volume forecast is the next important consideration that affects the CNS requirements. We study the forecast from ITU, RTCA, and FAA and adopt the latest forecast that seems most realistic. Some of the previous forecasts were based on extending the manned aircrafts growth which is not appropriate since the UAS applications are numerous and different from the manned aircrafts.

This paper reviews these architectures and classifications, and presents a new classification building on our UAS classes that includes the level of autonomy. In particular, our emphasis is on features of the UAS and missions that affect the requirements and architecture. These considerations have helped us set a number of requirements for CNS, which are reported in a companion paper.

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Fred Templin is a computer networking R&D professional with focus on Internet protocol and data link specifications, operating system networking internals, networked applications, and networked platforms. He has in-depth experience in Internet networking and security architectures for unmanned air systems, civil aviation, tactical military, space-based systems and enterprise network applications. Mr. Templin has been an active contributor to the Internet Engineering Task Force (IETF) since 1999. He is currently a senior research engineer in Boeing Research & Technology (BR&T) since May 2005, where he is an Associate Technical Fellow of the Boeing Company.

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**Abstract** **182**

## Assessing Vertical Flight Profiles in the US and Europe

**Student** **No**

*Marc Meekma, Federal Aviation Administration (FAA)*

**Topic Area(s)**

Performance-Based CNS/ATM, Air Traffic Management, Airport & Airspace Optimization/Operations

Air traffic management (ATM) analysis efforts today are focusing more on trajectory-based operations as a basis for better air traffic control and modernization. Developing proper indicators that correctly characterize these operations has been a key activity for both EUROCONTROL and the FAA. Teams in both organizations are working jointly towards harmonizing the generation of existing metrics, so as to allow for a more analogous comparison between ATM in Europe and in the USA. Harmonization efforts have been challenging due to numerous factors, e.g. missing data or processes that cannot be easily changed due to various system dependencies.

One such metric under consideration is vertical flight efficiency, which measures the amount of level flight occurring after the Top of Descent (ToD) until an aircraft reaches its destination airport. Various causes of level flight include weather conditions, airport capacity, airspace design and restrictions, and air traffic flow control. A higher level flight value (in terms of the number of level-offs, the total time flown level, or the total level distance) is an indicator of reduced vertical flight efficiency, since a gradual, consistent descent without level-offs from the ToD to the runway is seen as ideal. Benefits of a continuous descent operation (CDO), also referred to as an optimized profile descent (OPD), include better fuel economy, reduced noise, and less pollution.

Since EUROCONTROL and the FAA had previously examined vertical flight efficiency independent of

each other, methodologies for generating the metric differed. EUROCONTROL utilized a vertical speed threshold to detect level segments of flight, while the FAA used a combination of vertical distance and time limits to identify level-offs. Harmonization efforts led to a more robust methodology that leverages facets from both approaches. Thus, results are not only more reliable, but the singular process allows the organizations to better compare vertical flight efficiencies across the Atlantic.

After finalizing the implementation of the harmonized methodology, trajectories for flights arriving into the top 34 airports in Europe and the top 34 airports in the USA were evaluated for vertical flight efficiency. This assessment was conducted for the two year period from 2015 through 2016, in order to analyze time trends. Various metrics related to vertical flight efficiency were analyzed, e.g. the average level distance (time) per flight by arrival airport and the total level distance (time) by arrival airport.

While numerous vertical flight efficiency metrics were assessed, several metrics, in particular, warranted a closer examination. Level flight grouped by arrival bearing and runway allowed the research teams to identify specific traffic flows exhibiting unique vertical flight characteristics. These set of flights and associated approach procedures were further evaluated to determine root causes. Another metric that merited a closer look was the average potential fuel savings per flight, provided that the flown level-offs had been removed from the trajectory. This metric helped quantify the benefit of continuous descent operations and represents the amount of time and fuel that could be saved with unlimited capacity and optimal trajectories.

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Marc Meekma is an operations research analyst with Office of Performance Analysis at the Federal Aviation Administration (FAA). He studied electrical engineering at Valparaiso University and information systems management at the University of Erlangen-Nuremberg in Germany before getting involved in aviation. He has been supporting FAA initiatives for over five years and is currently involved in collaborating with stakeholders on vertical flight efficiency measures.

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| Abstract | Challenges and Possibilities for Integrating UAS Operations in Mixed Manned and Unmanned Airspace | Student |
|---|---|---|
| 183 | | No |

*Leila Ribeiro, MITRE Corporation*

**Topic Area(s)**

UAS Integration in the NAS, Air Traffic Management

The Federal Aviation Administration's (FAA) long-term vision for full and safe integration of Unmanned Aircraft Systems (UAS) into the National Airspace System (NAS) includes UAS operations in airspace utilized today by manned aircraft in a non-segregated, mixed environment where manned and unmanned aircraft share the air space and the NAS air traffic services and resources as needed, with appropriate technology, infrastructure, procedures and policies in place to ensure safety and efficiency of operations.

There are plenty of challenges that will need to be addressed in order to allow smooth operations in a fully integrated manned and unmanned environment. These challenges include ensuring reliable command, control and obstacle avoidance capabilities, communications with air-traffic-services as needed, and supporting automation, flight information and mobility management. We also discuss the need for procedures, training and policies that ensure safety of operations in the integrated environment.

This paper provides an overview of these key challenges, discusses potential approaches and opportunities to overcome them, and identifies key trade-offs expected when considering different alternatives.

Approved for Public Release; Distribution Unlimited. Case Number 17-0169

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Leila Ribeiro is a Principal Communications Engineer at MITRE Corporation, at the Center for Advanced Aviation System Development (CAASD). She currently oversees multidisciplinary work on variety of domains related to the National Airspace System.

As part of her work with MITRE, Leila has led several technical activities related to aeronautical communications. Prior to joining MITRE in 2009, she worked in the wireless industry developing solutions for wireless networks design and optimization. Leila holds a Ph.D. degree in Electrical Engineering from Virginia Tech.

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**Abstract 184** | **Internet Protocol Suite for Safety Services: Progress toward a Validated Standard** | **Student No**

*Michael Olive, Honeywell*

**Topic Area(s)**

Future Communications, Safe & Secure Air Transportation Systems, Air Traffic Management

Current regional implementations and deployments of aircraft-to-ground data communications are based on existing, aviation-unique Aircraft Communications Addressing and Reporting System (ACARS) and Aeronautical Telecommunications Network (ATN) communication protocols. While regional objectives are being met, Air Traffic Management stakeholders recognize the benefits of enhancing the communications infrastructure to support emerging advanced services while striving towards global data communications harmonization and interoperability. To support that objective, the International Civil Aviation Organization (ICAO) is specifying a new network infrastructure for safety services based on the Internet Protocol Suite (IPS). IPS will leverage commercial Internet Protocol (IP) technologies, profiled and tailored to meet the challenging requirements of aeronautical safety services.

Using a preliminary IPS specification, ICAO Doc. 9896, Boeing and Honeywell previously conducted initial trials using Communications Management Unit (CMU) avionics and prototype IPS software to demonstrate the technical feasibility of IPS. The most recent validation efforts focused on end-to-end performance tests that leverage the operational INMARSAT Swift Broadband satellite communications network, as well as initial flight trials of IPS using an existing SITA Very High Frequency (VHF) Digital Link (VDL) Mode 2 ground station, modified to support IPS traffic. While much has been learned, on-going and expanding efforts by the research partners will explore other areas such as multilink, mobility, security and transition strategies.

Industry stakeholders recognize that further standardization work is necessary to complete the preliminary IPS specification and to develop companion specifications and guidance. To that end, ICAO, RTCA, and the Airlines Electronics Engineering Committee (AEEC) have initiated complementary standardization efforts to fully define the technical provisions necessary to support globally interoperable IPS implementations and deployments. The ongoing Boeing-Honeywell trials and results-to-date represent a key input to these standardization efforts through initial validation of the IPS technical provisions as well as the identification of potential technical gaps. And, as future work addresses open technical issues, the IPS prototype offers an environment for assessing technical alternatives under consideration by the standardization organizations.

This paper will present an overview of a prototype IPS environment developed by Boeing and Honeywell; summarize the results of recent IPS end-to-end performance testing; present an overview of in-progress and planned IPS industry standardization efforts; and describe expected contributions of the IPS prototype activity to standardization and validation activities.

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Michael Olive is Technology Fellow within Honeywell Aerospace Advanced Technology, with over 35 years of experience. He holds a Master of Science degree in Computer Science from the Johns Hopkins University and a Bachelor of Science degree in Electrical Engineering from Cornell University.

Mr. Olive leads Honeywell's Aeronautical Communication/Datalink Technology Council and serves as the principal investigator for several Honeywell-internal advanced datalink technology R&D projects. In addition, Mr. Olive participates actively on several aviation industry standards committees, including the International Civil Aviation Organization (ICAO) Communications Panel (CP) Project Team I and AEEC Network

Infrastructure and Security (NIS) Subcommittee.

Me. Olive holds several patents in communications and information security, and he is the recipient of the Airline Avionics Institute (AAI) Volare Award.

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**Abstract 185**

**Designing a Robust Detect and Avoid Alerting Function**

**Student No**

*Fabrice Kunzi, General Atomcis Aeronautical Systems, Inc.*

**Topic Area(s)**

Surveillance & Situational Awareness, UAS Integration in the NAS

In the context of the development of the Minimum Operational Performance Standards (MOPS) for UAS Detect and Avoid (DAA) systems by RTCA Special Committee 228 (SC-228), three new traffic-related alerts have been defined: Preventive, Corrective and Warning. Those alerts are issued to support the pilot in not violating the Well Clear Boundary (WCB), which was also defined as part of the work in SC-228. The algorithm that is used to make the alerting decision uses the information received from sensors onboard the aircraft, and must make a decision - based on a prediction of future aircraft motion - whether to issue an alert. Similar to the Traffic Alert and Collision Avoidance System (TCAS) the Conflict Prediction and Display System (CPDS) designed by General Atomics Aeronautical Systems, Inc. (GA-ASI), uses a combination of future predicted spatial and temporal separation to make this decision.

The correctness of the declaration of an alert depends on the accuracy of the predicted future spatial and temporal separations. This accuracy in turn depends on the match between the true trajectories and the model(s) and input assumptions used to estimate them by extrapolating from the current state into the future. Furthermore, the accuracy depends on the match between the true position and velocities (direction and magnitude) and the measured/estimated positions and velocities. The error characteristics of the latter differ between sensor types. For example, in case closure-rate is estimated from subsequent range measurements (as performed in case of Mode-S and radar), the accuracy of the estimate of Time to Closest Point of Approach (TCPA) increases with an increase in closure-rate at a given level of error in the measurement. On the other hand, the effect of the same level of error on the estimated direction of the relative velocity will be larger for larger closure-rates, and thus the error in the estimate of the Distance at the Closest Point of Approach (DCPA) will be larger. Depending upon the choice of alerting thresholds in the algorithms, the result of limited accuracy of the predictions will be an increase in incorrect alerts and/or an increase in missed- or late- alert declarations. Furthermore, the likelihood of re-alerting on the same intruder increases. From an operational perspective both are undesirable system behaviors.

To achieve an acceptable balance between missed/late alerts and incorrect alerts and minimize the occurrence of re-alerts on the same target, mitigations are needed that increase the robustness against the aforementioned types of measurement and associated prediction errors.

The proposed paper will discuss what methods were applied to CPDS to improve robustness to the above-mentioned measurement errors as well as their effectiveness at reducing undesirable system behaviors. Using examples, it will be illustrated how the use of time to co-altitude, data filtering, alert filtering, alert hysteresis and sensor specific adaptive thresholds can be applied to increase the robustness of the alerting function. The examples will use the MOPS test cases and sample encounter tracks to compare performance before and after the implementation of the various filtering and thresholding approaches.

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Dr. Fabrice Kunzi currently serves as Staff Engineer, UAS Civil Airspace Integration, for the Aircraft Systems business unit of General Atomics Aeronautical Systems, Inc. (GA-ASI) where he leads the development of airborne collision avoidance systems.

Dr. Kunzi's primary interests are in the design and operation of air transportation systems, aircraft operations, and the interactions between such systems and their human operators. Funded by the FAA, his

Master's and Ph.D. projects developed the international standard for the Traffic Situation Awareness ADS-B application (TAS-A). TAS-A provides reliable conflict alerting for all operations, including the airport pattern, and is designed as an upgrade to today's legacy airborne conflict alerting systems such as TAS or TCAS I. His Ph.D. thesis was awarded the 2014 RTCA's William E. Jackson Award.

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| Abstract | Multi-Mode Reconfigurable Software Defined Radio (SDR) Architecture for Avionic Applications | Student |
|---|---|---|
| 187 | | Yes, Full-time graduate |

*Abdessamad Amrhar, LASSENA*

**Topic Area(s)**

CNS Integration, Consolidation and Miniaturization, Future Communications, Air Traffic Management

Reducing SWaP-C (Size, Weight, Power and Cost) is a major concern in aeronautical equipment design. This was the main drive to migrate from a Federated design to Integrated Modular Avionics (IMA) architecture. As the former was based on the concept that avionic applications are handled by at least one self-contained hardware module (with its own processing unit and power supply) that ease the certification procedure and maintenance. However, the unnecessary redundancy that comes with these modules puts a burden on the aircraft with each addition of a new system. Additionally, federated modules struggle to adapt to the continued evolution of Communication, Navigation and Surveillance (CNS) and Air Traffic Management (ATM) standard.

In contrast, the IMA concept is based on resources sharing. This results in a noticeable reduction in cable length, processing units and power supplies. Furthermore, this approach is characterized by favoring code reusability, portability, dynamic and static reconfigurability (respectively when aircraft is in flight and when a function is not used), legacy equipment interfacing and the usage of Commercial off-the-shelf (COTS) hardware.

A similar approach could be adopted for aeronautical communication equipment to harness the benefits of IMA by using a Software Defined Radio (SDR) architecture. Offloading the hardware from waveform generation and/or decoding enables integration of multiple radio modules in a single hardware module. The resulting multi-mode avionic architecture will allow computational resources, RF front-end and antenna sharing with the potential to relocate the SDR anywhere.

The aim of this work is to demonstrate a proof-of-concept architecture highlighting the integration of five avionic systems consisting of four CNS/ATM commercially existing applications and one custom-made, namely: Transponder Mode-S (TMS), Automatic Dependent Surveillance - Broadcast (ADS-B) OUT, ADS-B IN, Distance Measuring Equipment (DME) and an in-flight connectivity radio service equipment referred as Wide-Band Radio (WBR). Featuring dynamic radio system reconfiguration in a low-cost COTS SDR platform, dynamic resources reallocation with minimum downtime while complying with their respective MOPS (minimum operational performance standard).

The SDR platform is a hardware module composed of an RF transceiver, a Field-programmable gate array (FPGA) chip and a General-Purpose Computer (GPC). The entirety of the radio application is running on GPC while the FPGA handles processing-heavy tasks like filtering, rate changing, channel synchronization and signal impairment compensation. Currently, the design considers only hardware related impairment (i.e. DC-offset, LO leakage, IQ imbalance, phase noise, and frequency offset) as the effect of most of these imperfections could be reduced through signal processing algorithms. Furthermore, a synchronization mechanism is implemented (on FPGA) for time-sensitive applications like DME. Since the aim is to demonstrate the feasibility, a regular (not real-time) Linux-based OS was used.

A proof-of-concept demonstrator was implemented on a COTS SDR platform (PicoSDR 2x2E) allowing 2 integrated avionic subsystems to operate simultaneously. Besides, the provided Application Programming Interface (API) adds a layer of abstraction, which increases code reusability. In order to verify the compliance of each integrated avionic subsystem with their respective MOPS requirement, multiple tests are performed using certified equipment. The preliminary experimental results show that dynamic reconfiguration and

resource allocation does not hinder the system performance, hence confirms the claimed feasibility. Nevertheless, there are some requirements that can only be met with additional Hardware (i.e. an integrated RF front-end). Finally, after the design and integration of that integrated RF front-end, the next step will consist to evaluate the performance of the proposed multi-standard avionic architecture in real flight-test scenarios.

Abdessamad Amrhar is currently a graduate research student at Ecole de Technologie Supérieure of Montréal (Canada) and a member of LASSENA laboratory. Has a bachelor of science in electrical engineering and computer science form Ecole National des Science Appliquées of Marrakech (Morocco). His research interests are: embedded systems, avionics, and digital communication. And he is working on design and implementation multi-mode software defined radio system for avionics.

| **Abstract** | **Multi-Sensor Fusion for UAS Ground-Based Detect and Avoid Capability** | **Student** |
|---|---|---|
| **188** | | **No** |

*Raymond Young, NUAIR Alliance*

**Topic Area(s)**

UAS Integration in the NAS, Surveillance & Situational Awareness, Air Traffic Management

The New York Griffiss International Airport Unmanned Aircraft Systems (UAS) Test Site is evaluating next-generation UAS ground-based detect and avoid (GBDAA) systems capable of enabling extended UAS beyond visual line-of-sight (BVLOS) operations in terminal area and transition airspace. The Griffiss UAS Test Site has set up an initial instrumented test range for air traffic surveillance, extending from the Griffiss airport and its Class D airspace to about 40 NM to the north. The Griffiss test range instrumentation system employs a combination of wide area multilateration, ADS-B, and primary radar to track cooperative and noncooperative air traffic. The system is designed to operate in combination with other air traffic surveillance sensors, including airborne detect-and-avoid sensors. Griffiss test range instrumentation supports live air traffic surveillance, with an ability to incorporate simulated air traffic. An extensive data collection system supports the test range. The data collection, storage, and analysis system supports evaluation of the safety case for UAS integration into terminal and transition airspace. The paper discusses GBDAA accuracy and reliability requirements, the ability to extend the system to track very low level (VLL) traffic, as well as to support live, virtual and constructive simulation in distributed environments (LVC-DE). The paper also discusses the role of Griffiss UAS research in RTCA Special Committee 228 development of UAS standards.

Dr. Ray Young is Technical Director for the Northeast UAS Airspace Integration Research Alliance (NUAIR), a consortium of over 90 organizations. NUAIR serves as Test Site Manager for Griffiss International Airport, in Rome, New York, one of seven national UAS Test Sites designated by the Federal Aviation Administration in 2013. Before joining NUAIR, he was director of the Saab Sensis Reston Technology Center, supporting NASA and FAA R&D projects involving integration of advanced aircraft, including unmanned aircraft, into the NextGen air transportation system. Earlier in his career he served as a policy executive in the U.S. Department of Transportation He received an ROTC commission as a U.S. Army artillery officer. Ray holds a Ph.D. in civil and environmental engineering from UNLV, an MBA from Harvard Business School, and a BSEE from Princeton. He is an AIAA associate fellow.

| Abstract | Fuel Burn Estimation Modeling for the Evaluation of NextGen Operations | Student |
|---|---|---|
| 189 | | No |

*Gabriele Enea, MITRE CAASD*

**Topic Area(s)**

Climate Change and Aviation Weather, Air Traffic Management

One of the main focuses of the National Airspace System (NAS) modernization effort being led by the Federal Aviation Administration (FAA) is the reduction of emissionsâ€™ impact of the aviation system. Emissions are directly related to the amount of fuel burnt by aircraft operating in the NAS. Projects, such as Metroplex and performance-based navigation (PBN), promise to deliver some of the desired reductions that will allow more efficient operations than today. To evaluate the performance of these projects, the FAA needs an accurate approach to calculate fuel consumption from recorded four-dimensional trajectories. This approach, applied to trajectories flown both under legacy and new operational paradigms, provides the tool to estimate the achieved fuel reduction benefits. The problem is that, per single trajectory, the benefits that are being measured are often small and sometimes of the same magnitude of the error in the estimation technique. For this purpose, several fuel estimation models, internal and external to the FAA, have been evaluated and their performance on a common set of flights has been compared to provide with recommendations on the pros and cons of each model.

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Dr. Gabriele Enea has extensive experience in analyzing the operations of the global air transportation system under the NextGen and SESAR frameworks. As a researcher in the Air Traffic Management (ATM) field, he has developed knowledge in airport operations analysis, delays modeling, data-link communications, airlines operations, and air transportation simulation. Through his work for the NASA Ames Research Center he has established himself as an expert in the field of Trajectory Prediction (TP) and the decision support tools based on the TP process. During the 10+ years working on ATM projects he has developed the ability to lead groups of researchers while also to participate as a team player. Dr. Enea has written and presented technical papers in air transportation-related topics.

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| Abstract | Enabling Access to Centralised UTM Services through GSM Network | Student |
|---|---|---|
| 191 | | No |

*Emre Koyuncu, Istanbul Technical University*

**Topic Area(s)**

UAS Integration in the NAS, Air Traffic Management

The growing rate of "drone" market and applicability size of many types of drones is extensive, and it is clear that drones will eventually operate in all levels of airspace with a diverse degree of interaction with other airspace users, even people "sitting in their backyards." The drone industry, through associated programs within NextGen and SESAR in U.S. and Europe, seeks new mechanisms for an unmanned traffic management (UTM) system enabling to share of airspace of manned and unmanned systems and allowing small UAVs safely operate in urban areas, without posing an unacceptable danger to other airspace users, or people and property on the ground. By focusing the small drones use in monitoring crops, wildlife, forest fires, and urban traffic, as well as package delivery, aerial photography, and movie production, it is necessary to seek for "fast-track" and low-cost approaches that rely on available technologies capable of achieving goals of safe and efficient UTM. The aim is to reduce the costs and lead-time to the market for new solutions to avoid that their unavailability could become a major barrier to further development of the industry.

In this work, we present a low-cost small onboard UTM system allowing UAV operators to access to a various type of centralized services for e-identification, flight tracking, dynamic geofencing and automated flight permission with multi-level link redundancy that meets the requirements of future flight operations for small UAVs. The presented low-cost system provides ADS-B like positional information broadcasting through GSM (i.e. 4G or LTE) out-link, which makes small UAVs visible for traffic controllers and other operators enabling continuous tracking and collaborative sense-and-avoid. The system further provides short-range information broadcasting, which uses standardized 24bit data frame, through a wireless link for multi-level redundancy. Moreover, GSM based localization based on triangulation provides additional geolocation information for the UAV. A centralized ground station, which is a UTM "cloud server," provides tactical data such as digital elevation map, geolocations for buildings, no-fly-zones based on aeronautical information (including NOTAMs), weather and traffic information. The e-identification and registration are done with automated procedures through GSM data-link where each drone with proper ID is associated wit a mobile phone of the operator/owner. This binding allows UTM ground server to send text messages or cellular notifications to operator, if a further interaction is needed, e.g. sending such text message "you are flying in a restricted area with XX ID, change your heading toward XX" or "due to the expected XX mph wind, we strongly recommend to terminate your flight for your safety." The presented onboard system might enable heartbeat signal checking or link binding checking and automated landing or parachute/air-cushion deployment. Moreover, through geolocation sharing, the system allows hard flight terminate in case detects unwanted behaviors such as trespassing no-fly zones and not responding to the warning for a while.

The experimental onboard UTM is deployed in a small quadrotor drone, and a web-based UTM ground server with GSM link is designed to perform proof-of-concept experiments.

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Emre Koyuncu is an Assistant Professor at Istanbul Technical University in the Department of Aeronautical Engineering. He has received his B.Sc. degree in Electrical Engineering from ITU in 2005, M.Sc. degree in Mechatronics Engineering from ITU in 2008, and Ph.D. degree in Aerospace Engineering from ITU in 2015. He was a visiting researcher at Boeing Research and Technology of Europe during 2013-2014, and Massachusetts Institute of Technology (MIT), Aero-Astro Department during 2014-2015. In his Ph.D. research, he has received SESAR WP-E HALA! Research Network Ph.D. fellowship. Prof. Koyuncu has developed optimized trajectory design methods, which rely on large-scale data analysis and stochastic search methods. He also designed an in-cockpit decision support systems utilizing these algorithms. His current research focuses on; developing planning algorithms; airborne conflict avoidance and resolution; high-level autonomy in air traffic control; flight-deck decision support.

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**Abstract**
**192**

## Design and Implementation of a Wideband Radio using Software Defined Radio for Avionic Applications

**Student**
**Yes, Full-time graduate**

*Eric Zhang, École de Technologie Supérieure*

**Topic Area(s)**

Future Communications, CNS Integration, Consolidation and Miniaturization, Air Traffic Management

This paper presents the design and implementation of a Wideband Radio (WBR) in a Software Defined Radio (SDR) multi-system avionic architecture able to send and receive channel data in real time, via direct link or using a satellite link, from/to an Aircraft (A/C) and a Ground Station (GS). The implemented WBR characteristics share resources with other avionic systems, into a single piece of re-programmable hardware, intends to facilitate In-Flight Connectivity (IFC) services, drone evolution asking for a rapid transition towards a modernization of the Communications, Navigation and Surveillance (CNS) standards in future systems as Next Generation Data Communication of the NextGen program [1]. Boeing and Airbus acknowledge that Service Oriented Avionics (SOA) architecture will be an important asset of tomorrow’s air traffic management (ATM) systems [2]. This architecture is based on SDR to be used as a flexible and modular multi-avionic communication system. The goal of the SOA Architecture is to be able to deliver critical flight related data such as flight management, flight control and cockpit Human Machine Interface (HMI) as well as non-critical

passenger data such as entertainment. The proposed WBR architecture is to be able to provide these avionic communication data and to enable robust satellite link via relay station such as SatCom, for example. The main challenges of this work are: to minimize the size, weight, power and cost (SWap-C) requirements of future avionic equipments implementing a flexible solution over SDR; and to establish a suitable robust communication link using Adaptive Coding Modulation (ACM) and a BER better than 10-5.

Early results in laboratory and in flight tests using standard flight test instrumentation under real operating conditions in order to characterize protocols compliance and system performance, demonstrate the feasibility of the system as well as provide some performance metrics. The design of the radio is done with GNU Radio, an open source software widely used in digital signal processing for software defined radios. The Wideband Radio is implemented on Nutaq's PicoSDR™ platform. The performance analysis was performed on the channel emulator RT Logic T400 which can emulates real life conditions in order to evaluate the performances of the radio. Hence, the paper presents the results of the performance analysis obtained in laboratory with the channel emulator as result of the implementation and operation of the Wideband Radio. Finally, the results obtained in laboratory will provide important insights on areas to improve and to eventually prepare for more challenging flight tests.

[1] Next Generation Air Transportation System is an Air Traffic Control Modernization program led by the Federal Aviation Administration (FAA) in United States of America (USA).

[2] EUROCONTROL/FAA, "Final Conclusions and Recommendations Reports," Action Plan 17, Nov. 2007.

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Eric Zhang received the B.S degree in microelectronic engineering from Université du Québec à Montréal (UQAM), Montreal in 2014. He is currently pursuing a M.S degree in electrical engineering from École de Technologie Supérieure, Montreal. His research interests include software defined radio, adaptive coding and modulation, digital signal processing and analog-to-digital converter.

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**Abstract**
**195**

## Efficient Dynamic Frequency Allocation Algorithms for Unmanned Aircraft System

**Student**
**Yes, Part-time graduate**

*Ahmed Saied Abdel monsef abdel aziz, Egyptian Civil Aviation Authority*

**Topic Area(s)**

UAS Integration in the NAS, CNS Integration, Consolidation and Miniaturization, Future Communications

Unmanned aircraft systems (UAS) consist of the unmanned aircraft (UA), ground control station (GCS), and the communication links that connects the two element. Since the pilot in command is at the GCS and remote from the UA, communications is critical for aircraft command and control. In order to incorporate the UAS into the airspace system, other communication is necessary such as the UA relaying messages from air traffic control (ATC) to the GCS pilot and vice-versa. Detect, sense, and avoid capabilities may depend on data being sent back to the GCS for processing and pilot-in-the-loop evasive maneuvers.

So UAS requires sufficient new radio spectrum to support the data bandwidth for UA command, control, and remote sense and avoid, and payload communication.

Previous Studies show that spectrum is underutilized for most of the time. According to the FCC in the US, there is a large variation in the use of spectrum bands in space and time. The utilization varies from 15% to 85% indicating large portions of usable spectrum are underutilized or 'vacant'. Such unused spectrum is referred to as spectrum white spaces.

As the spectrum becomes congested day by day, researchers come out with the idea to use the idle or available license channel to secondary user. The crucial part is to assign the available channels to the priority user. So Many approaches had been made by the researchers and most of them were using Dynamic Channel Assignment. It's because of the high flexibility of the scheme and effective spectrum management performance.

In this paper I discussed

-The spectrum allocation based on graph coloring theory include A color sensitive graph coloring (CSGC) spectrum allocation algorithm and parallel spectrum allocation algorithm.

-how the parallel algorithm can reduce the CSGC algorithm Allocation time, and how CSGC algorithm based on users bandwidth requirement can improve the total system utilization and the secondary users satisfaction rate.

Finally, my intention is to improve the total spectrum reward, the satisfaction rate of secondary user and reduce time overhead as much as possible comparing with traditional CSGC and PARALLEL algorithm by introduce a new parallel algorithm based on user's bandwidth requirement.

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It is my pleasure to write for you my interest to join your Conference and becomes one of the participate in this avenue .I have worked as “air defense officer” for about three years at Egyptian army, “Communication engineer " for about one year in (NTG Clarity - Etisalat ) and then I transferred to work at the aviation industry as “CNS systems engineer - Safety Oversight Inspector ". I am responsible about measuring safety and risk level at the air navigation field according to ICAO SARPs and providing the optimum solutions to raise the competency levels of the employees and enhancing safety level by minimizing risk level.

About my latest Achievements during my work at Egyptian Civil Aviation Authority: - Nominated to be Focal point of Egypt in MANDD (MID Air Navigation Deficiency Database) and focal point of Egypt during ICAO USOAP/CMA audit program on November 2014 for ANSAbout my latest Achievements during my work at Egyptian Civil Aviation Authority:

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| **Abstract** | **A Flexible Architecture for Secure "ACARS over IP" supporting both legacy and new ACARS features** | **Student** |
|---|---|---|
| **196** | | **No** |

*Terry Davis, AtF Consulting*

**Topic Area(s)**

Future Communications, Cyber Security, CNS Integration, Consolidation and Miniaturization

ACARS over IP has three major architectural challenges:

1- Appropriate and different cyber security for each message type and destination domain.

2- An ability to support both legacy aircraft ACARS and developing new ACARS functionality.

3- Providing these 'ACARS over IP' functions without requiring major upgrades to existing aircraft.

As industry moves to develop the ACARS over IP technology, it has the opportunity to create a system that will equally well support legacy aircraft ACARS communication and new or updated aircraft that support advanced ACARS functionality as well as providing appropriate level cyber security for ACARS message communications to each of the aircraft domains (AC, AIS, PIES, and PEDS).

Existing aircraft that already have IP connectivity to any domain, could easily support new ACARS over IP capability with probably as little as 5 pounds of new weight and no impacts at all to the existing CMUs.

In addition, ACARS messages could readily be prioritized by urgency in the transmission over the IP link as well as encrypted and/or authentication by their aircraft domain destination requirements for cyber security. And the architecture allows ACARS messaging to be continuously updated with new features or message without impacting in-service aircraft.

Finally, the architecture allows the inclusion of 'cyber protection mechanisms' that can be literally updated overnight to block new cyber threats that may evolve over the life of the aircraft.

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Terry L. Davis has a BS in Engineering and an MS in Strategic Planning for Critical Infrastructure. He is currently consulting on communications and cyber security for government and industry as well as researching new advanced cyber technologies.

At the Boeing prior to retiring, he worked in super computer networking, aircraft simulation, network programming, Internet design, and cyber security. He served as the first Boeing Corporate Security Architect in the late 90's, in "Connexion by Boeing" as Chief Network Engineer and CIO. then at BCA on advanced Communications, Network, and Security Architecture until his retirement in 2010. Prior to joining Boeing, he worked with the US government for various agencies in the Departments of Defense, State, Interior, and Energy. He holds 8 patents with two pending. He is a registered professional engineer in Oklahoma, Colorado, and Washington. He is active with IEEE, ARINC/SAE, ICAO, IETF, and ICANN.

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**Abstract 197**

**A Secure and Trusted Protocol for UAV Enhancing Safety of On-Ground Airplanes**

**Student No**

*Raja Naeem Akram, Information Security Group, Royal Holloway, University of London*

**Topic Area(s)**

Cyber Security, Future Communications, Surveillance & Situational Awareness

Airplanes are expensive vehicles that needs to minimize their time stayed parked on-ground of airports to be profitable. However, for safety reasons, lot of maintenance procedures are required before an aircraft can leave the airport for a new flight. Some of them might be achieved in a faster and more efficient ways if they might be done with the support of unmanned aerial vehicles (UAV).

For instance, an UAV can be used to securely collect data required for maintenance and that were recorded during the previous flight by different systems (like sensors of Aircraft Data Networks), to examine the fuselage, to send some parameters to dedicated systems, etc.In this paper we present a secure and trusted protocol to enable a drone to communicate with dedicated wireless systems embedded in airplanes (like the future avionics wireless networks).

In order our proposal that an UAV assists the maintenance staff in safety operations the protocol has to provide some guarantee. Thus it first provides the assurance that all communicating entities can trust each other, and can trust their internal (secure) software and hardware states. Second, the protocol has to establish a fair key exchange between all communicating entities so as to provide a secure channel to exchange the securely data.The proposed protocol is implemented and performance measurements are presented based on this implementation. In addition, we formally verify our proposed protocol using CasperFDR.

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Raja Naeem Akram is currently a Post Doctoral research assistant at Information Security Group (ISG), Smart Card Centre, Royal Holloway, University of London. He is currently involved with research projects involving avionics and banking sector. Previously, he worked as the Research Fellow at the Cyber Security Lab, University of Waikato, New Zealand. At the Cyber Security Lab, he was involved with the user centric security and privacy paradigms. Before joining the University of Waikato, he worked as a Senior Research Fellow at Edinburgh Napier University. During his work at the Edinburgh Napier University, he worked on the RatTrap project. The RatTrap project was involved in designing a suite of preventive technologies to avoid online fraud â€“ especially in the online affiliate marketing. He obtained his PhD in Information Security from Royal Holloway, University of London.

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**Abstract 198** | **An Efficient Protocol for UAS Security** | **Student No**

*Raja Naeem Akram, Information Security Group, Royal Holloway, University of London*

**Topic Area(s)**Cyber Security, Future Communications, Commercial, Military, and Consumer UAS

Drones becoming widely deployed for a large range of applications, the security of the collected data and of communications in unmanned aerial systems (UAS) is a paramount. Sensed data are often sensitive and must be ciphered before storage in persistent memory embedded on the unmanned aerial vehicles (UAV). When communication with the ground station (GS) is possible ciphered data are then sent to it.This way to proceed minimizes the chance for an adversary to retrieve original plaintext data even if he succeeds to get a physical access to the storage of an UAV. However, he can still try to retrieve the keys used to protect communication and stored data.In this paper, we propose an efficient protocol to establish cryptographic keys used for internal storage of data and to securely communicate them to the GS.

The protocol only relies on use of an ephemeral keys generation scheme combined with two famous cryptographic primitives (AES and SHA) that are well-known to be efficient and resistant against an adversary with a high attack potential.The protocol is dealing with the aforementioned issues.It ensures the perfect forward secrecy and thus, by design, if an strong adversary succeeds to access to any key present in memory of a captured UAV, he will not be able to decrypt any of the stored data (present and past).The proposed protocol has been implemented and tested both on real UAV and a GS of our experimental UAS test-bed. It is compared with other similar protocols in terms of security and performance. A formal analysis is carried out on the protocol to ascertain its security.

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Raja Naeem Akram is currently a Post Doctoral research assistant at Information Security Group (ISG), Smart Card Centre, Royal Holloway, University of London. He is currently involved with research projects involving avionics and banking sector. Previously, he worked as the Research Fellow at the Cyber Security Lab, University of Waikato, New Zealand. At the Cyber Security Lab, he was involved with the user centric security and privacy paradigms. Before joining the University of Waikato, he worked as a Senior Research Fellow at Edinburgh Napier University. During his work at the Edinburgh Napier University, he worked on the RatTrap project. The RatTrap project was involved in designing a suite of preventive technologies to avoid online fraud - especially in the online affiliate marketing. He obtained his PhD in Information Security from Royal Holloway, University of London.

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**Abstract 199** | **Recent Implementations and Challenges of an IP network for Air traffic Management In Colombia** | **Student Yes, Full-time graduate**

*Oscar Pico, National University of Colombia*

**Topic Area(s)**Future Communications, Performance-Based CNS/ATM, Air Traffic Management

This paper describes the recent implementations and future challenges of an aeronautical telecommunications network (ATN) for the air navigation services provider in Colombia. The paper presents a general model of aeronautical telecommunications network (ATN) based on the operational concept of the International Civil Aviation Organization (ICAO) embodied in its guidance documents and regulatory material, describing the most commonly used generic applications, showing an analytical comparison between the current system and the proposed ATN concept. Also is reviewed the national perspective and planning of the development of CNS/ATM (Communications, Navigation, Surveillance/Air Traffic Management) technologies and procedures, a special emphasis to the description of the national air space organization and its volume of traffic is given. The recent implementations for the improved telecommunications systems are treated in detail.

Finally examines future trends for the development of the aeronautical telecommunications network (ATN) in the country, its contributions to the operational safety and conclusions are made about the raised topics.

Oscar Pico, is Electronics Engineer graduated from District University of Bogotá. Telecommunications Specialist degree in Engineering. Master of Engineering on Telecommunications at the National University of Colombia.He was in charge of the development of many projects in CNS/ATM systems for the Special Administrative Unit of Civil Aeronautics of Colombia (UAEAC), the civil aviation authority and Air Navigation Services provider in Colombia. Actually is in charge of the project for the local ATN development in Colombia

| Abstract | Automatic Dependent Surveillance - Broadcast for Surveillance of Unmanned Aircraft System | Student |
|---|---|---|
| 200 | | No |

*Taehwan Cho, George Washigton University / Space Policy Institute*

**Topic Area(s)**

Satellite-Based Navigation & APNT, Surveillance & Situational Awareness, Air Traffic Management

Unmanned Aircraft System(UAS) must fly only with IFR(Instrument Flight Rule), not with VFR (Visual Flight Rule). Therefore, air surveillance systems such as radar are very important. However, the radar provides aircrafts position every 5 ~ 10 seconds, also if the aircrafts size is small, it is difficult to obtain the aircraft position.

Automatic Dependent Surveillance - Broadcast(ADS-B) is a new technology that is redefining the paradigm of communications, navigation, and surveillance in air traffic management today. ADS-B allows UAS pilots and air traffic controllers to see and control aircraft with more precision over a far larger percentage of the Earth's surface than has ever been possible before. According to recent studies, the position accuracy of conventional radar is 200 m. However, ADS-B achieves a position accuracy of 33 m. Also, the ADS-B provides aircrafts position every 1 second.

To enhance the position accuracy of ADS-B, an improved aircraft tracking method is proposed. The method can not only improves the aircraft tracking performance but also track aircraft continually when the aircraft position data losses occur.

Taehwan Cho is Republic of Korea Air Force (ROKAF) officer, his rank is major with 15 years of experience in Air Force. He received a Ph. D. in electronic engineering from Inha University, Korea, His research area is satellite-based aviation system such as ADS-B, SBAS, and GBAS. He worked for space policy branch of ROKAF HQ in 2014 and department of electronic engineering of ROKAF Academy as an assistant professor from 2015 to 2016. He has been a visiting scholar at Space Policy Institute since December.

| Abstract | Detection Probability Estimation Model for Wide Area Multilateration | Student |
|---|---|---|
| 201 | | No |

*Junichi Naganawa, Electronic Navigation Research Institute*

**Topic Area(s)**

Surveillance & Situational Awareness

Wide Area Multilateration (WAM) is a promising en-route surveillance technology in the near future. Compared with the conventional radars, the WAM can provide better accuracy and shorter update rate. However, theoretical models of the update rate have not been established yet.

This makes it difficult to optimize the receiver constellation. Also, this means that there is no theoretical guarantee that the WAM is better than the radars in the update rate. Therefore, this paper models the probability of detection which is closely related to the update rate, as a first step toward update rate modeling.

To do so, measurement result by an experimental WAM system is analyzed.

The experimental system covers Kanto airspace which includes Tokyo. The effects of 1090-signal interference, radio propagation, grouping, and localization algorithm on the probability of detection were quantitatively analyzed. Models of each factor is then discussed, and prediction by the model is compared with the measurement.

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Junichi Naganawa received the D.Eng. degree from the Tokyo Institute of Technology, Tokyo, Japan, in 2015. Since 2015, he has been with the Electronic Navigation Research Institute, the National Institute of Maritime, Port and Aviation Technology, Tokyo, Japan. His research interest includes aeronautical communication/surveillance, air-ground radio propagation, and numerical electromagnetics.

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**Abstract** **202**

**Flight Test of ADS-B Technology for Winged Reusable Launch Vehicle Re-entry**

**Student** **No**

*Nickolas Demidovich, FAA - Office of Commercial Space Transporation*

**Topic Area(s)**

Special Topic/Other, Surveillance & Situational Awareness, CNS Integration, Consolidation and Miniaturization, Commercial Space - Ops over 60Kft

With the emergence of frequent commercial space transportation operations, the airspace integration challenges of such operations must be addressed. Various tracking technologies can provide both operators, ranges/launch sites as well as the FAA situational awareness capabilities that reduce the airspace volumes that must be 'sterilized' for the vehicle ascent and descent . The longer term goal is full integration of these vehicles with manned aircraft, UASs and unmanned free balloons into the National Airspace (NAS) with (as yet undeveloped) separation standards and procedures using low cost tracking technologies. Although Automatic Dependent Surveillance '“ Broadcast (ADS'“B) was developed for manned aircraft and UASs, testing of ADS-B prototypes modified for the low temperature, low temperature, high G environments of launch vehicles show great promise.

To date, ADS-B payloads have been successfully flown on (stratospheric) high altitude balloons, a prototype re-entry vehicle dropped from a stratospheric high-altitude balloon and various reusable launch vehicles (RLVs) that return to land on their own 'retro-propulsion' rocket power or by parachute.

However there are numerous commercial winged RLV designs under development and there have been, as yet, no opportunities to fly ADS-B payloads on them.

The entry, descent and landing profiles of these winged vehicles differ from other RLVs. Instead of descending to land by parachute or 'retro-propulsion' rocket power, winged RLVs return to the NAS in unpowered, controlled, transonic (and then subsonic) flight from above 60Kft (Class E airspace) into Class A airspace (60 Kft to 18 Kft) and then to airspace below permitting them to glide to a landing on runways.

Therefore these winged RLVs present both challenges and opportunities for the FAA to integrate them into the NAS and thus flight testing to obtain early information about performance of ADS-B on winged RLVs which informs how to best utilize the technology by itself or combined with others (as well as in support of CONOPS development) is highly desirable.

Although ADS-B flights are planned for actual winged RLVs, as these vehicles are in early development with frequent flight delays and technical changes ( that could impact ADS-B payload integration) an opportunity was sought to obtain early flight test information about performance of ADS-B on winged RLVs by means other than actual RLV flights and simulations.

A novel approach to use a surrogate RLV test bed with ADS-B consisting of a winged UAS deployed from a stratospheric balloon was discovered and pursued to emulate re-entry, descent and landing of a winged RLV. This decoupled technical and schedule risk from actual winged RLV flights to obtaining early data on ADS-B.

The Near Space Corporation (NSC) operates the High Altitude Shuttle System, or HASS, which is a winged, 'lifting body'□ shaped UAS for NASA and other customers. The HASS is lofted by balloon to carry new technologies to high altitude for testing and then released to fly back and land at NSC's range semi-autonomously.

This vehicle can be modified to change its aerodynamic performance (i.e.; lift versus drag). Depending on release altitude, it can re-enter the NAS at a variety of velocities, flight path angles and trajectories potentially useful to evaluate flight profiles of various RLVs from above 60Kft (Class E airspace) into Class A airspace to glide to a landing on runways. Working with NASA and the FAA, NSC installed a modified COTS 1090MHz ADS-B and transponder as well as a radar retro-reflector for primary radar detection so all three could be compared for value in tracking or data fusion .

On October 3, 2016 the first proof-of-concept test flight occurred. The stratospheric balloon system reached 70,000 feet altitude before it released the HASS in Class E Airspace to simulate a winged spacecraft's entry into FAA Class A controlled airspace. The descent back to the launch site lasted slightly over 30 minutes, and was followed by the FAA using the modified ADS-B payload and the transponder installed in the HASS. Primary radar data was also collected.

The presentation and paper will discuss results and lessons learned A second test with a deployment from 90,000 feet of the HASS containing the both original ADS-B and a more advanced 978MHZ ADS-B may occur before the conference. If so, data reduced by that time will also be presented.

NASA's Flight Opportunities program, under the agency's Space Technology Mission Directorate, funded the balloon flight of the FAA payload on the HASS.

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Nickolas Demidovich joined FAA's Office of Commercial Space Transportation in 2007.

He is currently the Program Manager of Payloads and Technologies. He has been deeply involved in the management, technical execution and post flight data processing of four separate successful experimental payloads on six different platforms operated by the NASA Flight Opportunities Program.

Nick has over 30 years experience serving in leadership roles in systems engineering and program management on a wide variety of space and space-related programs.

He has managed mission design, development, manufacturing and launch/flight tests of satellites and missiles, and upgrades to prolong the operational life of complex systems.

Nick received a BS from Purdue University in Aeronautics & Astronautics, an MS in Aerospace Engineering from the University of Southern California. He is a graduate of the Advanced Program Manager's Course at Defense Acquisition University at Fort Belvoir, Virginia.

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**Abstract**
**203**

**Formal Verification of Trustworthiness Requirements for Small Unmanned Aerial Systems**

**Student**
**No**

*Radu Babiceanu, Embry-Riddle Aeronautical University*

**Topic Area(s)**

UAS Integration in the NAS, Safe & Secure Air Transportation Systems, Cyber Security

In the recent years there has been a rapid increase in use of Small Unmanned Aerial Systems (sUAS) for a wide range of applications ranging from precision agriculture to drone deliveries by logistics companies. However, with increasing use comes increasing need for safe integration of these sUAS into the National Airspace System (NAS). This work addresses the trustworthiness problem for the needed sUAS safe integration, where trustworthiness is defined to include, besides safety requirements, reliability, security, privacy, and resilience requirements. A formalized model for safety requirements verification purposes is developed. Previous work on needed security and privacy characteristics is enhanced with new system resilience models. Resilience is defined as the ability to bounce back to the desired level of performance after an initial reduction resulted from an unexpected disruption in the regular operations. Liveness, temporal logic, and system performance models account for the resilience characteristic in the overall trustworthiness framework.

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Dr. Babiceanu is an Associate Professor of Systems Engineering with the Department of Electrical, Computer, Software, and Systems Engineering at Embry-Riddle Aeronautical University, where he also serves as the Associate Director of the Cybersecurity and Assured Systems Engineering Center. He received his Ph.D. degree in Industrial and Systems Engineering from Virginia Tech in 2005. Dr. Babiceanu's research emphasizes design and operational requirements such as safety, reliability, security, and resiliency for a large spectrum of complex engineered systems. Dr. Babiceanu published more than 60 technical publications in reputed journals and conference proceedings.

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| **Abstract** | **How Much Money You Could Make If the U.S. had European Airline Consumer Protection Laws?** | **Student** |
|---|---|---|
| **204** | | **No** |

*Lance Sherry, Center for Air Transportation Systems Research at George Mason University*

**Topic Area(s)**

Airport & Airspace Optimization/Operations, Air Traffic Management, Safe & Secure Air Transportation Systems

Airline travel is now considered a commodity. Despite significant reductions in airfares, passenger expectations remain high with regard to comfort and amenities, cleanliness, and reliability of service.

Whereas the airlines have 'unbundled' their services to give their consumers more choice in comfort and amenities (e.g. seat selection, checked baggage, carry-on baggage, food and drink, entertainment, wi-fi -), there has been no attempt to differentiate the airline's core service of origin to destination transportation.

The absence of differentiation in transportation service is largely considered to be due to the inability of the airlines to control the reliability of flights due to the inability to manage access to airspace and airport resources, weather impact on air travel, effects of airspace and airport closures due to labor actions, political events etc. This has been reinforced by the wide-spread media coverage of air travel disruptions due to severe weather (e.g. snow), natural disasters (volcanic eruption), or political/terrorist activities.

Recent studies, however, show that the proportion of delayed flights for which airlines are responsible is around 40 per cent.

To address the phenomenon of airline service reliability, in 2004, the European Union (EU) adopted Regulation No. 261/2004, establishing common rules on compensation and assistance to passengers in the event of denied boarding, cancellation or long delay of flights (between 250 and 600 Euros for flights delayed more than 3 hours, or cancelled 24 hours before departure). Other countries have followed suite with regulations that compensate passengers including: China, Saudi Arabia, Israel, and Brazil.

Consumer protection in the United States, however, is limited to compensation for passengers involuntarily denied boarding and establishes a maximum time (i.e. three hours for domestic flights and four

hours for international flights) for tarmac delays

This paper estimates the payouts to passengers (and costs to airlines) operating domestic flights in the U.S. if the EC-261 rules for passenger compensation are applied. Statistics are provided by airline, by departure airport, and by arrival airport. For example, in 2014, passengers flying To or From Washington National Airport (DCA) could have earned $96.9M. That's equivalent to $12.16 for all passengers that flew or $612 per disrupted passenger.

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Lance Sherry, is Associate Professor of Systems Engineering and Operations Research at George Mason University. Dr Sherry also serves as the Director of the Center for Air Transportation Systems Research at George Mason University. Dr. Sherry has over 26 years experience in the industry ranging from flight test, avionics design and certification, program management, strategic planning, and research. He has published over 100 papers and journal articles, holds several patents, and has received several awards for his work.

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| **Abstract** | **Method for Calculating Net Radiative Forcing from Contrails from Airline Operations** | **Student** |
|---|---|---|
| **205** | | **Yes, Part-time graduate** |

*Denis Avila, Center for Air Transportation Systems Research at George Mason University*

**Topic Area(s)**

Climate Change and Aviation Weather, Air Traffic Management, Performance-Based CNS/ATM

Condensation Trails are long, thin clouds that are generated under certain atmospheric conditions by jet engine aircraft. , contrails form as hot humid exhaust from jet engines mixes with the cold low pressure atmosphere. The water vapor condenses and freezes on particles left by the engine's exhaust creating an artificial induced cirrus clouds made of ice particles. The shape and duration of the contrail is dependent on existing atmospheric conditions. Under the right conditions they can persist for hours or days.

These high and thin clouds are highly transparent to shortwave radiation, presenting a small albedo force, allowing most of the incoming energy to reach the surface. Although contrails do absorb a portion of the outgoing longwave radiation, a fraction is sent back to the surface adding to the shortwave energy. The overall effect is therefore to enhance atmospheric greenhouse warming.

The 1999 Intergovernmental Panel on Climate Change (IPCC) estimated that contrails covered 0.1% of the Earth's surface and projected a growth of 5% per year until 2015. In 2013 the IPPC revised its estimates and 'elevated the potential impact of contrails, due to new evidence.' The positive net radiative forcing by contrails is now considered to have a significant anthropogenic (i.e. human-made) impact on climate change.

This paper describes a comprehensive methodology, drawn from several disciplines, for modeling the location of Ice Super Saturated Regions, the presence and duration of contrails, and the resulting net radiative forcing. A case study demonstrates the method for a combination of Ice Super Saturated Region (ISSR) found in the U.S. combined with U.S. airspace traffic trajectories. Preliminary results show that alternative cruise flight levels for air traffic can decrease contrail induced RF by 39%.

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Mr Avila is a systems engineer with 15 years of experience developing functional architecture and implementing efficient solutions in the United States, Mexico, and Brazil. I have expertise in large-scale data analytics, modeling, and system deployment. Mt Avila's expertise is in the delivery of technologies that improve usability, streamline operations, and save money. Mr. Avila is pursuing a PhD in systems engineering with a focus on air traffic analysis at the Center for Air Transportation Systems Research at George Mason University.

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| Abstract | Value-Added Capabilities using the FAA Data Communications Implementation | Student |
|---|---|---|
| 206 | | No |

*Dongsong Zeng, The MITRE Corporation*

**Topic Area(s)**

Performance-Based CNS/ATM, Future Communications, CNS Integration, Consolidation and Miniaturization

To leverage the existing Future Air Navigation System (FANS) avionics and the Federal Aviation Administration (FAA) data communications Segment 1 en route implementation, value-added capabilities using FANS messages are being investigated. Path stretch is one of the capabilities being investigated for potential future inclusion in the FAA data communications system.

In order for a flight to meet the scheduled time at the metering point, the controller often needs to issue a path stretch clearance, which re-routes the aircraft to fly through an extra way point (i.e., extending flight distance) at adapted speed to absorb the necessary metering delay. One of the challenges of path stretch data service is whether the existing FANS avionics and the FAA data communications implementation are able to support a path stretch clearance safely, efficiently, and cost effectively.

This paper addresses various message options using FANS avionics to implement the path stretch. We examine the messages implemented in the FAA Data Communications Segment 1, the ground ability to concatenate FANS clearance and speed messages, and avionics ability to autoload the path stretch clearance and its impact on loaded forecast winds. Results to date show that the path stretch capability using the existing FANS implementations is feasible, with certain limitations concerning message loadability and concatenation.

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Dongsong Zeng is a communication lead at the MITRE Corporation, where his responsibility includes developing system concept and system requirements for the FAA data communications program. As a system designer, architect, and implementer of Air Traffic Control systems for over 15 years, he has extensive knowledge and experience in communication network, systems engineering, acquisition planning, and risk management.

Dongsong Zeng received his Ph.D. in Electrical Engineering from Virginia Tech. Dr. Zeng is currently the Chair of RTCA SC-214 VDL subgroup and Secretary of RTCA SC-223 IPS and AeroMACS. He was honored for significant contributions to the development of aeronautical standards by RTCA, Inc. in 2012 and 2014, respectively.

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| Abstract | Integrated Traffic Avoidance and Separation System | Student |
|---|---|---|
| 207 | | No |

*Balaji Raman Katta, Hindustan Aeronautics Limited*

**Topic Area(s)**

Surveillance & Situational Awareness, Safe & Secure Air Transportation Systems, Air Traffic Management

Aircraft need to be separated from other aircraft by either a minimum vertical distance of 1000ft or by a minimum horizontal distance of 5NM to avoid mid-air collisions. In the current ATM the primary responsibility of separation assurance lies with the ground controller while pilots have limited role. Next generation ATM aims to achieve increase in airspace capacity and improve safety factor. With steady increase in air traffic, current Air Traffic Control (ATC) may not handle proper separation assurance. Traffic Alert and

Collision Avoidance System (TCAS) work well as a tactical safety backups to avoid collision, but cannot perform separation assurance. Free flight concept envisages delegation of separation assurance responsibility to flight crew either completely or partially with help of an on-board advisory system which would maintain standard separation.

This paper presents the design aspects of system that would predict separation Infringement and provide flight crew with necessary guidance for avoidance and recovery. This paper discusses formulation of Traffic Avoidance and Separation System based on ADS-B, system functional architecture, mathematical models, software design, simulation and results. System design considers navigation uncertainty and look-ahead time for design of separation infringement detection function and aircraft performance for design of resolution maneuver function. The Separation Infringement Detection and Resolution (SIDAR) utilized by the system is based on Geometric CD&R method. A functional model of SIDAR function has been implemented in MATLAB and various encounters with different speed ratios at various conflict angles has been fed as input to system model with a goal of avoidance and recovery to original waypoint. Both Heading and Speed maneuvers are evaluated and results are presented. The required strength of resolution maneuver as a function of conflict geometry is studied and automatic maneuver selection function is implemented in system model and maneuver selection function is evaluated with discussion of results

Balaji Raman Katta
MSc (Avionics Design) From Cranfield University UK.
Currently Working as Manager (Design) at Strategic Electronics R&D Centre, Hindustan Aeronautics Limited Hyderabad, India.
The above work carried out as a part of Masters thesis under guidance of Dr. Irfan Madani.
School of Aerospace, Transport & Manufacturing
Cranfield University, Cranfield, United Kingdom

**Abstract** **208**

**Satellite Signal Impact Analysis on Shipboard Automatic Landing Using Satellite Navigation**

**Student** **Yes, Full-time graduate**

*Liuming Yue, Beihang University*

**Topic Area(s)**

Satellite-Based Navigation & APNT, Airport & Airspace Optimization/Operations, Performance-Based CNS/ATM

Carrier-based aircraft landing can be a highly difficult work involved in precise and reliable navigation, positioning and control. Global Navigation Satellite System (GNSS) is a highly precise, continuous, all-weather and a real-time technique, playing a significant role in high precision navigation, positioning, timing, and that related to precise positioning. There is wide-spread interest in the use of GNSS for precision approaches in a civil aviation environment; therefore, shipboard automatic landing using satellite navigation might be a critical technology in future.

And so far, only the United States NAVSTAR Global Positioning System (GPS), the Russian GLONASS, the Chinese Beidou navigation system and the European Union's Galileo positioning system can be called GNSS. A precision approach and landing requires both precise vertical and horizontal guidance from navigation system. Since the GPS has the longest development history and many reference materials, this paper focuses on shipboard automatic landing using GPS satellite navigation. Shipboard automatic landing using satellite navigation can be influenced by several factors, such as satellite signal, ship motion, sea conditions, airwake, and others, however, no satellite signal, no navigation data, and no landing, satellite signal should be the critical factor to the system, and this paper focuses on the satellite signal impact analysis on the shipboard automatic landing system. What's more, given its importance and limited to space, only vertical navigation and control is analyzed.

Satellite navigation system works with the Automatic Carrier Landing System (ACLS) providing an

automatic flight approach control until touchdown on an aircraft carrier. Satellite navigation system measures aircraft's position and velocity with respect to carrier. ACLS incorporates shipboard computer and a data link to the aircraft. Shipboard computer with internal landing guidance controller computes vertical rate commands from aircraft's position and ship motion data, and then transmits them back to aircraft via a radio frequency data link.

This paper builds Hornet aircraft model, its flight control system, its landing guidance controller, simulated deck motion and airwake model and all of these are simplified to facilitate follow-up work. Flight control system includes an autopilot that adopts H-Dot control law and an approach power compensation system (APCS). The former is used to steer the aircraft in response to data link commands and the latter automatically controls the engine thrust to maintain onspeed angle of attack. The guidance controller gets altitude errors from satellite navigation system and computes altitude vertical rate and send it to aircraft through data link and continue the iteration until touchdown and this paper adopts PI-D-DD controller. It uses proportional, integral, derivative and second derivative control action; in addition, an Î±-Î² filter and a first-order inertia element are also pulled-in. The F/A-18A model and its flight control system are built with some efforts based on the exiting data in some published papers. Airwake model is based on the MIL-F-8785C definitions and deck motion comes from ESSEX class aircraft carrier. All the works are achieved with MATLAB®.

The system considers low-visibility weather, night visibility, airwake in the approach path, deck motion caused by high seas, satellite signal errors and pilot fatigue at the end of difficult missions if pilot performs the flight task. The main aim of the system design is to minimize the flight-path error due to turbulence and to maintain a small actuator response range.

Satellite navigation signal is the critical information for the system introduced above and the focus of this paper is to analyze how satellite navigation signal affects shipboard automatic landing. This paper simulates various satellite navigation signals which are available for civil aviation and conjectures this paper required signals with this. The signals will be introduced into guidance controller and flight control system and its influence can be analyzed from the aircraft actuator response, flight-path error and landing errors according to corresponding assessed criterions. And then this paper will propose automatic landing satellite navigation signal demands and some possible boundaries. The results might be helpful to the satellite navigation development and improve aircraft carrier performance.

This paper has finished the basic models, assessed criterions, and is engaged in simulating the satellite navigation signals.

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Yue Liuming was born in Xichuan County, Henan Province, China on 17th August 1992. He has a bachelor's degree in Aircraft Design and Engineering from Beihang University, China. He is a full time graduate in Beijing University of Aeronautics and Astronautics majoring Flight Dynamics and Flight Control. He has published a paper Research on Practical Technology of Ship Air-wake Model in APCATS 2015 and a paper Design and Simulation of F/A-18A Automatic Carrier Landing Guidance Controller on the AVIATION 2016-AIAA Aviation and Aeronautics Forum .

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| Abstract | How to Organize a UAS Department for Revenue Generating Drone Operations | Student |
|---|---|---|
| 209 | | No |

*Bryan Baker, Leica Geosystems AG*

**Topic Area(s)**

UAS Integration in the NAS, UAS Integration in the NAS

sUAS regulations, known as Part 107, are now in effect. The proposed rules now provide a clear path for individuals and companies that want to use drones in their businesses.

Part of the requirements to operate a UAS under the new Part 107 regulations is that the operator has to pass the new FAA Part 107 Knowledge Exam to obtain their Remote Pilot Operator certificate with the Small UAS Rating. It doesn't matter what type of UAS you fly. If it is between 0.5 and 55 pounds and you are using it for your business, you need the certificate and rating. This exam consists of 60 multiple choice questions covering five different subject areas.

In addition to the Remote Pilot Operator certificate with the Small UAS Rating, your drone operator must be able to prepare and operate the sUAS safely and efficiently. This includes vehicle design, pre-flight preparations, and in-flight monitoring and safety assurance. In particular, the remote pilot operator must be able to operate the vehicle with proficiency to maintain trajectories with the tolerance required by the sensor package.

Whether you run a small business or a large multi-disciplinary firm, there are several factors you need to seriously consider before organizing your UAS department. This paper helps you navigate the risks to avoid in this new arena and prepare your firm to utilize UAS technology to its fullest extent. This paper discusses the following topics:

- How the proposed FAA regulations could impact your business

- What are the limitations of operating your system

- What flight training and certifications are needed and what authority your operator has for various missions

- How to appropriately designate crew responsibilities

- How to properly manage client expectations

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Bryan Baker is UAS Sales Manager - NAFTA at Leica Geosystems AG.

In Mr. Baker's role as Unmanned Aircraft Systems (UAS) Sales Manager, he has the opportunity to combine passion for aviation and expertise in geospatial solutions and work with some REALLY cool technology. Mr. Baker's responsibilities extend beyond just the sales aspect of UAS to include interfacing with dealers and customers across the entire North American geospatial community to working on the product development, application engineering, and system integration.

Mr. Baker's specialties: Instrument Rated Pilot, GPS for Land Surveying, Mapping, Construction, Land Surveying Technology, Mobile Mapping Technology, CAD, GIS. 3D Laser Scanning, Hydrographic Surveying

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| Abstract | An Effective Pulsed Interference Mitigation Approach for L-DACS1 System | Student |
|---|---|---|
| 212 | | No |

*Dongxia LI, Tianjin Key Lab for Advanced Signal Processing, Civil Aviation University of China*

**Topic Area(s)**

Future Communications

L-DACS1 is a candidate for the future digital aeronautical communications system in L-band. As unused spectrum is very scarce in the L-band, L-DACS1 employs the spectral gaps between two adjacent channels assigned to the Distance Measuring Equipment (DME) system as an inlay system, the interference that DME pulses cause to the OFDM receiver of L-DACS1 system is inevitable. To mitigate the DME interference, a pulsed interference mitigation approach based on Compressed Sensing (CS) theory is proposed in the paper. The block-sparse characteristic of DME pulses is considered and the fact that the virtual sub-carriers in L-DACS1 system don't carry modulated symbol is also utilized to obtain measurement vector. Block-sparse Bayesian learning algorithm and the Expectation Maximum estimation method are applied to derive the learning rules of statistic parameters in sparse DME impulse signal, and the DME pulses are recovered. Simulation results demonstrate that DME pulsed interference can be suppressed effectively using the proposed approach and hence the L-DACS1 system performance is improved significantly.

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Dongxia Li ,Female , vice-professor,Ph.D.of EE Beijing Institute of Technology.

Now teaching in Department of Communications Engineering , Civil Aviation University of China, advisor of graduate student.

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**Abstract 213**

## Getting UAS Airborne: Self-certification for Over the Road Operations

**Student No**

*Suzette Matthews, Washington Progress Group LLC*

**Topic Area(s)**

UAS Integration in the NAS, Airport & Airspace Optimization/Operations, Air Traffic Management

In this paper, the authors offer two concepts for getting a significant segment of UAS'"both private and commercial'"flying in the near term: Self-certification of qualified UAS, and immediate authorization for those UAS to operate over public roads.

First, the paper explores the unique nature of UAS safety standards and certification challenges, and how traditional/legacy FAA safety and certification paradigms are insufficient for the diversity and numbers of expected UAS. The authors then propose a new paradigm of "self-certification" for small UAS, analogous to safety assurance regimes in place in other transportation modes, specifically automotive, and consumer product safety. The paper then discusses how the third-party tort liability system and insurance industry norms can be applied, along with UAS registration, to provide a safety assurance construct equal to, or better than, regulation.

But airframe certification alone does not get UAS flying'"they also must be operationally authorized to fly in some area of airspace. The authors propose an immediate pathway to authorization of small private and commercial UAS, that is, to approve their operation under 400 feet over public roads, using existing rules of the road applicable to ground vehicles. The paper discusses how this operating paradigm avoids the most difficult safety, air traffic management, policy and public acceptance barriers to UAS operations (e.g. privacy, nuisance, safety), and considers risk factors and how risk might be analyzed, mitigated, and addressed including application of state third party liability insurance requirements for road vehicles.

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Suzette Matthews is an aviation attorney. She represented major foreign and domestic airlines before the CAB, FAA, DOT, and Federal Courts. She has served as Executive VP and General Counsel, and Director of the Air Traffic Control Association, and Editor of ATCA's Journal of Air Traffic Control; was a Senior Subject Matter Expert to the FAA Joint Planning and Development Office (JPDO). She is the author of numerous

published articles on aviation law, technology policy, unmanned aircraft issues, and public-private partnerships. She received the Aviation Week and Space Technology Laurel Award (2001), the Air Traffic Control Association Clifford Burton Award (2004) and Chairman's Citation of Merit (2012). She holds a B.A. With Distinction and Phi Beta Kappa from Cornell University, and a Juris Doctor degree from Cornell Law School. She is a Member of the Bars of Virginia and the District of Columbia.

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**Abstract 214** | **SCMA Codebook Design Scheme Based on Circular-QAM** | **Student**

*Triratana Metkarunchit Thai-Nichi Institute of technology, triratana@tni.ac.th*

**Topic Area(s)**

Future Communications

Spare code multiple access (SCMA) promises to be a multiple access scheme with massive connection for 5G cellular system.This paper proposes a new method to create multidimensional mother constellations of SCMA codebook by using circular-QAM scheme. This proposed scheme can mitigate the complexity of message passing algorithm (MPA) due to the sparsity of SCMA codewords. The complexity commensurates with the number of projection point. The less number of projection point is, the less complex MPA will be. Furthermore, the new codebook and low projections have been simulation with MIMO-SCMA performed in Rayleigh fading channels. The result shows that the efficiency of the codebooks and the performance of bit error rate (BER) are comparable to the existing ones.

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Triratan Metkarunchit received the M.Eng., in Electrical Engineering from Chulalongkorn University, Bangkok, Thailand, in 2003.From 2003 to 2004, he was with test Deparment of celestica Thailand, design and implementation of high power amplifier for cellular systems. From 2004-2008, he was with telecommunicaion deparment, Dhurakij pundit university, workin in the field of Mobile communication. In march 2008, he joined faculty of information technology, Thai-Nichi Institute of Technology, Thailand, to work on new radio access techniques and machine learning.

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**Abstract 215** | **Integrating RPAS into Existing ATM Structures – Published Approach Procedures vs. Local Arrangements** | **Student No**

*Dagi Geister, German Aerospace Centre (DLR e.V.)*

**Topic Area(s)**

UAS Integration in the NAS, Surveillance & Situational Awareness, Air Traffic Management

The importance of Unmanned Aircraft Systems (UAS) is growing in all aspects of aviation. Platforms range from small, user-friendly off-the-shelf drones ('micro UAS') to large transportation aircraft. One possible scenario for civil UAS or Remotely Piloted Aircraft System (RPAS) operation is freight transport, ranging from small and urgent deliveries (e.g. organs or spare parts) and crisis relief (e.g. humanitarian logistics or optimal coverage of a crisis area) to scheduled large freight transport, replacing or extending current conventional manned freight transportation. However, the airspace integration of such novel systems is still a major challenge. Within this work, a flight trial was performed to investigate several issues of the integration of large RPAS into the existing ATM architecture.

In June 2016, a flight trial with an Airbus A320 was conducted. The A320 was used to simulate a RPAS flying into a cargo hub airport (Leipzig/Halle, EDDP). The purpose of the test was to check the overall functionality, the flight path following accuracy of the aircraft under those conditions and the behavior of the

experimental FMS in case of a datalink loss. The aircraft received trajectory instructions from a RPAS ground station via an experimental Flight Management System (FMS). A ground based S-Band data link was used to exchange information with the aircraft. It is based at the institute of flight guidance at the German Aerospace Centre in Braunschweig. It requires a direct line of sight. Therefore, it was obvious that the data link would be lost at a certain time of the approach into Leipzig/Halle which is approx. 90nm away.

In preparation of this flight, the routing was negotiated with the responsible ATC supervisor. Standard IFR routing was explicitly and deliberately used to ensure predictable flight behavior. A standard instrument departure, a published en-route segment and a standard arrival route were chosen. As arrival route, the published RNP procedure for RWY 26R was used. This approach has a lateral routing that leads towards the parallel runway (RWY 26L) first and then leads to RWY 26R for landing. In practice, this approach is not used by approaching aircraft, as they usually get radar vectors and follow a trombone procedure for the approach. This was not apparent to the people involved in the planning of the trials and led to confusion on ATC side during the trials.

In this paper, the flight test infrastructure and the results of the flight trial will be presented. It will show the behavior of the aircraft during a data link loss and the flight path following performance during flight. Additionally, it will show that the use of an on-site RPAS pilot who is aware of local procedure and capable of speaking the local language could facilitate the integration. The pilot would be located at the landing airport next to the controller to assure direct communication.

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Dr. Dagi Geister received her diploma (2004) in Economic Sciences and PhD (2011) in Computer Sciences from the Leibniz University Hannover, Germany. Since 2016 she is group leader of 'Unmanned Aircraft Systems' at DLR's institute of flight guidance. She is highly experienced in the field of ATM and Unmanned Aircraft Systems (UAS) and supports and coordinates several projects in the field of UAS integration into (non-) segregated airspace.

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**Abstract 216**

## Study of UAS Satellite Earth Station Emission Limits for Terrestrial System Interference Protection in Ku Band

**Student No**

*Robert Kerczewski, NASA Glenn Research Center*

**Topic Area(s)**

UAS Integration in the NAS, Commercial, Military, and Consumer UAS

Unmanned aircraft (UA) are projected to have a major impact on future aviation. Larger UA operating at altitudes above 3000 feet will require at least occasional access to non-segregated, that is, controlled airspace. In order for unmanned aircraft to be integrated into the airspace and operate with other commercial aircraft, a very reliable command and control (a. k. a. control and non-payload communications, (CNPC)) link is required. For operations covering large distances or over remote locations, a beyond-line-of-sight (BLOS) CNPC link implemented through a satellite is required. Protected aviation spectrum would normally be required for such a safety-critical link, however currently available aviation safety satellite spectrum is inadequate to support BLOS CNPC link bandwidth requirements.

To address this inadequacy, the 2015 World Radiocommunication Conference (WRC-15) provided a provisional allocation allowing the use of the Fixed Satellite Service (FSS) to provide CNPC, including allocations in Ku-Band and Ka-Band, under WRC-15 Resolution 155. For the Ku-Band allocation, a serious complication exists in that there are co-primary terrestrial service allocations in these bands, in particular, Fixed Service (FS) point-to-point and point-to-multipoint microwave digital links. During the WRC-15 study cycle, much opposition to the UAS allocation was generated based on fears that UA CNPC satellite transmitters in these bands would impose unacceptable levels of interference to the FS receivers.

To address protection of the FS receivers, Resolution 155 contains a requirement for power flux density (pfd) limit to be imposed on UA transmitters operating in Ku-Band (14.0-14.47 GHz). The Resolution left the

details of the pfd limit undefined, to be agreed upon at the next WRC in 2019. Thus, work is continuing to prepare technical arguments regarding selection of a pfd limit adequate to protect FS receivers in preparation for WRC-19.

NASA has studied the transmission characteristics from the UA transmitters for WRC-15 sharing studies, and is now studying aspects of interference from UA transmitters into FS receivers in order to investigate pfd limits being proposed for consideration by WRC-19 and their potential impact on UA BLOS CNPC links operating in Ku-Band. This paper will provide an overview of that on-going work. It will include a review of WRC-15 outcomes, a discussion of pfd limits as applied to protecting FS receivers and how they are derived, analysis and measurement of assessment of expected emissions from UAS Earth Stations and an assessment of possible impacts of pfd limits on UA operations.

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Robert J. Kerczewski has been involved with research and development of satellite and aeronautical communications systems and applications for the Analex Corporation (1982-1986) and NASA (1986-present). He holds a BEE degree from Cleveland State University (1982) and an MSEE degree from Case Western Reserve University (1987). He is currently the Spectrum Element Manager for the NASA's Unmanned Aircraft Systems Integration in the National Airspace System (UAS in the NAS) Communications Sub Project.

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| **Abstract** | **Communications for UAS Integration in the NAS Phase 2 – Satellite Communications and Terrestrial Extension** | **Student** |
|---|---|---|
| **217** | | **No** |

*James Griner, NASA Glenn Research Center*

**Topic Area(s)**

UAS Integration in the NAS, Commercial, Military, and Consumer UAS

In order to provide for the safe integration of unmanned aircraft systems (UAS) into the National Airspace System, the control communications (also known as control and non-payload communications, CNPC) link connecting the ground-based pilot with the unmanned aircraft must be highly reliable and robust, based upon standards that enable certification. Both line-of-sight (LOS) links using terrestrial-based communications and beyond-line-of-sight (BLOS) links using satellite communications are required to support UAS operations. The development of standards has been undertaken by RTCA Special Committee 228 (SC-228), with supporting technical data developed by NASA under the Communications Sub-Project of the UAS Integration in the National Airspace (NAS) Project. As a result of work completed in the first phase of the Communications Sub-Project, minimum operational performance standards (MOPS) have been completed and published for the LOS CNPC system.

The second phase of work involves the BLOS CNPC systems and extension of the terrestrial LOS MOPS. The development of technical data to support MOPS development for UAS BLOS satellite-based CNPC links and MOPS extension for LOS CNPC links has now been initiated by NASA, and RTCA SC-228 has organized itself to begin the MOPS development process. The Communications Sub-Project will focus on three objectives.

First, extension of the Phase 1 MOPS for terrestrial-based UAS control communication system is needed to cover mid-sized UAS unique waveform considerations for the operational environment of smaller, lower altitude, higher traffic density mid-size UAS operations. This includes flight testing both C & L-Band terrestrial systems in a relevant flight environment to support the extension of the current RTCA SC-228 C2 Terrestrial MOPS, performed as a series of lab and flight tests of a prototype CNPC terrestrial radio system.

Second, definition and development of a civil UAS Beyond Line of Sight (BLOS) satellite-based control communication system link between the UAS and the GCS that supports the required performance of the unmanned aircraft will be undertaken to inform the development of MOPS for the use of Ku and Ka Band fixed satellite service for civil UAS CNPC. This will include flight testing of both Ku & Ka-Band SatCom systems in

a relevant flight environment.

Third, definition and development of a civil UAS beyond Line of Sight (BLOS) satellite-based control communication system link between the UAS and the GCS, to a design level, that supports the required performance of the unmanned aircraft will be undertaken to inform the development at C-band. Because operational satellites are not yet available in the portion of C-Band intended for UAS control communications operations (5030-5091 MHz), the approach will be to develop initial design parameters of airborne and ground station equipment, and to develop a preliminary payload design, in order to assess the feasibility of an operational C-Band satellite-based CNPC system.

This paper will provide an overview of the scope and objectives of the Phase 2 Communications Sub-Project and the initial analysis, system development and testing approach and design.

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Jim Griner is a senior electrical engineer at the NASA Glenn Research Center, in Cleveland, OH. He has over twenty years experience in computer network and system engineering for satellite and terrestrial communications, including extensive ground and flight testing. Currently, Mr. Griner is the project engineer for the communication portion of NASA's Unmanned Aircraft Systems integration in the NAS project. Mr. Griner has a BEE from Georgia Tech and MSEE from Case Western

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| **Abstract** | **The Extensible Authentication Protocol (EAP) for VDL-2 in the ATN/IPS** | **Student** |
|---|---|---|
| **218** | | **No** |

*Thomas McParland, BCI*

**Topic Area(s)**

Cyber Security, Future Communications

ICAO has defined a security protocol which was originally designed for ATN applications (CPDLC, CM, and ADS-C) in the ATN/OSI environment. The protocol was subsequently modified to support ATN applications in the ATN/IPS environment. In its modified form it is called the Secure Dialogue Service (sDS). Most recently the sDS has been modified to be more general and to support non-ATN applications to include, for example, FANS 1/A applications.

In its latest form the sDS is not limited to end-to-end application layer security but may also be in other environments. This paper first reviews the sDS in its abstract form describing the cryptographic exchanges between air and ground entities. This paper next describes using the sDS as an EAP method for VDL-2. The paper describes general EAP triggering methods and session key derivation as well as optimizations to these functions based on VDL-2 handoff and provisions in the sDS protocol itself. This paper also addresses a common issue in using EAP, namely, Handover Keying re-authentication. The paper describes a technique of transferring the authentication context to new base stations after handoff using techniques similar to those used in WiMAX and AeroMACs to avoid re-executing the EAP method. The paper finally describes how keys derived from the VDL-2 EAP exchange may also be used to secure not only VDL-2 access network exchanges but also exchanges for global mobility management.

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Thomas McParland is a Vice President at Basic Commerce & Industries, Inc. (BC) responsible for FAA operations. He is a systems engineer and has supported work in ICAO, RTCA, and AEEC in networking and security. He was a key contributor in development of ICAO's Security Standard and the first standard for the ATN/IPS, ICAO Doc 9896.

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| Abstract | An XML Datalink Message Exchange Model (DMXM) for command and control data sharing | Student |
|---|---|---|
| 219 | | No |

*Antonio Correas, Skymantics, LLC*

**Topic Area(s)**

CNS Integration, Consolidation and Miniaturization, Air Traffic Management, Future Communications

ATC services use datalink communication systems such as FANS/ACARS, FAA DCIS and EUROCONTROL DLS/Link2000+. This communication domain, specific for ANSP safety applications, uses dedicated Communication Service Provider (CSP) networks, such as Rockwell Collins (ARINC) and SITA. A need has been identified in the broader aviation community to share the updated status of ATC instructions and clearances with stakeholders other than the ANSPs. This information sharing capability should use the widely-accepted XML data format in order to leverage open publish/subscribe services, and SWIM architecture and governance. Therefore, a standard data model and interface should be defined.

This paper explores the creation of a new 'XM'□, Datalink Messaging Exchange Model (DMXM), for datalink information sharing. Datalink messages and communication functions supported by current FANS 1/A (RTCA DO-258A/EUROCAE ED-100A) and ATN-B2 (RTCA DO-350/EUROCAE ED-228) service standards are identified for inclusion in the model. The relevant ATC communication service (AFN/CM, CPDLC, ADS-C) messages are discussed, and XML syntax options are described based on identified use cases. Flight datalink information to support functions such as dispatch, metrics and performance collection, and operational efficiency improvements are also considered. Architectures for data parsing and data brokering functions using this scheme will vary based on the stakeholder requirements.

DMXM can enable the use of a common reference data model for datalink information globally, such as through SWIM, integrated with the ATM Information Reference Model (AIRM). Aviation industry data exchange standards (e.g. AIDX and ACRIS) can also benefit from the use of this information. Targeted users of applications for DMXM include airline dispatchers, pilots, airport operation control centers, ground and tower controllers, and fixed-based operators such as ground handlers.

DMXM will provide the aviation community with a standard data model enabling ATC consumer applications using interoperable semantics, thus achieving a higher productivity rate at a lower cost and a shorter time to deployment. Such applications will support common situational awareness for controlled flights and enable collaborative decision making among stakeholders.

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Antonio is a co-founder and President of Skymantics, LLC. He is a specialist in air/ground data link products for air traffic services and airline operation communications.

Antonio is a graduate of Embry-Riddle Aeronautical University with an MBA in Aviation. He holds a B.S. in Telecommunications Engineering from Universidad de Zaragoza, Spain and a specialization in the Master of Wireless Networks from the Royal Institute of Technology, Sweden.

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**Abstract** **Dynamic Generation of Air Traffic Flow Networks** **Student**

**220** **No**

*Brian Capozzi, Mosaic ATM, Inc.*

**Topic Area(s)**

Air Traffic Management

The FAA's NextGen initiative aims to enhance the safety and efficiency of the US national airspace system (NAS) through improved air traffic operations along with other strategies involving upgrading and standardization of the nationwide infrastructure both on the ground and in the air. For improving the quality of air traffic control and its operations, the on-ground systems support air traffic controllers (ATC) with advanced decision support systems, which enable the controllers to effectively predict, visualize, manage, track and control the air traffic in the NAS. Mosaic ATM's National Flow Advisory Manager (NFAM) is one such decision support tool being developed that aims to help traffic managers understand the effect of 'tactical' air traffic management actions on 'strategic' Traffic Management Initiatives (TMIs) and vice versa. Fundamentally, such TMIs aim to address imbalances between the traffic desiring to utilize certain NAS resources (e.g., demand) and the ability of those resources to accommodate that traffic (e.g., capacity). If such imbalances are not properly addressed, then inefficiencies occur including over-delivery / delays or under-delivery / wasted capacity. NFAM is designed to assist traffic managers in understand when such imbalances are present or predicted and then to provide modeling tools to generate effective traffic management strategies to resolve them. In order to facilitate the computationally-efficient evaluation of the complex interactions between TMIs, NFAM models air traffic not at the individual aircraft level, but rather in the aggregate by propagating time-varying flow rates along a spatial network. A core technical aspect of NFAM is thus the generation of a representative spatial flow network based on predicted flight plan and trajectory data. This flow network is intended to capture and aggregate the noisy spatial paths taken by individual aircraft over a given period of time into a simplified set of flow 'bundles' or segments. The motivation for this network is two-fold: from a user's perspective, it enables visualization of dominant flows while removing much of the 'noise' that results from the naÃ¯ve overlay of raw per-flight data on a single display; secondly, this spatial structure naturally serves as a convenient modeling context for propagation of aggregate traffic flows along a capacitated flow network. In this paper, we introduce an efficient methodology used in NFAM for dynamically generating an air traffic flow network from the lateral geometry of a set of flight trajectory predictions. We also discuss the subtleties involved in generating such a network in both arrival and departure contexts. We further address the need to map the per-flight timestamped input data onto the resultant spatial flow network as a starting point for modeling the time-varying motion of aircraft through the network. We demonstrate the behavior of the methodology by applying the flow generation algorithm to several representative data sets. The computational complexity of the algorithm is analyzed and the implications of this methodology, its limitations and future improvements are discussed.

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Dr. Brian Capozzi is a Principal Analyst at Mosaic ATM, Inc. His primary research interests are related to autonomy and decision-making / optimization in the context of uncertainty. Prior to joining Mosaic ATM in 2009, Dr. Capozzi worked at Insitu in roles ranging from program manager to embedded software for Insitu's Integrator UAS, specifically focused on the integration of the GuideStar autopilot with Insitu's next generation avionics and software architectures. Dr. Capozzi is a graduate of the University of Washington where he received a Ph.D. in Aeronautics and Astronautics in 2001 for research related to the application of evolutionary algorithms to UAV path planning and cooperation. Dr. Capozzi also received a B.S. in Aeronautical & Mechanical Engineering from the University of Notre Dame.

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| Abstract | Seamless Integration of UAV Surveillance Data in the NAS | Student |
|---|---|---|
| 221 | | No |

*Dave Whitman, Sunhillo Corporation*

**Topic Area(s)**

UAS Integration in the NAS, Special Topic/Other

Sunhillo has developed a solution that addresses the primary challenges of UAS NAS Integration for Beyond Visual Line of Sight (BVLOS) Operations, utilizing existing FAA deployed products.

Sunhillo is a growing, employee-owned business, with 25 years' experience in ATC Mission Critical Data (i.e. Radar Data, Flight Data, and Maintenance Data) communications. Sunhillo has been a major contributor to FAA's NAS infrastructure since 1990 providing for the movement of ATC mission critical data throughout the NAS, including radar, flight and ATC system maintenance information. This includes critical communication links for all NAS surveillance and flight data for terminal, EnRoute and oceanic air traffic movement. As a result, Sunhillo touches all real-time ATC surveillance nodes.

The objective of this solution is to provide UAS Integration into non-segregated airspace. One of the primary technical and operational challenges of UAS Integration in non-segregated ATC tracking and surveillance of an aircraft's position is with today's radar, both primary and secondary. Today's FAA radars are not specified, nor capable to identify UAS targets reliably, with small cross-sections and unique aerodynamics the results are false target filtering in radar processing. With ADS-B, the commonly stated concerns are related to the cost of transponders for UAVs, concerns with increase in payloads, and with frequency spectrum overload.

Looking at the first challenge of surveillance and tracking of UAVs, Sunhillo's UAS- Connector (patent pending) or UAS‟C product in conjunction with our UAS Virtual Radar (UAS VR) software (copyright) can provide seamless surveillance tracking of UAVs without significant modification to the national airspace system. The UAS-C performs security verification and interfaces UAV position data from ground control stations, cellular networks LTE, and other sources to provide a message format that is common to the Terminal and EnRoute NAS ATC systems. The UAS VR receives front-end processed UAV position data from the UAS-Connector. Data will be in a common format that includes latitude, longitude, altitude, status data, etc. The Processing converts the position data into FAA Radar Data messages (e.g. Range, Azimuth, Status and Sweep, etc.). This includes message output conversion and formatting for message compatibility with Situational Awareness systems and ATC systems that are expecting ASTERIX and CD-2 or many other messages types available. The UAS VR also provides standard message processing for systems expecting ADS-B, i.e. - ASTERIX messages. The messages are mapped based on location into Virtual Radars that are created and configured for no gaps in coverage across the US with no gaps in coverage. Processing is performed to further map the targets to the applicable ATC facilities (Terminal, EnRoute).

Aircraft to aircraft see and avoid requirements is another challenge facing UAS Integration. In normal ATC procedures, aircraft pilots must be able to look out of the cockpit, and see and avoid other aircraft. BVLOS UAV pilots are likely to be in a different location than the actual UAV and cannot meet the procedural requirement, therefore there needs to be a means to provide this function.

The challenge related to see and avoid is addressed using the Sunhillo Surveillance Monitoring System (SMS‟Lite) which provides a situation display at the UAS operator position, pilot in command called the Traffic Information Display (TID), which displays situational awareness similar to Traffic Information System-B (TIS-B) displays in manned aircraft cockpits.

Some of the key benefits of the Sunhillo UAS BVLOS NAS Integration Solution include:

- The UAS-C and UAS Virtual Radar seamlessly provides real-time UAV target surveillance data to the NAS
- The solution can utilize, but does not rely on ADS-B transponders on UAVs and the associated

frequency spectrum concerns and/or payload concerns. It also does not rely on physical Radar detection of UAVs and the associated small radar cross-section / run-length concerns

- UAS-Connector can employ 3D filtering, resulting in passing only data when the UAV (particularly sUAS) is outside the planned geographic limitations or a UAV has violated airspace restrictions
- Security features protect the NAS from potential intrusions

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Dave Whitman is a graduate from the University of Delaware, with a Bachelors of Electrical Engineering. He has designed and developed numerous real-time data communications systems fielded in the US and abroad. His expertise includes hardware, software, embedded systems, networked systems, and network management applications for Air Traffic Control. Dave has authored and presented numerous articles on surveillance data distribution systems and is considered a preeminent authority in this field.

Dave is the President and CEO of Sunhillo Corporation, a global leader in surveillance data distribution and conversion products and Technical Services. Dave co-founded Sunhillo over 25 years ago and has been handling all life-cycle aspects of surveillance data distribution systems for the Federal Aviation Administration, US Military, civil aviation authorities, and national defense organizations across the globe.

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| **Abstract** | **Airport Network Architecture Concept for Information Exchange** | **Student** |
|---|---|---|
| **222** | | **No** |

*Rafael Apaza, NASA Glenn Research Center*

**Topic Area(s)**

Airport & Airspace Optimization/Operations, CNS Integration, Consolidation and Miniaturization

The National Airspace System (NAS) Air Traffic management, control and operation depends on a timely and efficient distribution of real time information generated by stakeholders and published from a variety of sources. The Federal Aviation Administration System Wide Information Management (SWIM) is a service oriented architecture design to provide stakeholders with timely NAS information. However, there are other sources of useful information generated by stakeholders that can be included in the management of NAS operations. Airport facilities are host to most stakeholders operating in the NAS (airspace user, airport authority, ground handling, controller tower) and thus large information is generated and consumed at these facilities. The NASA Glenn Research center has been investigating an information exchange architecture framework that would enable the timely, efficient and secure gathering and distribution information generated at airport facilities. This presentation describes the framework architecture concept for the efficient information exchange of airport information.

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Rafael Apaza works for NASA Glenn Research Center in the investigation and development of modern Communications and Networking Systems. He holds a bachelor and masters degree in Electrical Engineering from Wayne State University and a Masters in Computer and Information Science from The University of Michigan.

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| Abstract | Cyber-Security Challenges Experienced on a Wireless Networked Aircraft | Student |
|---|---|---|
| 223 | | Yes, Full-time graduate |

*Ramya Kanlapuli Rajasekaran, University of Colorado, Boulder*

**Topic Area(s)**

Cyber Security, Future Communications

In this paper, we discuss the key cyber-security challenges for network enabled aircraft and also discuss possible solutions to help mitigate or prevent such challenges.

Network enabled cloud services can improve flight operations - increase operation consistency, reduce need for on-board software and sub-systems to reside in every aircraft and enable optimisation. The flow of information relies on a secure network connection and a timely flow of information. The cyber-physical security aspects of the aircraft determine the utility, efficiency and the cost of a network enabled aircraft, as compared to an aircraft that doesn't have access to the Internet.

The concept of extending networked architecture for aircraft systems can be applied to piloted aircraft as well as unmanned aircraft systems. Air traffic management systems can benefit from having real-time, high-frequency data to map out trajectories, especially in the case of adverse weather conditions or use the network to run algorithms that help with path-planning in different environments. Taking this into consideration, it is necessary to protect the integrity and availability of data to ensure efficient mapping and rerouting of aircraft (in this scenario) as well as the working of other systems taking advantage of the wireless network. The limits and unique challenges of a networked cockpit and the differences in the kind of security issues experienced as compared to a conventional aircraft/UAS are outlined as well.

This paper will develop a taxonomy of cyber security threats. Examples of such threats would be radio-frequency jamming or manipulation of signals, which could lead to node impersonation (data manipulation), data delay, malware upload and such, which in turn could have adverse effects, especially if the aircraft relies on the network for important information like GPS, weather data or such. The adversary could also use the wireless connection to exploit and misuse the aircraft systems and procure unauthorised data, and also seriously jeopardise the safety of the aircraft by denial of necessary services to the aircraft systems. The paper elaborates on the effects and consequences such threats have on aircraft systems if the aircraft relies on the wireless network for timely supply of critical information.

The paper also explores existing solutions which directly translate into this domain, helping address these concerns at a lower level as well as different original and adaptive security architectures that could to be developed to address the consequences of a compromised network. The establishment of minimum cyber-security standards to ensure safe and secure exchange of data for aircraft connected to a wireless network are also outlined in the paper.

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Ramya Kanlapuli Rajasekaran is a Masters student at University of Colorado Boulder in the department of Aerospace Engineering Sciences. She received her undergraduate degree in Aerospace Engineering as well, with research focusing on quadcopters to study atmospheric conditions. Her current research focuses on the integration of networked and wireless enabled architecture into aircraft and the challenges associated with the same.

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| Abstract | AeroMACS Field Trial at Haneda Airport | Student |
|---|---|---|
| 224 | | No |

*Toshiyuki Inagaki, AVICOM JAPAN CO.,LTD.*

**Topic Area(s)**

Future Communications, Safe & Secure Air Transportation Systems, Airport & Airspace Optimization/Operations

AeroMACS (Aeronautical Mobile Airport Communications System) is a WiMAX (Worldwide Interoperability for Microwave Access) -based full IP mobile communication technology and is standardized at ICAO (International Civil Aviation Organization) today as next generation airport surface data communication platform to enhance regularity and safety of any air flights even under day-by-day increased air traffic environment worldwide. AeroMACS technology development has been intensively done and validated through more than several field trials in US, Europe, China and Japan last few years. In order to accelerate AeroMACS deployment, it is essential to validate the technology in an actual field as an economical platform to simultaneously accommodate both of ATC and AOC data traffic. This paper reports AeroMACS field test at Haneda Tokyo international Airport, which is one of the busiest airports in Japan, installing 3 BSs(Base Station) at operating gate areas to seamlessly cover ground services, and discusses its operation as a high-secure platform for both of ATC and AOC.

AVICOM JAPAN is a Japanese private enterprise wireless communication service provider.