INTEGRATING UAS INTO THE MANAGED AIRSPACE THROUGH THE EXTENSION OF ARINC CLOUD SERVICES

George Elmasry, Rockwell Collins, Carlsbad, California
Diane McClatchy, Rockwell Collins, Annapolis, Maryland
Rick Heinrich, Rockwell Collins, Cedar Rapids, Iowa
Boe Svatek, Rockwell Collins, Cedar Rapids, Iowa

Abstract

Rockwell Collins is working closely with government agencies such as the FAA and NASA to extend its service provider portal that offers National Airspace System (NAS) services to range of aircraft operators to include Unmanned Aerial System (UAS) operators. These UAS services, offered in a cloud infrastructure, are referred to as WebUAS™. In this paper, we will present the WebUAS™ architecture -- its layers of security, its adaptability to future FAA interfaces, and its organic growth capability as UAS applications expands. We will present its current architecture serving a scaled system of large and small UAS operators and its interfaces to air-traffic control. The paper will also show this current suite of services applied to representative railroad operations -- weather, precision navigation, aircraft situation display (ASD), temporary flight restrictions and an authentication engine. One important aspect of WebUAS™ is the separation of computational engines (e.g., authentications engine) from services infrastructure and the ability to use different engines either developed in-house or by 3rd party vendors for the same purposes. Mapping a specific computational engine to a service package depends on the service package and factors such as minimum cost to maximize capability for the specific operational needs but also use a set of "*engine elements*" to qualify an engine for a service package. In this paper, we will cover the "*engine elements*" studied by Rockwell Collins. These *engine elements*" will be applied to the sUAS notification and authentication engine currently addressed by the FAA.

Introduction

Rockwell Collins ARINC offers many cloud-based services to the aviation community. For example, ARINCDirect [1] is a Rockwell Collins service provider portal that offers National Airspace Services (NAS) to business aviation and military aircraft operators. WebUAS™ is a natural extension of our cloud-based service-oriented infrastructures. WebUAS™ adheres to the FAA rules [2] and is organically growing to serve the needs of each different UAS operations types. WebUAS™ provides a service infrastructure with the flexibility to incorporate services from 3rd party computational engines through agile APIs. WebUAS™ is not a tactical situational display tool; it is an infrastructure that can adapt to the diverse needs of UAS operations to include situational awareness, operational awareness, resource management, and adherence to FAA rules and regulations. All functionality that requires any form of computation is modularized forming sets of stand-alone tools that can be selected by WebUAS™.

Offering UAS services is drastically different from offering flight planning and filing services for manned aircrafts. UAS services include the equivalent of flight following for manned aircraft. UAS services will continue when aircraft is airborne. Many aspects of our flight following and flight management services will be included in UAS services. These aspects include conflict probe, conflict detection and resolution, flow management, capacity planning, contingency planning, surveillance data processing, etc. All aspects are expected to be met through the use of computational engines.

The WebUAS™ cloud has the following characteristics:

1- Secure information exchange with computational engines, UAS operators and FAA systems. WebUAS™ provides multilayered firewalling hosted in the Rockwell Collins Cyber Security Operations Center (CSOC).
2- Leverages the current FAA interfaces (SWIM model [3]) adaptable to future standardization

sponsored by government agencies such as NASA [4-8] and the FAA.

3- Computational engines are separated from services infrastructure such that third party computation engines (e.g., drift calculations, weather, and flight authentication) can be used seamlessly (in-house or any third party) based on the each specific UAS operator's needs. These computational engines can run as an application on a server or can be utilized through an API to the computation engine vendor.
4- Dedicates a server for each large UAS operator. UAS services are integrated into UAS operations as specified by the large operator requirements. Firewalling the large operator from WebUAS™ is agreed upon with the operator; dataflow to and from the UAS operations to WebUAS™ are part of a service level agreement (SLA) with the large UAS operator. This SLA reflects the FAA rules and regulations for the specific UAS operations; and the large operator can have an integrated view of its operation and the services provided by WebUAS™.
5- WebUAS™ supports dedicated servers for air-traffic control interfaces. These servers provide bi-directional filters passing only relevant UAS information to the air-traffic control.
6- For small UAS operators, WebUAS™ dedicates servers amongst operational types and offers pre-defined levels of SLAs. Each SLA is developed for the specific industry needs.
7- WebUAS™ has a hierarchical architecture that can add regional servers for future extension to UAS services

This paper presents: (1) critical aspects of the WebUAS™ architecture with emphasis on its layers of security and interface to Air Traffic Control (ATC); (2) UAS services to large and small UAS operators with the rail operations as an example of open architecture, security implementation, integration of UAS operation with UAS services; (3) the separation of computational engine from services infrastructure with the application of "*engine elements*".

Critical Aspects of WebUAS™

WebUAS™ is hosted in a cloud-based service-oriented infrastructure and was developed applying open architecture principals. The WebUAS™ cloud architecture provides for multiple dedicated virtual and physical servers. These servers can be dedicated to external interfaces, by UAS operational size and/or service type. Our architecture employs agile APIs emphasizing modularity to account for future requirements and capabilities. External computational engine APIs are separated from the service infrastructure. Some critical aspects of the WebUAS™ architecture follow.

WebUAS™ Notional Architecture

Figure 1 shows a notional architecture of WebUAS™ Cloud. Please notice the following:

1- WebUAS™ utilizes AviNet® – a Rockwell Collins secure global network for airlines and airports – to interface to FAA systems. AviNet® is a trusted provider of secure connectivity to FAA systems.

2- The same FAA approved firewalling used with all our aviation customers is used with WebUAS™ insuring that UAS operations will meet or exceed FAA approved security constraints.

3- There are national centralized WebUAS™ servers that are peers to our ASD servers and are under the same security constraints as ASD servers. This allows for the secure use of ASD data in real time with UAS services as needed.

4- WebUAS™ cloud supports regional servers for future expansion of UTM service.

5- WebUAS™ cloud supports dedicated servers for ATCTs-interfaces.

6- WebUAS™ cloud supports dedicated servers for interfacing with other industry partners.

7- WebUAS™ cloud supports dedicated servers for large UTM operators such as railroads and power lines operators.

8- Any communications infrastructure can be part of the WebUAS™ cloud.

9- WebUAS™ cloud supports secure links to remote operator's Ground Control Stations (GCSs).

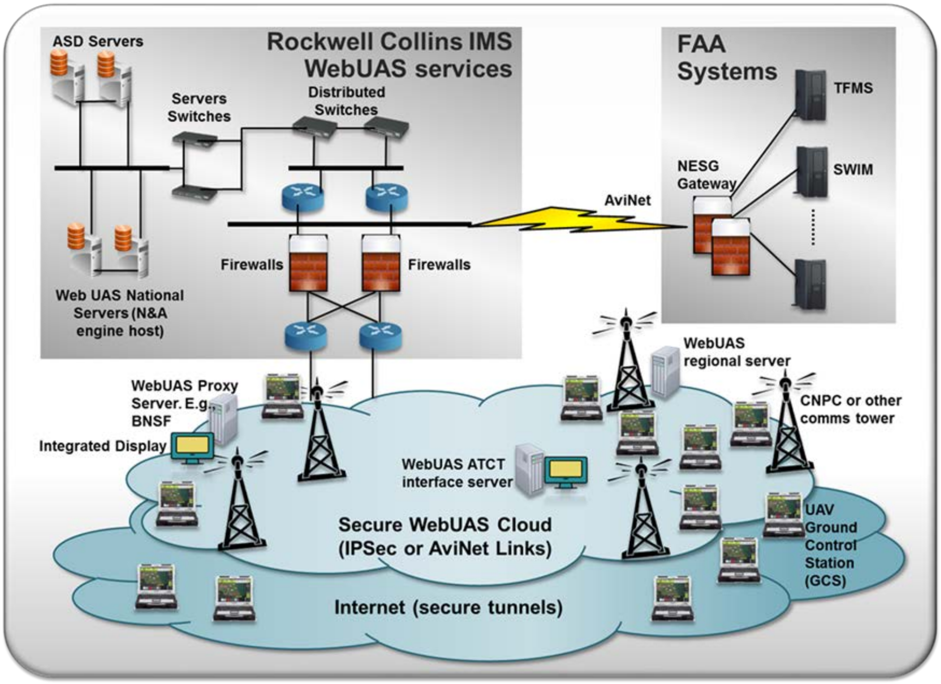

Figure 1: WebUAS™ Notional Architecture

Further security capabilities of WebUAS™ are discussed below. The WebUAS™ cloud extension can use dedicated IPSec tunnels or AviNet® links as shown in Figure 1. Another extension layer of WebUAS™ cloud can use secure access over the Internet for Ground Control Stations (GCSs) that may only have Internet access.

Interface to ATC

The WebUAS™ service-oriented architecture relies on specialized servers to meet specific needs. The architecture creates servers dedicated for external interfaces. These dedicated servers insure security while interfacing to external systems, performing specific data processing and filtering information that are not relevant to the external entity. The WebUAS™ network can dedicate servers for the integration of manned and unmanned aircrafts in the airspace. These servers could process UAS data and present relevant information to the associated ATC entities looking at the tactical separation management of the integrated airspace. The needs of these ATC entities can be met with minimal demands on the operator. Relevant UAS data can be displayed on a separate screen, or a mix of manned ASD and UAS data can be displayed for the ATC operator. These dedicated virtual servers can also create warnings and inform both the air traffic control tower (ATCT) operator and UAS operators of potential conflicts. These dedicated servers can also be used to pass messages from the ATCT to UAS operators such as a message to abort a UAS flight.

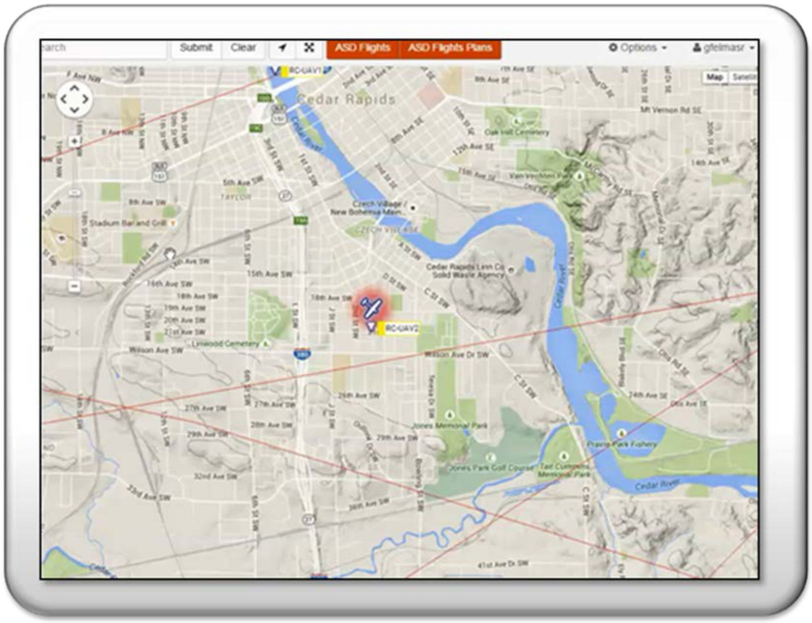

Figure 2: WebUAS™ Interface to an ATCT Operator Showing a UAS Infringing on a Manned Aircraft Flight Path

Figure 2 shows an experimental WebUAS™ interface to an ATCT operator showing a sUAS infringing on a manned aircraft flight path (red line).

Notice that the interface to ATC uses a computational engine. An in-house or third party engine can be used for this interface and this computation engine will be vetted through a set of "*engine elements*". This paper presents a set of "*engine elements*" created for the sUAS authentications engine.

UAS Services to Operators

The WebUAS™ architecture, cloud-based and service-oriented is designed for scalable a la-cart capabilities. Dependent upon the enterprise size and needs, WebUAS™ is tailored for each customer requirements. In addition to the standard and relevant services envisioned for UAS service suppliers, the WebUAS™ architecture facilitates add-ons such as the ability to monitor and manage private communication networks for both command and control links and payload data. In support of BNSF's pathfinder efforts, Rockwell Collins installed a command and control data link network into the test ranges. WebUAS™ is used to support the command and control tower radio monitoring and management. A WebUAS™ proxy server is currently collocated with BNSF's pathfinder operations center in Playas, NM. WebUAS™ is integral to the private network for radio tower data backhaul and other railroad operations infrastructure. WebUAS™ is designed to support both larger operators likely demanding locally controlled proxy servers as well as smaller subscribers dependent upon a Rockwell Collins hosted and maintained server supporting many smaller customers. BNSF has been operating WebUAS™ for the purpose of radio network health monitoring per FAA authorization, beyond visual line-of-site (BVLOS) without the use of visual observers. The UAS operations management component of WebUAS™ for large operators provides tailorable views for a multitude of users both inside the enterprise and selectively outside the enterprise.

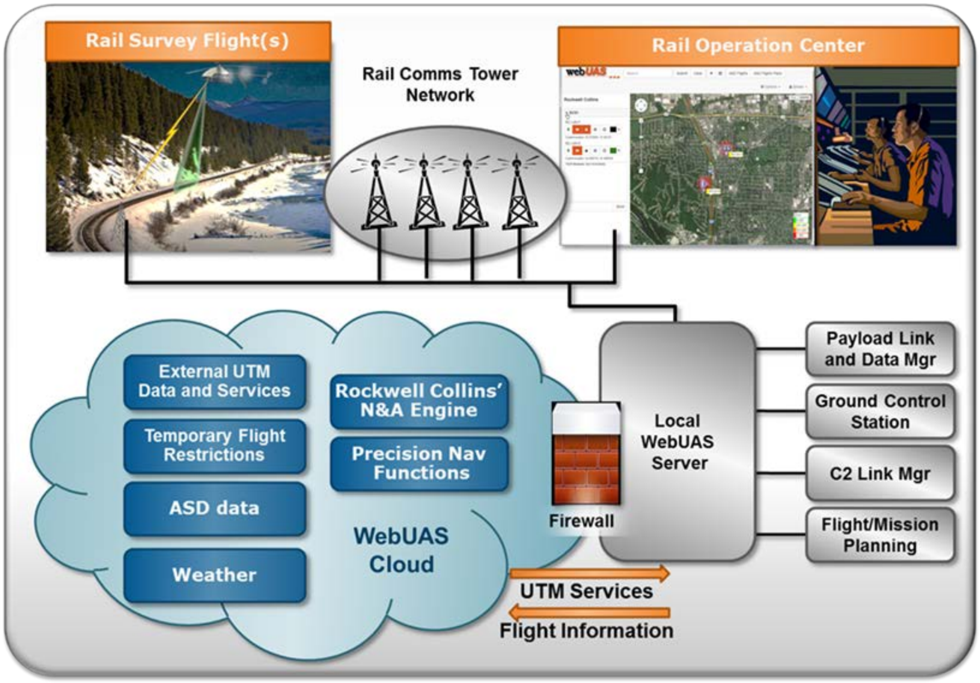

Figure 3: Notional View of WebUAS™ UTM Services to Railroad Operation

Figure 3 shows a notional view of the UTM services supplied to railroad operations. The rail survey flights, the communications towers and the rail operation center are all controlled and operated by the UAS operator. Other functions such as payload link and data manager, GCS, C2 link manager and flight mission planning are also internal to the operation center although they interface to the local WebUAS™ server (proxy server). The firewall of the WebUAS™ proxy server is agreed upon by both Rockwell Collins and the UAS operator. This agreement insures that UTM services flow to UAS operations and flight information relevant to UAS traffic management systems are communicated to the WebUAS™ cloud, per the agreed upon SLA. Flight information relevant to UTM systems can be processed and communicated to the FAA and other UAS service providers' networks as needed. The WebUAS™ cloud brings a bundle of services to the UAS operations to include external UTM data and services, flight restrictions data, ASD data and weather data. Rockwell Collins also uses its in-house authentication engine and a precision navigation function that aids the railroad UAS operations.

The concept of using a proxy server at the large UAS operator operational facility can be extended to the many types of UAS operators such as sUAS manufactures who also provide services. Our flexibility in packaging services will allow us to cater for to each specific need.

The Engine Elements

WebUAS™ is a service-oriented infrastructure-focused cloud. From one angle, WebUAS™ uses specialized servers for external interfaces and to create tailored services for UAS operators while relying on firewalling to ensure security. From another angle, WebUAS™ separates services infrastructure from computational engines in order to make it possible for UAS operators to select computational engines they desire and also to create the flexibility to generate service packages for a myriad of UAS operations in the future. The type of UAS operation, the location of UAS operation (sparse versus dense airspace) and many other factors can lead to one computational engine being suitable for an industry type and location while another computational engine developed for the same purpose can be more suitable in another location and another industry type.

The concept of separating computational engines from services infrastructure has been used successfully by other Rockwell Collins cloud based services, like ARINCDirect for NAS services [1]. Users can chose one flight plaining engine over another flight planning engine as part of their service package. This concept is even more valuable for UAS services due to the different types of UASs, the different types of airspace (dense or sparse, flat or mountainous, temperate or extremes), and the diverse industries planning to use UAS services. In this section, we present the *engine elements* for a sUAS authentication engine. The FAA is studying an authentication engine as the first step in developing sUAS services. Rockwell Collins is developing its own sUAS authentication engine, WebUAS™ But because WebUAS™ open architecture supports 3rd party API, WebUAS™ can support both its in-house and 3rd party sUAS authentication engines. The *engine elements* discussed herein provides insight into how a sUAS authentication engine may be vetted to be included as a WebUAS™ service package.

For each computational engine, a set of *engine elements* will be developed. The sUAS authentication engine elements include the elements listed in the following subsections.

Comprehensive reference to fenced areas

The FAA has decided that the first step of a sUAS authorization is the reference to fenced area element. The FAA offers data services for UAS restriction facility maps to be used to authorize a sUAS flight. The engine element of a comprehensive reference to fenced areas (airports, military bases, government restricted area, etc) will be the first engine element for a UAS authentication engine.

The ability to make recommendations

UAS flight planning will need more automation and must allow for millions of flights to exist safely. There are significant differences between manned aircraft flight planning and UAS flight planning. For example, traditional flight planning considers an origin and destination with a trajectory between. A UAS operation may originate and terminate at the same point and the flight path may be a gridded pattern not a linear trajectory. So a flight planning engine for UASs will require different planning algorithms from manned aircrafts planning engines. The algorithms are critical to an ability to make recommendations to the operator.

Both manned and unmanned flight planning systems will need to accommodate system constraints – altitude, terrain, temporary flight restrictions (TFR), special use airspace (SUA), air defense information zones (ADIZ), etc. UAS flight planning will need to consider airport perimeter boundaries that may limit operations as mentioned in the previous engine element.

An important element of an authorization engine for sUAS is to make recommendations to the UAS operator instead of rejecting their flight plan. Flight plan recommendations capabilities will include the following:

1- Change altitude recommendation. Since some fenced areas such as those in the vicinity of an airport will have a gradual altitude restriction, a recommendation to lower an altitude of a sUAS can lead to an authorization of a sUAS flight instead of a rejection.

2- Time interval exclusion. As UAS services grow, the path of different UAS flights will intersect even in rural areas. An authentication engine would need the ability to exclude certain time intervals from one flight plan to allow another flight plan to exist.

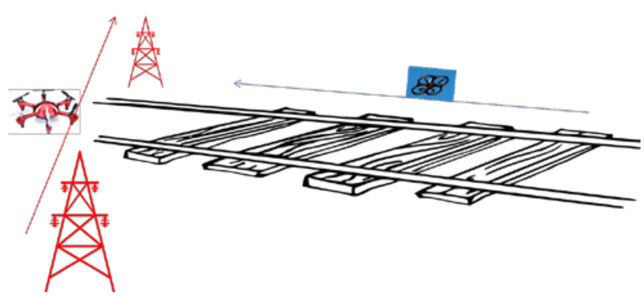

Figure 4: The intersection of Railroad inspection flight path with powerline inspection flight path.

Figure 4 shows an example of rural area where a railroad inspection flight path and a powerline inspection flight path can intersect. An authentication engine would be expected to exclude certain time interval from one flight path in order to allow these 2 flight path to exist. Notice that a third flight path may also exist in the same area where a crop duster UAS may cross the same area. Time exclusion can be expected to work with more than 2 flights plans and must be able to access flights plans from all service providers in the area.

3- Format conversion. In a dense airspace, time interval exclusion may not suffice. An authentication engine should be expected to convert a flight path from a 3-D format (altitude, latitude and longitude weigh points) to 4-D format where a timestamp is added to each weigh point based on the aircraft type and ability. In essence, this capability extend time interval exclusion to as narrow as specifying flight time.

3- Weather-based flight grounding. Under certain weather conditions, the sUAS authentication engine should be able to recommend flight grounding or the abort of ongoing flights for sudden weather changes.

The speed of making recommendations

UAS operators' requirements can include the need to receive flight path recommendations promptly. An engine element that quantifies the response speed of the authentication engine can be used to approve the use of that engine in certain operations.

Airspace status monitoring

This is a critical component of insuring airspace safety and it parallels the NAS ASD data. It is therefore a critical sUAS flight authentication engine element. This element will measure how well airspace is monitored for all operations for all UAS types in order to avoid potential conflicts and account for nonconforming flights.

Access to special activities

sUAS operations can be expected to have an unexpected events that may trigger the need to abort some UAS flights or make changes to their path. An example of these unexpected events is an emergency landing of a manned aircraft or police and emergency operation of sUAS. This engine element will vet an authentication engine for its access to these special events and its ability to make recommendations to ongoing UAS flights (abort or change of path) in reaction to these unexpected events. Notice that this engine element has a parallel in manned aircraft flight operation where a flight path can be changed under special conditions.

Real-time separation assurance in dense air space

In dense airspace, real-time monitoring of all sUAS activities and the ability to create ground-based separation assurance [9] may become a critical engine element for sUAS authentication. Notice that there are no approved flight plans that can be used as with NAS services. The future may bring a database of securely separated routes and the authentication engine may need to assign UASs to routes and monitor conforming to the assigned routes or more autonomous algorithms may be accepted by the FAA. Regardless of these requirements emerge, the ability of an authentication engine to assure real-time separation in dense airspace may become a critical element.

Regional versus national flights

As UAS services grow, the selection of an authentication engine for certain operators may depend on the region or area of operation. In the future, authentication engines may be required to be area focused.

Industry type

sUAS operators may have specific requirements that may be met with one authentication engine over another. This engine element may become a discriminator in engine selection for the type of operation.

Route optimization

Specifically for long range flights, route optimization will become an important engine element for sUAS authentication. This will tied with the ability to make recommendations of flight path change in order to optimize the route for factors such terrain and weather effects. It will be necessary for long range UAS flights to avoid turbulence.

Collaborative decision making

As the airspace becomes denser; as different UAS service providers merge; and as UAS aircraft capabilities develop, sUAS authentication engines will require a collaborative decision making interface. The engine interface will collaborative decision making and will include the use of negotiation protocols with different UAS service providers and with the aircraft types.

Graphic depiction of recommended routes

It is critical for the UAS operator to be able to visualize the recommended routes facilitating optimal route selection from a set of recommended routes. WebUAS™ will depict these recommended routes to the operator but the authentication engine will be expected to make graphic depiction user friendly. An engine element will quantify the graphic depiction ease and how helpful it is for the UAS operator.

Prediction and warning capabilities

This engine element will measure the proactive capabilities of the authentication engine [9 - 10]. As actual flight path deviates from a planned route, the risk of airspace collision is increased. As airspace density increases, the ability of an engine to analyze current situational data and create escalating warnings that can prevent potential accidents will become a critical engine element.

Summary

This paper presented a cloud-based service-oriented infrastructure for the UAS domain referred to as WebUAS™. We presented how WebUAS™ creates a multi-layer of security in its architecture and how the service provider infrastructure is separated from interfaces to the FAA and other external systems as well as the separation of computational engines from services infrastructure.

The paper presented critical aspects of WebUAS™ with notional architecture that shows the layers of this service-oriented cloud. The paper also presented how WebUAS™ dedicates servers for ATC interfaces and how services are provided to large and small UAS operators.

A special focus of this paper was regarding the *engine elements* that are created for each computational engine and vetted to be used with WebUAS™. A set of engine elements was created for each computational engine type and is used to vet and map each engines use to a specific service package. The paper focused on the sUAS authentication engine as an example of how each engine elements are created and can be used to vet a computational engine.

As the standards of UAS services evolves, WebUAS™ will evolve and will be able to account for future capabilities through its open cloud architecture, dedicated servers or virtual servers, and the separation of computational engines from each service infrastructure.

References

[1] https://www.rockwellcollins.com/arincdirect

[2] https://www.faa.gov/uas/

[3] https://www.faa.gov/nextgen/programs/swim/

[4] https://utm.arc.nasa.gov/docs/Rios_DASC_1570265251.pdf

[5] Prevot et. el., 2016, "UAS traffic management (UTM) concept of operations to safely enable low altitude flight operations," *Proceedings of the 16th AIAA Aviation Technology, Integration, and Operations Conference*, no. AIAA-2016-3292.

[6] Kopardekar, 2014, "Unmanned Aerial System (UAS) Traffic Management (UTM): Enabling Low-Altitude Airspace and UAS *Operations*," NASA Technical Memorandum, NASA/TM-2014-218299.

[7] Kopardekar et, el., 2016 "*Unmanned Aircraft Systems Traffic Management (UTM) Concept of Operations,*" *Proceedings of the 16th AIAA Aviation, Technology, Integration, and Operations Conference*.

[8] Rios, 2016, "*UTM Client Interface Control Document*," version 2.0, NASA Ames Research Center.

[9] https://utm.arc.nasa.gov/docs/Denney_DASC_1570263561.pdf.

[10] Ishihara et. el., 2016, "Rapid Trajectory Prediction for a Fixed-Wing UAS in a Uniform Wind Field with Specified Arrival Times," *Proceedings of the 16th AIAA Aviation, Technology, Integration, and Operations Conference*.

Disclaimer

The information presented in this paper contains the views and opinions of Rockwell Collins engineers who are working on forward looking concepts for UAS services and is not necessarily the current views and policies of Rockwell Collins or any of its subsidiaries.

Email Addresses

george.elmasry@rockwellcollins.com
diane.mcclatchy@rockwellcollins.com
richard.heinrich@rockwellcollins.com
boe.svatek@rockwellcollins.com

2017 Integrated Communications Navigation and Surveillance (ICNS) Conference
April 18-20, 2017